The Effect of Slower Speech on Comprehension of two German Non-Canonical Sentence Structures in Aphasia with and without Hearing Impairment

INAUGURAL-DISSERTATION

zur Erlangung des akademischen Grades

Doktor der Philosophie (Dr. phil.)

dem

Fachbereich Sprach- und Kulturwissenschaften

der Carl-von-Ossietzky Universität Oldenburg

vorgelegt von

ANGELA JOCHMANN

geb. 10.10.1968 in Bremerhaven

Vom Fachbereich Sprach- und Kulturwissenschaften der Carl von Ossietzky Universität Oldenburg als Dissertation angenommen am 16.05.2016.
Referentin: Prof. Dr. Esther Ruigendijk
Korreferentin: Prof. Dr. Nanna Fuhrhop

Tag der Disputation: 29.09.2016

TABLE OF CONTENTS

LIST OF FIGURES 6
LIST OF TABLES 7
LIST OF ABBREVIATIONS 8
ACKNOWLEDGMENTS 9
ABSTRACT 12
1 INTRODUCTION 1
2 A SHORT OVERVIEW ON SYNTACTIC AND MORPHOSYNTACTIC PROPERTIES OF ACTIVE TRANSITIVE CLAUSES IN GERMAN 10
2.1 Word order 10
2.2 Embedding 15
2.3 The morphosyntactic markers of case and agreement 17
2.3.1 Case 17
2.3.2. Agreement 24
3 NON-CANONICAL SENTENCE PROCESSING IN GERMAN 28
3.1 Word order 28
3.1.1 Syntactic complexity 30
3.1.2 Informational complexity 33
3.1.3 Subject-first preference 35
3.2 Embedding 43
3.3 Timing and processing speed 47
3.3.1 Processing speed 48
3.4 Cognitive processes 52
4 NON-CANONICAL SENTENCE PROCESSING IN APHASIA 58
4.1 Word order processing in agrammatism 58
4.2 Morphosyntactic deficits in agrammatic aphasia: Cross-linguistic differences 63
4.2.1 Processing case 65
4.2.2 Processing agreement 68
4.3 The nature of canonicity effects in agrammatism 73
4.3.1 The Trace Deletion Hypothesis 73
4.3.2 The Slowed Processing Hypothesis 77
4.4 Processing speed in aphasia 84
4.5 Cognitive processes in aphasia 87
4.6 Effects of slower speech on comprehension in aphasia 90

5 NON-CANONICAL SENTENCE PROCESSING IN HEARING IMPAIRMENT 95
5.1 Hearing loss- prevalence, degrees and types 95
5.1.1 Prevalence of hearing loss 97
5.1.2 Degrees of hearing loss 97
5.1.3 Types of hearing loss 98
5.1.4 High-frequency hearing loss 99
5.1.5 Presbyacusis 100
5.2 Speech perception in hearing impairment 101
5.2.1 Auditory word recognition and sentence intelligibility 104
5.2.2 Speech perception in presbyacusis and age 106
5.3 Non-canonical sentence processing in hearing impairment 108
5.4 Processing speed in hearing impairment 112
5.5 Cognitive processes in hearing impairment 113
5.6 Effects of slower speech on comprehension in hearing impairment 116
5.7 Correcting hearing loss 117
6 HEARING IMPAIRMENT AND SPEECH PERCEPTION IN APHASIA 120
6.1 Speech perception and auditory word recognition in aphasia 123
7 HYPOTHESES 125
8 METHODS 128
8.1 Participants 128
8.1.1 Hearing status assessment 132
8.1.2 Results of the hearing screening 133
8.1.3 Excluded PWA 134
8.1.4 Language assessment 134
8.2 Material 134
8.2.1 Sentence stimuli 134
8.2.2 Time manipulation 138
8.2.3 Picture stimuli 139
8.3 Design and Procedure 140
8.4 Statistical analyses 142
9 RESULTS OF EXPERIMENT 1: VERB SECOND (V2) STRUCTURES 148
9.1 Validation of the experiment: Young Controls 148
9.1.1 Accuracy 148
9.1.2 Response latencies 150

9.2 Group comparison **151**

9.3 The effect of hearing impairment and slower speech on aphasic comprehension Fehler! Textmarke nicht definiert.

9.3.1 PTA-4 155

9.3.2 PTA-6 156

9.4 Agrammatic PWA **157**

9.5 The effect of hearing impairment and slower speech on non-brain-damagednon-brain-damaged comprehension **161**

9.5.1 PTA-4 162

9.5.2 PTA-6 164

9.6 Summary of all results **165**

9.7 Interim discussion **166**

9.7.1 Performance patterns in aphasia 166

9.7.2 Agrammatic performance patterns 168

9.7.3 Effect of hearing impairment and age 174

10 RESULTS ON EXPERIMENT 2: CENTRE-E EMBEDDED RELATIVE CLAUSE (RC) STRUCTURES 177

10.1 Validation of the test: Young controls **177**

10.1.1 Accuracy 177

10.1.2 Response latencies 179

10.2 Group comparison **180**

10.3 The effect of hearing impairment and slower speech on aphasic comprehension **182**

10.3.1 PTA-4 185

10.3.2 PTA-6 186

10.4 Agrammatic PWA **187**

10.5 The effect of hearing impairment and slower speech on non-brain-damagednon-brain-damaged comprehension **190**

10.5.1 PTA-4 192

10.5.2 PTA-6 193

10.6 Summary **194**

10.7 Interim discussion **195**

10.7.1. Performance patterns in aphasia 196

10.7.2 Agrammatic performance patterns 198

10.7.3 The effect of slower speech on agrammatic comprehension 202

10.7.4 Effects of slower speech on normal comprehension 206
10.7.5 Effects of hearing impairment and age 207
10.8 Overall summary 208
11 GENERAL DISCUSSION 210
11.1 Slower speech compensates partially for sentence comprehension deficits in agrammatic aphasia 210
11.1.2 A note on comparisons of studies on slower speech 216
11.1.2 Individual dissociations in performance between OVS and OR: Tentative evidence for intermittent deficiencies in agrammatic aphasia? 217
11.1.3 The problems with group studies 222
11.2 The effect of hearing impairment on comprehension in aphasia 223
11.2 Slower speech does not improve non-canonical sentence comprehension in hearing-impaired non-brain-damagednon-brain-damaged adults 225
11.3.1 The impact of high frequencies 225
11.4 Implications 227
11.4.1 Implication for aphasia therapy and research 227
11.4.2 Implications for audiology practice and research 228
11.5 Future research 229
11.6 Limitations of the study 229
11.7 Conclusion 230
12 REFERENCES 231
13 APPENDICES 249
13.1 Demographic data of PWA 249
13.2 Material 252
13.2.1 Sentence stimuli 252
13.2.2 Lemma frequencies 253
13.2.3 Duration of sentences 256
13.2.4 Examples of pictures 258
13.3 Results 259
13.3.1 Results of all groups 259
13.3.2 PWA 260
13.3.3 Young Controls 263
13.3.4 NBD 264
13.3.5 Item per group 266
13.4 Hearing status check in aphasia studies 267

CURRICULUM VITAE 270

List of figures

Figure 2.1. Object movement in OVS 13
Figure 2.2. Object movement in OR 14
Figure 5.1. Audiogram of a normal-hearing listener 96
Figure 5.3. Distribution of phonemes across frequencies 102
Figure 5.4. Impact of hearing acuity on phoneme perception 102
Figure 8.1. Examples of pictures for V2 139
Figure 8.2. Examples of pictures for RC. 140
Figure 8.3. Procedure of the sentence-picture matching task. 141
Figure 9.1. Accuracy on V2: YC 149
Figure 9.2. Response latencies on V2: YC 150
Figure 9.3. Group comparison: Accuracy on V2 152
Figure 9.4. Accuracy on V2: PWA 154
Figure 9.5. Age effects on accuracy: PWA 157
Figure 9.6. Accuracy on V2: PWA 159
Figure 9.7. Effects of age on accuracy on V2: Agrammatic PWA 161
Figure 9.8. Accuracy on V2: NBD 162
Figure 9.9. Effects of age on accuracy on V2: NBD 164
Figure 10.1. Accuracy on RC: YC 178
Figure 10.2. Response latencies on RC: YC 179
Figure 10.3. Group comparison: Accuracy on RC 181
Figure 10.4. Accuracy on RC: PWA 185
Figure 10.5. Accuracy on RC: Agrammatic PWA 189
Figure 10.6. Accuracy on RC: NBD 191
Figure 10.7. Effects of age on accuracy on RC: NBD 193
Figure 13.1. Example of pictures for V2 items 258
Figure 13.2. Example of RC items 258

List of tables

Table 2.1. Case marking on German determiners 18
Table 2.3. Case marking on relative pronouns in German.. 20
Table 2.4. Agreement marking in German 25
Table 4.1. Research on effects of slower speechon aphasia 92
Table 5.1. Degrees of hearing loss 98
Table 8.1. Overview of PWA.. 129
Table 8.2. Overview of all groups of the experimental task 131
Table 8.3. Overview of all groups of the hearing screening 133
Table 8.4. Examples for V2 and RC items. 136
Table 8.5. Average speech rates and durations of items 139
Table 9.1. Statistical results for accuracy on V2: YC 149
Table 9.2. Statistical results for response latencies on V2: YC 151
Table 9.3. Statistical results for accuracy on V2: Group comparison**Fehler! Textmarke nicht definiert.**
Table 9.4. Statistical results for accuracy on V2: PWA with PTA-4 as factor. 155
Table 9.5. Statistical results for accuracy on V2: PWA with PTA-6 as factor. 156
Table 9.6. Statistical results for accuracy on V2: Agrammatic PWA. 160
Table 9.7. Statistical results for accuracy on V2: NBD with PTA-4 as fixed factor. ... 163
Table 9.8. Statistical results for accuracy on V2: NBD with PTA-6 as factor. 164
Table 9.9. Performance accuracy on V2: Individual agrammatic PWA....................... 171
Table 10.1. Statistical results for accuracy on RC: YC 178
Table 10.2. Statistical results for response latencies on RC: YC.................................. 180
Table 10.3. Statistical results for accuracy on RC: Group comparison 182
Table 10.4. Statistical results for accuracy on RC: PWA with PTA-4 as factor. 186
Table 10.5. Statistical results for accuracy on RC: PWA with PTA-6 as factor. 187
Table 10.6. Statistical results for accuracy on RC: Agrammatic PWA 190
Table 10.7. Statistical results for accuracy on RC: NBD with PTA-4 as factor. 192
Table 10.8. Statistical results for accuracy on RC: NBD with PTA-6 as factor. 194
Table. 10.9. Table 9.9. Performance accuracy on RC: Individual agrammatic PWA .. 200
Table 13.1. Demographic data of all pWA. 249
Table 13.2. Items... 252
Table 13.3. Lemma frequencies.. 253
Table 13.4. Duration and speech rate per item 256
Table 13.5. Mean accuracy per group across sentence structure and speech rate 259
Table 13.6. Accuracy of individual PWA on V2... 260
Table 13.7. Accuracy of individual PWA on RC 261
Table 13.8. Accuracy per symptom group... 262
Table 13.9. Accuracy of individual YC 263
Table 13.10. Accuracy of individual NBD 264
Table 13.11. Accuracy per item.. 266
Table 13.12. Overview on speech perception and comprehension studies in aphasia.. 267

List of abbreviations

ACC	Accusative case
CP	Complementizer hrase
AMB	Ambiguous
dB	Decibel
DP	Determiner Phrase
FEM	Feminine gender
HI	Hearing impairment
IP	Inflectional Phrase
IPh	Intonational Phrase
MASC	Masculine gender
NBD	Non-brain-damagedNon-brain-damaged persons
NOM	Nominative case
NP	Nominal Phrase
OLACS	Oldenburger Linguistically and Audiologically Controlled Sentences
OR	Object relative clause
OVS	Object-verb-subject clause
POA	Place of articulation
PTA	Pure tone audiometry
PWA	Persons with aphasia
RL	Response latencies
SD	Standard deviation
SE	Standard error
SR	Subject relative clause (canonical order)
SLT	Speech and language therapy/therapist
SPS	Syllables per second
STM	Short-term memory
SVO	Subject-verb-object clause (canonical order)
TDH	Trace Deletion Hypothesis
VP	Verbal Phrase
VOT	Voice onset time
WM	Working memory

Acknowledgments

Without the help of many people, this research and this book would have never been possible.

First and foremost, I want to express my deepest gratitude to my mentor Prof. Dr. Esther Ruigendijk. She supported me with constructive criticism, shared her knowledge and expertise with me and showed me ways out of the woods when I got lost in irrelevant “darlings”. Furthermore, she enabled me to attend many workshops and conferences, which not only deepened my knowledge on aphasia, but also taught me much about audiology, statistics, scientific writing and other relevant topics for this research. Beyond the academic aspects, she was very patient and encouraging, and always there when needed.

Second, I thank my referee, Prof. Dr. Nanna Fuhrhop, for pointing out aspects in my thesis, which I was not aware of. Also a big thank you to the committee, Prof. Dr. Wolfgang Gehring, and Prof. Dr. Cornelia Hamann and Prof. Dr. Birger Kollmeier, the latter were also part of the interdisciplinary DFG-funded research project AULIN, which enabled my research. I express my gratitude also to the other members of AULIN, namely Dr. Rebecca Carroll, Dr. Verena Uslar, Dr. Dorothea Wendt and Dr. Thomas Brand, who gave invaluable help and information. Thanks also to the department of audiology for providing me with participants for my study. My gratitude extends to Dr. Petra von Gablenz of the Jade Hochschule Oldenburg who let me use one of the portable audiometry devices.

Lots of thanks to my colleagues and friends Hendrikje Ziemann, Katharina Hupe and Ilka Floeck for patiently listening to me rambling over and on about my project and providing invaluable feedback. Thanks deserve Axel Budrat, the IT angel who was always there when I needed technological help, and the members of the linguistic colloquium who provided useful feedback during all stages of the project.

A deep gratitude goes out to Dr. Wilbert Heeringa without whom I’d still be brooding about the statistical analysis of my data.

This project would not have been possible without the participation of 50 persons with aphasia. I express my gratitude to all the members from the aphasia self-support groups of Oldenburg, Bremerhaven, Leer, Emden, Vechta and Schortens and their speech and language therapists. Also, I want to thank the patients of the Helios Kliniken Leezen and their speech and language therapists, namely Andreas Boensch. Furthermore, my gratitude goes out to the 50 non-brain-damagednon-brain-damaged participants, as well as to the 38 students who took part in the study.

Thank you, Yvonne Altermann and Frauke Sziedat, who are not only my friends but also happen to be speech and language therapists, for checking and counterchecking my ideas on aphasic and neuropsychological aspects and providing helpful advice.

A heartfelt thanks to Giuosy and Paloma for letting me have their cottage in Sicily to write the final version.

Thank you, Frans and Mieke, for your loyalty, patience and unwavering love.

Finally, I express my deepest gratitude to my parents who always believed in me and supported me not only morally and financially but also recruited all their friends to participate in my study.

This book is dedicated to my parents, Elisabeth and Jürgen Jochmann

Abstract

In aphasia, and especially in agrammatic aphasia, comprehension of auditorily presented non-canonical, e.g., object-first, sentence types, is more impaired than that of canonical or subject-first sentences. Furthermore, persons with aphasia (PWA) often complain that people speak too fast. Studies have shown that agrammatic PWA improve significantly in processing object-first structures when speech rate is slowed down. The *Slowed Processing Hypothesis* (e.g., Burchert, Hanne, & Vasishth, 2013; Love, Swinney, Walenski, & Zurif, 2008) suggests that in agrammatic aphasia syntactic knowledge as such is not impaired, but that lexical, morphosyntactic or syntactic parsing is slowed down, i.e., slower than that of unimpaired listeners, and that therefore the time course of the acoustic presentation is too fast for agrammatic PWA in order to compute a syntactic representation of the sentence in the given time. For German agrammatic PWA, this *timing* deficit may affect in particular the integration of morphosyntactic case and/or agreement features (e.g., Hanne, Sekerina, Vasishth, Burchert, & de Bleser, 2011).

Many PWA also experience deficits of intelligibility because of a hearing impairment, and may thus be even more handicapped in understanding conversational speech, as reduced intelligibility has also been seen to impact on comprehension. Slower speech has been found to facilitate intelligibility and thus comprehension for spoken sentences in hearing-impaired non-brain-damaged adults, who are also assumed to be slower in processing caused by a higher perceptual load due to the degraded acoustic signal.

Following these findings, the aims of this study were to investigate the effect of hearing impairment on aphasic comprehension, as well as the effect of slower speech on comprehension for normal-hearing and hearing-impaired PWA, and in particular for agrammatic PWA. Slower speech was expected to compensate for the timing deficit, specifically by aiding processing of morphosyntactic markers. It was predicted that prolonged presentation time in terms of a slower speech rate would facilitate comprehension performance for normal-hearing PWA for non-canonical sentences, compared to performance at a normal speech rate. Hearing-impaired PWA were supposed to benefit even more from a slower speech rate in general comprehension than their normal-hearing counterparts. Also, hearing-impaired non-brain-damaged listeners (NBD) were predicted to profit from slower speech for non-canonical sentence comprehension. Hypotheses were tested by measuring comprehension accuracy on four different German syntactic structures (canonical and non-canonical verb-second- and centre-embedded relative clauses) in three different speech rates. 37 PWA, including 15 agrammatic PWA, were assessed; 25 of them presented with normal-hearing and 12 were hearing-impaired. In addition, 27 NBD with hearing impairment and 23 normal-hearing NBD were assessed. Results showed that especially agrammatic PWA improved comprehension of centre-embedded relative clauses in slower speech. For hearing-impaired PWA, slower speech did not facilitate comprehension to a higher degree, and even more, hearing-impaired PWA had a higher rate of non-canonical sentence comprehension accuracy compared to their normal-hearing counterparts. Neither did slower speech improve comprehension of non-canonical sentences in hearing-impaired NBD significantly. The results of the agrammatic PWA, indicating improved recognition and/or integration of morphosyntactic features through slower speech, were tentatively in line with the Slowed Processing Hypothesis.

1 Introduction

It is well known that in agrammatic and other types of aphasia, auditory comprehension of non-canonical sentences, e.g., object-first clauses, is often more deficient than that of canonical ones, e.g., subject-first clauses (Caramazza, Berndt, Basili, & Keller, 1981; Dick, Bates, Wulfeck, Utman, Dronkers, & Gernsbacher, 2001; Wilson & Saygin, 2004), which may partly be caused by insufficient processing of morphosyntactic features distinguishing a syntactic subject from a syntactic object (Bates, Friederici, & Wulfeck, 1987; Burchert, de Bleser, & Sonntag, 2003; MacWhinney, Osmán-Sági, & Slobin, 1991): In recent eye -tracking studies, German agrammatic and other persons with aphasia (PWA) were noted to be affected in the timely integration and/or interpretation of case and agreement features (e.g., Hanne *et al*., 2011; Hanne, Burchert, de Bleser, & Vasishth, 2015; Schumacher *et al*., 2015). For supporters of the *Slowed Processing Hypothesis* (e.g., Burchert *et al*., 2013; Burkhardt, Avrutin, Piñango, & Ruigendijk, 2008; Dickey, Choy, & Thompson, 2007; Love *et al*., 2008), this so-called *canonicity effect* is assumed to be caused by slower-than normal processing, which may lead to a deficient timing between linguistic parsing operations and the auditory sentence presentation, and consecutively to processing delays, which in particular may affect comprehension of non-canonical structures. Slowing the input might counteract slowed-down processing speed and compensate for the timing deficit, and may facilitate PWA's general auditory speech and sentence processing (Blumstein, Katz, Goodglass, Shrier, & Dworetsky, 1985; Dickey *et al*., 2007; Love *et al*., 2008).

Auditory processing of non-canonical sentences can also be impaired in hearing impairment (Wingfield, *et al*., 2006; Wendt; Kollmeier, & Brand 2015). Here, prolonged perceptual processing time resulting from the degraded auditory input in hearing loss (Arlinger, Lunner, Lyxell, & Pichora-Fuller, 2009; Pichora-Fuller, 2003) might aggravate the risk of information loss. Similar to aphasia, slowing parts or the whole of the speech signal may compensate for potential processing delays and facilitate comprehension (e.g., Wingfield, Peelle, & Grossman, 2003; Gordon-Salant, Fitzgibbons, & Friedman, 2007).

The incidence of hearing loss in aphasia has been suggested to be even higher compared to that of non-brain-damaged hearing-impaired adults, which might be caused by cortical pathway degeneration (Torre, Cruickshanks, Klein, Klein, & Nondahl, 2005). Hearing-impaired PWA may thus face a double challenge in auditory language processing, and specifically for comprehension of non-canonical sentences, due to both aphasic and hearing-loss induced deficits.

The present study investigates the impact of hearing loss on sentence comprehension, and in particular on non-canonical sentence comprehension in aphasia, and also the potential facilitation of slower speech on comprehension. The present document is structured according to the following topics.

The first background part, chapter 2, gives a short description of syntactic and morphosyntactic properties of German active transitive clauses with a subject-direct object argument structure, which are used to test the hypotheses of this research. German, similar to English is assumed to have a subject-before-object (SO) basic word order. But in contrast to English, German has a relatively free word order, which allows word order reversal of subject and object in not only relative clauses, but also in verb-second clauses, such as in the active transitive object-before-subject (OVS) sentence in example (1.1).

(1.1) Den alten König tröstet der junge Prinz.
The$_{\text{ACC}}$ old$_{\text{ACC}}$ king comforts the$_{\text{NOM}}$ young$_{\text{NOM}}$ prince.
'It is the old king whom the young prince comforts.' (Uslar *et al*., 2013)

Within Generative Grammar (Chomsky, 1982), this reversal is explained as *movement* of the object from its original position to a position left to the subject in a surface structure. Because of this movement, *object-first* clauses can be considered to be syntactically more complex than subject-first clauses (e.g., Gibson, 1998). With regard to syntactic *complexity*, also centre-embedded clauses are argued to be more complex than non-embedded clauses (e.g., Caplan, Alpert, & Waters, 1998), and this chapter also describes the structure or German centre-embedded subject- and object- relative clauses, which are also implemented in this study.

In order to construct a syntactic representation of a clause, assignment of thematic roles to the syntactic subject and object is needed, which in German is aided by overt *morphosyntactic* features of *case* and *agreemen*t, where the subject can be identified by its overt nominative (NOM), and the object by its overt accusative (ACC) case-marking, seen in example (1.1) for the active transitive OVS example from above, and in example (1.2) for an active transitive subject-before-object verb-second clause (SVO). non-brain-damagednon-brain-damaged

(1.2) Der alte König tröstet den jungen Prinzen.
The$_{NOM}$ old$_{NOM}$ king comforts the$_{ACC}$ young$_{ACC}$ prince$_{ACC}$.
'The old king comforts the young prince.' (Uslar *et al*., 2013)

Chapter 3 provides an overview about processing object-first structures in German, namely active transitive OVS and active transitive centre-embedded object relative clause (OR) in German, with special reference to processing of morphosyntactic features in normal, non-brain-damaged listeners. While subject-first sentences, which have been termed *canonical* sentences, are assumed to be parsed *incrementally*, i.e., in a synchronous word-by word fashion in order to assign thematic roles and construct a syntactic representation (e.g., Bornkessel-Schlesewsky & Schlesewsky, 2012), for *non-canonical* object-first sentences, which may be regarded as structures deviating from the basic word order in German, additional processes are assumed. According to Generative Grammar, the moved syntactic object has to be reactivated and then integrated at the original position, i.e., the *trace* (e.g., Love *et al*., 2008). This process has been claimed to increase processing *load*, reflected by e.g., longer processing times and/or lower accuracy for object-first sentences compared to those for subject-first ones (e.g., Frazier & Fodor, 1978). However, observations of online processing of German non-canonical sentences indicate that healthy, non-brain-damaged, listeners are able to assign the correct thematic role to overtly case-marked sentence-initial objects immediately, which suggests an alternative morphological processing route (e.g., Bornkessel & Schlesewsky, 2006). Despite this rapid integration, *canonicity effects* because of a higher processing load have also been noted for unambiguously case-marked sentences (e.g., Carroll & Ruigendijk, 2013; Hanne *et al*., 2011), which may result from having to override a *subject-first processing preference*. Therefore, in German syntactic sentence processing may be influenced by morphological as well as cognitive processing routes.

Auditory processing of sentences is considered to demand the exact *timing* of several lexical, morphological and syntactic parsing processes with the time course of the presentation (e.g., Love *et al*., 2008). Timing has been considered to be related to *processing speed*, which may impact on the temporal processing course of linguistic operations (e.g., Caplan, Waters, & Albert, 2003). Disturbed timing has been argued to result in processing delays in particular for non-canonical sentences, which may increase the risk of neglect or decay of information and thus the risk of a misinterpretation. Furthermore, other cognitive functions, such as working memory and cognitive control, are assumed to be especially involved in non-canonical sentence parsing in order to supervise syntactic parsing and revise incorrect representations (e.g., Gibson, 1998).

Difficulties processing non-canonical sentences is a main feature of sentence comprehension deficits in aphasia, and chapter 4 introduces findings and discusses possible underlying cause(s). While comprehension of canonical structures seems to be less difficult, object-first structures have been noted to be often misinterpreted by persons with aphasia (PWA). To some extent, this might be caused by an impaired ability to process case and/or agreement features sufficiently for a correct syntactic object integration: If these morphosyntactic cues cannot be processed completely, inverted word order might not be noticed and thematic roles might not be assigned correctly, which in turn might result in a predominant reliance on non-syntactic, heuristic processing strategies. Insufficient processing of morphosyntactic cues in aphasia has been demonstrated by results from cross-linguistic aphasia research (e.g., Bates *et al.*, 1987), and recently, German researchers using the visual world paradigm task to study online behaviour of German agrammatic and other PWA (e.g., Hanne *et al.*, 2011; Schumacher *et al.*, 2015). Their findings suggest that PWA may be sensitive to the features but appear to have difficulties integrating those for a correct thematic role assignment.

While the underlying cause of these difficulties might be different for each of the several types of aphasias, for agrammatic aphasia, one account, the Trace Deletion Hypothesis (TDH; Grodzinsky, 1995) seeks to explain the canonicity effect through *loss of syntactic knowledge* resulting in particular in deletion of traces left by a moved noun phrase (NP). The supporters of the *Slowed Processing Hypothesis* (SPH) (e.g., Burkhardt *et al.*, 2003, 2008; Garaffa & Grillo, 2007; Hanne *et al.*, 2011, 2015; Love *et al.*, 2008; Zurif *et al.*, 1993) on the other hand assume that deficient comprehension of non-canonical structures is caused by *temporal* linguistic processing deficits, i.e., that in agrammatic aphasia the *timing* between presentation and processing is disturbed. According to the SPH, agrammatic PWA have an intact syntactic knowledge, but syntactic parsing procedures might be affected by processing or capacity limitations, resulting in slowed-down parsing with the risk of parsing breakdowns, in particular for non-canonical structures. Agrammatic PWA have been found to be slower-than-normal in their linguistic processing (e.g., Hanne *et al.*, 2011, Love *et al.*, 2008; Schumacher *et al.*, 2015), and this slowed-down processing has been seen to delay parsing, which affected in particular object-first sentences: If lexical and/or syntactic processing of a sentential element is slower, i.e. takes longer than the presentation time of this element, processing of the element before the trace may overlay the occurrence of the trace, and the object may not be integrated into the representation. Within this account, there are differences regarding the cause of the processing limitation. Some researchers trace it down to specific linguistic limitations, leading to processing delays in either lexical access (e.g., Love *et al.*, 2008), lexical integration (e.g., Dickey *et al.*, 2007), morphosyntactic integration (e.g., Hanne *et al.*, 2011) or syntactic parsing (e.g., Burkhardt *et al.*, 2008), while others assume that slower-than-normal processing in agrammatic aphasia is caused by a pathological reduction of processing speed (e.g., Swinney *et al.*, 1993). However, some researchers claim (e.g., Burchert *et al.*, 2013) that those proposed syntactic breakdowns do not necessarily have to be a permanent feature of agrammatic processing (and also for other PWA), but may be due to intermittent deficiencies, caused by temporary reductions in processing resources, produced by e.g., higher demands on working memory (e.g., Caplan, Waters, DeDe, Michaud, & Reddy, 2007).

It has been seen that PWA in general are not only impaired in processing speed (e.g., Neto & Santos, 2012), but often also present with deficits of working memory and executive functions (e.g., Laures-Gore, Shisler Marshall, & Verner, 2011; Hula & MacNeill, 2008) which may also affect their abilities of non-canonical sentence processing, because storage abilities of the antecedent may be limited and/or initial canonical interpretations of non-canonical items cannot be revised (e.g., Miyake, Carpenter, & Just,1994). Cognitive abilities may interact, in as such that a reduction of working memory capacity may impact on speed of processing (e.g., Miyake *et al.*, 1994), while vice versa, reduced processing speed may affect working memory and/or executive abilities (e.g., Tun, 1998). Slower speech is assumed to compensate at least partially for the timing deficiency, and the chapter reviews the facilitating effect of slower speech on sentence processing in aphasia.

Chapter 5 discusses sentence processing in hearing impairment. Hearing loss, which can be distinguished by different caused and degrees, has been seen to affect perception of phonemes and words, which in turn may affect in particular non-canonical sentence comprehension (e.g., Uslar, 2014; Wendt *et al.*, 2015; Wingfield *et al.*, 2006). Similar to aphasia, the canonicity effects of hearing-impaired adults are also assumed to be induced by a timing deficit, but in hearing loss, the timing insufficiency is proposed to occur by needing more time for the perceptual decoding of the degraded acoustic signal, leaving less time for parsing (e.g., Arlinger *et al.*, 2009; Gordon-Salant & Fitzgibbons, 2004), which also bears the risk of not recognizing or neglecting postulated traces in non-canonical structures and/or not perceiving less-accentuated morphosyntactic cues. Timing may also be affected in older adults and the combination of age and hearing loss may aggravate problems in non-canonical sentence comprehension (e.g., Wingfield *et al.*, 2003, 2006) because of the presence of two factors taken responsible for slowed-down processing: While processing in hearing loss is assumed to be slower because of an increased perceptual load, in age (from 60 years), a general pathological reduction of processing speed is hypothesized (Salthouse, 1996, 2000). Besides that, cognitive straining through hearing loss and cognitive ability or capacity reductions through age may also exacerbate processing difficulties of complex syntactic structures in hearing-impaired older listeners (e.g., Tun, 1998). Similar to aphasia, slower speech may aid sentence comprehension in hearing-impaired and/or older adults (e.g., Wingfield *et al.*, 2003; Digiovanni & Stover, 2008; Gordon-Salant *et al.*, 2007), implying that the timing deficit can be at least partially compensated for with a longer presentation duration. In contrast, hearing aids used to correct for insufficient hearing thresholds, can only partially restore timing insufficiencies (e.g., Martin & Jaeger, 2005).

The incidence of hearing impairment in aphasia may have an aggravated negative effect on non-canonical sentence comprehension, as discussed in chapter 6. There is evidence that a high number of PWA present with hearing loss (e.g., Torre *et al.*, 2005), and that in a high number of PWA, hearing loss is undetected (e.g., Läßig, Kreter, Nospes, & Keilmann, 2013). Many PWA have been noted to present with deficits in speech perception and auditory sentence comprehension, which might be partly caused by hearing loss.

The aim of this research was to study systematically the effect of a prolonged auditory presentation on sentence comprehension, and markedly that on non-canonical sentence comprehension for PWA with and without hearing impairment. While the effect of slower speech on comprehension has been studied before, test items were in English without overt morphosyntactic markers, so potential lexical effects could not be distinguished from morphosyntactic ones. Besides implementing active transitive verb-second (V2) clauses, i.e., the canonical subject-verb-object clause (SVO) and the centre-embedded subject relative clause (SR), testing accuracy on German non-canonical structures, i.e., the verb second object-verb-subject clause (OVS), and the centre-embedded object relative clause (OR) with overt case markers and/or agreement cues, might shed further light on potential causes of the canonicity effect in aphasia and hearing impairment.

This study investigates if prolonged presentation can compensate for the proposed timing deficit in aphasia and hearing impairment. The results may contribute to a better understanding of sentence processing in aphasia, and specifically of that in agrammatic aphasia. Likewise, the results may add to theories on sentence processing in hearing impairment. This study, part of the DFG-funded research project "AULIN" (AUdiology and LINguistics; *Understanding Speech Under Fluctuating Noise in Children and Adults from an Audiological and Psycholinguistic Viewpoint*), seeks more insight into the following questions:

1. Are PWA, and in particular agrammatic PWA, with a hearing impairment more affected in general auditory sentence comprehension, and especially in non-canonical sentence comprehension, than their normal-hearing counterparts?
2. Can slower speech facilitate general and non-canonical sentence comprehension for agrammatic and other PWA, and is this hypothesized positive effect of slower speech higher for hearing-impaired PWA compared to normal-hearing PWA?
3. Is non-canonical sentence comprehension affected in hearing-impaired non-brain-damaged adults (NBD), and can slower speech facilitate in particular the comprehension of non-canonical sentences for hearing-impaired NBD?

In chapter 9 and 10, results of accuracy on a sentence-picture matching task on the verb-second structures respectively centre-embedded relative clause sentences are presented. First, results of a young control group demonstrated the validity of the test. Second, the results of a group comparison between the non-brain-damaged and the aphasic group are investigated. This is followed by the results of the group of PWA, where the effect of aphasia and the effect of hearing impairment in aphasia on comprehension performance are analysed. Thereafter, the impact of agrammatic aphasia on sentence comprehension is examined. Last, in order to see the impact of hearing impairment on non-brain-damaged sentence comprehension, results of NBD are shown. In the discussion section of each result chapter, the results are discussed with regard to findings of other studies. In particular, group and individual performance of agrammatic PWA are analysed with regard to performance patterns postulated by the TDH, and also with criteria allowing to compare individual agrammatic accuracy to that of the NBD.

While hearing-impaired PWA demonstrated a lower accuracy on general comprehension than the normal-hearing PWA, hearing loss had a reverse effect on non-canonical comprehension performance in as such that hearing-impaired PWA demonstrated better comprehension for OVS and OR than the normal-hearing group. Slower speech did not facilitate aphasic and agrammatic comprehension of verb-second sentences, but comprehension of centre-embedded relative clause sentences improved for agrammatic PWA at the very slow speech rate. Hearing-impaired NBD demonstrated a marginal canonicity effect in their comprehension of OR. Slower speech did not facilitate their comprehension, but that of the normal-hearing NBD for the centre-embedded relative clause items.

The findings, discussed in in interim discussion sections accompanying each result sections as well as in chapter 11, imply tentatively that in agrammatic and other aphasia, the syntactic processing deficit may be partly induced by a pathologically slowed-down processing of morphosyntactic features, resulting in a timing deficit, which can partly be compensated for by slower speech. Also, it is speculated that slower speech might have reduced working memory load in agrammatic aphasia, reflected in the positive effect of slower speech on both centre-embedded SR and OR. While agrammatic group performance on OVS might not contradict the assumption of trace deletion, performance patterns and the positive effect of slower speech on the embedded relative clauses give tentative evidence in favour of the Slowed Processing Hypothesis. Dissociations in performance patterns across syntactic structures and speech rates within the agrammatic group and within individual agrammatic PWA may indicate that the postulated processing limitations in agrammatic PWA may rather be caused by intermittent deficiencies than by a permanent processing deficit.

Hearing loss did not affect non-canonical sentence comprehension in the whole group of PWA in this study, which might have been due to the lack of matching of certain variables between the hearing-impaired and the normal-hearing aphasic sub groups. In contrast, high-frequency hearing loss in NBD seemed to affect general comprehension, and tendentially also that of OR. This might have been caused by a perceptual deficit of identification and/or discrimination of non-accentuated morphosyntactic agreement features.

Although the effect of hearing loss on non-canonical sentence comprehension in aphasia could not be established in this study, the potential negative impact of hearing impairment should always be considered in aphasia therapy as well as in aphasia research. In addition, hearing level assessment and classification of hearing status including the hearing level of higher frequencies might give a more distinguished overview on intelligibility abilities, as higher frequency hearing loss has been seen to affect auditory sentence comprehension in this study.

2 A short overview on syntactic and morphosyntactic properties of active transitive clauses in German

Compared to English, German has a relatively free word order, allowing a reversal of positions of syntactic subject and object in not only relative clauses but also in verb-second-clauses. While there are different approaches trying to explain word order reversal, this chapter only describes this process according to one account within Generative Grammar as movement of the object from its original position after the verb in an underlying structure to a position left to the subject in a surface structure. Object-first clauses are considered to be syntactically more complex than subject-first clauses. Another structure argued to be syntactically complex is embedding of a clause within another clause.

For a syntactic representation of a transitive clause and its semantic interpretation, assignment of thematic or theta roles, is needed, which in German is aided by morphosyntactic features, which can mark the subject and object overtly for *case*, and the verb for *agreement* with the subject. Case is argued to be closely related to the thematic roles of a syntactic element, which it marks, and overt case may facilitate early syntactic and semantic processing. . non-brain-damagednon-brain-damagedAgreement features on the other hand aid interpretation in particular when case markers are ambiguous.

This chapter can only give a short overview and describe some features of German (morpho)syntax, i.e., active verb-second (V2) and relative clauses (RC) with an active transitive verb demanding a subject and a direct object as arguments, and the morphosyntactic features of nominative and accusative case and agreement, leaving out other clause structures, such as questions and passives, other verbs, such as transitive verbs with an indirect object or ditransitive verbs, and other morphosyntactic cues, such as e.g., dative and genitive case, plural markers and personal pronoun. Nevertheless, studying processing differences between active transitive subject-first and object-first V2 or RC sentence types has been the focus of a number of recent German studies as well as the current one because these can be constructed as syntactic minimal pairs with the only difference being the word order of the verb arguments.

2.1 Word order

The majority of languages in the world seems to follow a basic subject-before object order (cf. Tomlin, 1986, who compared the syntax of over 400 languages), and also in German it is argued that the basic or *unmarked* word order in sentences consists of a subject before object order (SO) (e.g., Bader & Frazier, 2005; Bader & Häussler, 2010). However, there is ongoing debate (Bader & Häussler, 2010) whether the *unmarked*, basic word order in German is one of subject-object-verb (SOV) (e.g., Haider, 2010) or of subject-verb-object (SVO) (Anderson, 1993; Hawkins, 1983), Supporters of the SOV account claim that German is a head-final language (i.e., the head of a phrase is in the right position), and that both subject and (object) Noun Phrases (NP) are generated in the verbal phrase (VP) as arguments of a transitive verb in positions left or fronted to the verb position, shown in example (2.1) (in the case of an intransitive verb, only the subject, and in the case of a ditransitive verb, a subject, a direct and an indirect object are generated) (cf. Haider, 2010).

(2.1) $[_{VP}[$ NP NP V]

In the case of many active transitive verbs, these VP-internal positions of NP are argued to assign the thematic or theta *roles*, such as *agent* and *recipient* or *patient*[1], to the syntactic subject and object (Chomsky, 1982; Grodzinsky, 1995)[2]. This argument structure of transitive verbs with a direct object may be regarded as a "who did what", and those of transitive verbs with an indirect object as "who did to whom" manner, and in the case of ditransitive verbs as a "who did what to whom" manner (cf. Bornkessel, Zysset, Friederici, von Cramon, & Schlesewsky, 2005). Furthermore, the unmarked word order in German is believed by some supporters to be determined by the verb and its arguments, in as such that the subject precedes the object(s) already in the VP[3] (cf. Haider, 1985; and Haider, 2010 for an overview). The underlying structure of German word order is far from being without controversy among

[1] Dependend on the semantics of the verb, the direct object may either be a recipient of an action executed by the agent or a patient (cf. Dowty, 1991). For the sake of simplicity, only the term *patient* will be used in this book.
[2] Note that this notion is also highly controversial (cf. Haider, 2010; Marantz, 2013 among others). For example, many transitive verbs can also be intransitive, demanding only one argument. Psych-verbs (verbs referring to an emotion and/or mental state). may behave completely different than other transitive verbs, and active transitive verbs in one language may take different arguments in another language (see Marantz, 2013 for an analysis of argument structures of verbs).
[3] In contrast, it is argued that the specific lexical-semantic properties of a verb may determine the NP order in the VP. For example, in some psych-verbs, OS has been considered to be the unmarked word order (cf. Bader & Häusler.

different syntactic theories and even within Generative Grammar, and there are many different approaches to explain and describe object-before-subject structures. Accounts[4] postulating German to be a SOV language assume that an unmarked, *basic* clause has its verb in a final position, as shown in example (2.2).

(2.2) (Es ist schön, dass) der kleine Junge den dicken Nikolaus umarmt.
(It is nice that) the$_{\mathrm{NOM}}$ small$_{\mathrm{NOM}}$ boy the$_{\mathrm{ACC}}$ fat$_{\mathrm{ACC}}$ Santa Claus hugs.
'(It is nice that) the small boy hugs the fat Santa Claus.'

Some authors assume that SVO clauses are derived from an underlying SOV structure by two *movements* or *transformations* of the subject and the verb to the first respectively second sentential position. One approach (e.g., Bayer, 2008; Haider, 2010) suggests a movement of both verb and subject out of the VP into a higher phrasal node within the syntactic tree, the Inflectional Phrase (IP), whereby the subject is assumed to move to the Specifier position (SPEC) and the verb to the head position of the IP. This is argued to happen in order to form an agreement relation between subject and verb, which is specified for German, unlike in English, in terms of *number* (i.e., singular or plural feature of the subject) and partially also for *person* (see chapter 2.3.2 for an example). In order to generate the verb-second clause SVO, the verb is assumed to move to the head position of CP (see also example 2.4) , while the subject has been suggested to move to the SPEC position of the CP (cf. Penke, 2013), which alternatively has been named Frontal Phrase (XP) (e.g., Bayer, 2008; Rizzi, 1997). Figure 2.1 depicts this assumed subject movement from a postulated SOV sentence in example (2.2) to an SVO sentence in (2.3), not showing the postulated verb movement for terms of simplicity.

(2.3) Der kleine Junge umarmt den dicken Nikolaus.
'The small boy hugs the fat Santa Claus.' (Uslar *et al.*, 2013)

---

[4] The concept of movement is not uncontroversional, and among the different sub accounts within Generative or Transformational Grammar, there are different ideas about number of phrases, phrasal structure, and the original positions of sentential elements and their positions after movement. For the sake of simplicity, I only describe one conceptual approach with a simplified phrasal structure because transformational grammar as such is not the scope of this thesis.

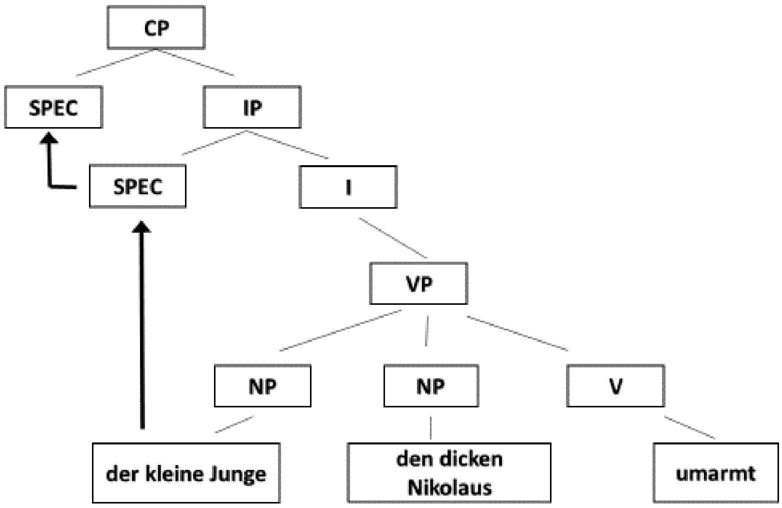

Figure 2.1. Simplified description of subject movement in a SVO structure according to an SOV account.

In contrast, in subject-relative clauses like example (2.2), which is proposed to follow the underlying SOV word order, the head position of the higher Complementizer Phrase (CP) is assumed to be occupied by a complementizer, such as “dass” (*that*) in example (2.2).

These postulated movements are assumed to leave traces (t) at both the original and the intermediate positions, signified by a proposed gap (_), as shown in example (2.4).

(2.4) [CP [der kleine Junge] [C umarmt$_V$] [IP [I_$_{tV}$ [VP [den dicken Nikolaus] _$_{tV}$]]]]]

While the proposed verb movement is also controversial within Generative Grammar (cf. Weyerts, Penke, Münte, Heinze, & Clahsen, 2002), verb movement nevertheless does not seem to affect comprehension in healthy and/or language impaired individuals (e.g., Weyerts *et al*., 2002), maybe because the verb-second-position may provide an earlier availability of the syntactic properties of the verb, e.g., information about the arguments of the verb in terms of thematic or *theta* roles, as compared to the V-final position, where verification of this information can only be obtained after the occurrence of all the arguments of the verb (Bayer, 2008).

In German, unlike in English, OVS sentences are possible. In example (2.5), the object “den dicken Nikolaus” (*the fat Santa Claus*) precedes the subject “der kleine Junge” (*the little boy*), while the verb keeps its sentence-second position.

(2.5) Den dicken Nikolaus$_i$ umarmt der kleine Junge_$_i$.
‘It is the fat Santa Claus whom the small boy hugs.’ (Uslar *et al*., 2013)

According to some supporters of Generative Grammar (e.g., Chomsky, 1982), the object has moved from its original site preceded by the finite verb (_) to a leftward position in SPEC/CP, as shown in figure (2.2), while the subject is argued to stay in the SPEC/IP position where it has moved to from its original position within the VP. In addition, the verb, as already described above, is assumed to move to the head of IP (not depicted in figure (2.2)).

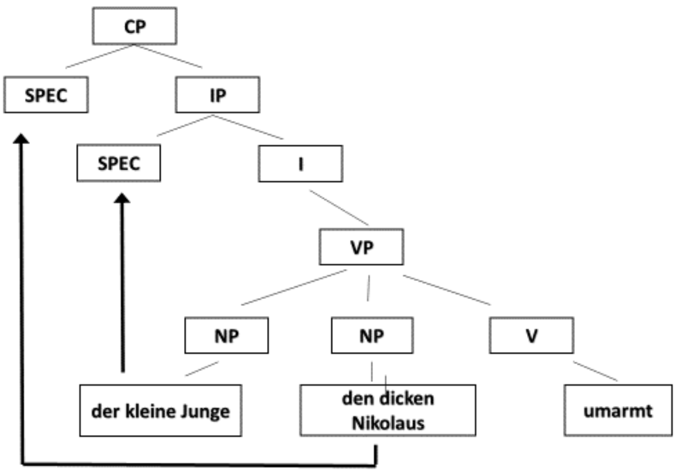

Figure 2.1. Simplified description of movement of the object from its canonical position over the subject to the Spec/CP position.

This movement of the object ($_i$) is also assumed to leave a gap (_) behind the verb, and a trace (t) signifying that gap (cf. Bader & Frazier, 2005; Chomsky, 1982; Fanselow &

Lenertova, 2011). This *antecedent-trace dependency* or *relation* defines the moved object as the antecedent of the trace left behind. It is argued that the thematic role of the syntactic object can only be assigned at its original position (e.g., Grodzinsky, 1995), and consecutively, the moved element can only be identified as syntactic object when the trace is encountered and recognized as original site of the moved constituent, and the *antecedent* is filled in or *integrated*. Because of this movement, this object-first structure is considered syntactically more *complex* than the simpler SVO structure (e.g., Chomsky, 1982; Gibson, 1998). In addition, (2.3) and (2.5) can be viewed as a *syntactic minimal pair*, because they only differ in one property, namely the order of the arguments (cf. Haider, 2010).

Not only verb-second clauses, but relative clause structures can be transformed in object-first structures. In example (2.6), the object relative clause is assumed to contain a moved object occurring to the left of the subject, whereby the object has been suggested to have moved to the head position to CP, because the SPEC position is argued to be occupied by the complementizer "dass" (*that*), while both subject and verb have moved to the IP (e.g., Haider, 2010).

(2.6) (Es ist schön, dass) den dicken Nikolaus$_i$ der kleine Junge umarmt_$_i$.
'(It is nice that) the fat Santa Claus is hugged by the small boy.'
Es ist schön) $_{CP}$[dass den dicken Nikolaus $_{IP}$[der kleine Junge umarmt]]

2.2 Embedding

Besides branching relative clauses, such as the right-branching examples (2.2) and (2.6), German, like English and many other languages, also allows *centre-embedded* relative clauses (RC) enclosed by a verb-second clause, the *matrix* clause, such as centre-embedded subject-relative (SR) and object-relative clauses (OR). Due to this property, centre-embedded clauses have been considered also as syntactically more complex than branching relative clauses. Examples (2.7 to 2.9) may be regarded with increasing complexity. First, it is argued that (2.8) and (2.9) contain two thematic propositions, and while in (2.8) the thematic propositions are coordinated, in (2.9), they are not coordinated. More, the proposition of the matrix clause is also part of the relative clause, which cannot be interpreted without an interpretation of the matrix clause (Caplan *et al*., 1998)

(2.7) Der Junge umarmt den weinenden Nikolaus.
‘The boy hugs the crying Santa Claus.’

(2.8) Der Junge umarmt den Nikolaus, der weint.
‘The boy hugs the Santa Claus who cries.’

(2.9) Der Junge$_j$, der$_j$ den Nikolaus umarmt, weint.
‘The boy, who hugs the Santa Claus, cries.’

Second, in embedded RC, a relative pronoun normally establishes the relationship between the matrix subject and another NP in the embedded clause. The subject of the matrix clause and the subject of the embedded SR in (2.9) are co-indexed (j). This *antecedent-pronoun dependency* may also add to the syntactic complexity.

Moreover, complexity is assumed to increase even more in embedded structures containing an object-relative clause, as for example (2.10). Also, semantic complexity is assumed to increase: In (2.10), the subject of the matrix clause is the object of the relative clause, which is also associated with rising syntactic complexity (MacWhinney & Pleh, 1988). Still, is is possible to consider (2.9) and (2.10) as members of a syntactic minimal pair due to the difference in the argument order.

(2.10) Der Junge, den der Nikolaus umarmt, ist klein.
‘The boy$_j$ whom$_{ij}$ the Santa Claus hugs_$_i$ is small.’

Recent research using verb-second and centre-embedded sentences with the same number of words (e.g., examples 2.3, 2.5, 2.9, 2.10) found longer processing time for the RC sentences compared to the V2 sentences (e.g., Wendt, Brand, & Kollmeier, 2014) or lower accuracy (e.g., Carroll & Ruigendijk, 2013), indicating that centre-embedded sentences seemed to be more difficult to process than verb-second clauses. Moreover, accuracy was lower on centre-embedded OR compared to OVS (e.g., Carroll & Ruigendik, 2013; Wendt *et al*., 2014).

2.3 The morphosyntactic markers of case and agreement

The relatively free word order in German, reflected for example in topicalized OVS, is assumed to be generated through a relatively rich morphological system for case and agreement marking, compared to that of English. In particular, morphosyntactic *overt* marking of case has been seen to facilitate sentence comprehension from early stages (e.g., from the sentence-initial NP) on.

2.3.1 Case

Case, at least abstract case, is obligatory for every NP containing an overt or covert determiner, realized in the Determiner Phrase (DP) (Haider, 2010), While case can be assigned *covertly*, i.e., without visible morphological cues, *overt* case marking can change the morphological form of a determiner, adjective, noun or.

In the following, the morphosyntactic system of in particular nominative and accusative case for determiners and relative pronouns (and in less detail for adjectives and nouns) will be outlined. German has four cases, i.e., nominative, *accusative, dative* and *genitive*. Nominative case marks the subject, accusative case the direct object, and dative case the indirect object. Genitive case also marks nouns, which often act as modifier for other nouns. All relative pronouns, determiners and adjectives in pre-nominal position are marked for case, and in the case of *weak* nouns (see below) the noun itself may be morphologically inflected for case.

In German, all nouns except for mass nouns and countable plural nouns demand determiners, which can be definite or indefinite. Determiners are not only marked for case and definiteness -definite vs indefinite-but also for gender-feminine, masculine, neutral- and number. While definite determiners for feminine and neutral nouns have the same morphological form for both nominative and accusative case, definite determiners for masculine singular nouns display different morphological forms with overt case markings. Plural nouns in contrasts, regardless of the gender, only have one morphological form for as well nominative and accusative case; which has the same form as the singular feminine determiner, but distinct forms for the other two cases. This case *syncretism* can lead to *ambiguity*[5] in sentences (cf. Burchert *et al.*, 2003; see below). A similar case syncretism occurs for indefinite determiners. Masculine and neutral nouns can be considered as either *strong* or *weak*, and in the case of weak nouns, they carry case markers for accusative and dative case[6]. Table 2.1 depicts the German case system for definite and indefinite determiners for a strong masculine noun ("Mann", *man*), a weak masculine noun ("Junge", *boy*) a feminine noun ("Frau", *woman*), and a neutral noun ("Kind", *child*) and a plural masculine noun ("Männer", *men*)[7]. Note that overt case can mark the noun itself in form of affixes.

Table 2.1. The German case system for definite (def) and indefinite (ind) determiners. Case syncretisms are marked in bold.

Gender	nominative	accusative	dative	Genitive
masculine:				
a) strong (def)	der Mann	den Mann	dem Mann	des Mannes
strong (ind)	ein Mann	einen Mann	einem Mann	eines Mannes
b) weak (def)	der Junge	den Jungen	dem Jungen	des Jungens
weak (ind)	ein Junge	einen Jungen	einem Jungen	eines Jungens
feminine(def)	**die** Frau	**die** Frau	**der** Frau	**der** Frau
feminine (ind)	**eine** Frau	**eine** Frau	**einer** Frau	**einer** Frau
neutral (def)	**das** Kind	**das** Kind	dem Kind	des Kindes
neutral (ind)	ein Kind	einen Kind	einem Kind	eines Kindes
Plural (def)	**die** Männer	**die** Männer	den Männern	der Männer
Plural (ind)	Männer	Männer	Männern	-

Adjectives preceding a noun with a definite determiner are also case-marked, but, seen in table 2.3, not as distinctively as definite determiners themselves. In contrast, adjectives preceded by an indefinite determiner show more distinct morphological forms, especially for nominative case.

[5] While there are many different forms of ambiguity (e.g., structural *garden pathes* or other ambiguities resulting from verbs, which can have different argument structures), the concept of ambiguity in this book is constrained to case-invoked ambiguity.
[6] Note that in German, many nouns- mostly with masculine or neutral gender- are morphologically strong because they do not demand a case inflection of the noun, hence DPs containing a morphologically strong noun and an adjective have two case cues only (on the determiner and the adjective), whereas DP with a morphologically weak noun and an adjective contain another case cue on the noun itself. Carroll (2013) showed that this morphological variance was equal for SVO and OVS in the stimuli used for the present research, so it is expected that statistical analyses should not be confounded by this difference.
[7] Indefinite forms will be neglected, because they do not occur in the present study.

Table 2.2. Case marking on adjectives before definite (def) and indefinite (ind) determiners.

Gender	**nominative**	**accusative**	**Dative**	**genitive**
masculine (def):	der kleine Mann	den kleinen Mann	dem kleinen Mann	des kleinen Mannes
masculine (ind)	ein kleiner Mann	einen kleinen Mann	einem kleinen Mann	eines kleinen Mannes
feminine (def)	die kleine Frau	die kleine Frau	der kleinen Frau	der kleinen Frau
feminine (ind)	eine kleine Frau	eine kleine Frau	einer kleinen Frau	einer kleinen Frau
neutral (def)	das kleine Kind	das kleine Kind	dem kleinen Kind	des kleinen Kindes
neutral (ind)	ein kleines Kind	ein kleines Kind	einem kleinen Kind	eines kleinen Kindes
plural (def)	die kleinen Männer	die kleinen Männer	den kleinen Männern	der kleinen Männer
plural (ind)	kleine Männer	kleinen Männer	kleinen Männern	kleinen Männern

A more detailed look at the verb-second clause examples from above show that the determiners of both DP are overtly case-marked, enabling to identify the first DP in (2.11) as the subject and thus agent through its nominative (NOM) case markers, and the first DP in (2.12) as the object and patient through is overt accusative (ACC) markers.

(2.11) Der kleine Junge umarmt den dicken Nikolaus.
The$_{\mathrm{NOM}}$ small$_{\mathrm{NOM}}$ boy$_{\mathrm{NOM}}$ hugs the$_{\mathrm{ACC}}$ fat$_{\mathrm{ACC}}$ Santa Claus
'The small boy hugs the fat Santa Claus.'

(2.12) Den dicken Nikolaus$_i$ umarmt der kleine Junge_$_{ti}$.
The$_{\mathrm{ACC}}$ fat$_{\mathrm{ACC}}$ Santa Claus hugs the$_{\mathrm{NOM}}$ small$_{\mathrm{NOM}}$ boy$_{\mathrm{NOM}}$.
'It is the fat Santa Claus whom the small boy hugs'. (Uslar *et al.*, 2013)

Likewise, mentioned above, adjectives and weak nouns can also be case-marked. Note that both bold-marked affixes in example (2.13) are accusative case cues, resulting in a three-way case marking for this object DP.

(2.13) **Den** kleine**n** Junge**n** umarmt der dicke Nikolaus.
The$_{\mathrm{ACC}}$ small$_{\mathrm{ACC}}$ boy$_{\mathrm{ACC}}$ hugs the$_{\mathrm{NOM}}$ fat$_{\mathrm{NOM}}$ Santa Claus.
'It is the small boy whom the fat Santa Claus hugs.'

In contrast, the first DP in the verb-second clause OVS (2.14) is initially *ambiguous* for case (AMB), because the nominative case and the accusative case for female nouns have the same morphological form; the thematic role can only be assigned at the occurrence of the second DP, which is marked overtly for nominative case, signalling the agent role.

(2.14) Die stolze Frau tadelt der brave Soldat.
The$_{\mathrm{AMB}}$ proud$_{\mathrm{AMB}}$ woman$_{\mathrm{AMB}}$ scolds the$_{\mathrm{NOM}}$ nice$_{\mathrm{NOM}}$ soldier.
'It is the proud woman that the good soldier scolds.' (Uslar *et al*., 2013)

In transitive sentences, where both DPs signify singular female entities (or proper names), a disambiguation is not possible within the sentence structure, shown in example (2.15).

(2.15) Die stolze Frau tadelt die böse Hexe.
The$_{\mathrm{AMB}}$ proud$_{\mathrm{AMB}}$ woman scolds the$_{\mathrm{AMB}}$ bad$_{\mathrm{AMB}}$ witch.
‘The proud woman scolds the bad witch.’ or
‘It is the proud woman who the bad witch scolds.’

In contrast to English, in German, *relative pronouns* are also marked for gender, and only in the case of singular masculine antecedents, those pronouns have morphologically distinctive markers for all four cases. For feminine and neutral relative pronouns, the morphological forms for nominative and accusative case are the same. Plural relative pronouns are not distinguishable for nominative, accusative and dative case. On top of that, most of the relative pronouns have the same form as the definite determiners for the same case and gender, which adds to case syncreticism, seen in table 2.3 (marked boldly), and may enhance ambiguity.

Table 2.3. Case marking on relative pronouns in German. Case syncretisms are marked in bold.

Gender	**nominative**	**Accusative**	**dative**	**genitive**

masculine:	**der**	**den**	**dem**	dessen
feminine	**die**	**die**	**der**	deren
neutral	**das**	**das**	**dem**	dessen
plural	**die**	**die**	denen	deren

Unlike English, which uses the ambiguously case-marked relative pronouns “who” and “that” (and more rarely “whom”), German relative pronouns co-indexed with singular masculine entities in a DP may aid early thematic role assignment in both subject relative (example 2.16) and object-relative clauses (2.17). Similar to verb-second clauses, also in relative clauses a relative pronoun co-indexed with a singular female entity in a DP may lead to an initial ambiguity, which is solved at the occurrence of a second DP with a masculine noun, where the determiner is either marked for nominative case, as in the SR in example (2.18), or for accusative case in the OR in example (2.19). In contrast, ambiguity may not be solved in clauses containing two DP with singular feminine entities (2.20) or with plural entities (example 2.21).

(2.16) Der Junge$_j$, der$_j$ den Nikolaus umarmt, weint.
The$_{NOM}$ boy$_{NOM}$ who$_{NOM}$ the$_{ACC}$ Santa Claus hugs cries.
‘The boy, who hugs the Santa Claus, cries.’

(2.17) Der Junge$_j$, den$_j$ der Nikolaus umarmt, weint.
The$_{NOM}$ boy$_{NOM}$ whom$_{ACC}$ the$_{NOM}$ Santa Claus hugs cries.
‘The boy whom the Santa Claus hugs cries.’

(2.18) Die Frau$_j$ die$_j$ der Soldat tadelt, weint.
The$_{AMB}$ woman$_{AMB}$ who$_{AMB}$ the$_{NOM}$ soldier scolds, cries.
‘The woman who the soldier scolds, cries.’

(2.19) Die Frau$_j$ die$_j$ den Soldaten tadelt, weint.
The$_{AMB}$ woman$_{AMB}$ who$_{AMB}$ the$_{ACC}$ soldier$_{ACC}$ scolds, cries.
‘The woman who scolds the soldier cries.’

(2.20) Die Frau, die die Hexe tadelt, weint.
The$_{AMB}$ woman$_{AMB}$ who$_{AMB}$ the$_{AMB}$ Hexe scolds cries.
'The woman who scolds the witch cries.'or
'The woman who the witch scolds cries.'

(2.21) Die Frauen, die die Hexen tadeln, weinen.
The$_{AMB}$ women$_{AMB}$ who$_{AMB}$ the$_{AMB}$ Hexe scold cry.
'The women who scold the witches cry.'or
'The women who the witches scold cry.'

Case can be assigned *structurally* or*inherently, the latter not only by verbs but even* by *prepositions and nouns*. One difference between structurally- and inherently assigned case is that in inherent case assignment, a DP is argued to keep the same case independent of the syntactic construction (e.g., in certain psych-verbs, where the *experiencer* is always in dative case, no matter in what sentence-position it appears), whereas with structural case, a DP may change its case, depending on the syntactic , e.g. an accusative-marked DP in an active clausemay change to nominative marking in a passive construction (cf. Haider, 2010).

Case assigned by prepositions may also change dependent on the sentential context, e.g., the preposition "auf" (at) may assign accusative or dative case. While nominative and accusative case can be assigned structurally by (transitive) verbs, dative and genitive case are supposed to be inherently assigned by verbs or prepositions (dative) or nouns (genitive) (Haider, 1985; Heinz & Matiasek, 2004; Ruigendijk, 2002). In principle, any head is assumed to be able to assign case (Haider, 2010), but as in this research only test items with nominative and accusative case are used, the following description is constrained to these two cases. Nominative and accusative case are considered to be two forms of *structural* case, which is assigned by the argument structure of the transitive verb: Transitive verbs are assumed to assign nominative case to the subject by their agreement feature, and accusative case due to their transitive status as *internal* argument of the verb (cf. Haider, 2010), shown in example (2.22

(2.23) Der Junge umarmt den Nikolaus.

In addition, some researchers consider that the subject as an *external* argument of a transitive verb receives its nominative case in the SPEC/IP position by the inflected verb in the head position of the IP, while assignment of accusative case to the internal direct object argument is believed to happen within the VP (e.g., Heinz & Matiasek, 2004; Penke, 2013), but again this notion is not supported by all researchers (see e.g., Bornkessel-Schlesewsky & Schlesewsky, 2006, 2009).

Syntactic case- and thematic role assignment seem to be closely linked. While there is no linear mapping of a specific case to a specific thematic role, and vice versa, nominative case in German is nevertheless often associated with the agent role, and accusative case with the patient role in many active transitive verbs (the roles of agent and patient have been also named *actor* and *undergoer*; see e.g., Bornkessel-Schlesewsky & Schlesewsky, 2009) (e.g., Bader & Häusler, 2010; Dowty, 1991; Heinz & Matiasek, 2004). In contrast, in other transitive verbs, the psych-verbs, the dative object is associated with the thematic role *experiencer*; while in unaccusative verbs, there seems to be no agent at all (cf. Bader & Häusler, 2010; see also Dowty, 1991; Heinz & Matiasek, 2004). For instance, in some transitive verbs, such as “umarmen” (*to hug*), “tadeln” (*to scold*), “fangen” (*to catch*) or “erschiessen” (*to shoot*) the thematic relationship between the *action* of the verb and the thematic role of agent for the subject and patient for the direct object seems to be more clearly outlined, than for other transitive verbs, such as “kochen” (*to cook)* or “grüssen” (*to greet),* which may be used without an object and thus do not demand a patient role (Marantz, 2013; Heinz & Matiasek, 2004).

For German native speakers, overt case markings have been seen to facilitate syntactic processing, i.e., construction of a syntactic representation, because the presence of overt case in determiners already depicts the syntactic identity of subject or object of the DP and therefore the thematic roles. Studies investigating processing of German OVS with the visual world paradigm found that in overtly case-marked sentences, the case-marking information was rapidly processed and integrated into the representation (e.g., Hanne *et al.,* 2011; Schumacher *et al*., 2015; Wendt *et al*., 2015; see chapter 3 for more details on current research). For example, Hanne *et al.* (2011) for example used OVS items, such as example (2.23), and presented two pictures, one depicting the target and the other one a foil with reversed roles.

(2.23) Den Sohn küsst der Vater.

The$_{\mathrm{ACC}}$ son kisses the$_{\mathrm{NOM}}$ father.

'It is the son whom the father kisses.' (Hanne *et al*., 2011)

They observed that their participants rapidly recognized the first DP as object and patient, because their eye movements reflected a preference for the correct picture already during the verb region. This finding suggests that thematic role assignment took place before the second DP was presented.

2.3.2. Agreement

Not only case but also verb information in terms of *agreement* cues has been observed to aid identification of the subject, in particular when there is ambiguous case marking for either subject or object. The results of Hanne *et al*. (2015) and Knöferle (2007) experiments on ambiguous case processing indicate that in case of ambiguity participants use agreement features for correct sentence interpretation (but see chapter 3.1.1 for revision analyses triggered by agreement cues).

In German, the verb may not only be distinctively marked for number but also (partially) for person. Table 2.4 shows all forms of the verbs "umarmen" (*to hug*) and "weinen" (*to cry*) for the six person forms. Compared to English with only two forms, German has four distinctive agreement markers for regular verbs, but not as many as for example Italian, which provides different morphological inflections for each of the six grammatical persons.

Table 2.4. Verb inflections of agreement with singular (sing) and plural personal (pers) pronouns in German.

Person	**pronoun**	**umarmen**	**weinen**
1st pers sing	ich	umarme	weine
2nd pers sing	du	umarmst	weinst
3rd per sing	er/sie/es	umarmt	weint
1st pers plural	wir	umarmen	weinen
2nd per plural	ihr	umarmt	weint
3rd pers plural	sie	umarmen	weinen

In the examples (2.16) to (2.20), agreement does not help to identify subject and object, because all DP within one clause either contain singular or plural entities. In contrast, in the subject relative clause example (2.23), the singular number inflection (SG) of the verb "umarmt" (*hugs*) (marked boldly) agrees with the singular relative pronoun "der", while the plural inflection (PL) in the object-relative clause example (2.24) "umarmen" (*hug*) agrees with the DP "die Nikoläuse" (the Santa Clauses).

(2.23) Der Junge$_i$, der$_i$ die Nikoläuse umarm**t**$_{SG}$, ist klein.

Subject

'The boy who hugs the Santa Claus is small.'

(2.24) Der Junge$_i$, den$_i$ die Nikoläuse umarm**en**$_{PL}$, ist klein.

Subject

'The boy whom the Santa Claus hug is small.'

While in these examples agreement aids identification of the subject, which is already recognizable by the overt case features of the relative pronoun respectively determiner, in the centre-embedded subject-relative clause (2.25) and object-relative clause (2.26), singular or plural agreement features (marked boldly) are the only cue to identify the syntactic subject of the embedded clause, which is considered to be initially ambiguous effected by the covert case marking of the relative pronoun and the determiner of the DP.

(2.25) Die Detektive, die die Braut berühr**en**, gähnen.
The detectives, who$_{\mathrm{AMB}}$ the$_{\mathrm{AMB}}$ bride touch$_{\mathrm{PL}}$, yawn.
'The detectives who touch the bride yawn.'

(2.26) Die Detektive, die die Braut berühr**t**, gähnen.
The detectives, who$_{\mathrm{AMB}}$ the$_{\mathrm{AMB}}$ bride touches$_{\mathrm{SG}}$, yawn.
'The detectives who the bride touches yawn.' (Uslar *et al.*, 2013)

While German listeners were observed to use both case and agreement for sentence interpretation (Bates, McNew, MacWhinney, Devescovi, & Smith, 1982; Hanne *et al.*, 2015), case seems to be processed faster than agreement in terms of response times and/or target eye fixations (Adelt *et al*., 2017; Meng & Bader, 2000). This dissociation might be caused by the differences in *distance*: Case is assumed to be a *local* morphological feature, which can be processed quickly because of its immediate neighbourhood of the element, which it specifies (e.g., a case-marked determiner in a determiner-noun relationship), while *global* agreement features can be more distant from the element, which they agree with (e.g., with the subject in a subject relative clauses). In relative clauses such as (2.25) and (2.26) with verb-final position, identification of the of subject and object and thematic role assignment can only take place *after* occurrence of the verb and therefore after the occurrence of the two DP. Therefore, integrating agreement cues is thought to be more complex than that of case cues (Bates *et al.*, 1987; de Bleser *et al.*, 2005).

Summary

Due to a rich morphosyntactic system for case and (and lesser for) agreement marking, German allows a flexible word order including verb-second structures with the object in first position, something that is not possible in English. Overt case and agreement markers enable to construct syntactic minimal pairs of not only relative clause structures but also of verb-second sentence types, which allows to systematically investigate differences in processing between subject-first and object-first items of the same sentence type.

3 Non-canonical sentence processing in German

In this chapter, processing of auditorily presented object-first or non-canonical sentences by normal, language-unimpaired listeners is described as a process associated with a higher processing load induced by syntactic, informational, preferential and/or heuristic processing operations favouring a subject-first analysis. Higher processing costs in terms of e.g., processing times for object-first or non-canonical structures have been seen in many SO languages, but in this chapter, I will focus on canonicity effects in German.

The concept of canonicity is far from being uncontroversial, and definitions and underlying causes may not only vary between theories but also within the same theoretical account. This chapter gives an overview on some approaches on the underlying causes of the canonicity effect, without adopting a specific approach, because taking a stance does not add to the topic of this book. Moreover, while the term non-canonical may refer to all structures deviating from a basic word order in a specific language (e.g., in OS languages a subject-first structure may be considered as non-canonical), I will use the term *non-canonical* structures to refer to sentence structures violating the unmarked basic SO word order in German, and in particular to active transitive sentences containing an object in sentence-initial position, without forgetting that there are many types of non-canonical sentences, and not all may be object-first structures.

Moreover, *auditory* processing of non-canonical sentences is assumed to demand the exact timing of several linguistic operations, and deficient timing may increase the canonicity effect. Timing is assumed to depend on *processing speed*, which has been seen to impact on the temporal processing course of object-first sentences, e.g., on reactivation and integration of moved objects respectively on integration of morphosyntactic features. Besides processing speed, non-canonical sentence processing is assumed to be supported by other cognitive functions, such as cognitive control and working memory, in order to supervise the parsing process and revise, when parsing got wrong.

3.1 Word order

Despite early identification of the object with overt accusative markers in active transitive V2 and RC structures, as described in chapter 2, processing German OVS sentences was noted with e.g., longer response times, lesser comprehension accuracy, later target fixations or different event-related brain potentials (ERP) compared to SVO stimuli in German healthy non-brain-damaged speakers (e.g., Carroll & Ruigendijk, 2013; de Bleser, Burchert, & Rausch, 2005; Hanne *et al.*, 2011, 2015; Knöferle, 2007; Wendt, & Brand, & Kollmeier, 2014). Similar, processing unambiguously case-marked OR sentences, irrespective of branching site or embedding may result in longer processing times, lower accuracy, later target fixations or different ERP than those of the subject-first counterparts (e.g., Adelt *et al*., 2017; Bornkessel, Schlesewsky, & Friederici, 2002; Bornkessel, Schlesewsky, & Friederici, 2003). These differences may increase when both DP of a transitive sentence are ambiguous in their case marking (e.g., Felser, Clahsen, & Münte, 2003; Knöferle, 2007; Schriefers, Friederici, & Kühn, 1995). Longer processing times, lower accuracy, different eye movements and/or different brain activation (in terms of different activation sites or different event-related potentials) for healthy, non-brain-damaged adults processing object-first sentences are common and have been noted in many SO languages, such as e.g., for English or Dutch (e.g., Caplan, DeDe, Waters, Michaud, & Tripodis, 2011; Frazier, 1993; Santi & Grodzinsky, 2012). These so-called *canonicity effects* for object-first structures are assumed to reflect a higher processing load compared to subject-first structures.

Processing sentences involves several linguistic operations. These operations involve *lexical activation*, i.e., the mapping of a sound to a meaning, followed by *lexical integration* (the activation of information associated with the lexical item, such as the subcategorization of the verb, the thematic roles of a NP, and/or the selectional restriction or contextual information of a lexical element), and syntactic *parsing*, i.e., the combination of all lexical elements to a sentence representation. C*anonical* structures in SO-languages, where the subject is in the first sentential position, such as the SVO sentence in example (3.1), are assumed to be parsed *incrementally*, in a word-by-word fashion: Syntactic functions of subject and object and the accompanying thematic roles are argued to be assigned consecutively in a "who did (what) to whom"-fashion, i.e., the agent or actor role to "der faule Bäcker" (*the lazy baker*) and the patient or undergoer role to "den bösen Koch" (*the evil cook*). In other words, the presentation of the lexical elements of the sentence is considered to be *coherent* with the lexical and syntactic integration within the time course of the presentation (Bornkessel-Schlesewsky & Schlesewsky, 2012). In *non-canonical* OVS on the other hand, such as example (3.2), the unmarked word order may be regarded as being *deviated*, and syntactic subject and object are reversed, which may lead to -temporary- difficulties assigning thematic roles (in this example the agent role to "der böse Koch", *the evil cook*), because the word order does not adhere to the "who did (what) to whom" manner (see chapter 2.1). Some researchers assume that in order to assign agent to the second DP, additional processes are needed (see chapter 3.1.1). Similarly, the word order of the centre-embedded object relative clause (OR) in example (3.4) does not allow incremental syntactic integration compared to that of the embedded subject relative clause (SR) in example (3.4).

(3.1) Der faule Bäcker ersticht den bösen Koch.
The$_{\text{NOM}}$ lazy$_{\text{NOM}}$ baker stabs the$_{\text{ACC}}$ evil$_{\text{ACC}}$ cook.
'The lazy baker stabs the evil cook.'

(3.2) Den faulen Bäcker ersticht der böse Koch.
The$_{\text{ACC}}$ lazy$_{\text{ACC}}$ baker stabs the$_{\text{NOM}}$ evil$_{\text{NOM}}$ cook.
'It is the lazy baker whom the evil cook stabs.' (Uslar *et al*., 2013)

(3.3) Der Bäcker, der den Koch ersticht, weint.
The$_{\text{NOM}}$ baker who$_{\text{NOM}}$ the$_{\text{ACC}}$ cook stabs cries.
'The baker who stabs the cook cries.'

(3.4) Der Bäcker, den der Koch ersticht, weint.
The$_{\text{NOM}}$ baker whom$_{\text{ACC}}$ the$_{\text{NOM}}$ cook stabs cries.
'The baker whom the cook stabs cries.' (Uslar *et al*., 2013)

The canonicity effects of higher processing load in object-first structures is associated with linguistic *complexity*, in terms of syntactic or thematic/semantic complexity. A different information structure might also result in a higher degree of complexity

3.1.1 Syntactic complexity

Within Generative Grammar, some researchers consider object-first structures, such as OVS and branching or centre-embedded OR to be syntactically more complex than their subject-first counterparts, because besides lexical activation, integration and syntactic parsing, at least one more operation than those of canonical processing is assumed, i.e., the *reactivation* and/or *integration* of the object at the original site in order to assign a thematic role (e.g., Mecklinger, Schriefers, Steinhauer, & Friederici, 1995; Schriefers *et al*., 1995). Described in chapter 2, in Generative Grammar object-first structures are assumed to be generated through *movement* of the object from a latter sentence position to the first sentential DP position (note that the assumption of additional operations as well as the concept of movement is controversial). In order to assign the thematic role of patient to the moved element, the gap has to be *filled*, i.e., the antecedent has to be integrated at the site of the trace. For moved constituents this has been argued to include lexical activation of the element at first encounter and then reactivation at the site of the trace (Nicol & Swinney, 1989), or alternatively, identification of the antecedent, active temporary storage in memory and then integration at the site of the trace (e.g., Clifton & Frazier, 1989; Friederici, Fiebach, Schlesewsky, Bornkessel, & von Cramon, 2006; Gibson, 1998, 2000). In example (3.5), the sentence-initial DP “Den guten Soldaten” (*the good soldier*) is argued to receive its thematic role only when it is integrated after the second DP “der freche Cowboy” (*the naughty cowboy),* thus it has to be stored in memory until verb and the second DP have appeared (and been processed). This storage is considered to be executed in *working memory* (WM) where it is assumed to cause higher memory costs than that of incremental parsing (e.g., Felser *et al*., 2003; Gibson 1998, 2000). Higher memory costs have been associated with an increase in processing load in terms of *higher integration costs*, reflected e.g., in longer processing times (e.g., Felser *et al*., 2003; Friederici *et al*., 2006; Gibson, 1998).

(3.5) [Den guten Soldaten$_i$ fängt der freche Cowboy _$_{ti}$. (Uslar *et al*., 2013)

‘It is the good soldier whom the naughty cowboy catches.’

In addition, higher processing costs are argued to result from *reanalysis* processes, which may occur if the first DP is not recognized as an object and parsed as a syntactic subject with its related thematic role. Upon being presented with a second DP with e.g., overt nominative case marking it as a subject, or verb information not agreeing with the first DP, initial parsing needs to be revised. Reanalysis is also associated with longer processing times and/or the risk of misinterpretations in form of lower accuracy (e.g., Friederici *et al*., 2006; Gorrell, 2000). Reanalysis may in particular occur in German sentences where the first DP is ambiguously case-marked. A reanalysis as a *conflict resolution* (e.g., being faced with two potential agents in a transitive sentence) may consist of several steps: Recognition of the conflicting information, which does not fit with the construction that has been built up so far, a recall of the already parsed elements, and a resolution through rebuilding another syntactic representation. While reanalysis processes have been noted to happen very fast (e.g., as soon as the second unambiguously case-marked DP appears, or the information of the verb is not in agreement with the first DP), it still seems to need additional time, indicated by longer response times compared to those on canonical sentences (e.g., Adelt *et al*., 2017; Hanne *et al*., 2011; Kamide *et al*., 2003; Knöferle, 2007).

According to other researchers within Generative Grammar, it is not the movement as such leading to canonicity effects, but the *distance* between the antecedent and the trace, which can provoke processing difficulties. Gibson (1998) formulated a theory, in which the *locality* of the antecedent in proportion to its original site is considered to determine the processing load: The longer an element has to be kept in memory before it can be integrated, the higher are the integration costs. In example (3.5), the object “den guten Soldaten” (*the good soldier*) has to be kept in memory and can only be integrated after both the verb and the second DP have been presented and processed.

Closely related to the notion of distance is the *Relativized Minimality* account by Rizzi (1990), who claims that processing costs increase when the elements intervening between antecedent and trace are of the same sstructural type as the moved element.

The Relativized Minimality Principle (Rizzi, 1990)[8]

Y is in a Minimal Configuration (MC) with X iff there is no Z such that

(i) Z is of the same structural type as X, and

(ii) Z intervenes between X and Y.

In (3.5), the DP X „den guten Soldaten“ and its trace Y are intervened by The DP Z „den frechen Cowboy“ (*the naughty cowboy*), which has the same structural properties, i.e., is another DP. Similar to Gibson’s Theory, intervening is associated with a higher memory load, and the more intervening elements are in the chain, the higher the processing load is

[8] Note that Rizzi published another versions of his theory with respect to governing and commands („Z intervenes between X and Y when X c-commands Z and Z c-commands Y“, Rizzi, 2013:173), and later with respect to feature specifications („A local relation (e.g., movement) cannot hold between X and Y if Z intervenes and Z fully matches the specification of X in the relevant morphosyntactic features“, Rizzi, 2013: 179), but explaining the concepts of Government and Binding (Chomsky, 1982) as well as featural distinctions of NP are beyond the limit of this book. See for the latter Adelt *et al*., 2017).

assumed (e.g., Zurif, Swinney, Prather, Wingfield, & Brownell, 1995; see also chapter 3.4. for an overview of working memory impact on sentence processing).

Furthermore, if the intervening elements are of the same type as the antecedent, difficulties might increase because the intervening element might become a potential candidate for the assignment of the patient role, and a potential reanalysis of the thematic role might be necessary (cf. Frazier, Clifton, & Randall, 1983; Rizzi, 1997). This risk of role competition and thus reanalysis might be higher in sentences containing DP without overt case marking, which often occur in English, and where word order has been seen to govern sentence interpretation to a much higher degree than morphosyntactic information (e.g., Bates *et al.*, 1987; see below). In German sentences with overt case markers, role competition due to an intervening element may occur to a lesser degree (see chapter 3.1.3).

Also, a higher distance might result in *decay* or even *forgetting* of information (Kamide *et al.*, 2003; Kamide, Altmann, & Haywood, 2003a): By the time the listener encounters the trace, the activation of the information about the antecedent might have already decayed to a certain degree, i.e., not being accurate anymore, increasing the risk of a neglect of processing the dependencies of the antecedent-trace chain, or assigning roles to overtly case-marked DP. Decay, forgetting and the risk of neglect may result into a canonicity effect in terms of a misinterpretation (cf. Love *et al.*, 2008; Patil, Hanne, Burchert, de Bleser, & Vasishth, 2015).

While there are some differences with regard to the underlying cause of canonicity effects, both the movement and the distance or intervener approach have in common, that they assume a non-local integration of a moved object, which is claimed with higher processing costs through higher demands on working memory.

3.1.2 Informational complexity

According to a number of authors, the transformation from a SO- into a OS clause seems to need special syntactic or semantic *licencing*. In particular for OVS, it is proposed that this so-called *topicalization* (e.g., Bader & Häusler, 2010; Fanselow & Lenertova, 2011*)* demands a special context in terms of information structure.

The syntactic object and semantic patient[9]) “den netten Papst” (*the nice pope*) is claimed to receive the discourse role of *topic* beside its semantic patient role inhabited in the SVO of example (3.6, marked boldly) in the OVS example (3.7).

(3.6) Der gute Soldat küsst **den netten Papst**.
The$_{NOM}$ good$_{NOM}$ soldier kisses the$_{ACC}$ nice$_{ACC}$ pope.
‘The nice pope kisses the good soldier.’

(3.7) **Den netten Papst** küsst der gute Soldat.
The$_{ACC}$ nice$_{ACC}$ pope kisses the$_{NOM}$ good$_{NOM}$ soldier.
‘It is the nice pope whom the good soldier greets.” (Uslar *et al*., 2013)

This topicalization is argued to demand a *discourse*, in which the topic can stand as focus of already *given* information (Bader & Häusler (2010); see also Heylen, 2005; Weber & Müller, 2004). According to some authors, semantic rather than syntactic reasons seem to determine topicalization: A *semantic focus* within a given amount of information is considered to define whether a sentence part may be *accentuated* in terms of fronting it to a sentence-initial position (Fanselow & Lenertova, 2011). Thus, a sentence like example (3.6) might entail that there were more popes than one, and only the nice pope was hugged, or that among several nice popes this particular one was hugged, and this information was already disclosed in the preceding context. The semantic accentuation might adhere to a phonological one, noted in spoken OSV sentences: Topicalized OVS is considered to be realized often with an intonation contour different from that of SVO sentences, e.g., with more accentuated stress placed on the object DP, or on parts of the DP (cf. Carroll, 2013).

Also, there seem to be some semantic-lexical constraints permitting not all objects to become topicalized. Dative case-marked indirect objects of ditransitive sentences have been noted to be topicalized or moved to the front of the sentence more often than accusative case-marked direct objects, especially in the case of psych-verbs. In the case of accusative objects, the semantic concept of *animacy* has been noted to play a role: Topicalization appears to occur more often, when the subject is animate and the object inanimate (Bader & Häusler, 2010; for

[9] Note that this is overgeneralized, as there is a number of transitive verbs without a thematic agent-patient/benificiary argument structure; also, not all moved objects in OVS are topics (cf. Bader & Häusler, 2010 for a corpus analysis on thematic relations).

the concept of animacy see also chapter 3.1.3). However, whether topicalized or not, active transitive object- first structures in German tend to occur with a lesser frequency than subject-first structures (cf. Bader & Häusler, 2010; Weber & Müller), in particular, when there is no context preceding them.

Hanne *et al* (2011, 2015) noticed longer response times for overtly case-marked OVS like example (2.24) compared to SVO sentences despite early target fixation, which they interpreted as longer processing time to "[…] determine the sentence's global grammatical and semantic relations and to use these for identifying the correct picture in a sentence-picture matching task." (Hanne *et al*, 2011: 237). Still, there was lower accuracy for the object-first items compared to the subject-first sentences, which may reflect a higher processing load effected by these structures presented in isolation instead of within a context. Lower accuracy, also noted in Adelt *et al*. (2017) study (see examples 2.25 and 2.26), may also signal information decay caused by higher processing load: By the time the listener encountered the case information of the second DP, the case information of the first NP has already decayed to a certain degree (cf. Altmann, van Nice, Garnham, & Henstra, 1998; Stevenson, 1994), because there was no discourse antecedent to associate the topic with.

3.1.3 Subject-first preference

The higher frequency of subject-first structures may be related to a *subject-first preference* in processing. For German, a subject-first processing preference has been observed (e.g., Bader & Häusler, 2010; Bornkessel-Schlesewsky & Schlesewsky, 2009; Bornkessel *et al*., 2003; Bornkessel & Schlesewsky, 2006; Weskott, Hörnig, Fanselow, & Kliegl, 2011). There may be different interlinked reasons for this phenomenon.

The basic word order in German as subject-before-object and other languages is considered to be unmarked in Generative Grammar because it seems to contain the least amount of description for its transformation from the underlying to the surface structure (cf. Chomsky, 1982). The *Minimal Attachment* account by Frazier & Fodor (1982) assumes that a sentence is initially processed through constructing as few phrasal nodes as possible, i.e., to keep the syntax of the construction as simple as possible. Within this account, a *Late Closure* principle was formulated, which postulates that an incoming lexical element is rather incorporated in the phrase, which is being constructed at the moment instead of building another phrase. For the famous sentence in (3.8), this would include that the PP „with binoculars“ would rather be attached to the DP „the cop“ than to the DP „the spy“, because the DP containing „the cop“ is the one currently processed.

(3.8) The spy saw the cop with binoculars. (Rayner, Carlson, & Frazier, 1983)

In an account based on the notion of minimal structures processes, Bornkessel & Schlesewsky, 2006) suggested in their *Minimality* Account, that “[…] in the absence of explicit information to the contrary, the human language comprehension system assigns minimal structures. This entails that only required dependencies and relations are created.“ (Bornkessel & Schlesewsky, 1996, p. 790). Upon parsing a linguistic stimulus, e.g., a noun, speakers are assumed to anticipate or *predict* that this is followed by a verb. Moreover, the argument structure of the verb is initially predicted to be intransitive, meaning that the noun is expected to be the first and only argument of the verb, thus it will be parsed as subject and assigned the agent role. According to Bornkessel & Schlesewsky (1996), an intransitive structure requires only two phrases with two heads, while a transitive structure demands three phrases (one within the VP) with three heads, an additional one for the direct object. Therefore, it is argued that a subject interpretation is preferred because it demands fewer categories, which are claimed to result in a lower working memory load. Thus, besides a syntactic parsing route, a faster cognitive route driven by expectations and anticipations may be used in order to assign thematic roles. What is more, it is claimed that this subject-first processing mode needs extra and explicit information in order to be overridden by syntactic parsing: The occurrence of another noun may trigger to change the intransitive construction. According to this approach, the first DP (“der kluge Pilot” (*the clever pilot*) in example (3.6) will be treated as agent of the intransitive verb “grüßen”, and only upon presentation of the second DP “den alten Pfarrer” (*the old pastor*), a transitive argument structure will be constructed. This process of switching to another, syntactic processing route when faced with information not fitting a subject-first preference may prolong processing time, because another construction has to be built. Therefore, a *violation* of a prediction or expectation may result in a syntactic route overriding and/or suppressing the subject-first route, resulting in higher processing costs (Carroll, 2013; see also Burkhardt, Piñango, & Wong, 2003).

Moreover, in the presence of other “explicit information” (Bornkessel & Schlesewsky, 2006), such as e.g., overt case marking or other morphological information, the intransitive subject-first preference may be quickly overridden, or not even built, because the accusative marking may signal the immediate construction of a transitive representation: In example (3.7), the presence of overt accusative case marking of “den alten Pfarrer” (the old pastor) is suggested to result in an incremental parsing of the first DP as a patient and treating the verb as a transitive one.

Cross-linguistic observations of early role assignment (e.g., reflected by eye fixations to the target or different ERP) led Bornkessel *et al.* (2003) to propose an alternative processing route relying on morphological information in order to process sentences, and to detect reversed word order. Reanalysis processes on the other hand are suggested to be applied if the case marking of the first DP is ambiguous.

Evidence for a morphological processing route comes from recent eye-tracking research: Eye fixations patterns in sentence-picture matching tasks (SPM) reflected early object identification of overtly case-marked DP (e.g., Adelt *et al*., 2017; Hanne *et al*., 2011, 2015; Kamide, 2007; Wendt *et al*., 2015). Hanne *et al.* (2011) noted early target preference during the verb region for overtly case-marked OVS sentences, such as example (3.9), indicating thematic patient role assignement already took place before presentation of the second DP.

(3.9) Den Sohn küsst der Vater.

The$_{\text{ACC}}$ son kisses the$_{\text{NOM}}$ father.

‘It is the son whom the father kisses.’ (Hanne *et al*., 2011)

Hanne *et al.* (2011) interpreted this pattern as a *predictive* behaviour: “[…] early fixation of the correct picture in OVS sentences is due to the fact that the first accusative-case-marked NP is sufficient to allow participants to predict the sentence’s thematic interpretation; hence the fixation preference arises at the verb." (Hanne *et al.*, 2011, p. 236)[10]. In another German eye-tracking study, Schumacher *et al*. (2015) noticed that in OVS sentences with unambiguous case marking, such as in example (3.10), healthy participants already showed a target preference upon hearing the attribute (the PP within the first DP), before the verb was presented,

.

(3.10) Den Mann mit dem Korb folgt das Kind.

The$_{ACC}$ man with the basket follows the$_{NOM}$ child.

'It is the man with the basket whom the child follows.'

(Schumacher *et al*., 2015)

Early eye fixations on the target (i.e., before the second DP was presented) were also noticed in other German eye-tracking studies using full DP (Hanne *et al.*, 2015; Kamide, Scheepers, & Altmann 2003; Knöferle, Crocker, Scheepers, & Pickering, 2005; Knöferle, 2007; Wendt *et al*., 2014, 2015). Furthermore, early target preference has also been observed in sentences where relative pronouns are overtly case-marked. Adelt, Lassotta, Adani, Stadie, & Burchert (2017) found that eye fixations on targets in subject-relative and object-relative clauses like (3.11) and (3.12), where the relative pronoun was overtly case-marked, already took place while the relative clause was still presented. Adelt *et al*. (2017) even found that eye fixations in case-marked sentences, such as examples (3.11) and (3.12) were faster for the overtly case- marked SR than for the overtly case-marked OR, indicating that a subject-first preference may even take place when the first morphological information indicates otherwise, and additional time might have been needed to override this subject-first preference

(3.11) Wo ist der Hamster der den Frosch wäscht?

Where is the$_{NOM}$ hamster whom$_{NOM}$ the$_{ACC}$ frosh washes?

---

[10] In contrast, even if regarded less complex, a similar fixation preference for canonical sentences was only seen from the post-verbal NP region onwards. This was interpreted as a waiting strategy because of insufficient thematic role information of the pre-verbal NP. But Hanne *et al.* (2011) used passive constructions as fillers, and the presence of two structures with a nominative case-marked initial DP, i.e., SVO and subject passives, might have provoked listeners to wait in order to see which structure was presented.

Where is the hamster who washes the frog?

(3.12) Wo ist der Hamster den der Frosch wäscht?

Where is the$_{NOM}$ hamster whom$_{ACC}$ the$_{NOM}$ frog washes?

Where is the hamster whom the frog washes? (Adelt *et al*., 2017)

The hypothesized subject-first preference may be even more obvious in initially ambiguously case-marked sentences. Carroll & Ruigendijk (2013) implemented SVO and OVS items, such as (3.6) and (3.7), as well as ambiguous OVS items, such as (3.13) Their word-monitoring experiment with language unimpaired adults demonstrated longer processing times for the ambiguous OVS sentences (e.g., Carroll & Ruigendijk, 2013), which they interpreted as a reanalysis effect, i.e., due to the extra time allotted to change the initial subject-first interpretation to an object-first one.

(3.13) Die gute Köchin erschießt der brave Polizist.
The$_{AMB}$ good$_{AMB}$ cook shoots the$_{NOM}$ good$_{NOM}$ policeman.
'It is the good cook who the good policeman shoots.' (Uslar *et al*., 2013)

In contrast, Wendt *et al*. (2015) (using using the same sentence structures as Carroll & Ruigendijk (2013)) noted that their participants showed earliest target fixation for ambiguous OVS items, followed by SVO and then unambiguous OVS items. This finding might result from the gender difference between the entities in the stimuli: In the ambiguous items, a feminine and a masculine entity were depicted, while both SVO and OVS contained only masculine entities.

Longer response times and later target fixation were also found by Hanne et al. (2011): In initially ambiguous OVS items, which could only be disambiguated by the agreement information of the verb, such as example (3.14), participants’ fixation to the target increased *after* hearing the verb, signalling that an object-first structure was not anticipated.

(3.14) Das Kind fangen die Frauen.

The$_{AMB}$ child catch$_{PL}$ the$_{NOM}$ women.

'It is the child whom the women catch.' (Hanne *et al*., 2015)

Adelt *et al* (2017) found in healthy, i.e., non-brain-damaged, German listeners a subject-first preference in terms of early eye fixations on the foil for ambiguously-marked relative clauses, such as for SR items like example (3.15) and OR sentences like (3.16), which was only overridden by appearance of the agreement features at the end of the sentence, reflected in an increase in target fixations after occurrence of the verb.

(3.15) Wo ist das Kamel das die Igel wäscht?

Where is the$_{NOM}$ camel$_{SG}$ that$_{AMB}$ the$_{AMB}$ hedgehog washes$_{SG}$?

'Where is the camel that washes the hedgehogs?'

(3.16) Wo ist das Kamel das die Igel waschen?

Where is the$_{NOM}$ camel$_{SG}$ that$_{AMB}$ the$_{AMB}$ hedgehogs wash$_{PL}$?

'Where is the camel that the hedgehogs wash?' (Adelt *et al*., 2017)

This eye fixation pattern was also observed by Knöferle (2007) who noticed increased target fixations in case-ambiguous OVS stimuli, such as (3.17) also only *after* hearing the verb, but before the second DP was presented.

(3.17) Die Frau Orange schlägt in diesem Moment der Sir Apfel.

The$_{AMB}$ Ms Orange hits currently the$_{NOM}$ Sir Apple.

'It is the Ms Orange whom the Sir Apple currently hits.'

(Knöferle, 2007)

Moreover, in permanently ambiguous sentences, such as (3.18), where neither agreement nor overt-case marking aids disambiguation, a subject-first interpretation was noticed to be the preferred one (Burchert *et al*., 2003; Mecklinger *et al*., 1995).

(3.18) Die Köchin küsst das Mädchen.
The$_{AMB}$ cook kisses the$_{AMB}$ girl.
'The cook kisses the girl.' or
'It is the cook whom the girl kisses.' (Burchert *et al*., 2003).

Besides this subject-first processing preference, there seem to be other preferences with respect to the order of arguments in a sentence, such as the order of case markings, and the order of thematic roles, and both may partially be linked to each other: A preferred subject-before object word order may adhere to a preference of nominative-before-accusative case order (cf. Bader & Meng's (2006) proposed case hierarchy), and/or to a preference of agent-before-patient order (e.g., Bader & Häusler, 2010; see also proposed thematic role hierarchies discussed in Dowty, 1991). While a detailed description and discussion is beyond the scope of this book, it is safe to assume that syntactic as well as semantic aspects determine the word order in (German) sentences, and that some word orders are preferred over other word.

Closely related to the hypothesised subject-first preference seems to be a *heuristic* strategy, based on world-knowledge, in order to interpret sentences. This *agent-first strategy* is based on the assumption that the first DP of the sentence of an active transitive sentence is the agent and the second the patient. This order is assumed to be a cognitive processing *preference*, and sentences with this order are considered to not necessarily need syntactic parsing abilities (cf. Bornkessel-Schlesewsky & Schlesewsky, 2009; see also the account on *good-enough processing* by Ferreira, 2003 and Ferreira, Bailey, & Ferraro, 2002).

A second heuristic entails that in sentence processing, listeners combine lexical items of a sentence in the most *plausible* way, i.e., that sentences are treated as unordered string of words, which meaning is derived by plausibility or world knowledge (cf. van Herten, Chwilla, & Kolk, 2006). One plausibility principle is *animacy,* in that listeners have been noted to expect and predict the animate noun to be the agent in a transitive sentence with an animate and an inanimate noun, regardless of the position of that noun (e.g., Altmann & Kemper, 2006; Mak, Vonk & Schriefers, 2002; 2006). Plausibility may work well on active transitive sentences without *reversible* thematic roles, such as (3.19), where only the first DP is animate and therefore can only be the subject and thus the agent of the verb “beissen” (*to bite*). In sentences, where all DP are animate and may be possible agents, such as (3.20), the plausibility heuristics may favour the first animate DP to be the agent (adhering also to the agent-first preference), because both DP are ambiguously case-marked. In contrast, for correct comprehension of (3.21), morphosyntactic parsing of the nominative case of the second DP is necessary. For this reason, semantically reversible sentences have been shown to be more difficult (e.g., in terms of longer processing times and/or lower accuracy) because all DP within a sentence are able to take all possible thematic roles specified by the argument structure of the verb (e.g., Meltzer, McArdle, Schafer, & Braun, 2010).

(3.19) Die Hündin beisst die Plüschmaus.

The$_{\text{AMB}}$ dog bites the$_{\text{AMB}}$ toy mouse.
‘The dog bites the toy mouse.’

(3.20) Die Hündin beisst die Frau.

The$_{\text{AMB}}$ dog bites the$_{\text{AMB}}$ woman.
‘The dog bites the woman.’

(3.21) Die Hündin beisst der Mann.

The$_{\text{AMB}}$ dog bites the$_{\text{NOM}}$ man.
‘It is the dog that is bitten by the man.’

While according to some researchers normal language processing might even consist dominantly of applying heuristic strategies (e.g., Bates *et al.*, 1987), these heuristics work only well for canonical sentences, while for non-canonical sentences they may not aid correct interpretation, especially when all DP are animate. In particular for ambiguously case-marked sentences, a subject-first preference or agent-first strategy may lead to wrong anticipations or predictions of semantic information (e.g., Kamide, 2008; Pickering & Traxler, 1998; Pado, Keller, & Crocker, 2006). Correcting this prediction has been seen to demand extra processing costs, which are necessary to revise the initial analysis (Kamide, 2008).

In linguistically low predictable or context reduced environments, canonicity effects might increase (Bader, Meng & Bayer, 2000; Carroll, 2012; Carroll & Ruigendijk, 2013; Kamide *et al.*, 2003; Meyer, Mack, & Thompson, 2012). Furthermore, canonicity effects may be caused by acoustically challenging situations, such as background noise (Carroll & Ruigendijk, 2013; Carroll, 2013; Yampolski, Waters, Caplan, Matthies, & Chiu, 2002), which may mask grammatical morphology, such as morphosyntactic markers, more than content words (see chapter 5.2 for more information on noise effects). Moreover, if the acoustic situation (or hearing status of the listener; see chapter 5) does not allow for perception of all elements, especially semantically reversible object-first sentences with animate nouns are prone to be interpreted as subject-first structures (cf. Mak *et al.*, 2002, 2006), and/or in case of unclear plausibility, world-knowledge is applied, which may lead to similar incorrect interpretations (Obler, Fein, Nicholas, & Albert, 1991).

3.2 Embedding

It was already mentioned in chapter 2.2, that a structure containing a centre-embedded SR as example (3.24) is assumed to be syntactically more complex than a left- or right-branching SR, such as example (3.22), due to the structural complexities of containing two clauses, a matrix- and a relative clause, two non-coordinated propositions and/or an antecedent-pronoun dependency (co-indexed by (j)). While all the three clauses below have the same length in terms of number of words, processing load might be different. The right-branching SR in (3.22) may be processed incrementally, in a “who did to whom”-manner. In order to comprehend the centre-embedded SR in (3.24), the thematic propositions of both matrix- and relative clause have to be interpreted, which involves resolving the antecedent-pronoun dependency. Similarly, both propositions of matrix and right-branching SR in (3.23) have to be processed, which also involves an antecedent-pronoun dependency. But in contrast to (3.24), in (3.23) the clauses are coordinated, and the relative clause appears after the matrix clause. In (3.24) on the other hand, processing of the matrix clause can only be completed after the relative clause has been processed, which according to some researchers increases processing costs because of the higher demand on working memory, in which the matrix clause has to be stored until the end of the sentence (e.g., Gibson, 1998; Lewis & Vasishth, 2005; McElree, Foraker, & Dyer, 2003).

(3.22) Schön, dass der Maurer die Metzger grüßt!

Nice that the$_{NOM}$ mason$_{SG}$ the$_{AMB}$ butchers$_{PL}$ greets.

'It is nice that the mason greets the butchers.'

(3.23) Der Maurer grüßt die Metzger, die weinen.

The$_{NOM}$ mason$_{SG}$ greets$_{SG}$ the$_{AMB}$ butchers$_{PL}$, who$_{AMB}$ cry$_{PL}$.

'The mason greets the butchers who cry.'

(3.24) Der Maurer, der die Metzger grüßt, errötet.

The$_{NOM}$ mason$_{SGj}$ who$_{NOMj}$ greets$_{SG}$ the$_{AMB}$ butchers$_{PL}$ blushes$_{SG}$.

'The mason who greets the butchers blushes.' (Uslar *et al*., 2013)

Another structural property, which has been suggested to raise processing load in centre-embedded compared to branching subject relative clauses, is the lacking adjacency of the verb to the subject. In the relative clause in (3.24), the DP "die Metzger" (*the butchers*) intervenes between the nominative-marked DP and the verb, which has been suggested to boost working memory load because the first relative clause DP has to be stored until occurrence of the verb (e.g., Weyerts *et al.*, 2002). Moreover, the verbs of as well matrix and relative clause are in sentence-final position, which again is associated with higher integration costs compared those in verb-second structures, because the agreement information of both verbs can only be processed after the occurrence of three DP. This structural difference again has been argued to increase working memory load compared to the load imposed by main clause structures (e.g., Lewis & Vasishth, 2005: Weyerts *et al*., 2002).

In contrast, in the centre-embedded OR in (3.25), the relative verb is adjacent to the subject, which may facilitate processing, but still occurs sentence-finally. Also, the potential movement of the object DP into sentence-initial position may enhance processing costs through higher memory load. But even if movement as such is not considered to heighten complexity, the distance between antecedent and trace is long, filled by a similar intervener, the DP “die Metzger” (*the butchers*), which may increase processing load, similar to that of OVS.

(3.25) Der Maurer, den die Metzger grüßen, errötet.
The$_{\mathrm{NOM}}$ mason$_{\mathrm{SG}}$ whom$_{\mathrm{ACC}}$ the$_{\mathrm{AMB}}$ butchers$_{\mathrm{PL}}$ greet$_{\mathrm{PL}}$, blushes$_{\mathrm{SG}}$.
‘The mason whom the butchers greet blushes.’ (Uslar *et al*., 2013)

In addition, another complexity related to information structure occurs which is not present in the centre-embedded SR: The syntactic subject of the matrix clause becomes the syntactic object in the relative clause in OR, which also adheres to a thematic role change: The agent or actor of the matrix clause transforms into the patient (or even topic) of the relative clause in (3.25). Syntactic function changes and assignment of different thematic roles has also been noted to aggravate processing load (Just & Carpenter, 1992; MacWhinney & Pleh, 1988; Traxler, Morris, & Seely, 2002).

To my knowledge, there has been no research so far, which systematically compared processing load on embedded vs branching relative clauses using the same participants. Also, there is few research allowing to compare the degree of canonicity effects of verb-second compared to centre-embedded relative clauses, in particular when the different sentence types are matched to number of words or other criteria, and participants are the same for all stimuli. Carroll & Ruigendijk (2013) found that accuracy of SVO and OVS sentences, such as examples (3.6) and (3.7) was higher than for centre-embedded SR and OR (examples (3.24) respectively (3.25)). Wendt *et al.* (2014), implementing the same stimuli as Carroll & Ruigendijk (2013), noticed that processing times for SVO were shorter than for SR. In contrast, Burchert *et al*. (2003) did not find accuracy differences between verb-second, branched and embedded relative clauses (that were not matched in number of words).

Last but not least, ambiguously case-marked centre-embedded relative clauses may impact on processing load to a higher degree than their unambiguously case-marked counterparts, and an initially ambiguously case-marked OR (example 3.27) may demand more working memory capacity than an initially ambiguously case-marked SR, such as in example (3.26), which again may raise the risk of a canonicity effect not only in terms of processing duration, but also of misinterpretations.

(3.26) Die Witwen, die das Gespenst erschießen, zittern.
The$_{AMB}$ widows$_{PL}$ who$_{AMB}$ the$_{AMB}$ ghost$_{SG}$ shoot$_{PL}$ shiver$_{PL}$.
'The widows who shoot the ghost shiver:'

(3.27) Die Witwen, die das Gespenst erschiesst, zittern.
The$_{AMB}$ widows$_{PL}$ who$_{AMB}$ the$_{AMB}$ ghost$_{SG}$ shoot$_{SG}$ shiver$_{PL}$.
‘The widows who the ghost shoots shiver.’ (Uslar *et al*., 2013)

As mentioned above, this higher processing load does not necessarily consist of higher integration costs suggested to arise from a non-local integration of the antecedent, but may also reflect a reanalysis.

Carroll (2013), implementing unambiguous and ambiguous centre-embedded subject and object relative clauses, such as examples (3.24), (3.25), (3.26), and (3.27) in a word-monitoring task, found that reaction times measured on the two verbs were highest for the two ambiguously case-marked sentence types, indicating that processing times for these sentence types took longer than for the overtly case-marked sentences. Moreover, comprehension accuracy was highest for unambiguous SR, followed by unambiguous OR and ambiguous SR, and the lowest accuracy rate was seen for ambiguous OR. Similarly, Wendt *et al*. (2014), using the same stimuli as Carroll (2013), found that ultimate eye fixations to the target took longer for the ambiguously marked relative clauses compared to the unambiguously marked ones, and accuracy was also lower for the case-ambiguous OR compared to the overtly case-marked OR.

Embedded sentence structures may be even more prone to reanalysis effects as well as to an imposed risk of decay than other structures. The assumed higher processing load may lead to a higher degree on reliance on heuristic processing modes such as the agent-first strategy.

In summary, canonicity effects may result from additional time needed to integrate a moved object at its original site. This might include a reanalysis of a structure initially parsed as subject-first structure. A reanalysis may increase processing costs because additional time is needed to revise a syntactic representation. A subject-first processing preference is argued to result from anticipation and prediction of minimal structures: The first DP is anticipated with an inflected verb, and by encountering an inflected transitive verb, listeners predict an object to follow. Predicting words by their syntactic context has been seen to guide sentence processing (e.g., Bornkessel & Schlesewsky, 2006; Hanne *et al*., 2015; Kamide *et al*., 2003, 2003a). On the other hand, overt morphosyntactic case information may trigger early object-first parsing in German, which led some researchers to suggest a morphological processing route besides a canonical processing preference. For German (and other languages with a richer morphosyntactic system compared to English), there might be thus a number of processing routes for non-canonical sentence interpretation: A subject-first preference, which in case of information to the contrary has to be overridden by a syntactic parsing route including resolution of antecedent-trace dependencies and/or a morphological route. Still, even early identification of a sentence -initial object may increase processing costs. Moreover, heuristic strategies, argued to be based on cognitive preferences, may also impact on (non-canonical) sentence processing.

3.3 Timing and processing speed

While written sentences have a stable presentation and may be re-accessed if a difficulty in processing occurs, auditorily presented sentences unfold over a restricted time and the acoustic stimuli are rapidly changing on a moment-to-moment base, and rewinding them in case of doubt is not possible.

Besides lexical activation and integration and syntactic parsing (and according to Generative Grammar, reactivation and integration of the moved object in object-first sentences), spoken sentence processing also involves acoustic-perceptual processes: The acoustic stimuli have to be *decoded* perceptually, before they can be *encoded*, i.e., mapped to lexical, syntactic and semantic representations in order to interpret the sentence.

The linguistic processes involved in auditory sentence processing are therefore considered to depend on *timing*, i.e., on an exact synchronization between the acoustic presentation and the processing operations involved, in order to successfully execute the operations needed to construct a correct syntactic representation of the presented sentence. While integration of the elements in canonical sentences may be aided by incremental parsing and/or cognitive strategies (see above), timing is in particular crucial for parsing non-canonical sentences. With regard to antecedent-trace relations, it is argued that if reactivation and/or integration is not executed at the precise moment the trace is encountered, reactivation of the antecedent may dissolve and sentence interpretation may break down, because the trace may not be noticed (e.g., Grossman *et al.*, 2002; Love *et al*., 2008). On the other hand, a longer distance of the antecedent to its trace may also result in decay of information and raises the risk of not integrating the object in a timely manner. Likewise, a subject first preference in processing can result in timing insufficiencies because the preference has to be overridden or suppressed, causing extra costs.

If timing is for some reason disturbed, processing of a sentence may lead to *delays*, meaning that when parsing of a sentential element takes longer than the presentation time of the element and overlays presentation time of the next element, this and other following elements cannot be processed in timing with the presentation of these elements. Delays can be seen in eye-tracking experiments, e.g., when listeners display eye fixations to a target picture at a later point of the sentence than other listeners, or in priming tasks, when lexical decision takes longer for some compared to other listeners (e.g., Hanne *et al*., 2011; Love *et al*., 2008). This delay poses in particular a risk for antecedent-trace relations, because if processing of the element preceding the trace overlays the presentation of the trace, it may not be recognized, jeopardising object integration. Delays can be compensated for by a reanalysis process, which in turn has been argued to demand additional processing time. Moreover, insufficient timing may also bear a higher risk of a non-canonical structure to be processed in a *shallow* manner, in the sense that movement or other complexities are neglected, causing a misinterpretation of the sentence (cf. Clahsen & Felser, 1995; Ferreira, 2003; Miyake *et al.*, 1994). Timing thus seems to be an essential component for non-canonical sentence processing essential and has been suggested to be based in sufficient processing speed.

3.3.1 Processing speed

While the role of processing speed has been considered to be of crucial relevance for auditory processing of speech (e.g., Caplan *et al*., 2003; Miyake, Carpenter, & Just; 1995; Shinn & Cummingham, 2008), the notion of processing speed and its effects on processing sentences is controversial. Processing speed may be determined by response times, and a longer response time of one person to a stimulus than another person may reflect a different degree of the speed of processing. While some researchers assume that processing complex stimuli may delimit the actual degree of speed, alternatively, this degree may be maintained, and prolonged response times may reflect extra time needed for additional operations produced by the complexity.

Processing speed may be defined as the rate in which information is processed in a given time. It can be measured as the ability of how fast information can be processed without any losses of earlier processed information by the time the whole processing is completed. Likewise, it can be calculated as the number of processing operations that can be performed at the same time (Salthouse, 1996, 2000)[11]. Speed of processing has been considered not only to be relevant for linguistic or other processing; rather, it has been regarded as a task-independent cognitive construct (Fry & Hale, 2000), or even as a cognitive *primitive* (Salthouse, 1996, 2004; Kail & Salthouse, 1994; Turken, Whitfield-Gabrieli, Bammer, Baldo, Dronkers, & Gabrieli, 2008).

Some researchers have argued for different *types* of processing speed, such as *motor* and *perceptual* speed (Salthouse 1992, 1994), in order to distinguish between purely perceptual operations and higher-order cognitive computations, or for a specific type of *cognitive* processing speed (Fry & Hale, 2000; Schneider, Daneman, & Murphy, 2005; Turken *et al.*, 2008), which seems to rely on perceptual processing speed (Schneider *et al.*, 2005). Because cognitive processing is assumed to include linguistic processing, this cognitive processing speed may determine the speed of linguistic processing. Within sentence processing research, some researchers even suggest distinct linguistic types of speed, such as *semantic* or *syntactic* processing speed (e.g., Caplan, Waters, & Albert, 2003). On the other hand, the *degree* of processing speed may vary, depending on the type of information, which has to be processed: Some operations, as e.g., role assignment, might need more time than lexical activation (Mc Elree & Griffith, 1995; Love *et al*., 2008), or perceptual processes, such as phonetic analyses. The speed of retrieval of lexical elements from long-term memory might also determine the speed of sentence processing (see Hüttig & Janse, 2016).

Processing speed is assumed to function with a time mechanism, limiting the available time for processing a task. According to Salthouse (1996, 2000), a simple stimulus, for example a spoken word, may be processed keeping the normal degree of processing speed,

---

[11] Processing speed can be measured using a range of cognitive tests, such as the Digit Symbol Substitution Test (DSST) from the WAIS (Wechsler, 1958), where digits have to be substituted with symbols, or vice versa in the Symbol Digit Modalities Test (SDMT, Smith, 1968), and time is measured until completion. Alternatively, processing speed can be assessed by the Letter Comparison and Pattern Comparison (Salthouse, 1993), which requires the comparison of two sets of letters or patterns. But as these tests are claimed to involve other cognitive processes, such as working memory and executive functions (Albinet, Boucard, Bouquet, & Audiffren, 2012; Baudouin, Clarys, Vanneste, & Isingrini, 2009; Bugaiska *et al.*, 2007), extracting the effect of processing speed from other cognitive abilities might pose some difficulties.

but processing a complex stimulus, such as a spoken word presented in noise compared to one presented in silence, has been argued to slow down processing speed[12] (Salthouse, 1996, 2000). If higher perceptual load through degradation results into a decrease[13] of processing speed, less information can be processed in the same time without added strain: “Processing deficits could therefore emerge because of discrepancies between the time course of loss of information and the speed with which critical operations such as encoding, elaboration, search, rehearsal, retrieval, integration, or abstraction can be executed.” (Salthouse, 1996, p. 405). For auditory sentence processing this argumentation entails that if more time is needed to *decode* a signal, e.g., a spoken word, less time is left over for *encoding* the signal into a linguistic representation, e.g., by lexical activation and integration, which may affect the *timing* of parsing. Slower processing speed has been seen to result in delays processing the rapid on-going auditory signal: While still processing the first signals, other elements are already presented, so successful completion may not be achieved in the available time (e.g., Gordon-Salant, 2005). As a consequence, a perceptual processing *delay* may result in delayed lexical, syntactic and/or semantic processes. More, if processing takes much longer than the duration of the presentation, some of the crucial linguistic operations may not even take place because of time limits, increasing the risk of information loss. Later incoming information may decay, or be neglected because its presentation may be overlaid by processing of preceding elements. Earlier processed information may also be decayed or forgotten before it can be implemented in latter processing stages. Salthouse (1996, 2000) suggests that this discrepancy will be even more pronounced for complex stimuli demanding an additional number of operations, because executing each single operation may need a certain amount of time. Slowed-down processing speed may thus in particular decrease the number of operations having to be executed within a limited presentation time (Salthouse, 1996, 2000). Following this line of reasoning, parsing of non-canonical sentences, which have been claimed to require integration of the moved object, a reanalysis and/or suppressing an initial subject-first parsing,

---

[12] Note, that in this dissertation, I use the term *slower* to refer to a decreased rate of processing speed as well as to refer to longer response times usually seen for stimuli that require a longer processing time compared to other stimuli in normal, healthy adults. Furthermore, expanded speech rates will be referred to as slower speech or slower speech rates. In order to compare longer response times and/or pathological reductions in processing speed induced by the incidence of aphasia, hearing impairment and/or age, the terms *slowed-down, slowed* or *slower-than-normal* will be used.

[13] The term „decrease“ will be used to refer to a slowing of processing speed through higher processing load, while „reduction“ or „reduced“ processing speed will refer to a pathological slowing-down of processing speed due to age-related or aphasic deficits.

might slow down processing speed, which in turn may affect further parsing of other elements within the time course of the presentation. If for example the rate of information processing is decreased because processing speed is slower, parsing of the element preceding the trace may not be completed at the occurrence of the trace, the trace might be not recognized, and the integration of the antecedent cannot take place in time.

However, these phenomena described above have also been described for non-canonical sentence processing without the assumption of a decrease in processing speed: Longer processing times in complex sentences compared to simple sentences have been considered to reflect extra time needed for additional processes. It has been argued in the 3.3, that in Generative Grammar antecedent reactivation and/or integration, which are assumed not to take place in canonical structures, demand additional time. Similarly, longer processing times may reflect revision and/or reanalysis processes caused by initially incorrect processing (Hanne *et al.*, 2011; 2015). Reanalysis may happen after sentence offset for e.g., case-ambiguous relative clause where disambiguation can only happen at the last element of the clause, the inflected verb (e.g., Adelt *et al*., 2017, see examples 3.15 and 3.16). Thus, following Salthouse lines, it could be argued that an initial canonical parsing should not have decreased processing speed, and the longer response times found resulted from a revision. And, as already mentioned, additional operations to be executed during stimulus presentation may delay processing, but this does not have to affect processing speed.

Some researchers believe that in older age (e.g., a lifetime of 60+ years) people need more time to process information, which might cause the crucial difference between prolonged processing times and slower processing speed, both linked to longer processing times and/or lower accuracy. Salthouse (1996, 2000) based his assumption on a comparison of processing times for several tasks between younger and older (i.e., 60+ years) adults, where older participants often demonstrated longer response times than the younger groups. Response times differences between younger and older adults for the same stimuli have been measured in a number of studies (e.g., van der Werff, 2007; Wingfield *et al*., 2003; see also chapter 5.4).

Nonetheless, processing speed may have a limit even in younger adults, in particular when complexity is increased by another component. When presentation of stimuli gets too fast, e.g., by speech compressed to 50% of its rate or even lower (which can be measured in words per minute or syllables per second), processing speed may not keep up with presentation speed, and processing delays may result in significantly longer processing times compared to those at the normal speech rate (e.g., Janse, 2004; Wingfield *et al*., 2003, Wingfield, McCoy, Peelle, Tun, & Cox, 2006). Likewise, processing of degraded acoustic stimuli, such as sentences presented in noise, have been associated with a slowing of processing speed (e.g., Obleser, Woestmann, Hellbernd, Wilsch, & Maess, 2012; Pichora-Fuller, 2003), reflected by longer response for sentences presented with background noise than for those without noise (e.g., Carroll & Ruigendijk, 2013; Wingfield *et al*., 2006). Processing two tasks simultaneously may also decrease processing speed (e.g., Ackerman, Beier, & Boyle, 2002, see also below).

3.4 Cognitive processes

Not only exact timing and thus sufficient processing speed is considered to be mandatory for non-canonical sentence processing, but also the involvement of cognitive abilities, such as e.g., working memory and attention. Already mentioned, the proposed reactivation of an already activated element and successive integration operations are thought to demand memory capacity, as the antecedent has to be stored temporarily in memory until it can be integrated at its canonical position (Clifton & Frazier, 1998; Felser *et al.*, 2003). Storage and integration of antecedent-trace-chains are supposed to take place in *working memory* (WM) (e.g., Clifton & Frazier, 1998; Felser *et al.*, 2003; Friederici *et al.*, 2006; Gibson, 1998). Also, attention and processes necessary to monitor and control the parsing processes are considered to be involved in sentence processing.

In order to understand spoken language, the acoustic presentations have to be mapped with phonological representations stored in *long-term* memory, a process, which takes place over time. Thus, to process even one word, some mechanism is needed to maintain the activation of this representation until its processing is complete. This short duration of maintenance is assumed to be executed by working memory.[14] The serial order of the information is argued to be processed too in working memory in order to extract the

[14] Some researchers assume that storage is executed by a special part of WM, the *short-term memory* (STM) (Kalinyak-Fliszar, Kohen, & Martin, 2011; Martin & Saffran, 1999), which is thought to store the serial order of the verbally coded information in a *phonological loop* (Baddeley, 2003). In this manner WM encompasses STM, by storing phonological information *while simultaneously manipulating or integrating other information*, in this case for comprehension of auditory language. But the borders between working memory, short-term memory, and long-term memory are not clear cut. Plus, there are different notions about STM and WM. Here, I will refer to WM as a resource pool for temporary storage of information while simultaneously manipulating or integrating other information (cf. Caplan & Waters, 1999, 2013).

information and to identify the relationships between the single components, i.e., to parse the lexical elements syntactically. Both processes of storage and integration are proposed to be space- and time-limited (Baddeley, 2003; Caplan & Waters, 1999; Just & Carpenter, 1982; Miyake *et al.*, 1994, 1995), and decay or forgetting of information may follow if those limits are exceeded. This might affect in particular the integration of a moved object, especially when one or more similar element(s) intervene in the parsing process (cf. Gibson, 2000; Rizzi, 1997). The degree of *capacity* of the cognitive function may also determine the limit: For working memory it has been noted that a higher WM capacity may aid a longer temporal storage (e.g., McElree, Foraker, & Dyer, 2003). This positive relationship has been seen in correlations between performance on certain working memory tests as the digit span task (Blackburn & Benton, 1955) and syntactic complexity tasks (Kemper, 1987). However, it is argued that a higher amount of temporary storage abilities may only facilitate offline *post-interpretive* processes for extracting the propositional meaning of the sentence (Caplan & Waters, 1999), but not online processing (cf. Caplan *et al*., 2011).

Not only memory, but also other cognitive abilities are thought to be involved in processing sentences: E*xecutive* functions are suggested to control, which information occupies the work space of working memory, and also to guide the encoding of information towards the most relevant parts of a sentence (e.g., Miyake *et al*., 1994, 1995). These executive processes are assumed to involve attentional switching, inhibition, and updating and monitoring. *Attentional switching* is thought to be required to shift from one task to another, such as reactivating the antecedent at the trace site before continuing parsing. *Inhibition* is needed in order to suppress irrelevant information- e.g., noise- while focussing on relevant information. *Updating* has been seen to require monitoring, coding, and adapting of the information with other incoming information (Miyake *et al.*, 1994), such as choosing the correct lexical meaning for a particular sentence context. In other words, executive functions may serve to *control* differentiating, decoding and encoding the acoustic stimuli of the auditorily presented sentence into a meaningful interpretation. Information lying outside these mechanisms are assumed to be neglected and thus not remembered (Awh, Vogel, & Oh, 2006). Moreover, insufficient resource allocation of a cognitive capacity might lead to problems of keeping various products of sentence processing active in memory, with the risk of forgetting or decay, i.e., only parts of the information staying in memory (cf. McNeil, Odell, & Tseng, 1991). If too many computational products are forgotten, e.g., due to limited capacity or deficient allocation, then the parsing mechanism is suggested not to be able anymore to link new information into the ongoing process. Besides, even if the information is still available, the products may be forgotten at the end of the presentation. Both memory failures may then result in misinterpretations of the sentence (Miyake *et al.*, 1994).

Described above, initial, intermediate or even final constructions of a syntactic representation of a sentence may have to be revised in the presence of new information. This is thought to be executed via *cognitive control*, which encompasses processes involved to resolve competing representations, such as suppressing a subject-first representation of a non-canonical sentence. *Competition* might stem from potential *conflicts* in thematic role assignment arising from information not fitting a canonical agent-first assignment. Cognitive control is assumed to resolve those conflicts in language processing e.g., by overriding an a subject-first preference (cf. Novick, Trueswell, & Thompson-Schill, 2005; Vuong & Martin, 2011). Alternatively, cognitive control is thought to be used to resolve the conflict by reanalysing parts or the whole of the information (see Caplan & Waters, 1999; Bornkessel-Schlesewsky & Schlesewsky, 2013). More, cognitive control is considered to supervise the reanalysis process when a wrong interpretation has been noticed after completion of the sentence, as in the case of garden path sentences, such as the famous sentence by Frazier & Fodor (1978) in example (3.28) where the initial parsing of *barn* as the object of the verb second clause has to be revised, and *barn* has to be reanalysed as object of the embedded relative clause.

(3.28) The horse raced past the barn fell (Frazier & Fodor, 1978)

In this sense, conflict resolution abilities are associated with planning, inhibition of responses, updating and switching abilities (cf. Miyake, Friedman, Emerson, Witzki, Howerter, & Wager, 2000), and may be regarded as a special aspect of executive functions or executive control[15].

[15] The two terms cognitive control and executive functions are both used as umbrella terms, which in a way define the same cognitive abilities. Therefore, I refer to cognitive control as ability of conflict resolution, while the term executive functions is applied for the complex functions (and network of functions), such as attention, inhibition, flexibility, planning, reasoning, and sequencing.

Many researchers assume executive functions to be part of working memory (e.g., Baddeley, 2000, 2003, Caplan & Waters, 1999; Caplan & Waters, 2013; Martin & Reilly, 2012; Miyake *et al.*, 2000)[16]. According to this account, working memory is thus a complex operation system, which includes several cognitive processes, such as attention to the stimuli, manipulation of the stimulus in terms of sequencing, analysing and potential revision, as well as a storage system in order to keep the stimulus active for as long as the operation(s) take place. In this sense, working memory is thought to permit or control interactions between attention, perception, and memory (Baddeley, 2003), and may be considered a foundation for executive abilities necessary in order to process non-canonical sentences.

Furthermore, there are suggestions of the specificity of working memory: The *single resource theory* assumes a global set of resources for all verbal and non-verbal operations (Just & Carpenter, 1992; Miyake *et al.*, 1994), in that all storage and processing functions are served by a single source of activation. According to this account, general WM capacity, measured in *span size*, is related to complex processing, e.g., non-canonical sentence processing. In that manner, limited or deficient capacity of memory or executive functions is argued to exert a negative impact on complex sentence processing. While the single resource theory does not make a distinction between subsystems in sentence processing, Caplan & Waters (1999) postulate a system with specific verbal and non-verbal resources (Caplan & Waters, 1999, 2013): This *dual* or *multiple resource account* even specifies a specific verbal working memory component responsible for syntactic comprehension and the extraction of semantic and syntactic features from linguistic signals, which is claimed to be independent of other verbal working memory components. This assumption entails that syntactic processing is not influenced by limited capacity of non-verbal working memory abilities, evidenced by e.g., neuropsychological or dementia patients with limited memory spans who had no deficits comprehending complex syntactic structures (e.g., Caplan & Waters, 1999). In this respect, increased syntactic processing load is assumed not to affect the capacity of other working memory components.

Moreover, while some researchers postulate syntactic parsing mechanisms as a specialized variant of general processing mechanism (e.g., Lewis, 2000; Lewis & Vasishth,

---

[16] In Baddeley's model of WM (Baddeley, 2000, 2003), all parts are integrated; the episodic buffer may serve as STM, and the central executive seems to control and regulate attentional and other processes crucial for the necessary linguistic operations.

2005), other studies claim that the syntactic parsing operations of retrieval, encoding and integration are different from those of general memory and integration processes (Caplan & Waters, 2013). Still, independent of the architecture of working memory, there is general agreement that working memory is crucially involved in non-canonical sentence processing.

Working memory and processing speed are assumed to be strongly related (e.g., Caplan *et al.*, 2011; Kail & Salthouse, 1994; Manard, Carabin, Jaspar, & Collette, 2014; Waters & Caplan, 2005), and are considered by some researchers to interact in non-canonical sentence processing: Higher memory load because of storage and integration of antecedent-trace relations (Gibson, 2000; Kaan & Swaab, 2002) has been argued to slow down syntactic processing speed (Just & Carpenter, 1992; Waters, Caplan, Alpert, & Stanczak, 2003). Also, slower processing speed may be the consequence of increased processing load for decoding degraded acoustic stimuli, which leaves less capacity to encode the stimuli in working memory (Arlinger *et al.*, 2009; Obleser *et al*., 2012; Pichora-Fuller, 2003; Wingfield *et al.*, 2006). Some researchers even claim that speed of processing determines the amount of data that can be manipulated in a given amount of time (e.g., Fry & Hale, 2000; Salthouse, 1992). Salthouse himself assumes processing speed to determine the efficiency of other cognitive capacities, such as working memory, by limiting the amount of information, which can be stored and manipulated at the same time (Salthouse, 1992). However, the degree of processing speed may not necessarily decrease while processing non-canonical or other complex sentences, but, as pointed out above, longer response times may reflect a longer processing time arising from the additional operations assumed to be carried out, while the degree of processing speed is maintained.

Summary

Construction of a syntactic representation of a non-canonical active transitive sentence includes identification of subject and object and assignment of correct thematic roles. In non-canonical sentences, integration of a postulated moved object has been seen to increase processing load and to result in a canonicity effect. Nonetheless, in German overt non-nominative case marking may aid fast identification of the object in a reversed word order and thus rapid role assignment, while case-ambiguous sentence-initial elements may be initially processed as subject on account of processing preferences. However, reanalysis induced by the occurrence of elements not fitting the first assumption has been noted to be a fast process, too. In German, parsing might include a morphological and a syntactic route. These may be slower than subject-first and heuristic processing preferences and overriding the latter may be reflected in canonicity effects.

In auditory sentence processing, processing of non-canonical sentences is considered to need an exact timing between the acoustic presentation and the linguistic operations necessary to construct the correct syntactic representation. Timing abilities seem to be influenced by processing speed, which determines the rate of information being processed in a given amount of time. Linguistic processing, in particular syntactic parsing, is assumed to be also supported and/or regulated by other cognitive functions, such as working memory and cognitive control. Non-canonical sentences do not only seem to impose a higher processing load on working memory and other cognitive functions, but have also been seen to prolong processing. Longer processing duration due to increased processing load may disturb timing and may even lead to delayed processing, especially for non-canonical sentences. Delays increase the risk of neglect, decay or forgetting of linguistic information, which poses a higher risk to misinterpret a non-canonical structure as a canonical one.

4 Non-canonical sentence processing in aphasia

In this chapter, non-canonical sentence processing in agrammatic and other types of aphasia is described and possible underlying cause(s) are discussed. Difficulties processing non-canonical sentences seem to be a main feature of sentence comprehension deficits in aphasia. While processing subject-first structures seems to be less problematic because of the possibility to apply heuristic strategies and/or to follow processing preferences, object-first structures are often misinterpreted by persons with aphasia (PWA). The canonicity effect in agrammatic and also in other types of aphasia might partly be caused by an impaired ability to integrate morphosyntactic features of case and/or agreement in order to assign thematic roles, demonstrated by results from cross-linguistic aphasia research. In contrast to non-brain-damaged listeners, where object-first sentence processing was seen to result in longer response times due to the complexity involved, PWA may be pathologically slowed-down in their linguistic processing, and PWA and other brain-damaged individuals have demonstrated longer response times on verbal and non-verbal tasks compared to non-brain-damaged controls. In particular for agrammatic PWA, this suggested slower-than-normal processing was observed to result in delayed processing of especially antecedent-trace relations, i.e. in object integration. The *Slowed Processing Hypothesis (*SPH) with its several sub-accounts assumes, that the cause of the syntactic deficits in agrammatic PWA is a timing insufficiency of either slower-than normal lexical, morphosyntactic, syntactic or general parsing. Slower-than-normal processing may be caused by a pathological reduction of processing speed. Besides reduced processing speed, aphasia is considered to be often accompanied by other cognitive deficiencies, which can also affect non-canonical sentence processing, and potential relationships are discussed. The last section of this chapter reviews the facilitating effect of slower speech on sentence processing in agrammatic and other aphasia.

4.1 Word order processing in agrammatism

Most research on non-canonical sentence comprehension has been conducted on PWA with *agrammatic aphasia*, *Broca's aphasia* or *agrammatic Broca's aphasia*, which often are regarded as synonyms (e.g., Caramazza & Zurif, 1976; Drai & Grodzinsky, 1999), and are defined mainly by *production* deficits.

Broca's aphasia has been traditionally defined as an aphasia type or *syndrome* with predominant expressive disorders defined by deficits in production, such as non-fluent, halting, labourful speech, often accompanied by word finding difficulties (especially for closed-class words) and paraphasias, and problems producing morphosyntactic markers or other grammatical elements in spoken and written utterances (Ingram, 2007).

Agrammatism on the other hand is a symptom strongly associated with Broca's aphasia and consists of spoken utterances, which often lack morphosyntactic cues for case, agreement, tense, gender and/or number, and contain a higher degree of infinitives and uninflected nouns and adjectives. Utterances are generally shorter, and may consist of 2-3 word sentences. In moderate or severe agrammatism, production may even only contain uninflected forms, a pattern termed "telegraphic". Depending on the severity, agrammatic production might contain less or more morphosyntactic features and closed class words (Ingram, 2007).

Still, characterization of agrammatism only by omission behaviour of bound and free grammatical morphemes is regarded by a number of researchers not to be entirely correct, because it is mainly based on the analysis of utterances from English-speaking PWA. In the speech of English agrammatic PWA, morphosyntactic markers for agreement, number and tense on verbs, nouns and/or adjectives are often omitted (cf. Bayer, de Bleser, & Dronsek, 1987). But PWA with a richer morphological first language were observed to be able to *substitute* grammatical elements as well, and substitutions may sometimes even occur to a higher degree than omissions. Italian and German agrammatic PWA were seen to produce case-inflected articles in a picture description task, and errors consisted more of substitutions than omissions (Bates, Friederici, & Wulfeck, 1987a). German agrammatic PWA were noted to produce morphosyntactic markers for case and number for determiners, even if those were the wrong markers (Bastiaanse, Jonkers, Ruigendijk, & van Zonneveld, 2003; for picture description; Bayer *et al*, 1987, for sentence completion). Specifically, in German, where definite and indefinite determiners specified for gender are also case-marked, agrammatic PWA were observed to substitute determiners with a wrong case inflection rather than omitting them altogether (Bastiaanse *et al.*, 2003). These findings suggest that case as a syntactic feature is not deleted in the representational knowledge of German agrammatic PWA, it rather seems that they suffer from an impaired ability to encode that particular syntactic information in their sentence construction (see also Ruigendijk, 2002).

Turning to *comprehension*, agrammatic or Broca's aphasia has been linked with comprehension deficits of morphosyntactic features, such as case and agreement, and deficits interpreting non-canonical word order. In contrast to the syntactic impairment, Broca's aphasia is also associated with -relatively- unimpaired lexical comprehension (Ingram, 2007). This latter assumption has proved to be an over-generalisation, because some PWA with Broca's aphasia have demonstrated impaired lexical activation (e.g., Milberg, Blumstein, & Dvoretzky, 1988; Utman, Blumstein, & Sullivan, 2001; see also chapters 4.3.2 and 6.1). Likewise, some researchers have characterized comprehension deficits in agrammatic or Broca's aphasia as being similar to their production deficits (e.g., Berndt & Caramazza, 1980; Caramazza & Zurif, 1976), which neither has proven to be entirely correct, because dissociations between production and comprehension have been reported: Agrammatic PWA may not be able to produce cues, which they can comprehend (e.g., Caramazza, Capasso, Capitani, & Miceli; 2005; Friedmann & Grodzinsky, 1997; Swinney & Zurif, 1995). In some cases, agrammatic production may even occur without any comprehension deficits (Bastiaanse, 1995; Burchert *et al.*, 2003; Caplan *et al.*, 2007; Miceli, Mazzuchi, Menn, & Goodglass, 1983, Miceli & Caramazza, 1988; Nespoulous *et al.*, 1988).

For English with its rather rigid word order, agrammatic PWA appear to rely rather heavily on a SVO word order, and sentences deviating from the basic subject-first word order were noticed to be comprehended with (within-) chance performance, or even with below-chance performance[17] (e.g., Bates *et al.*, 1987; Caplan, Waters, DeDe, Michaud, & Reddy, 2004; Choy & Thompson, 2010; Dick *et al.*, 2001; Dickey *et al.*, 2007; Love *et al*, 2008). But also in languages with a more flexible word order, and thus a higher degree of occurrence of non-subject-first structures, comprehension of non-canonical sentences have proved to be difficult for PWA: Canonicity effects were seen for Dutch (e.g., Friederici & Kilborn, 1989; Wassenaar, Brown, & Hagoort, 2004; Wassenaar & Hagoort, 2007; Greek (Varlokosta, Valeonti, Kakavoulia, Lazaridou, Economou, & Protopapas, 2006), and German (Burchert *et al.*, 2003; Burchert, Friedmann, & de Bleser, 2003a; Burchert & de Bleser, 2004; Hanne *et al.*, 2011, 2015), Hebrew (Friedmann & Gvion, 2003; 2012; Friedmann & Shapiro, 2003),

[17] The notion of chance performance is a mathematical one: *Chance level* is at 50% accuracy, responding to half of the number of the stimuli used. Within-chance, above-chance and below-chance *ranges* are computed by the number of the stimuli used. Within-chance performance of e.g. 15 stimuli corresponds roughly to 33%-67% accuracy (Within-) chance performance implies an almost equal distribution of correct and incorrect answers to a stimulus, meaning that accuracy is not very different from chance value. Below-chance performance includes a higher degree of incorrect answers, while above-chance performance contains a higher degree of correct responses.
The notion of chance performance in aphasic performance has been defined by the TDH as a performance pattern with either within-chance, above-chance or below-chance ranges for *group* results. Guessing would result in within-chance performance, while intact knowledge should be reflected by above-chance performance (see chapter 4.3.1).

Italian (Bates *et al.*, 1987; Garaffa & Grillo, 2007; Papagno, Bricolo, Mussi, Daini, & Cecchetto, 2012), Hungarian (Lukatela, Crain, & Shankweiler, 1988; MacWhinney *et al.*, 1991), Serbo-Croation (Milekic, Boskovic, Crain, & Shankweiler, 1995; Smith & Bates, 1987), and Turkish (MacWhinney *et al.*, 1991; Yarbay Duman, Altinok, Özgirgin, & Bastiaanse, 2011).

Some researchers (e.g., Grodzinsky, 1995; Friedmann & Gvion, 2012) have suggested that the underlying deficit might be caused by impaired processing of movement (see chapter 4.3), but the associated object integration may not be the main difficulty PWA face when processing object-first structures. Processing movement as such does not seem to be impaired in agrammatic aphasia, as agrammatic PWA demonstrated intact comprehension of sentences with verb- or subject movement, such as wh-questions or verb-initial sentences (e.g., Dickey *et al*., 2007; Hickock & Avrutin, 1995; Neuhaus & Penke, 2008; Sheppard *et al*., 2015). This finding led other researchers to assume that is the *distance* between antecedent and trace that provokes canonicity effects in agrammatic (and other) aphasia. Distance has been seen to affect non-brain-damaged listeners too, but may affect aphasic processing to a higher degree. Lengthening the distance between the antecedent and the trace and/or the occurrence of a similar intervener in the antecedent-trace chain was noted to increase the difficulties in object-first sentence processing in agrammatic aphasia (Sheppard *et al.*, 2015): Agrammatic PWA have demonstrated even more deficits in interpreting sentences, when a similar *intervener*, e.g., a referential NP, is present, than for sentences without such an intervening element (see also Friedmann & Gvion, 2012). While the SR with the subject-extracted wh-phrase in example (4.1) is assumed to contain no visible element between the trace and the moved DP in the Spec/CP-position, in example (4.2), the subject NP *the policeman* intervenes between the antecedent and the trace. Agrammatic PWA in this study both had longer response times and lower accuracy for items like (4.2), compared to those of (4.1) and compared to those of the control group.

(4.1) $_{CP}$[Which fireman]$_{i}$_$_{ti}$ pushed the policeman.

(4.2) $_{CP}$[Which fireman]$_{i}$ did the policeman push_$_{ti}$? (Sheppard *et al.*, 2015)

More, long-distance dependencies seem to pose problems for many PWA even in canonical structures (e.g., Ferrill, Love, Walenski, & Shapiro, 2012; Zurif, Swinney, Prather, Solomon, & Bushell, 1993; but see Friedmann & Gvion (2003) whose Hebrew-speaking agrammatic PWA did not have a worse performance in long-distance compared to short-distance dependencies in SR items). Zurif *et al.* (1993) found processing differences between persons with paragrammatic and agrammatic aphasia in sentences with a longer distance between antecedent and trace like in example (4.3). In these SR structures, the relative pronoun is co-indexed with the object of the matrix clause, and the distance between both antecedent and pronoun is defined as long owed to the intervening PP *from the Northwestern city*.

(4.3) The gymnast loved the professor$_i$ from the Northwestern city who_$_{ti}$ complained about the bad coffee (Zurif *et al*., 1993).

Longer distance due to the intervener did not decrease priming (see chapter 4.3.2 for more details on priming tasks) effects for the antecedent at the trace site for paragrammatic PWA, in contrast to agrammatic PWA, who displayed deficient priming at the trace site (Zurif *et al.*, 1993). This deficit of agrammatic PWA was interpreted as difficulties noticing and/or filling the trace (Caramazza *et al.*, 1981; Zurif *et al.*, 1993).

It has been claimed that agrammatic PWA do not primarily process syntactically, but rather seem to rely on heuristic strategies in order to interpret sentences (e.g., Grodzinsky, 1995). Canonicity effects in agrammatic and other aphasia often occur when processing semantically *reversible* sentences, where all available NP can serve as agent, and world knowledge cannot aid thematic role assignment. Here, agrammatic PWA often appear to choose the first sentential DP as agent (e.g., Berndt, Mitchum, & Haendiges, 1996; Burchert *et al.*, 2003, Caplan, 2001). Agent-first processing has also been seen in non-brain-damaged listeners (see chapter 3 and 5.3), but PWA may apply this strategy to a much higher degree. Likewise, the *animacy* effect of preferring an animate noun as agent may also be present to a higher degree than in non-brain-damaged listeners (cf. Bates *et al.*, 1987; MacWhinney *et al.*, 1991).

Recent research on the other hand demonstrated that an agent-first preference may not seem to be the first processing *choice* in German agrammatic and other PWA (Hanne *et al.*, 2011, 2015; Schumacher *et al*, 2015), especially when the sentence-initial DP has an ambiguous case marking (Hanne *et al.*, 2015; see chapter 4.2.1). These findings indicate that only in the presence of a syntactic processing difficulty, PWA may have to resort to heuristics in order to interpret a sentence. This strategy-based behaviour may also apply when PWA are in doubt about their processing results, reflected in unsuccessful attempts of reanalysis (see below).

Canonicity effects are not restricted to agrammatic or Broca's aphasia, rather, they are claimed to be a general feature of aphasia: Syntactic comprehension deficits, also termed receptive agrammatism (Bates & Goodman, 1997; Bates *et al*., 1987; Ingram, 2007), were found to be present in all aphasia syndromes (Bates & Goodman, 1997; Caramazza *et al*., 1981; Ingram, 2007; Lukatela, Shankweiler, & Crain, 1995). Canonicity effects have been observed in adults with paragrammatic or Wernicke's aphasia[18] (e.g., Bates *et al*., 1987; Dick, Bates, Wulfeck, Utman, Dronkers, & Gernsbacher, 2001; Wilson & Saygin, 2004), Conduction aphasia (e.g., Caramazza *et al*., 1981; Dick *et al*., 2001), and anomic or amnestic aphasia (e.g., Dick *et al*., 2001; Smith & Bates, 1987; Wilson & Saygin, 2004). More specific, processing of case or agreement features has also been seen to be deficient in residual, paragrammatic and anomic aphasia (e.g., Adelt *et al*., 2017; Bates *et al*., 1987; Hanne *et al*., 2015; see chapter 4.2).

4.2 Morphosyntactic deficits in agrammatic aphasia: Cross-linguistic differences

Cross-linguistic differences suggest that the canonicity effect in agrammatic and other aphasias may not only result from a general inability to notice or recognize the trace and/or integrate the antecedent at the trace site. Deficient comprehension of non-canonical sentences might also follow from an impaired ability to integrate or interpret semantically opaque function words, such as prepositions, pronouns and/or determiners (Ingram, 2007). Processing of morphosyntactic markers may be even more deficient, and canonicity effects in aphasia are considered to be at least partially caused by an impaired ability to fully use morphosyntactic cues, such as case and agreement markers for the assignment of thematic roles (e.g., Bates *et al.*, 1987; Ingram, 2007). If these morphosyntactic cues cannot be processed completely,

[18] In the following, I will refer to PWA with Broca's aphasia as agrammatic PWA, to PWA with Wernicke's aphasia as paragrammatic PWA, to PWA with amnestic aphasa as anomic PWA, and to PWA with a residual aphasia as residual PWA.

inverted word order might not be noticed. In example (4.4), both the case marking of the relative pronoun and the plural agreement cue indicate that the antecedent *man* is the object of the relative clause. PWA who are impaired recognizing or integrating these cues might recognize the inverted word order and/or the trace after the verb, but may not be able to interpret it correctly, and fall back on a canonical interpretation, seen in example (4.5).

(4.4) The man$_{j}$ whom$_{ij}$ the children despise_$_{ti}$ cries.

(4.5) The man$_{j}$ who$_{j}$ despises the children cries.

Morphosyntactic processing deficits were also seen for agrammatic and other PWA, whose native language owns a relatively rich system of case and/or agreement markers, such as Italian (Bates *et al.*, 1987; Garaffa & Grillo, 2007; Papagno *et al.*, 2012), Hungarian (Lukatela *et al.*, 1988; MacWhinney *et al.*, 1991), Serbo-Croation (Milekic, Boskovic, Crain, & Shankweiler, 1995; Smith & Bates, 1987), and Turkish (MacWhinney *et al.*, 1991; Yarbay Duman *et al.*, 2011).

Dependent on the system of the language, morphosyntactic processing may be impaired differently in PWA: Bates *et al.* (1987) compared comprehension performance of agrammatic and paragrammatic English, German and Italian PWA on sentences varying in word order, agreement and animacy. While German and English PWA demonstrated a word order effect by showing a strong subject-first interpretation tendency for the sentences presented, the Italian PWA were less affected by reversed word. This latter effect might be explained by the rich morphosyntactic system for agreement allowing the verb to occur in almost all positions in active clauses in Italian, making Italian a language with a more flexible word order than German and English. What is more, while all groups were impaired in using agreement markers for sentence interpretation, the Italian PWA seemed to be more aware of or sensitive to agreement violations, and/or to be able to use the agreement cues to a higher degree than their English counterparts. Still, all PWA tended to assign the agent role to the animate object NP in non-canonical sentence structures, reflecting a preference of animacy over word order (Bates *et al.*, 1987; see also Bates & Goodman, 1997). In another study, English and Italian agrammatic PWA were both worse detecting agreement violations than word order violations (Wulfeck, Bates, & Capasso, 1991), but the results indicated that English PWA relied more on word order, while Italian PWA tended to rely more on animacy and agreement features.

Bates *et al.* (1987) concluded that processing of morphosyntactic features and closed class words are differently affected in PWA, depending on their native language, but that morphosyntactic processing deficits seem to be the cause of the canonicity effect in aphasia (see also Bates & Goodman, 1997). However, these findings have to be taken with caution because Bates *et al.* (1987a) and Wulfeck *et al.* (1991) used ungrammatical and/or semantically odd sentences, which could have biased results (cf. Hanne *et al.*, 2015), because listeners might have tried to make sense of these items according to the plausibility strategy, even with the risk of violating or neglecting syntactic rules. Nonetheless, those findings add evidence for a general difficulty of morphosyntactic processing in agrammatic and other types of aphasia. Performance differences may be caused by the degree or the type of impairment, such as e.g., a higher degree of case processing impairment compared to that of agreement cue processing. This difference may be due to the morphological system of the respective first language of the PWA. In the next section, findings from agrammatic and other aphasic processing of overt morphosyntactic markers is described.

4.2.1 Processing case

In languages with a rich morphosyntactic system, a sentence-initial object is often visible by non-nominative case marking, such as accusative or dative case. Mentioned above, impaired processing of these case markers in languages with overt case morphology is common in aphasia. In agrammatic as well as in paragrammatic or anomic aphasia, PWA have been seen with deficits using overt case cues in order to assign thematic roles. Sentence picture matching studies in languages with an overtly-marked case system, such as Russian (Friedmann, Reznick, Dolinski-Nuger, & Soboleva, 2010), and German (Burchert *et al.*, 2003; Hanne *et al.*, 2015), did not find a significant facilitating effect of overt case marking for non-canonical sentence offline comprehension for agrammatic and other PWA. Though, these results do not automatically exclude that PWA were not aware of or sensitive to case features. Awareness or *sensitivity* to case features seems to be at least partly retained in many PWA, seen in above-chance performance on comprehension of sentences containing these features (e.g., Burchert *et al*., 2003; Hanne *et al*.; 2011). Moreover, even within-chance performance may reflect a sensitivity to overt morphosyntactic features in non-canonical word order, otherwise a conflict in role assignment, as proposed by the Trace Deletion Hypothesis (TDH; Grodzinsky, 1995; see chapter 4.3.1), would not arise (Ruigendijk, personal communication). For example, Russian agrammatic PWA were suspected to use an agent-first strategy predominantly, and accuracy on object-relative clauses in a SPM was low, but still higher than 50% accuracy, reflecting awareness of the reversed word order (Friedmann *et al*., 2010). In contrast, Hungarian and Turkish agrammatic, paragrammatic and anomic PWA had a strong tendency to assign the thematic patient role to the accusative case-marked noun, irrespective of the word order of simple transitive sentences in an enactment task (MacWhinney *et al.*, 1991). Only when overt case markers were absent, PWA assigned thematic roles according to their native unmarked word order. For Turkish agrammatic PWA, results were similar in a SPM study by Yarbay Duman *et al.* (2011), who concluded that PWA demonstrated awareness of case and word order information, but seemed unable to integrate both types of information for correct sentence interpretation. Evidence for preserved competence of case information in agrammatic PWA also comes from Milekic *et al.* (1995), who noted that their Serbo-Croatian speaking agrammatic PWA detected case violations correctly above-chance level in a grammaticality judgment task. Lukatela *et al*. (1995) even observed above-chance performance for some agrammatic and paragrammatic Serbo-Croation PWA for non-canonical sentences in a SPM, while others were within or below chance. Their findings were interpreted as preserved sensitivity to case features but as an impaired ability to fully use those, while the degree of the impairment might be different among the PWA within the group.

But, as Hanne *et al.* (2015) pointed out, grammaticality judgment may not be specific in order to test whether PWA actually used case markers as a cue for thematic role identification, because grammatical judgment focusses more on post-interpretive processes than on interpretive ones. Further, most studies used methods, which did not allow to explore online behaviour, and only offline results could be interpreted.

For German PWA, comprehension of overt case was also noticed to be deficient, but still, PWA seemed to be aware of case (e.g., Hanne *et al.*, 2011, 2015). Burchert *et al.* (2003), using a SPM, implemented reversible active SVO sentences with overt nominative and accusative case marking (marked boldly), such as example (4.6) as wells as OVS items (example 4.7), where the only difference was the word order.

(4.6) **Der** Junge sucht **den** Vater.
The boy$_{\text{NOM}}$ is seeking the$_{\text{ACC}}$ father
'The boy is seeking the father.'

(4.7) **Den** Vater sucht **der** Junge.
The$_{ACC}$ father is seeking the$_{NOM}$ boy.
'It is the father whom the boy is seeking.' (Burchert *et al.*, 2003)

They also implemented centre-embedded relative clause structures with overt marking (marked boldly) of the relative pronoun for nominative case in SR in (4.8) and for accusative case in OR in (4.9).

(4.8) Der Junge, **der** den Vater küsst, ist im Park.
The$_{NOM}$ boy who$_{NOM}$ the$_{ACC}$ father kisses is in the park.
'The boy who kisses the father is in the park.'

(4.9) Der Junge, **den** der Vater küsst, ist im Park.
The$_{NOM}$ boy whom$_{ACC}$ the$_{NOM}$ father kisses is in the park.
'The boy whom the father kisses is in the park.' (Burchert *et al.*, 2003)

While Burchert *et al.* (2003) did not find evidence of a significant facilitating effect of overt case on sentence comprehension for all of the tested agrammatic PWA, they did notice a high variability within the tested group of PWA, ranking from normal-like to below-chance performance. A more recent SPM study by Hanne *et al.* (2011), using similar V2 items, also noted a high degree of variability: Two of their seven agrammatic subjects showed almost normal-like comprehension of non-canonical OVS, while others were above-chance or within-chance level, indicating that they seemed aware of case but were not able to integrate the case features. In another SPM study by Hanne *et al.* (2015) again with those stimuli, six of their eight PWA (agrammatic, anomic and paragrammatic) displayed canonicity effects for the OVS stimuli. But, in contrast to all the studies mentioned above, they also recorded online eye movements displaying different patterns for correctly interpreted OVS and SVO structures: Eye fixations to the target increased at the *second* DP of OVS sentences compared to those at SVO items after the first DP, implying more intensive processing, which in turn was taken as evidence that PWA recognized the inverted word order. In addition, they needed significantly more time to process the case-marked sentences, and had significantly longer response times on all items compared to the control group. The authors interpreted their findings in as such that their PWA were sensitive to case cues, but seemed to be delayed in integrating the markers in order to assign thematic roles (see also chapters 4.3.2 and 4.6). This interpretation is supported by another German eye tracking study by Schumacher *et al.* (2015), using SVO and OSV sentences with an ambiguous second DP, such as the SVO item (4.10) and the OVS item (4.11).

(4.10) Der Mann mit dem Korb fotografiert das Kind.

The$_{\mathrm{NOM}}$ man with the basket photographs the$_{\mathrm{AMB}}$ child.
'The man with the basket photographs the child.'

(4.11) Den Mann mit dem Korb fotografiert das Kind.

The$_{\mathrm{ACC}}$ man with the basket photographs the$_{\mathrm{AMB}}$ child.
'It is the man with the basket whom the child photographs. '
(Schumacher *et al*., 2015)

In their study, aphasic PWA (agrammatic, paragrammatic, anomic and residual) also displayed longer reaction times and delayed eye fixations compared to controls. On top of that, while processing OVS, PWA demonstrated a target preference at or after the end of the sentence, similar to the behaviour of the PWA in Hanne *et al*.'s studies (2011, 2015): For correctly answered items, increased exe fixations to the target appeared at the post-off region. Moreover, while fixating the foil after the verb region, some PWA switched fixations to the target during the latter subject part, a pattern interpreted as evidence for a revision process. According to the authors this latter behaviour might have either reflected delayed morphosyntactic cue recognition or integration.

4.2.2 Processing agreement

Processing of verbal agreement inflections, indexing a relationship between verb and subject in person and/or number, is also often impaired in aphasia. For French and English, agreement via free morphemes such as auxiliaries was better preserved in agrammatic PWA compared to agreement marked by affixes in main verbs; but both groups showed deficits compared to non-brain-damaged controls in a SPM (Nicol, Jakubowicz, & Goldblum, 1996). Hebrew speaking agrammatic PWA did neither benefit significantly from overt agreement cues for their comprehension of non-canonical sentences, seen by Burchert *et al*. (2003a), but again, variability was high, and one out of eight PWA could profit significantly from overt agreement cues. For Serbo-Croatian agrammatic and anomic PWA, agreement features alone did not facilitate sentence comprehension (Smith & Bates, 1987), but in combination with case cues thematic role assignment improved.

German agrammatic and paragrammatic PWA were also found with an impaired ability to use agreement features to assign thematic roles, shown in a grammaticality judgment study by Bates *et al.* (1987). Burchert *et al.* (2003) examined comprehension performance of agrammatic PWA of minimal V2 pairs with ambiguous case for both DP, which could only be disambiguated via agreement features, such as canonical SVO with plural agreement for the subject (marked boldly), seen in example (4.12) and non-canonical OVS (4.13) where the verb agreed in number to the singular object DP.

(4.12) Die Frauen küss**en** das Kind.

'The women kiss$_{\mathrm{PL}}$ the child.'

(4.13) Die Frauen küss**t** das Kind

'It is the women who the child kisses$_{\mathrm{SG}}$.' (Burchert *et al.*, 2003)

In the same study, accuracy for centre-embedded relative clauses, such as for canonical SR (4.14) and non-canonical OR (4.15) was assessed, and in order to assign correct thematic roles, the subject had to be identified by integrating the agreement markers (marked boldly).

(4.14) Das Kind, das die Frauen küss**t**, ist im Park.

'The child that kisses$_{\mathrm{SG}}$ the women is in the park.'

(4.15) Das Kind, das die Frauen küss**en**, ist im Park.

'The child that the women kiss$_{\mathrm{PL}}$ is in the park.' (Burchert *et al.*, 2003)

Agrammatic PWA showed lower accuracy on both non-canonical OVS and OR compared to the canonical sentences, indicating that agreement features did not aid role assignment. Still, group performance was above-chance level, reflecting sensitivity to these morphosyntactic cues. Moreover, two of the seven agrammatic PWA were able to use the agreement features in an almost normal way. Similarly, in a sentence completion task, agreement features were integrated correctly by three out of nine PWA (eight agrammatic and one global) (Burchert, Swoboda-Moll, & de Bleser, 2005, using similar stimuli).

Few online research has been conducted on agreement processing in aphasia. Wassenaar *et al.* (2004) conducted an ERP study with Dutch SVO sentences where subject and verb did not agree, and noted a deviated P600[19] effect, indicating that their agrammatic PWA were less sensitive to the violations. In contrast, Hanne *et al.* (2015) found that their agrammatic, anomic and paragrammatic PWA were capable of using agreement features provided in SVO (example 4.16) and OVS (example 4.17) items, in which ambiguity could only be resolved via the agreement features, but, compared to the controls, PWA seemed to adopt a different processing strategy. Besides lower accuracy on OVS, eye gazes of PWA were different from those of controls. The language-unimpaired group showed a subject-first preference when encountering the first DP, reflected in increased fixations on the SVO picture, and changed fixations to the target after hearing the verb, indicating a reanalysis process. PWA however started fixation to one picture, e.g., the target, *after* hearing the verb and increased fixations after the second DP, which Hanne *et al.* (2015) interpreted as a wait-and-see strategy arising from impaired *predictive* processing, i.e., that PWA did process those agreement markers to some degree (otherwise they would not wait), but did not use those cues to anticipate or predict the thematic roles specified by the argument structure of the verb. Also, similar to the experiment on case markers by Hanne *et al.* (2011), PWA in general displayed delayed fixations, which were taken as evidence that their PWA were in principle able to process morphological agreement cues but were delayed in their integration. Again, similar to Burchert *et al.* (2003) study on case and agreement processing, a high degree of performance variability among the participants was apparent, with only three PWA affected by word order,

[19] The P600 effect appears when syntactic violations are encountered. It is characterized by a positive raise of the electric potential, beginning at about 500 ms after stimulus onset, and has been observed as response to many kinds of syntactic anomalies.

reflected in below-chance performance, while the remaining five scored above-chance level in the OVS condition.

(4.16) Das Kind fängt die Frauen.
The$_{AMB}$ child catches$_{\mathrm{SG}}$ the$_{AMB}$ women$_{\mathrm{PL}}$
'The child catches the women.'

(4.17) Das Kind fangen die Frauen.
The$_{\mathrm{AMB}}$ child catch$_{\mathrm{PL}}$ the$_{\mathrm{AMB}}$ women$_{\mathrm{PL}}$
'It is the child that the women catch.' (Hanne *et al*., 2015)

Adelt *et al*. (2017) noted no difference in comprehension accuracy in agrammatic and anomic PWA's accuracy between SR (example 4.18) and OR items (example 4.19), which both contained a case-ambiguous the relative pronoun and disambiguation could only happen via the agreement features. While accuracy was still lower compared to those of controls, eye fixations to the target (or to the foil) only occurred after sentence offset, suggesting that PWA waited for the verb in order to assign thematic roles. This observation indicates that PWA did process agreement features to some degree.

(4.18) Wo ist das Kamel das die Igel wäscht?
Where is the$_{\mathrm{NOM}}$ camel$_{\mathrm{SG}}$ that$_{\mathrm{AMB}}$ the$_{\mathrm{AMB}}$ hedgehogs washes$_{\mathrm{SG}}$?
'Where is the camel that washes the hedgehogs?'

(4.19) Wo ist das Kamel das die Igel waschen?
Where is the$_{\mathrm{NOM}}$ camel$_{\mathrm{SG}}$ that$_{\mathrm{AMB}}$ the$_{\mathrm{AMB}}$ hedgehogs wash$_{\mathrm{PL}}$?
'Where is the camel that the hedgehogs wash?' (Adelt *et al*., 2017)

In contrast, when word order and thus thematic role assignment was only distinguishable by overt case of the relative pronoun, such as in examples (4.20) for SR, and (4.21) for OR, PWA demonstrated a significantly better performance on SR than OR. This dissociation was argued to reflect that PWA processed agreement features to a higher degree than case cues to assign thematic roles, and had to rely more on an agent-first strategy in case-marked compared to agreement-marked sentences (Adelt *et al*., 2017).

(4.20) Wo ist der Hamster, der den Frosch wäscht?
Where is the$_{\mathrm{NOM}}$ hamster who$_{\mathrm{NOM}}$ the$_{\mathrm{ACC}}$ frog washes$_{\mathrm{SG}}$?
'Where is the hamster who washes the frog?'

(4.21) Wo ist der Hamster, den der Frosch wäscht?
Where is the$_{\mathrm{NOM}}$ hamster who$_{\mathrm{ACC}}$ the$_{\mathrm{NOM}}$ frog washes$_{\mathrm{SG}}$?
'Where is the hamster whom the frog washes?' (Adelt *et al.*, 2017)

However, processing, or more specifically integration of agreement cues might still be impaired to a higher degree than that of case markers in German agrammatic PWA. Comparison of comprehension accuracy on subject-first and object-first items, which differed only in their case marking, such as the sentences used in Adelt *et al.*'s (2017) experiment (examples 4.20-4.21) were comprehended with a higher percentage of accuracy (SR: 76%, OR: 69%), than those with only agreement differences (SR: 60%, OR: 59%). In contrast, Hanne *et al.* (2015) only found a dissociation in V2 sentence comprehension. While SVO differing in either case or number resulted in a similar accuracy (77% respectively 78%), accuracy in OVS with differing from SVO in case-marking (examples 4.6 and 4.7) resulted in 46% compared to 64% for OVS items distinguishable by agreement features from SVO (examples 4.16 and 4.17). These dissociations imply tentatively that not only morphosyntactic markers but also sentence structure may affect agrammatic PWA's performance.

Furthermore, while the findings suggest that PWA are sensitive to but still impaired in processing agreement features sufficiently, processing of other verb inflections might be even more impaired: Agreement features have been noted to be better preserved in agrammatic and other PWA than tense or aspect features, at least for subject-first structures (cf. Wenzlaff & Clahsen, 2004, for German agrammatic PWA; Clahsen & Ali, 2009, for English agrammatic PWA; Varlokosta *et al.*, 2006, for Greek fluent and non-fluent PWA).

In summary, a number of studies have found that comprehension for non-canonical sentences is deficient in agrammatic and other types of aphasia. This might partly be caused by an impaired ability to fully process morphosyntactic features, such as for case and agreement. While most agrammatic and other PWA seem to be sensitive to those morphosyntactic markers, it is assumed that integration of these features is insufficient in order to assign thematic roles. The degree of the impairment may vary among PWA, and the richness of the morphosyntactic system for either case and/or agreement of the native language may impact on the ability to recognize and interpret object-first clauses.

4.3 The nature of canonicity effects in agrammatism

While the causes of the insufficiencies in non-canonical sentence comprehension have not been extensively researched upon for e.g., paragrammatic and/or anomic aphasia (some researchers assume deficient inhibition for competing linguistic information as possible cause for the canonicity effect in paragrammatic aphasia; e.g., Wiener, Tabor Conner, & Obler, 2004), canonicity effects in agrammatic aphasia have been the topic of a long tradition of research, and a number of different theories try to explain the underlying cause/s. Within these theories, there are two main theoretical accounts, a *representational* approach and a *processing* approach. The account on *impaired representation* of syntax and/or syntactic parsing processes assumes a *loss* of syntactic knowledge in agrammatic aphasia, while the processing account suggests *procedural limitations in parsing* within an intact syntactic knowledge system.

4.3.1 The Trace Deletion Hypothesis

The most prominent model of the representational approach is the *Trace Deletion Hypothesis* (TDH) (Grodzinsky, 1995, 1999, 2000, 2006), based on Chomsky's Government and Binding Theory (Chomsky, 1982). According to the TDH, in agrammatism, traces of movements of NP in non-canonical structures are not formed, or formed but deleted, resulting in incomplete constructions of syntactic representations in agrammatic PWA and/or persons with Broca's aphasia (see Caplan, 2001 for an overview on different categorizations of agrammatic PWA whose performance patterns have been used for evidence for the TDH). The TDH proposes that in agrammatic aphasia, traces of thematic or theta role (θ)-positions are deleted, which means that NP who have moved to positions, where they cannot receive a theta role assignment, are at risk. These positions include the SPEC/CP position, which is according to the TDH not constructed in agrammatic aphasia. Deletion of formerly constructed traces are assumed to result in an impaired recognition of the moved NP[20] as the

[20] The TDH uses the term NP to refer to a moved object instead of DP, si I will employ that term solely when referring to the TDH.

syntactic object (Grodzinsky, 1995). According to the TDH, especially topicalization, clausal embedding and wh-questions with object movement, which are by some researchers assumed to occupy the Spec/CP position (see chapter 2), are prone to be misinterpreted in agrammatic aphasia, while movements of NP to a lower syntactic tree position (e.g., to SPEC/IP) is still available in agrammatic aphasia. Grodzinsky (1995) formulated following hypothesis:

The postulations of the TDH (Grodzinsky, 1995)
(i) in agrammatic syntactic representation, traces in θ-positions are deleted
(ii) assign a NP a role by its linear position iff it has no θ-role (first NP = agent)

Trace deletion and thus a deficit of correct thematic role assignment is assumed to result in competing information about the thematic role of the moved NP, which PWA cannot solve syntactically, falling back on relying to cognitive default heuristics, i. e., the agent-first strategy, in order to assign the thematic roles (Grodzinsky, 1986): Because the moved NP is in the first position, it receives the thematic role of the agent. While this strategy leads to correct interpretation of subject-first structures, where the first NP as the subject fulfils the agent role, in non-canonical structures, the strategy does not help in object-first structures: When encountering the second, unmoved, NP, a *conflict* is postulated to occur, and agrammatic PWA as a consequence have to *guess*, which of the two NP receives the agent role.

The assumption of trace deletion in agrammatism seems similar to the hypothesis of decay of traces, which was suggested to explain the canonicity effect in non-brain-damaged speakers (e.g., Altmann *et al.*, 1998; Knöferle, 2007; see chapter 3). But while decay of traces is suggested to result from e.g., forgetting already constructed traces because of an increased working memory load of otherwise unimpaired syntactic knowledge, the TDH assumes that the syntactic knowledge in agrammatic aphasia is incomplete. Also, while unimpaired speakers have been observed to apply reanalysis processes to counteract the decay of information, the TDH does not seem to include the possibility that PWA are able to revise a faulty syntactic representation.

According to the TDH, guessing behaviour leads to (within-) chance performance in thematic role assignment for non-canonical structures. A *preferred* agent-first strategy would be reflected in a pattern of above-chance performance for comprehension in subject-first clauses, and within-chance performance at non-canonical sentences, while a *consistent* agent-first strategy would even lead to 100% accuracy for canonical and below-chance performance at non-canonical sentences (cf. Burchert *et al*., 2003). While the TDH admits that occasional above-chance performance in agrammatic PWA is possible, this performance is considered to reflect a higher correct guessing score (cf. Burchert *et al.*, 2013).

Still, guessing behaviour implies that agrammatic PWA are sensitive of a reversed word order in non-canonical sentences, signalled by certain morphosyntactic or other cues, because otherwise they would not experience a conflict and as a consequence have to rely on guessing. Grodzinsky (1995) explains this by postulating that while syntactic role assignment is impaired, thematic role assignment is still part of the grammar in agrammatic PWA in as such that the thematic argument structure of verbs is still preserved, including the case features of the arguments of the verb (Grodzinsky, 1995).

The TDH, mainly motivated by offline results of studies using English language, cannot fully account for contradictory results from other research demonstrating above-chance performance patterns on non-canonical structures (e.g., Berndt *et al.*, 1996; Burchert *et al.*, 2003, 2013; Caramazza *et al.*, 2001; Caramazza *et al.*, 2005; de Bleser, Schwarz, & Burchert, 2006; Hanne *et al.*, 2011), which may be owed to the offline character of the results: Many offline tasks are considered to demand the listener to consciously reflect on the task, i.e., to perform post-interpretive processes *after* hearing the sentence (Caplan & Waters, 1999), and do not reveal information about *interpretive* processes executed *while* hearing the stimulus. Besides that, post-interpretive processing is argued to include a higher working memory load than interpretive operations, because the whole sentence instead of only some elements has to be remembered, and strategy and responses have to be formulated, which are difficult to disentangle from the pure semantic or syntactic parsing processes (Ingram, 2007). For these reasons, offline accuracy performance may not reflect all processing operations performed during stimulus presentation, an assumption backed by observed dissociations between correct online eye movements and wrong offline interpretations in studies by e.g., Hanne *et al.* (2011, 2015).

Described in chapter 4.3, research has shown that individual agrammatic PWA are sometimes not only able to perform above-chance level but may also have normal-like performance in non-canonical sentence comprehension (e.g., Berndt *et al.*, 1996; Burchert *et al.*, 2003; Caplan *et al.*, 2007; Hanne *et al.*, 2015; Wilson & Saygin, 2004). Moreover, it has been noted that traces are not always deleted in agrammatic sentence processing (e.g., Dickey *et al.*, 2007; Dickey & Thompson, 2009; Love *et al.*, 2008). Observations of online behaviour indicate that PWA may be sensitive to traces, and, in some cases, even possess residual normal-like processing abilities (e.g., Hanne *et al.*, 2011, 2015). These and other online results (e.g., Choy & Thompson, 2010; Dickey *et al.*, 2007; Meyer *et al.*, 2012) also suggest that the assumption of a pattern of chance performance on object-first structures might no longer be tenable (Ingram, 2007): Pure guessing would not explain above-chance performance and the online findings of aphasic processing behaviour, in which PWA showed attempts of conflict resolution in terms of re-analysing the structure (e.g., Hanne *et al.*, 2011; 2015; Schumacher *et al.*, 2015; see below). Besides that, some researchers argue that guessing implies that correct comprehension of non-canonical sentences just happens accidentally, which denies PWA the ability of syntactic parsing (cf. Burchert; Hanne, & Vasishth, 2013). It is also argued that the criterion of chance performance does not allow to compare aphasic behaviour to unimpaired performance of normal control groups, because also for unimpaired listeners, results have to be regarded as above-chance performance (Caplan *et al.* (2007). Some researchers also criticise that the chance performance criterion as a mathematical analysis is only based on statistical means (where median and mean are identical due to computing the mean of the number of items rather than on performance on the items), and does not take normal variance in performance into account (e.g., Caplan *et al.*, 2007). According to the chance performance criterion, the mean of a number of items is always the same, independent of the complexity of the items. But Caplan *et al.* (2007) argue that there is a high variability in normal performance on non-canonical sentences, which has to be taken in consideration when talking about performance (e.g., canonicity effects in non-brain-damaged adults, see chapter 3 and 5.3). More, they claim that this variability is always accounted for in statistical analyses in form of standard deviations (SD), which reflect the range of normal-like performance. They therefore propose to use a different parameter, which recognizes this variability in order to determine whether agrammatic performance is “good” or “normal” respectively “poor” or “abnormal” by implementing a “within-1.74 SD-of normal” criterion, which they claim allows to regard agrammatic results as normal or good when they are within this parameter, and abnormal or poor when results are below it. Similarly, Burchert *et al.* (2003) implemented a “2 SD-within-normal” criterion using raw means (number of correct answers) and their variability in normal listeners to categorize agrammatic PWA performance as either “normal” (within 2 SD), “partially impaired” (below 2 SD but still above chance-level), “at chance” (within-change performance) or “below chance” (below-).

Another aspect of the TDH under criticism is that according to many authors, the TDH does not take cross-linguistic variances into consideration (but see Drai & Grodzinsky’s (2006) analysis of performance data of PWA from several non-English languages), and that TDH principles are difficult to apply to agrammatic behaviour in languages that do not have a basic SVO order representing an agent-action-patient/experiencer thematic role order, such as Turkish, Arabic, Hebrew or Japanese, or in languages with a more flexible word order, such as German, Dutch, Croatian, Hungarian, Italian, and Spanish (Bastiaanse & van Zonneveld, 2006; Bates *et al.*, 1987; Bates, Wulfeck, & MacWhinney, 1991; Caramazza *et al.*, 2005; Dick *et al.*, 2001; Kuehnast, 2011). Following this line of reasoning, it is argued that the facilitating effect of morphosyntactic information, such as overt case marking or tense and agreement features (e.g., Bates *et al.*, 1991; Clahsen & Ali, 2009; Varlokosta *et al.*, 2006; Wenzlaff & Clahsen, 2004; Yarbay Duman *et al.*, 2011) has not been considered sufficiently by the TDH. In addition, on account of the substantial amount of variability among agrammatic PWA’s performance, it has been claimed that there is hardly a uniform pattern of performance observable (Burchert *et al.*, 2003a; Caplan, 2001; Caramazza *et al.*, 2001; Garaffa & Grillo, 2007).

These and other postulated shortcomings of the TDH have led to another hypothesis, which suggests that syntactic representations are still intact in agrammatic aphasia, but that the procedures of lexical and/or syntactic parsing may be disturbed.

4.3.2 The Slowed Processing Hypothesis

The supporters of the *Slowed Processing Hypothesis* (SPH), or the *Slowed Processing Account* (e.g., Burkhardt *et al.*, 2003, 2008; Garaffa & Grillo, 2007; Hanne *et al.*, 2011, 2015; Love *et al.*, 2008; Zurif *et al.*, 1993) assume that deficient comprehension of non-canonical structures is caused by *temporal* linguistic processing deficits, i.e., that in agrammatic aphasia the timing between the time course of the presentation and actual processing is disturbed. According to them, the underlying representation of syntax is unimpaired, and agrammatic PWA possess intact grammatical knowledge, but syntactic parsing is assumed to be affected by processing or capacity limitations, which may result in a parsing breakdown for non-canonical structures. Within this account, there are differences regarding the cause of the processing limitation. Some researchers trace it down to specific linguistic limitations, leading to processing delays in either lexical access (e.g., Love *et al.*, 2008), lexical integration (e.g., Dickey *et al.*, 2007), syntactic parsing (e.g., Burkhardt *et al.*, 2008), or morphosyntactic cue integration (e.g., Hanne *et al.*, 2011), while others assume that all linguistic processes in agrammatic aphasia are slowed down (e.g., Swinney *et al.*, 1993), or that slower-than-normal processing is a general feature in agrammatic aphasia (e.g., Patil *et al.*, 2015). What is more, some authors also suggest that the proposed processing delays do not have to be a permanent feature of agrammatic processing (and also for other aphasic PWA), but may be effected by *intermittent* deficiencies (e.g., Burchert *et al.*, 2013) affecting lexical activation, lexical integration and/or (morpho)syntactic processes.

Lexical access or *activation* involves the mapping of sound to meaning. Some researchers believe the underlying deficit in agrammatic aphasia to be of slowed-down lexical activation (Ferill *et al.*, 2012; Love; Swinney, Zurif, 2001; Love *et al.*, 2008; Myers & Blumstein, 2005; Prather, Zurif, Love, & Brownell, 1997), and claim that activation of word meanings is too slow in order to keep up with real-time sentence presentation speed. Priming experiments are often used in order to test on-line processing of auditorily presented linguistic stimuli, and priming effects for the antecedent in terms of faster response times at trace sites have been interpreted as indication of a reactivation of the antecedent. Priming includes lexical decisions (i.e., deciding whether or not a string of letters is a word), and has been seen to be faster for target words preceded by semantically associated words than preceded by unrelated words. In priming experiments using word lists, Prather *et al.* (1997), Prather, Zurif, Stern, & Rosen, (1992), as well as Prather, Shapiro, Zurif, & Swinney (1997) discovered delayed priming effects in agrammatic PWA, reflected by longer response times than those of non-brain-damaged controls, which they took as evidence that that not all possible meanings of a lexical item were processed rapidly. Other studies with cross-modal lexical priming (CLMP) also demonstrated that a priming effect of the antecedent at the trace site in OR sentences was present, but delayed in agrammatic PWA (Love, Swinney, & Zurif, 2001; Love *et al.*, 2008; Swinney, Zurif, Prather, & Love, 1996). The researchers interpreted this delayed reactivation of the antecedent as evidence that their PWA were able to recognize the trace but were too slow to fill it in time, i.e., that the timing of object integration was deficient. Additionally, delayed lexical activation was also found in canonical structures without movement, such as in SVO sentences (Blumstein *et al.*, 1985; Ferrill *et al.*, 2012). In contrast, Zurif *et al.* (1993)

did not find priming effects at trace sites in SR items (such as example 4.3) for agrammatic PWA. Love *et al*. (2008) explain the canonicity effect with "[…] that the adverse effect of a temporal prolongation of lexical access is felt only when because of it the failure to create a syntactic link in time allows the confusing entry of a non-grammatical strategy." (Love *et al*., 2008, p. 214).

According to the lexical account, delayed activation of the lexicon is thought to result in delayed consequential processes of lexical selection, lexical integration and syntactic parsing. Slowed-down syntactic processing is thus regarded as a consequence of slowed-down lexical access (e.g., Love *et al.*, 2008). On the other hand, several studies have shown that agrammatic PWA seem to be sensitive to some syntactic violations (e.g., Baum, 1996; Friederici & Kilborn, 1989: Haarmann & Kolk, 1991; Myers & Blumstein, 2005) or semantic violations within a sentence (Swaab, Brown, & Hagoort, 1997), indicating that lexical access must have had taken place in time, otherwise a syntactic presentation could not have been formed in order to detect grammatical and/or contextual errors.

Another possible slowed-down process might be *lexical integration*, i.e., the activation of information associated with the lexical item, such as e.g., the argument structure of the verb or the selectional restrictions of a lexical element necessary order to construct a syntactic representation (Meyer *et al*, 2012; Myers & Blumstein, 2005; Prather *et al.*, 1997; Swaab *et al*, 1998). Supporters of this account assume that deficits in non-canonical sentence comprehension are caused by a delayed integration of already activated lexical information, which may result in a delay in syntactic representation construction (e.g., Dickey *et al.*, 2007; Thompson & Choy, 2009). Dickey & Thompson (2009) conducted a SPM with three foils and implemented branching OR items. Findings included a slight postponement in antecedent integration, reflected by delayed eye movements to the object. They also noted a stronger effect of competition by the distractors, demonstrated by the number of eye fixations on foil pictures. These two findings were interpreted to reflect a deficit in integrating the antecedent into the syntactic representation. Similar results were reported by Choy (2012), who also noted that competition effects increased in incorrect responses. In another eye tracking experiment involving passive structures, Meyer *et al.* (2012) observed that correct interpretation happened *after* the end of the sentence was reached, whereas choice of the incorrect picture already emerged after the verb, concluding that "[…] successful lexical integration, which results in correct "non-canonical" interpretations of passive sentences (NP1 = theme), is generally slower than unsuccessful lexical integration, which leads to incorrect “canonical” responses (NP1 = agent).“ (Meyer *et al.*, 2012, p. 41). Added evidence for an integration problem has been proposed by a research studying agrammatic wh-questions processing (Dickey *et al.*, 2007; see chapter 4.6 for more details).

It is often not easy to distinguish between delayed lexical access and delayed lexical integration. Some of the results of Thompson and colleagues might be interpreted as lexical activation delay, such as the third experiment of Choy (2012), where eye movement latencies, i.e., the time from target presentation until fixation, of agrammatic PWA were (not significantly) slower than that of controls. More, eye movement latencies of PWA decreased in a task using slower speech (Dickey *et al.*, 2007), indicating that a prolonged presentation facilitated lexical processing (see chapter 4.6). From this perspective, the results of Dickey *et al.* (2007) might also be interpreted as lexical access delay because their stimuli were in a slower-than-normal speech rate, which might have enabled PWA to compensate for their slowed-down processing. Britz (2006) interpreted the results of her study with discourse-dependent sentences in as that “high-comprehending” agrammatic PWA showed lexical integration deficits, whereas “low comprehenders” suffered from both lexical access and lexical integration deficits. Britz suggested that severity of the comprehension impairment might be defined by the cause of the delay, i.e., that deficits in lexical activation and integration emanate in a more severely impaired comprehension performance than a deficit in only one lexical stage or in latter processing stages (Britz, 2006).

The third account on slower-than-normal processing in agrammatic aphasia concerns *syntactic parsing*: According to the *Slow Syntax Hypothesis* (SSH) (Piñango, 2000), agrammatic PWA have a syntactic timing deficit, in as such that they are considered to be impaired in forming a full syntactical presentation of non-canonical structures in the normal time course, but only with a temporal delay. Canonical structures on the other hand are argued to be processed in a normal time course, indicating that only some syntactic operations, e.g., antecedent-trace resolutions, are too slow (Piñango & Burkhardt, 2005, see also Hanne *et al.*, 2011). Piñango (2000) tested agrammatic PWA on their comprehension of OR and passives items, and concluded that because of slowed-down syntactic parsing a deficit of assigning thematic roles because of two competing syntactic representations arises. This interpretation included the assumption that agrammatic PWA were able to form antecedent-trace dependencies in as such, but were delayed in assigning thematic roles. In their CMLP study with OR sentences containing wh-movement, such as example (4.22), Burkhardt *et al.* (2003) found evidence for delayed priming effects of the antecedent of the wh-trace, leading them to conclude that "[…] the results suggest that dependency relations are affected because the basic syntactic processes by which they are instantiated have been slowed down. Nevertheless, the results also suggest that once syntactic activation is underway, all associated mechanisms will take place, including establishing long-distance dependencies in non-canonical constructions." (Burkhardt *et al.*, 2003, p. 18).

(4.22) The kid loved the cheese$_j$ which$_{j=i}$ the brand new microwave melted_$_{ti}$ yesterday afternoon while the entire family was watching TV.
(Burkhardt *et al*., 2003)

In another research, Dutch agrammatic PWA were noted to be delayed in resolving antecedent-reflexive dependencies (Burkhardt *et al.*, 2008), which again was suggested to result from a syntactic timing deficit, i.e., by limitations in building a syntactic construction during the time course of the presentation. In other words, according to the SSH, a slowed-down or even delayed syntactic parsing rate may thus develop into problems computing a fully formed representation of structures containing object movement while the syntactic knowledge is fully intact (Burkhardt *et al.*, 2003). Furthermore, this timing deficit may result in a *competition* between a rapidly built agent-first representation (which may be based on a cognitively motivated subject-first preference, as suggested by Bornkessel & Schlesewsky, 2006) and the syntactically constructed representation of a non-canonical sentence. It is proposed that when this fast agent-first representation cannot be overridden or suppressed, it wins, reflected in observed offline inaccuracy (see also chapter 3.1.3 for these two postulated processing routes). Evidence for problems overriding the heuristic representation comes from online observations: German agrammatic PWA sometimes seemed to notice that their interpretation was wrong, but appeared to be unable to change it (Hanne *et al*, 2011; Schumacher *et al*., 2015).

So in contrast to the TDH, which assumes a conflict between two NP competing for the agent role through trace deletion, supporters of the SSH argue that traces are not deleted but constructed in a slower-than-normal manner, which allows the construction of two different sentence representations, a too slow syntactic one *and* a faster heuristic one. Substantiation for intact syntactic knowledge also comes from the visual world paradigm: Eye tracking studies demonstrated that in correct interpretations of non-canonical sentences, the eye movement patterns of agrammatic PWA were identical or similar to those of unimpaired controls for wh-questions and object clefts, such as anticipatory eye movements towards a possible antecedent for the trace after hearing the verb (Dickey *et al.*, 2007), but generally slower than those of the control persons (e.g., Hanne *et al.*, 2011; Schumacher *et al.*, 2015), indicating a timing insufficiency. In contrast, incorrect interpretations were accompanied by an increase of fixations towards the competitor at the end of the sentence, which may have led to wrong thematic role assignment.

In the already mentioned SPM study by Hanne *et al.* (2011), using German OVS structures, such as example (4.7), incorrect offline responses showed a clearly visible online aberrance of eye movements from that of correct responses: Agrammatic PWA initially displayed more fixations to the wrong picture, as was seen from the first accusatively case-marked DP, mirroring an agent-first interpretation. At the time the verb was presented, fixations turned to the target picture, indicating sensitivity to or recognition of the overt accusative case. At occurrence of the second nominative case-marked DP, fixations to the foil picture increased again. Hanne *et al.* (2011) concluded from this pattern that PWA seemed to be *uncertain*, in that they noticed the trace but were not able to revise their interpretation: “This increase in uncertainty of eye movements might be seen as reflecting an unsuccessful attempt to reanalyse the structure.” (Hanne *et al.*, 2011, p. 239). These observations may reflect that syntactic operations in -agrammatic- aphasia per se are not impaired, and even led some researchers to conclude that: “[…] there is no difference between aphasic and normal grammar; at the relevant level of analysis it makes no sense to speak about agrammatism at all.” (Garaffa & Grillo, 2007, p.17).

However, the assumptions of the SSH cannot account for the finding that agrammatic PWA also seem to have difficulties comprehending canonical structures, reflected in lower accuracy scores compared to control groups (e.g., Caplan *et al.*, 2004; Hanne *et al.*, 2011, 2015; Love *et al.*, 2008; Sheppard *et al.*, 2015; Wassenaar & Hagoort, 2007).

The Potsdam group (e.g., Burchert *et al.*, 2003; Hanne *et al.*, 21011, 2015; Patil *et al.*, 2015) as well as Schumacher *et al.* (2015) assumes that pathological slowing of processing is a general feature in agrammatic (and also other aphasic) processing, which affects in particular morphosyntactic integration. The eye-tracking studies of Hanne *et al.* (2011, 2015) and

Schumacher *et al.* (2015) (see chapter 4.3) included SVO and OVS items with overt case and/or agreement markers (see examples 4.6, 4.7, 4.10. 4.11, 4.12, 4.13). Further, Hanne *et al.* (2015) also implemented items with ambiguous case markings, whereby ambiguity was resolved by the agreement features, such as ambiguous SVO (4.23) and OVS (4.24).

(4.23) Das Kind fängt die Frauen.
The$_{\text{AMB}}$ child catches$_{\text{SG}}$ the$_{\text{AMB}}$ women.
'The child catches the women.'

(4.24) Das Kind fangen die Frauen.
The$_{\text{AMB}}$ child catch$_{\text{PL}}$ the$_{\text{AMB}}$ women.
'It is the women who catch the child.' (Hanne *et al.*, 2015)

In all three studies, reaction times of the participating PWA[21] were longer than those of the non-brain-damaged controls for both canonical and non-canonical items, and while eye movement patterns reflected that PWA were capable of integrating case and/or agreement cues (indicated by similar eye patterns to those of the normal controls), PWA were noticed to be delayed in this process in both SVO and OVS conditions. This delay could have led to a certain degree of decay or forgetting of traces (cf. Patil *et al.*, 2015), and/or to uncertainty in assigning thematic roles. A general delay in integrating morphosyntactic information would enable to explain why PWA also demonstrated longer response times in SVO sentences, and had a lower accuracy score on those compared to the control group because these sentences contained morphosyntactic cues, too. These observations give evidence for syntactic processing of subject-first structures in aphasia instead of application of a heuristic strategy proposed by the TDH.

Moreover, besides slower-than-normal processing, *intermittent deficiencies* of general intact parsing operations might impact on sentence processing. According to the Potsdam group as well as Schumacher *et al.* (2015), comprehension deficits may be caused by a temporal rather than a permanent breakdown of the parser. Correct responses above-chance level or normal-like performance are assumed to reflect that agrammatic and other PWA do

[21] Note that in Hanne *et al.* (2015) and Schumacher *et al.* (2015) experiments, the aphasic groups tested were heterogenuous, including agrammatic, anomic and paragrammatic PWA.

employ syntactic parsing operations, also signalled by normal-like eye movement patterns. Incorrect responses on the other hand are thought to be caused by intermittent reductions in *processing resources* (cf. Caplan *et al.*, 2007; see also Caplan *et al.*, 2004). Burchert *et al.* (2013) suggest: "[…] the random guessing behaviour that persons with aphasia often display does not necessarily reflect a syntactic breakdown in sentence comprehension and a random selection between alternatives. Instead it should be regarded as a result of temporal deficient parsing procedures in otherwise normal-like comprehension routines." (Burchert *et al.*, 2013, p. 112). The degree of the intermittent deficiencies might change, and within-chance and below-chance performance respectively impaired behaviour may signal an increase of this degree, possibly induced by an accumulation of deficiencies, which may vary among PWA. While these deficiencies have been proposed to be caused by reductions in processing resources (e.g., Adelt *et al.*, 2017; Burchert *et al.*, 2013; Caplan *et al.*, 2007; Haarmann & Kolk, 1991), the nature of these lacks certainty so far (cf. Caplan *et al.*, 2007). Haarmann & Kolk (1991) suggest either a reduction in the size of a syntactic buffer, slow activation of syntactic information, or a fast decay of syntactic information, but the cause of those decreased resources has yet to be determined. One potential candidate might be a pathological reduction of processing speed, as proposed by Caplan, Michaud, & Hufford (2013) and Swinney *et al.* (1993), which is further investigated in the next chapter.

4.4 Processing speed in aphasia

Caplan *et al*. (2013) and Swinney *et al.* (1993) suggest that syntactic processing resources may be delimited by slowed-down processing speed. A general pathological reduction in processing speed might explain the timing deficit in agrammatic PWA, reflected by longer processing times, as well as by the delayed but correct agrammatic processing of lexical, morphosyntactic and syntactic elements in both canonical and non-canonical structures found by several researchers of the Slowed Processing Hypothesis. Further evidence for this assumption comes from agrammatic performance on other linguistic tasks. Besides in sentence processing, agrammatic PWA were also noted to be slower in lexical decision (e.g., Baum, 1996; Burkhardt *et al.*, 2003; Friederici & Kilborn, 1989; Murray, Holland, & Beeson, 1997; Myers & Blumstein, 2005; Silkes & Rogers, 2010) and grammaticality judgments (e.g., Shankweiler, Crain, Gorrell, & Tuller, 1989; Smith, 2011; Wulfeck *et al.*, 1991) than unimpaired controls. Also, agrammatic PWA demonstrated longer response times in productive tasks, such as naming (e.g., Hashimoto & Thompson, 2001; Hula & McNeil, 2008).

A reduction of processing speed may affect non-canonical sentence processing to a higher degree than canonical sentence processing, laid out in chapter 3.3.1. Following the lines of Generative Grammar, prolonged processing of one element may result in missing one or more successive element/s, which consecutively increases the risk of not recognizing the trace, because processing of the element(s) preceding the trace might have not been completed at occurrence of the original site of the moved antecedent. As a consequence, the antecedent may not be integrated at all, or only with delay. On top of that, information about the antecedent might be decayed or even lost. With regard to the morphosyntactic account this might entail that slower-than-normal processing could in particular result in a higher risk missing morphosyntactic markers, such as for case and agreement. Alternatively, a delay may result in decay or forgetting of lexical, morphosyntactic or other linguistic information.

The consequences of delayed information processing are manifold, besides slower processing of incoming information, they were noted to manifest in slower decision making (e.g., for thematic role assignment), slower encoding of information in memory (e.g., lexical activation), as well as in difficulties retrieving information from memory (e.g., lexical access), learning new information, and problems doing two things simultaneously (such as listening to a stimulus while ignoring background noise) (Winkens, 2009). These deficits may be enhanced when the task itself is time-limited, as in the case of auditorily presented language.

However, there may be differences in the actual degree of speed reduction across PWA: It might be that slowing of processing speed in PWA is a gradual affair; and that some agrammatic PWA might be less slowed down than others (Love *et al.*, 2008). This could be caused by the *severity* of the aphasia and/or occurrence of other cognitive or physical deficiencies. Also, higher age (from 60 years+) might aggravate the postulated reduction in processing speed (see chapter 5.4). In addition, the *degree* of the speed reduction within one individual PWA may change, depending on other aspects, such as the grade of the complexity of the sentence or a concurrent load (Caplan *et al.*, 2007) (see chapter 3.4 and 3.5 for the potential interplay between speed of processing and working memory load). These intermittent changes in the degree of the pathological speed reduction within the same individual could thus explain performance patterns in agrammatic PWA with normal-like and abnormal parsing procedures within the same task for the same sentence structure. Processing speed within an aphasic individual might be also affected temporarily by other cognitive factors, such as decreased vigilance through exhaustion or fatigue (e.g., Christensen & Wright, 2014; McNeil *et al.*, 1991).

Not only agrammatic but also other PWA seem to be impaired in their processing speed, reflected e.g., in delayed eye fixations of anomic and paragrammatic PWA (Hanne *et al.*, 2015; Schumacher *et al.*, 2015), or in prolonged response times to lexical decision of fluent PWA compared to non-brain-damaged controls (Silkes & Roger, 2010). Anecdotal evidence for slowed-down processing comes from PWA themselves, who often complain that people speak too fast (Silkes, 2012), indicating that their processing speed is reduced.

Not all PWA seem to suffer from slowed-down processing speed, as Korda & Douglas (1997) demonstrated: Between 14% and 57% of their acute PWA (fluent and non-fluent) displayed delayed processing, depending on the task. In contrast, Neto & Santos (2011) found that out of 23 recovered PWA, 22 still exhibited response delays, which moved them to the conclusion that "[…] linguistic aspects may fully recover, but not their processing speed in the brain." (Neto & Santos, 2012, p. 1360).

Slower-than-normal processing in aphasia may not be restricted to linguistic processes, but can affect non-verbal processing as well, indicating a *general* pathological slowing of processing speed. Studies focussing on reaction times found that PWA were also delayed in simple or choice reaction time tasks (Korda & Douglas, 1997; Tartaglione, Bino, Manzino, Spadavecchia, & Favale, 1986), non-verbal priming (Peristeri & Tsimpli, 2014), tone discrimination (Murray *et al.*, 1997), and planning (Purdy, 2002). On the other hand, it has to be kept in mind that even minimal linguistic processing demands may have caused the delayed response times in the tasks (Silkes & Rogers, 2010). Nevertheless, it is argued that a slowed-down information processing rate due to processing speed reduction is a general consequence of brain damage, found also in non-aphasic stroke patients (Schaapmeerders *et al.*, 201; Turken *et al.*, 2008; Winkens, 2009), which can persist for years (e.g., Barker-Collo *et al.*, 2010; Schaapmeerders *et al.*, 2013; Tartaglione *et al.*, 1986). Also, regeneration of a normal level of processing speed has been noted to determine recovery skills in brain damage (e.g., Barker-Collo *et al.*, 2010; Cumming, Marshall, & Lazar, 2013; Turken *et al.*, 2008).

4.5 Cognitive processes in aphasia

Besides a processing speed reduction, aphasia in general is also often associated with cognitive deficiencies, which may also affect language processing. Almost all PWA seem to suffer from a working memory deficit (Allen *et al.*, 2012; Ivanova & Hallowell, 2012; Laures-Gore *et al.*, 2011, Kalinyak-Fliszar *et al.*, 2011), and there is strong evidence that at least part of the sentence comprehension deficit in agrammatic and other aphasias is caused by a reduced working memory capacity (e.g., Caplan *et al.*, 2004, 2007). This decrease may in decrease storage and/or manipulation abilities (e.g., Caspari, Parkinson, LaPointe, & Katz, 1998; Christensen & Wright, 2014; Papagno *et al.*, 2012; Wright, Downey, Gravier, Love, & Shapiro, 2007). Deficits in lexical processing seem to be associated with reduced WM capacities (e.g., Allen, Martin, & Martin, 2012; Martin & Saffran, 1999), which may limit the amount of storage of lexical material (Ivanova & Hallowell, 2012; Hickock, 2009; Miyake *et al.*, 1994; Potagas *et al.*, 2011; Wright *et al.*, 2007), implying that for postulated antecedent-trace relations, the antecedent may not be held sufficiently long in working memory in order to be integrated at the trace site. This might be in particular the case if the distance between antecedent and trace is prolonged by the presence of an intervener similar to the antecedent (Friedmann & Gvion, 2012).

Severity of aphasia seems to strongly correlate with the severity of the working memory impairment (e.g., Miyake *et al*, 1994; Potagas *et al.*, 2011; Wright *et al.*, 2007). Improvement of WM capacity, e.g., seen in increased span length, may also enhance language comprehension in aphasia, such as auditory sentence comprehension (Papagno *et al.*, 2012; Salis, 2011), or better comprehension in background noise (Majerus, van der Kaa, Renard, van der Linden, & Poncelet, 2005), indicating the strong relationship between verbal (STM and/or) WM capacity and certain language abilities. More, while in the acute stage, 30% of German stroke patients suffer from aphasia (Breitenstein *et al.*, 2014), in the chronic stage, only 12% of these patients still have language problems (40% of the initial PWA), and this difference might be partially produced by recovered cognitive functions, such as WM capacity.

Besides working memory deficits, aphasia in general has also been noted to be often accompanied by impaired executive functions, which are considered to be after language the most vulnerable cognitive skills in brain lesions (Helm-Estabrooks, 2002). Described in chapter 2.2, executive functions, i.e., attention, inhibition and cognitive control, are considered to be necessary to process non-canonical sentences successfully. Attentional problems appear to be present in a high number of PWA (Hula & McNeil, 2008; Korda & Douglas, 1997; McNeil *et al.*, 1991), such as impaired *allocation* of attention or attentional *control* (Erickson *et al.*, 1996; LaPointe & Erickson, 1991; Murray, 1999, 2000; Tseng, McNeil, & Milenkovic, 1993), and/or attentional *capacity* (cf. Murray, 1999). Anecdotal evidence comes from PWA themselves, who often complain about problems concentrating in situations with background noise (Silkes, 2012). These deficient attentional abilities or capacities may affect language processing in as such that comprehension becomes difficult if an individual cannot focus on parts or the whole of the auditory signal. Also, the span of sustained attention was noted to be shortened in aphasia; many PWA do not seem to be able to keep their attention on a task for longer than 30 minutes (Laures, Odell, & Coe, 2003), and this span may become even shorter in dual tasks (LaPointe & Erickson, 1991). Attentional deficits are often associated with insufficient *inhibition* of irrelevant information, which may also accompany aphasia (Martin & Reilly, 2012; Martin, Kohen, Kalinyak-Fliszar, Soveri, & Lain, 2012). Insufficient inhibition can hinder comprehension, if e.g., associated word meanings or phonological neighbours of a lexical element cannot be suppressed (cf. Hoffman, Jefferies, Ehsan, Jones, & Ralph, 2012), and insufficient inhibition has been associated with paragrammatism and comprehension difficulties in paragrammatic aphasia (e.g., Wiener *et al*., 2004).

Moreover, the degree of vigilance is assumed to determine attentional capacity, and reduced vigilance seems to be very common problem in aphasia, reflected in the observation that PWA need more effort and are faster exhausted than non-brain-damaged controls (e.g., Christensen, 2012; Christensen & Wright, 2014; McNeil *et al.*, 1991).

Cognitive control, often measured in aphasia by The Tower of Hanoi (Simon, 1975), The Tower of London (Shallice, 1982), or the Stroop Interference task (Stroop, 1935), have been seen to be often affected in aphasia, too (e.g., Glosser & Goodglass, 1990; Hoffman *et al.*, 2012; Purdy, 2002). Problems in cognitive control may be closely linked to deficits in conflict resolution, e.g., overriding the preference for subject-first processing in object-first sentences: It has been seen that even when PWA notice that their interpretation is wrong, they might not have the capacity/ability to change it, and/or just persevere in their behaviour

(Hanne *et al*, 2011; Papagno & Basso, 1996; Schumacher *et al*., 2015)[22]. Especially in acute aphasic patients, neuropsychological problems may overlay language performance (Nys, Zandvoort, de Kort, Jansen, de Haan, & Kappelle, 2007; Tatemichi, Desmond, Stern, Paik, Sano, & Bagiella, 1994), but chronic patients often display cognitive deficits as well (Barker-Collo, Feigin, Parag, Lawes, & Senior, 2010; Schaapmeerders *et al.*, 2013; Winkens, 2009).

The described cognitive deficits, or their degree, do not necessarily have to be a permanent feature: Temporary deficits of (an already decreased) resource allocation of attention, other executive functions and/or working memory have been suggested to impact on aphasic linguistic processing, much may lead to a high degree of variability among PWA, and also within the same aphasic individual (e.g., Hula & McNeil, 2008; McNeil & Pratt, 2001; Petroi, 2011). Different degrees of performance might adhere to different degrees of deficits in working memory and/or executive functions (Burchert *et al*., 2013; Erickson, Goldinger, & Lapointe, 1996; Murray, 2000). Moreover, intra-individual data of PWA can display huge differences in performance across days of testing or duration of testing.

Described in chapters 3.3 and 3.4, processing speed and cognitive abilities, such as working memory or executive functions may interact on each other. Deficits in working memory in terms of a reduction of capacity may also affect processing speed, because a de-allocation of resources might lead to a competition between storage and processing abilities, which has been suggested to slow down processing and to affect timing (Miyake *et al.*, 1994). On the other hand, decrease of processing speed may also reduce working memory abilities (Gordon-Salant & Fitzgibbons, 1997; Tun, 1998; Vaughan, Storzbach, & Furukawa, 2006).

The presence of both processing speed reductions and cognitive deficits may therefore impact on auditory sentence processing in agrammatic and other aphasia, resulting in insufficient timing of linguistic processing, which may affect non-canonical sentence

[22] A word of caution is needed, because the strong association between cognitive functions, such as verbal working memory ability and language might be partially explained by the fact that most cognitive tasks as the WM span test or manipulation tasks have verbal requirements (see also Caspari *et al.*, 1998; Christensen & Wright, 2010; Wright *et al.*, 2007). Also, most other standard WM tests use linguistic material, which may pose difficulties for PWA to process. Still, tests implementing the n-back method with non-verbal stimuli also found strong correlations between language impairment and WM deficits (Allen *et al.*, 2012 with tones; Christensen 2012, with abstract objects called “fribbles”). For the same reasons, it is also often difficult to distinguish deficits in executive processes from language deficits caused by aphasia. This also has to be kept in mind when assessing attentional abilities in aphasia (e.g., Christensen, 2012; McNeil, Doyle, Hula, & Rubinsky, 2004; Murray, 2000; Murray *et al.*, 1997), making it difficult to distinguish between language and cognitive impairments. Some researchers also assume that impairments in executive function can affect verbal WM (Martin *et al.*, 2012), which in turn may affect language comprehension.

comprehension more than that of canonical sentences, where PWA can still rely on a heuristic or guessing strategy as "last resort" (Hanne *et al.*, 2011). These processing reductions do not necessarily have to be a permanent feature of agrammatic and other aphasic processing, but are considered to appear also as intermittent deficiencies in syntactic parsing due to occasional forgetting of traces (Patil *et al.*, 2015), which in turn may result from a temporary overload of the assumed already reduced working memory capacity in aphasia.

4.6 Effects of slower speech on comprehension in aphasia

In order to counteract slowed-down processing speed and its consequences on linguistic and cognitive processing, slowing down the auditory input might facilitate sentence processing, and specifically that of non-canonical sentences. Slowing of speech does not only seem to be beneficial because it is thought to provide more processing time and may thus counteract the normally rapid presentation rate of spoken language, but also because it may reduce the strains on cognitive functions, such as working memory and/or attention[23] (e.g., Hillary *et al.*, 2010; Neto & Santos, 2012).

A common intervention in speech and language therapy for aphasia is to apply a slower speech rate in terms of pauses and accentuated articulation in order to aid PWAs' comprehension (Huber *et al.*, 2006; Marshall, 2004; Silkes, 2012). Therapeutic *clear speech* does not only involve a slower speaking rate, but also lengthening of pauses and pronounced articulation, resulting in lengthened vowel durations, more salient stop releases and higher obstruent intensity. (e.g., Krause & Braida, 2002; Shaw & Krause, 2007; see also chapter 5.5).

Table 4.1. depicts an overview on research studying the effect of slower speech on comprehension, discrimination and/or identification of speech stimuli, and some of these studies are presented in more detail in the following. If given more processing time in terms of a prolonged presentation, English-speaking agrammatic PWA have been seen to be able to improve their comprehension performance for non-canonical OR. Love *et al.* (2008) used a *uniform* (i.e., a linear expansion of the whole auditory stimulus) slowing method and presented branching OR items with long distance antecedent-trace dependencies, such as (4.25).

[23] This beneficial effect might be dependent on the rate of expansion, and dependent on the subject group. Whereas moderately slower speech (e.g., expansion to 3.8. sps) facilitated comprehension in aphasia, it disturbed processing in healthy young adults (Love *et al.*, 2008).

(4.25) The audience liked the wrestler$_i$ that the parish priest condemned_$_{ti}$ for foul language. (Love *et al*., 2008)

Sentences were expanded to 3.8 from 5.5 syllables per second[24] (sps), increasing PWA's accuracy significantly. Dickey *et al.* (2007) also found raised accuracy when PWA were presented with branching OR, such as example (4.26), with a speech rate of 3.3 sps instead of 4-6 sps[25]. In contrast, Choy (2012) expanded OR items (example 4.27) similar to the ones of Dickey *et al*. (2007) to ca. 135% of the original speech rate, and did not find a significant benefit in either accuracy or processing times.

(4.26) It was the girl who$_i$ the boy kissed_$_{ti}$ that day at school. (Dickey *et al*., 2007)

(4.27) It was the boy who$_i$ the girl kissed_$_{ti}$ that day at school. (Choy, 2012)

Lasky, Weidner, & Johnson (1976) lengthened their presentation of active and passive sentences from 150 to 120 words per minute (wpm), which facilitated comprehension for PWA significantly. Pashek & Brookshire (1982) and Poeck & Pietron (1981) decreased the speech rate of the sentences of the Token Test (de Renzi & Vignolo, 1962), and found general improvement, a result confirmed by other research based on the TT or Revised Token Test (RTT) from the 1970's and 80's (see table 4.1). Some of the results even led researchers to suggest that with a uniform slower rate, agrammatic aphasics' parsing abilities are comparable to normal, unimpaired syntactic processing (e.g., Dickey *et al.*, 2007).

Selective expansion of silent intervals between words, phrases and/or major syntactic boundaries may also facilitate comprehension: Blumstein *et al.* (1985) expanded the intervals between syntactic boundaries with 1000 ms in different subject-first and object-first structures, such as examples (4.28) and (4.29), and while group improvement was not significant, they found improved comprehension accuracy for paragrammatic PWA compared

---

[24] The average speech rate of American English has been defined with 4.0-6.2 sps (Love, Walenski, & Swinney, 2009; Pellegrino, Coupe, & Marsico, 2011; Schelten-Cornish, 2007), or 140-180 wpm (Wingfield *et al.*, 2003; Wingfield *et al.*, 2006).

[25] Dickey *et al.* (2007) used text passages, such as *This story is about a boy and a girl. One day, they were at school. The girl was pretty, so the boy kissed the girl. They were both embarrassed after the kiss. Who did the boy kiss that day at school?*, and measured accuracy and eye movements on wh-questions.

to that at the normal speech rate. Lasky *et al.* (1976) lengthened the interval between phrases with 1000 ms, which improved accuracy for active and passive sentences for the participating PWA.

(4.28) The girl who fed the baby held the glass.

(4.29) The boy who hit the girl chased the dog. (Blumstein *et al*., 1985)

In addition, *selective* expansion of certain phonetic features can facilitate perception performance in agrammatic and other PWA, but research is rare: Lengthening vowel durations has shown to aid some PWA (Blumstein *et al.*, 1985), Studies investigating discrimination of voice onset times (VOT) have noted that agrammatic, paragrammatic and/or anomic PWA need longer VOT in order to differentiate voiced from unvoiced plosives (Baum, 2001; Blumstein, Burton, Baum, Waldstein, & Katz, 1994; Boyzcuk & Baum, 1999). Riedel & Studdert Kennedy (1985) and Blumstein *et al.* (1994) extended formant transitions for place of articulation (POA), and only detected improvement for some of the participating PWA. This lack of significant benefit might have been caused by using *synthetic* stimuli, assumed to affect phonetic processing abilities (e.g., Ji, Galvin, Xu, & Fu, 2013).

Table 4.1. Research on effects of expanded selective or uniform speech on perception and comprehension in aphasia. The table shows the kind of stimuli used (stimuli), the tasks (task, Cross Modal Lexical Priming (CMLP), Cross Modal Lexical Decision (CMLD), lexical decision (LD), list priming paradigm (LPP), Revised Token Test (RTT), sentence picture matching (SPM), Token Test (TT)), the PWA tested (aphasia, RHD = right hemispheric damage), type of expansion (expansion), and the expansion rate (rate, in terms of syllables per second (sps), words per minute (wpm), with the original rate in brackets, the percentage of expansion or the inter stimulus interval (ISI)). Note that the list is not exhaustive.

Authors	**Stimuli**	**Task**	**Aphasia**	**Expansion**	**Rate**
Albert & Bear, 1957	SVO?	comprehension	word deaf	uniform	45 wpm (150 wpm); 330%
Baum, 1996	SVO, SR	LD	Broca's, anomic, Wernicke's	selective	ISI of 100 and 1000ms
Baum, 2001	SVO	phoneme identification	fluent,non-fluent	selective	VOT expansion in ca 5 ms steps
Blanchard & Prescott, 1980	sentences	TT		uniform	110 wpm, 75 wpm, 50 wpm (150 wpm); 125%, 150%, 175%
Blumstein *et al.*, 1994	words	phoneme identification	Broca's, Wernicke's, Conduction	selective	VOT expansion in different duration steps

Authors	**Stimuli**	**Task**	**Aphasia**	**Expansion**	**Rate**
Blumstein *et al.*, 1985	SVO, SR, passives	SPM	Broca's, Wernicke's	uniform and selective	110 wpm (180 wpm); 160 %; vowel expansion; 140%; inter-lexical ISI of 250 ms; inter-phrasal ISI of 250-500 ms; inter-syntactical boundary ISI of 1000 ms
Brookshire & Nicholas, 1986	text passages	comprehension	PWA	uniform	110 wpm (150 wpm); 125%
Choy, 2012; experiment 2	SR, OR	SPM	Broca's	uniform	125 wpm/4.6 sps (169 wpm/3.5 sps); 131%-135%
Dickey *et al.*, 2007	SR, OR	SPM	Broca's	uniform	3.3 sps (4-6 sps); 135%
Lasky *et al.*, 1976	SVO, passives	SPM	PWA	selective and uniform	120 wpm (150 wpm); 120%, with or without ISI of 1000 ms between phrases; 150 wpm with or without ISI of 1000 ms between phrases
Love *et al.*, 2008	SR, OR	CMLP	Broca's	uniform	3.8 to 5.5 sps (125%)
Pashek & Brookshire, 1981		TT	PWA	uniform	120 wpm (150 wpm); 125%
Poeck & Pietron, 1981		TT	PWA, RHD	uniform	120 wpm (150 wpm); 125%
Raithel & Wrede, 2003		TT	PWA	uniform	2.2-4.5 sps (in steps); (4-6 sps); 200-125%
Riedel & Studdert Kennedy, 1985	syllables	identification	fluent, nonfluent	selective	Formant transitions (F1, F2, F3) for POA
Riensche, Wohlert, & Porch, 1983		RTT	PWA	uniform	75, 90, 110 wpm (150 wpm); 200%, 160%, 130%

Summary

Many agrammatic and other PWA are impaired comprehending non-canonical sentences, which is assumed to be caused by insufficient recognition and/or integration of the moved object. This in turn may be at least partly caused by deficient integration of case and agreement features. While for German non-brain-damaged adults, case and/or agreement features may aid overruling a potential subject-first preference in non-canonical sentences (Hanne *et al.*, 2015), German agrammatic and other PWA have been noticed to be impaired in revision or reanalyses processes. Despite that, a combination of both overt morphosyntactic cues and word order may facilitate sentence processing, and some German agrammatic and other PWA demonstrated unimpaired processing abilities of overt case and/or agreement markers, while other did not. The high degree on variability of processing performance indicates that the degree of morphosyntactic impairment may differ in German PWA, which has been associated with e.g., the severity of the aphasia. Online observations of German PWAs processing of non-canonical sentences indicate preserved sensitivity or recognition but a deficient timing, reflected in delayed integration of case and/or agreement cues. Insufficient timing can increase the risk of neglect or decay and thus forgetting of lexical or syntactic elements, and in particular traces. For agrammatic aphasia, insufficient timing is assumed by the Slowed Processing Hypothesis to be caused by slowed-down processing, which may result in delayed lexical activation, integration, morphosyntactic integration and/or syntactic parsing. Cognitive deficits may increase the processing insufficiencies, in as such that reduced memory and/or attentional capacities may exert a negative impact in particular on moved object integration.

Slower-than-normal processing does not always have to result in misinterpretations of object- as subject-first structures, and syntactic breakdowns may be a consequence of intermittent processing deficiencies, caused by temporary reductions in processing resources, e.g., through too-high demands on working memory, as in the case of non-canonical sentences compared to canonical ones. Cognitive deficits are associated with aphasia (e.g., Laures-Gore *et al.*, 2011; Hula & MacNeill, 2008), and a reduction of cognitive capacities may impact on speed of processing (e.g., Miyake *et al.*, 1994), while vice versa, reduced processing speed may affect cognitive abilities (e.g., Tun, 1998). Inter- and intraindividual variability of performance may reflect different and/or changing degrees of processing speed and/or cognitive capacity reductions. On the other hand, slowing the input might compensate for slowed-down processing and thus potential delays, and may facilitate PWA's general auditory sentence processing, and in particular processing of non-canonical structures.

In summary, slowed-down processing seems to affect the timing of several linguistic processes necessary for auditory sentence processing in particular in agrammatic aphasia, and may thus "[…] exert(s) a strong negative influence on the comprehension of aphasic patients by making inherently severe time constraints in auditory comprehension even more severe." (Miyake *et al.*, 1994, p. 684).

5 Non-canonical sentence processing in hearing impairment

In this chapter, non-canonical sentence processing of hearing-impaired adults is described. Similar to aphasia, hearing-impaired non-brain-damaged adult' difficulties in processing non-canonical sentences may also be attributed to a timing deficit, but in contrast to aphasia, this timing deficit is assumed to be caused by an increased perceptual processing load owed to the degraded acoustic reception. Therefore, this chapter is first concerned with the causes and types of hearing loss and the effect on speech perception and sentence comprehension. Hearing impairment (HI) effected by hearing loss is explained in terms of prevalence, severity, and types of hearing loss, with special respect to age-related hearing loss because most hearing-impaired listeners are of an older age (i.e., 60 years and older). Impaired speech perception has been seen to exert an influence on sentence comprehension, and in particular on non-canonical sentences. The canonicity effect in hearing impairment is assumed to be partly induced by the need of hearing-impaired listeners for more perceptual decoding time for sentential elements, which leaves less time to encode them. This may increase the risk of delayed processing of other elements in spoken sentences, which in particular heightens the risk of neglecting traces (e.g., Grossman *et al.*, 2000; Wingfield *et al.*, 2006). Furthermore, hearing loss may affect perception of less salient morphosyntactic markers. While processing in hearing loss is assumed to be slower through an increased perceptual load, in age, a general reduction of processing speed is hypothesized. Hearing-impaired older listeners may thus face a double challenge interpreting non-canonical sentences correctly. Furthermore, this chapter describes the impact of cognitive straining through hearing loss, and cognitive reductions through age on processing of complex syntactic structures. The last section demonstrates that corrected hearing acuity by hearing aids can only partially restore the timing deficits, and that conventional speech audiometry does not account for those timing deficits.

5.1 Hearing loss- prevalence, degrees and types

Unimpaired speech perception abilities are a prerequisite for successful auditory language processing, especially if there is no discourse or sentential context. In order to perceive and process speech, hearing acuity is crucial, not only for spectral cue perception, but especially for processing fine temporal features distinguishing phonemes from each other. *Hearing* is defined as the sensory perception of auditory signals or sounds, i.e., as a sense, and hearing loss entails decreased acuity of sound perception. *Sounds* are characterized by their *frequency* spectrum. While a pure or sine tone only has one frequency (expressed in Hertz (Hz)), most sounds, and speech sounds or phonemes in particular, consist of a *spectrum* of frequencies, and these spectral features can be used to discriminate and identify a sound for pitch and intonation. The frequencies of a sound also have defined *amplitudes* signifying intensity or volume, expressed in Decibel (dB). *Hearing acuity* is normally measured by assessing the perception threshold of pure tones. In most audiometric assessments, sine tones of 125 up to 8000 Hz are used. Figure 5.1 depicts the tone frequencies and the hearing thresholds of a normal-hearing person, assessed by a *pure tone audiometry* (PTA).

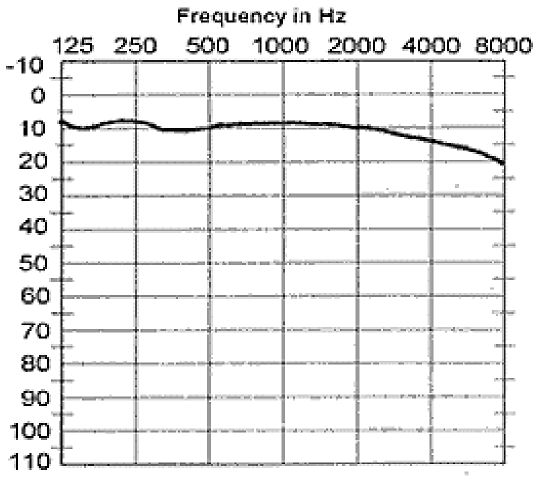

Figure 5.1. Audiogram of a normal-hearing listener with hearing thresholds of 10 to 20 dB, measured over seven frequencies from 125 to 8000 Hz (figure taken from www.hdhearing.com).

Hearing *loss* follows from a reduced sensitivity to auditory signals, resulting in an *impairment* of perception. This includes an impaired perception of *spectral* features of sounds, i.e., the loudness or volume of a signal. Hearing-impaired listeners need thus higher thresholds in order to perceive a sound. Figure 5.2 demonstrates the pure tone thresholds of a moderately hearing-impaired person.

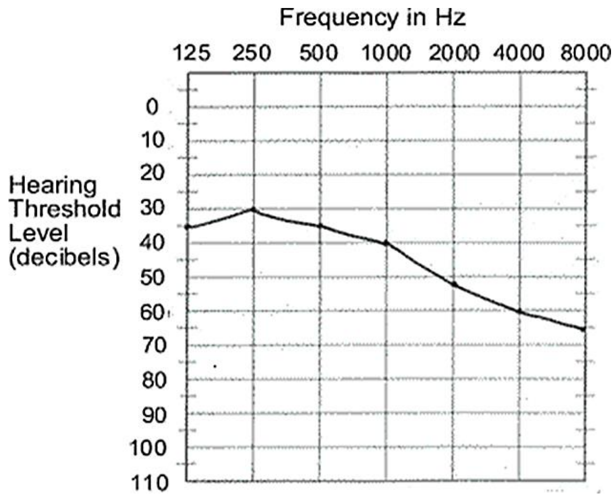

Figure 5.2. Audiogram of a moderately hearing-impaired listener with hearing thresholds of 30 to 65 dB, measured over seven frequencies from 125 to 8000 Hz (figure taken from www.hdhearing.com).

5.1.1 Prevalence of hearing loss

Hearing loss is a common deficit worldwide. Prevalence is high, and approximately 15% to 20% of the population suffers from a form of unilateral or bilateral hearing loss (Davis, Smith, Ferguson, Stephens, & Gianopolous, 2007; Lin, Thorpe, Gordon-Salant, & Ferrucci, 2011; Zahnert, 2011). In Germany, the prevalence ranges from 15.1% (Hougaard & Ruf, 2011), over 19% (Sohn & Jörgenshaus, 2001) up to 26.8% (Stackelberg, 1986) for adults between 15 and 75 years of age. For Northwestern Germany, the region where 90% of the participants of my research come from, a survey demonstrated a prevalence of 16.2% among adults at the age of 18+ years (Holube & von Gablenz, 2012, using the World Health Organisation (WHO) guidelines; see below)[26]. The mean prevalence in Europe is estimated between 14.7%-17% (see Heger & Holube, 2010, for an overview), a number similar to the prevalence of hearing loss in the USA (Agrawal, Platz, & Niparko, 2008, using the WHO guidelines).

5.1.2 Degrees of hearing loss

Hearing loss is categorized in different degrees of severity, and includes mild, moderate, severe and profound hearing loss or deafness. But classification of hearing loss and subsequent

[26] Different percentages may result from the type of the survey –interviews vs actual assessments- and figures may differ with regard to stated versus measured hearing acuity (Hougaard & Ruf, 2011). For example, in Great Britain, figures range from 11.5% (Hougaard & Ruf, 2011) up to 25% for adults presenting with a hearing loss (Davis, 1989, using the WHO guidelines).

categorisation in terms of degrees differ with respect to the guidelines used: The WHO (2012) diagnoses hearing loss with an average threshold of 25 dB and onwards for the better ear over the four frequencies of 500, 1000, 2000, and 4000 Hz, the so-called *PTA-4*, while the EU guidelines (Martini, 1996) already defines hearing loss from a mean average threshold of 21 dB, measured over the same frequencies. This distinction has to be kept in mind when talking about prevalence numbers. The degrees of hearing loss, its impact on speech perception, and the different scales of WHO and EU are depicted in table 5.1.

Table 5.1. Degrees of hearing loss, speech perception abilities in terms of volume of and distance from the speech input, and threshold in dB defined by WHO and EU Taken from WHO (2012)).

Degree of HI	**Speech perception ability**	**WHO (2001)**	**EU (1996)**
no impairment	whispered speech 1 m distance from better ear	< 25 dB	< 20 dB
mild/slight impairment	conventional speech 1m distance from better ear	26-40 dB	21-39 dB
moderate impairment	loud speech 1 m distance from better ear	41-60 dB	40-69 dB
severe impairment	only some words on the better ear when spoken very loudly	61-80 dB	70-94 dB
profound impairment including deafness	none at maximal volume	> 81 dB	> 95 dB

There are other relevant differences between the WHO and the EU guidelines for the classification and categorization of hearing loss, such as the thresholds for severity levels, seen in table 5.1. These severity differences also have to be taken in consideration when comparing estimates of prevalence and/or incidence of hearing impairment in the literature. Besides, not only moderate or severe hearing loss impairs speech perception; even mild hearing loss has been seen to exert a negative impact on speech perception and comprehension (e.g., Davis, Elfenbein, Schum, & Bentler, 1986; van Boxtel, van Beijsterveldt, Houx, Anteunis, Metsemakers, & Jolles, 2000), especially in a noisy background (Dubno, Dirks, & Morgan, 1984).

5.1.3 Types of hearing loss

Hearing loss is commonly distinguished in four major sub types: Conductive, sensory, neural, and sensineural, dependent on the area of the damage in the ear or of the cortical structures involved. The ear consists of three major areas, the outer ear, the middle ear and the inner ear. Sound waves pass through the outer ear and cause vibrations at the eardrum. The eardrum and three small bones of the middle ear -the hammer, anvil and stirrup- amplify the vibrations on their way to the inner ear. There, the vibrations pass through a fluid into the cochlea, a snail-shaped structure. The cochlea contains thousands of hair cells that transduce sound vibrations into electrical signals, which are then transmitted to the auditory cortex via the auditory nerve. Transduction of high frequencies occurs more at the entrance to the cochlea, that of lower frequencies in the middle cochlear areas (Schmidt & Tewes, 2013).

A blockage to the outer or middle ear may result in a *conductive* hearing impairment. As some blockages, for example earwax or cerumen, can be removed, a conductive hearing impairment may be temporary. A *sensory* hearing loss follows from damage to the inner ear. Destructions or injuries to the nerve or auditory cortices may result in *neural* hearing loss, which is more often than not permanent. The most frequent type of hearing loss is *sensineural*, i.e., a mix of damage to the cochlea, auditory nerve, auditory pathways and/or auditory cortices (Schmidt & Tewes, 2013).

The causes of hearing loss are manifold, it might be hereditary or congenital, or acquired because of lesions or tumours in the ear and/or brain structures. A head trauma, and/or an interruption of the cerebral blood flow caused by stroke, cardiovascular problems and/or hypertension may also result in hearing loss (Heger & Holube, 2010; Zahnert, 2011). In addition, hearing impairment can also follow from usage of certain drugs, such as antibiotics or diuretics. The most common causes though have been defined as acoustic trauma, i.e., exposure to loud noise, and aging, which may cause a degeneration of the cochlea and/or the auditory pathways, such as the auditory nerve and blood vessels and/or the auditory cortices (Agrawal *et al.*, 2008; Zahnert, 2011).

5.1.4 High-frequency hearing loss

Frequencies of 3000 Hz and above are among the earliest to be affected by hearing loss (Moore, 2012). The resulting *high-frequency hearing impairment* (HFHI) is very common (Agrawal *et al.*, 2008; Dobie, 2001): In a survey, 31% of adult US Americans demonstrated HFHI (Agrawal *et al.*, 2008). Because neither the WHO nor the EU classification includes frequencies higher than 4000 Hz, high-frequency hearing loss above this frequency is normally not seen in surveys, which might confound statistics.

A considerable part of the speech signal is distributed in the frequency areas of 6000-8000 Hz. Especially fricatives, but also plosives contain high-frequency information. The voiceless fricatives /f/ and /θ/ have high-frequency peaks of about 8000 Hz, whereas their voiced counterparts /v/ and /ð/ show frequency peaks around 7000-7500 Hz, similar to /s/ and

/z/ with 7000 Hz (e.g., Jongman, Wayland, & Wong, 2001; Monson, Lotto, & Story, 2012). Differences in high-frequency information of these phonemes also depend on the gender of the voice; female voices have generally higher frequency spectra than male voices (Monson, Hunter, Lotto, & Story, 2014). High frequencies in particular contain information about the *place of articulation* (POA), and are part of the formant transitions (see also chapter 5.2). This information is regarded to be necessary for identification of plosives (Dubno, Dirks, & Schaefer, 1989; Vitela, Monson, & Lotto, 2014) or fricatives (Monson *et al.*, 2014; Vitela *et al.*, 2014), especially in noise (Moore, Fullgrabe, & Stone, 2010). Thus, if higher frequencies are not assessed, many listeners with HFHI might be diagnosed with normal hearing, but show deficits in speech perception, which increase in noisy backgrounds (Turner & Cummings, 1999). On top of that, these listeners may not be fitted with hearing aids. The relevance of high-frequency information on speech perception and the potential presence of HFHI has been considered in the *PTA-6* assessment of Margolis & Saly (2007), who propose a new classification system, incorporating the frequencies of 250 and 8000 Hz[27].

Moreover, the inclusion of the low 250 Hz frequency allows to cover the spectrum of all phonemes, and enables to detect *low-frequency* hearing loss, which might affect the perception and/or discrimination of certain fricatives, sonorants, laterals, voiced consonants, nasals and even some vowels, which are situated in the frequency area between 250-500Hz (see figure 5.3).

5.1.5 Presbyacusis

High-frequency hearing loss is one of the main characteristics of age-related hearing loss or *presbyacusis.* Presbyacusis is the most frequent type of hearing loss, and thus a very common occurrence in age. In the US, hearing loss is even regarded as the third most common health problem among the older population (Lethbridge-Ceijku, Schiller, & Bernadel, 2004).

Presbyacusis is characterized by a sloping binaural hearing loss, which starts in the high-frequency range and later affects other frequencies as well. It is a gradual hearing loss, happening over years, and may not be recognized in the beginning stages. While the

[27] More, Margolis & Saly (2007) also suggest a modified severity rating scale combining the measures of both WHO and EU guidelines: A mild hearing loss is defined between 20 and 39 dB mean threshold level, a moderate between 40 and 59 dB, a severe form is classified from 60 to 89 dB, and a profound hearing loss from 90 dB, assessed over six frequencies of the better ear.

prevalence of hearing loss is rather low with 8.5% in young adults up to 30 years (Agrawal *et al.*, 2008), approximately 40% of the worldwide population above the age of 60 may suffer from presbyacusis (Agrawal *et al.*, 2008); in Germany, the percentage is assumed to be at least 28.4% (Hougaard & Ruf, 2011), but other studies have reported an incidence up to 40%-45% (Heger & Holube, 2010; Zahnert, 2011). With increasing age, the incidence of presbyacusis rises; at 70+ years of age, 74 % (Davis, 1995) up to 80% of the population may be affected (Tun, Benichov, & Wingfield, 2010; O'Halloran, Worrall, & Hickson, 2009), and at the age of 80+, 85% (Herbst & Humphrey,1980) up to 100% (Aydelott, Leech, & Crinion, 2011) of the aged population may present with a loss of hearing acuity.

Percentages do not only differ with regard to the assessment guidelines, but also between audiometry and self-judgment. Many older adults do not recognize a hearing loss, and even physicians sometimes do not seem to notice hearing loss in their elderly patients (Pichora-Fuller & Carson, 2000; Pichora-Fuller & Singh, 2006). Prevalence numbers also differ with regard to the inclusion of high frequencies in the assessment. If frequencies of 4000, 6000 and 8000 Hz are taken as measure, the percentage of presbyacusis has been shown to increase: A British study demonstrated that 98% of the participants in the age range between 71 and 80 years were hearing-impaired (Davis, 1995). What is more, there are several sub-types of presbyacusis involving a sensory loss with inner ear damage with a high-frequency hearing loss, and a neural damage to the auditory nerve without high-frequency loss. Last but not least, a central auditory processing degeneration may be present (Pichora-Fuller, 2008, see also chapter 5.2.2).

5.2 Speech perception in hearing impairment

Still, whether using a PTA-4 or PTA-6, hearing acuity diagnosed with a PTA only includes assessing hearing thresholds of pure sine tones, and does not give sufficient information about the hearing acuity for phonemes, which consist of more than one frequency and amplitude. More, while pure sine tones are perceptible in very low volumes, most phonemes need a certain volume in order to be perceived. Some fricatives can already be heard at 20 dB, but vowels have a spectral amplitude of around 40 dB, so a higher volume is needed in order to discriminate or identify them. And, described above, the frequency ranges of many fricatives and thus also those of affricates are also located in the high-frequency range. Figure 5.3 shows the distribution of speech phonemes across frequencies and amplitudes.

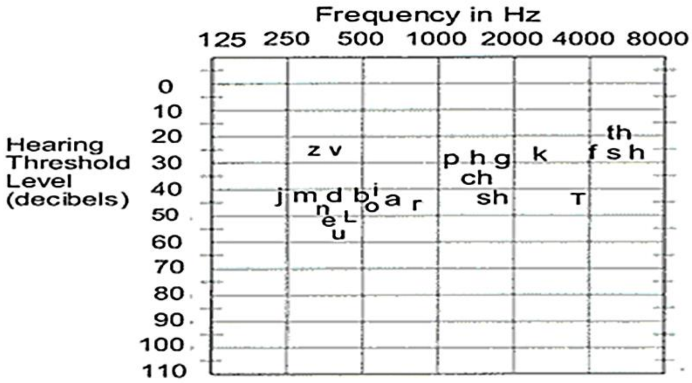

Figure 5.3. Distribution of phonemes across frequencies and volume (figure taken from www.hdhearing.com).

While normal-hearing listeners have no problems perceiving all phonemes, shown in the left audiogram of figure 5.4, a person with a mild hearing loss, depicted in the middle audiogram, will be impaired in the perception of high-frequency fricatives and some unvoiced plosives. For a moderately hearing-impaired person (right audiogram), almost all affricates, fricatives and plosives are beyond his or her hearing threshold.

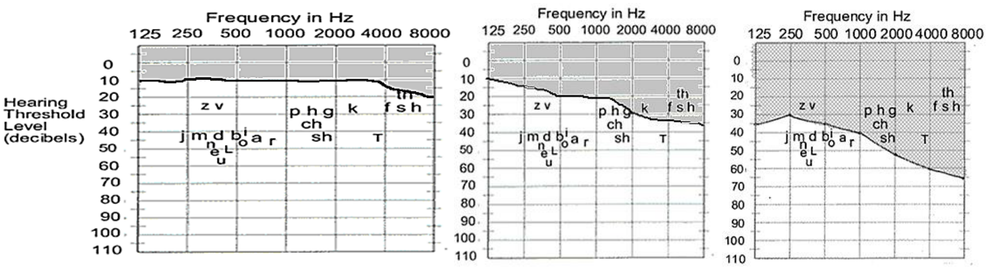

Figure 5.4. Impact of hearing acuity on phoneme perception (grey shaded area): Normal hearing (left audiogram), mild hearing loss (middle audiogram) and moderate hearing loss (right audiogram) (Figures modified from www.hdhearing.com).

What does that mean in terms of speech perception? Mild hearing loss of 30 dB may entail that 25%-40% of the phonemes are not perceptible anymore, for moderate hearing loss of 40 dB, this percentage may even be higher with a loss of 50%-55% (Anderson & Matkin, 2007). Phoneme perception deficits in mild hearing loss can impair discrimination and identification of auditorily presented words, such as deficits in differentiating between minimal pairs as “sieve” and “thieve”, and “siss” or “hiss” and “this”. For German, this would affect discrimination between words, such as “sieht” (***s**ees*) and “zieht” (*pulls*), or “Kanne” (*jug*) and “Tanne” (*fir*). In moderate hearing loss, these discrimination and identification abilities are even more limited; “kick”, “tick” and “chick” may sound the same; “rose” sounds like “road”, “catch” and “cat” might be undistinguishable, same as “lease” and “leave” or “vote” and “boat”. For German, moderate hearing loss would affect discrimination and/or identification between words such as e.g., “Tasche” (*bag*) and “Tasse (*cup*)”, “Ross” (*horse*) and “Rost” (*rust*), or “Tisch” (*table*) and “Fisch” (*fish*), and would also affect the perception of affricates, leading to e.g., “Stock” (*stick*) sounding like “Schock” (*shock*) or “stricken” (*knit*) like “schicken” (*send*).

Deficits on the phoneme or segmental level are not the only impairments, and hearing loss can also affect processing of phonetic or sub-segmental features. Complex sounds, such as phonemes, do not only consist of a spectrum of frequencies with different amplitudes. More importantly, these frequencies develop over time, and in order to discriminate and/or identify sounds, the different frequencies have to be distinguished. Phonemes are also characterized by *formant transitions*, i.e., frequencies changes within the spectral domain. Some of these transitions can be very fast and abrupt, such as voice onset times (VOT) in plosives, defined as the temporal interval between the release from the consonant stop closure or noise burst release and the onset of voicing (Tremblay, Piskosz, & Souza, 2003). In VOT, there is a clear transition point at ca 20 ms, distinguishing voiced from unvoiced consonants (Fink, Churan, & Wittmann, 2006; Hosom, 2009). Another rapid, spectral, formant transition characterizes POA by changing frequencies around a time interval of ca. 40 ms, differentiating alveolar from velar, or labial from alveolar consonants (Fink *et al.*, 2006; Poeppel, 2003). Hearing-impaired listeners are known to be impaired in the processing of those rapid transitions, resulting in *temporal processing deficits* (e.g., Turner, Smith, Aldridge, & Stewart, 1997; Turner, Souza, & Forget, 1994), reflected in deficient discrimination and identification of POA and VOT (Dorman, Marton, & Hannley, & Lindholm, 1984; Lindholm, Dorman, Taylor, & Hannley, 1988). Other transitions are gradual, such as at the boundary between a sonorant and a vowel in a CV-syllable (Fink *et al.*, 2006; Hosom, 2009), v*owel duration* in order to discriminate between long and short vowels, *silent interval duration* to distinguish between fricatives and affricates, and *transient durations* needed to differentiate between plosives and sonorants (Gordon-Salant, Yeni-Komshian, & Fitzgibbons, 2008; Rosen, 1992). While relatively unimpaired in perceiving gradual transitions, hearing-impaired listeners show deficits in the perception of rapidly changing temporal structures, reflected in deficient discrimination of VOT, and discrimination and/or identification of fricatives, affricates and plosives (Gordon-Salant, Yeni-Komshian, Fitzgibbons, & Barrett, 2006; Gordon-Salant *et al*, 2008; Tyler, Summerfield, Wood, & Fernandes, 1982). This deficiency to process temporal differences may arise from a timing deficit between presentation and perceptual processing, and hearing-impaired listeners have been noted to need more time to process speech sounds, reflected in longer response times than those of normal-hearing listeners. In studies using fast, time-compressed, speech, hearing-impaired adults had significantly more difficulties than normal-hearing listeners distinguishing consonants or vowels when the temporal features had a reduced duration (e.g., Gordon-Salant & Fitzgibbons, 2001, 2004; Gordon-Salant *et al.*, 2007; Humes, Burk, Coughlin, Busey, & Strauser, 2007). Problems discriminating different frequencies do not only affect recognition and decoding of temporal sound features, but also impair extraction of one signal from another, e.g., speech from surrounding background noise (Schneider & Pichora-Fuller, 2001; Wingfield, Tun, & McCoy, 2005). Furthermore, while spectral features are believed to be predominantly processed in the cochlea, i.e., in the auditory *periphery*, temporal processing is assumed to be a *central* mechanism, executed in the central auditory nervous system (CANS), and may thus be affected in sensineural hearing loss (Poeppel, 2003; Tremblay *et al.*, 2003; Wingfield *et al.*, 2005). Also, brain damage may affect temporal processing (see chapter 6).

5.2.1 Auditory word recognition and sentence intelligibility

Affected phoneme perception does not have to result automatically in impaired word recognition or sentence intelligibility, because context may counterbalance the deficit, i.e., when phonemes are presented within words, and words within sentences (Boothroyd & Nittrouer, 1988; Gordon-Salant *et al.*, 2008; Kollmeier & Wesselkamp, 1997; Mattys, Melhorn, & Wright, 2007). Sentential context may constrain the probability of a particular word (Stewart & Wingfield, 1999), and understanding the sentence meaning may thus aid understanding of single words within the sentence (Aydelott *et al.*, 2011; Benichov, Clarke Cox, Tun, & Wingfield, 2012; Gordon-Salant & Fitzgibbons, 2001; Pichora-Fuller, Schneider, & Daneman, 1995). Despite these effects, word recognition difficulties are a common deficit in hearing impairment, even if the volume of the stimuli is adapted to the hearing loss

(Benichov *et al.*, 2012; Boothroyd & Nittrouer, 1988; Bosman & Smoorenburg, 1995; Sommers, 1997), and has been shown to result in lower accuracy due to missed or misidentified items (Tun *et al.*, 2009).

Impaired word recognition is often reflected in lower recall scores of words for hearing-impaired compared to normal-hearing adults (e.g., Smith & Pichora-Fuller, 2015; Tun *et al.*, 2009; see also chapter 5.4 for the impact of WM capacity on recall scores). Moreover, lexical decision abilities were noted to be more affected in hearing-impaired adults compared to their normal-hearing counterparts (Hällgren, Larsby, Lyxell, & Arlinger, 2001; Kirk, Pisoni, & Miyamoto, 1997), as well as minimal pair discrimination or rhyme judgment (Anderson & Lyxell, 1998; Lunner, 2003), and the deficits were seen to increase with the severity of the hearing loss (Andersson & Lyxell, 1998; Lyxell, Andersson, Borg, & Ohlsson, 2003).

Auditory word recognition is a prerequisite for intelligibility and comprehension of especially low predictable sentences, as sentence processing does not only demand auditory word recognition, but also identification of the relationship between the lexical elements. Some of these elements, in particular morphosyntactic markers for agreement, case and or number elements, or functional elements such as determiners and prepositions, normally have a lesser intensity because of the lack of stress they receive. Moreover, they may not be articulated carefully or even be partially deleted in articulation, resulting in a less clear acoustic presentation, i.e., in degraded perceptual *salience*, which may decrease perception abilities (cf. Carroll, 2013).

Sentence intelligibility, often measured as recall accuracy or picture identification accuracy, was noted to be more affected in hearing-impaired listeners compared to normal-hearing adults: Adults with hearing loss were observed to need either a higher volume and/or longer processing times to match accuracy scores of the unimpaired group; often, despite intensity adaptation, hearing-impaired listeners still show a lesser degree of accuracy (e.g., Bosman & Smoorenburg, 1995; Uslar, 2014; Wendt *et al.*, 2015; Zenker-Castro, Carballo Gonzalez, Rodriguez Jimenez, Olleta Lascarro, Marro Cosials, & Barajas de Prat, 2012).

Intelligibility deficits have been observed to increase in background noise, which normally accompanies spoken communication, such as other people talking, environmental sounds or both. Phoneme recognition may be distorted, especially if the noise has a masking effect on the spectral and/or temporal features necessary to discriminate or identify a phoneme (Digiovanni & Stover, 2008; Mattys *et al.*, 2007; Mattys, Brooks & Cooke, 2009). While recognizing phonemes or phonemic features in noise is regarded to be already challenging for listeners with normal hearing, hearing-impaired adults display an even higher degree of impairment (Dubno *et al.*, 1984; Turner *et al.*, 1994; van Rooij & Plomp, 1990), shown for example in CV recognition tasks (Dreschler & Plomp, 1985; Gordon-Salant, 1985). Also, word and sentence intelligibility deficits of hearing-impaired listeners aggravate much more in noise compared to normal-hearing adults (Festen & Plomp, 1990; Rönnberg, Rudner, & Zekveld, 2010; Rudner, Foo, Rönnberg, & Lunner, 2009, Rudner, Rönnberg, & Lunner, 2011; Sarampalis, Kalluri, Edwards, & Hafer, 2009; Uslar, 2014; Wendt *et al.*, 2015). Especially non-canonical sentence processing was demonstrated to suffer in noise, presumably induced by the lack of clear acoustic information for grammatical elements, such as for morphosyntactic markers or function words, while content words, which are generally longer and more salient, were noted to be less affected (Carroll & Ruigendijk, 2013; Carroll, 2013). For normal-hearing listeners, non-canonical sentence processing in noise has been seen to result in even longer processing times and/or lower accuracy compared to the silent condition (Carroll & Ruigendijk, 2013; Wendt, Brand, & Kollmeier, 2012; Wendt *et al.*, 2014). For hearing-impaired listeners, noise poses an even higher disturbance of intelligibility and/or comprehension of non-canonical sentences than for their normal-hearing counterparts in the same condition, reflected in a higher degree of the canonicity effect (Brand, Uslar, Wendt, & Kollmeier, 2012; Wendt *et al.*, 2014). It seems that in cases of doubt effected by insufficient acoustic and/or syntactic information, the proposed general preference for a subject-first processing is increased. Also, besides reducing the degree of intelligibility, noise also increases processing load by placing a higher demand on cognitive functions, such as attention and inhibition, needed in order to extract the speech signal from the noise sound (cf. Mattys *et al.*, 2009).

5.2.2 Speech perception in presbyacusis and age

Age-related hearing loss has been seen to result in even more profound negative effects on perception and comprehension than hearing loss in younger and middle-aged adults. The combination of age and hearing loss has been found to result in even lower accuracy scores and/or longer response times compared to younger hearing-impaired adults for discrimination and/or identification of speech sounds (Gordon-Salant & Fitzgibbons, 2001, 2004; Gordon-Salant *et al.*, 2007; Sommers, 1997), and auditory sentence comprehension tasks (e.g., Sticht & Gray, 1969; Wingfield *et al.*, 2003, 2006). The higher degree of difficulties is supposed to be caused by an age-related degeneration of several perceptual and cognitive abilities (see chapter 5.4). Older adults, similar to PWA, often complain that other people speak too fast, and that they need more time to make sense of spoken utterances (Schneider & Pichora-Fuller, 2001, Pichora-Fuller, 2003), an indication for a timing deficit in as such that their speech processing lags behind the signal presentation. Age-related deficits of speech perception with or without accompanying hearing loss have been studied well: In age, even without hearing loss, older adults from the age of 60+ years have demonstrated decreases in perceptual abilities, and markedly in temporal processing, reflected in longer sound durations needed to distinguish short from long vowels compared to younger listeners (Gordon-Salant *et al.*, 2008). Besides, similar to the deficits caused by hearing loss, they have been found to experience problems discriminating consonants whose VOT difference is small (e.g., Gordon-Salant *et al.*, 2008; Tremblay *et al.*, 2003). Also, older adults have shown impairments processing other rapid formant transitions, reflected in deficient discrimination of consonants differing in POA (Dorman *et al.*, 1984; Gordon-Salant & Fitzgibbons, 2007; Gordon-Salant *et al.*, 2008). These deficits in discrimination and also in identification were noted to increase in noise, especially if higher frequencies are involved (Abel, Sass-Kortsak, & Naugler, 2000), reflected in even lower accuracy and/or longer response times than those for the silent condition, and than those of younger listeners (Tun *et al.*, 2010). Older adults have also demonstrated longer processing times in speech perception and sentence comprehension tasks than younger controls (Caplan *et al.*, 2003, 2011; Neto & Santos, 2012; Pichora-Fuller, 2003; Schneider *et al.*, 2005; Waters *et al.*, 2003; Wingfield *et al.*, 2003, 2006).

The temporal processing delay can also be seen in fast speech, where older adults have demonstrated disadvantages processing the even smaller differences in VOT (Gordon-Salant & Fitzgibbons, 2001; Gordon-Salant, Yeni-Komshian, Fitzgibbons, & Barrett, 2006; Gordon-Salant *et al.*, 2008). Effects of fast speech on older adults have also been recognized in word recognition (Janse, 2009; Spehar, Tye-Murray, & Sommers, 2004), sentence comprehension (Schneider *et al.*, 2005; Tun, 1998; van der Werff, 2007; Wingfield *et al.*, 1985; Wingfield, Lahar, & Stine, 1989, Wingfield *et al.*, 2003, 2006), or text comprehension (Wingfield, Tun, & Rosen, 1995; Wingfield & Stine, 1986).

The presence of hearing loss in age can enhance perception deficits in older adults (Akeroyd, 2008; Aydelott *et al*, 2011; Humes *et al*, 2007). Research comparing performance of older adults with and without hearing loss found that the latter group performed even worse on speech perception (Gordon-Salant & Fitzgibbons, 2004; Gordon-Salant *et al.*, 2006, 2007, 2008; Martin & Jerger, 2005; Sommers, 1997), and auditory sentence comprehension tasks (Humes *et al.*, 2007, Versfeld & Dreschler, 2010; Wingfield *et al.*, 2003, 2006). Furthermore, hearing-impaired older adults seem to be even more susceptible to noise than their normal-hearing counterparts (Gordon-Salant & Fitzgibbons, 2004, 2008; Gordon-Salant & Friedmann, 2011; Versfeld & Drescher, 2010). Thus, the combination of age and hearing impairment seems to increase the timing deficits induced by age or hearing loss.

5.3 Non-canonical sentence processing in hearing impairment

Similar to aphasia, canonicity effects in terms of lesser accuracy have also been noted in hearing-impaired listeners compared to normal-hearing listeners, but the degree of this canonicity effect might be smaller than for PWA. Similar to aphasia, in hearing impairment, the effect is suggested to be caused by a timing deficit, but in contrast to aphasia, the timing insufficiencies are assumed to result from impaired intelligibility and prolonged perceptual processing, and not from slowed-down processing as proposed by the Slowed Processing Hypothesis for agrammatic and other aphasia.

In hearing impairment, mentioned in chapter 5.2.1, deficient comprehension of non-canonical sentences is considered to be at least partly caused by impaired intelligibility, in particular for inflectional or derivational affixes including morphosyntactic features for case and agreement, and/or closed-class lexical elements, such as prepositions, determiners or relative pronouns, which are normally not emphasized and thus are articulated with a lower volume. In addition, on account of the degraded signal, hearing-impaired listeners seem to need more time to decode the perceptual features of words and sentences, which may jeopardize timing and may thus increase the risk of not noticing or neglecting some elements, such as postulated traces, whose recognition is thought to be highly dependent on exact timing. Thus left with only partial sensory information for functional elements, and additional loss of some information arising from timing deficits, hearing-impaired listeners have been noted to need even more time to process non-canonical sentences and are more prone to interpret non-canonical sentences as canonical ones compared to normal-hearing adults. Lower accuracy for English OR sentences, such as in example (5.1), compared to SR items (example 5.2) has been demonstrated by research from the Brandeis group (e.g., Stewart & Wingfield, 2009; Wingfield *et al.*, 2006).

(5.1) Boys that girls help are nice.

(5.2) Boys that help girls are nice (Wingfield *et al*, 2006)

In these studies, which used an agent-judgment task, young and older normal-hearing listeners were compared to young and older hearing-impaired listeners. While accuracy for SR did not differ for all four groups for a conversational speech rate, accuracy for OR was affected by hearing loss. Similar results were also seen for hearing-impaired listeners' performance on German OVS in a SPM, such as example (5.3) compared to SVO (example 5.4), and for OR (example 5.4) compared to SR (5.5) (Wendt *et al.*, 2015). Longer processing times for German non-canonical OVS for hearing-impaired compared to normal-hearing listeners have also been demonstrated by Wendt *et al.* (2015). Uslar (2014), too, found canonicity effects in intelligibility tests, using the same items: Hearing-impaired listeners had a lower recall score for OVS items, such as example (5.3) than normal-hearing.

(5.3) Den lieben Vater küsst der süsse Junge.

The$_{\text{ACC}}$ nice$_{\text{ACC}}$ father kisses the$_{\text{NOM}}$ sweet$_{\text{NOM}}$ boy.

'It is the nice father whom the sweet boy kisses.'

(5.4) Der süsse Junge küsst den lieben Vater.

The$_{\text{NOM}}$ sweet$_{\text{NOM}}$ boy kisses the$_{\text{ACC}}$ nice father.

'The sweet boy kisses the nice father.' (Uslar *et al*., 2013)

(5.5) Der Bauer, den die Ärztinnen, fangen, lacht.

The$_{\text{NOM}}$ farmer whom$_{\text{ACC}}$ the$_{\text{AMB}}$ doctors$_{\text{FEM}}$ catch$_{\text{PL}}$ laugh.

'The farmer whom the doctors catch, laughs.

(5.6) Der Bauer, der die Ärztinnen fängt, lacht.

The$_{\text{NOM}}$ farmer who$_{\text{NOM}}$ the$_{\text{AMB}}$ doctors$_{\text{FEM}}$ catches$_{\text{SG}}$ laugh.

‘The farmer who catches the doctors laugh. (Uslar *et al.*, 2013)

Older normal-hearing adults also demonstrated more difficulties with non-canonical sentences compared than younger adults, reflected in longer response times and/or lower accuracy (e.g., Caplan *et al.*, 2003, 2011; Obler *et al.*, 1991). Stine-Morrow, Ryan, & Leonard (2000) noticed lesser accuracy for centre-embedded OR sentences like example (5.7) for older adults compared to younger ones.

(5.7) The pilot that the nurse admired dominated the conversation.

(Stine Morrow *et al.*, 2000)

Similar findings were also seen by Davis & Ball (1989) and Feier & Gerstman (1980) who besides centre-embedded OR also included right-branching clauses, such as in example (5.8).

(5.8) The niece visited the aunt that hurt the uncle. (Davis & Ball, 1989)

They concluded that older adults from the age of 60 years on were both more impaired in processing antecedent-trace dependencies with a greater distance, i.e., with more intervening elements within the chain. While not investigated by these studies, the problem might not be the distance between antecedent and trace as such, but rather the nature of the intervening element, i.e., the same functional category as the antecedent, which has been seen to affect processing in normal-hearing adults, and especially to impair comprehension in aphasia (cf. Friedmann & Gvion, 2012; Sheppard *et al.*, 2015). Moreover, similar to hearing-impaired listeners, older adults’ difficulties with non-canonical sentences increased in fast speech, where perceptual and linguistic analyses are even more restricted because of the limited time of the compressed stimuli: Older normal-hearing adults demonstrated lower accuracy and longer response latencies for OR in time-compressed sentences compared to younger normal-hearing adults (Wingfield *et al.*, 2003).

What is more, if both sensory and cognitive processing mechanisms are impaired, as in the case of hearing-impaired older listeners, problems in auditory non-canonical sentence processing can aggravate. Older hearing-impaired listeners were seen to demonstrate significantly lower accuracy and/or longer processing times than their normal-hearing age-matched or hearing-impaired younger counterparts (Stewart & Wingfield, 2009; Vaughan *et al.*, 2006; Wendt *et al.*, 2015; Wingfield *et al.*, 2003, 2006; Wingfield, Tun, McCoy, Stewart, & Cox, 2006a), and this performance decreased even more in fast speech (Wingfield *et al.*, 2003).

Hearing-impaired and/or older adults have often been noted to compensate their insufficient sensory and/or cognitive processes by world knowledge, and have been suspected to apply heuristic strategies to a higher degree than normal-hearing and/or younger adults (Pichora-Fuller, 2008; Stewart & Wingfield, 2009; Vaughan *et al.*, 2006; Wendt *et al.*, 2015; Wingfield *et al.*, 2006a). They may also rely more on prediction and anticipation of sentence constituents than normal-hearing younger adults (cf. Hüttig & Janse, 2016 for age effects on prediction). World knowledge, prediction of elements and/or heuristic processing may even overrule the stimulus, even when it is acoustically adapted to the hearing loss: Uslar (2014) simulated hearing aids, but only those of her hearing-impaired older adults with regular usage of hearing aids benefitted from the modification, reflected in improved intelligibility scores for OVS and OR items. Uslar (2014) interpreted these results as ability of relearning reliance on sensory cues through the hearing aid, which aided perception and subsequently comprehension of complex German syntax (see chapter 5.7 for more information on hearing aids).

Hearing loss-induced and age-related deficiencies in non-canonical sentence processing seem to resemble those of agrammatic and other aphasic processing: Hearing loss, age and aphasia all seem to lead to slowed-down processing of acoustic elements, which may in particular affect integration of a moved object. However, the underlying causes(s) of slowed-

down processing may be different: while slowed-down decoding processes induced by prolonged perceptual processing have been regarded to increase the risk of a canonicity effect in hearing-impaired individuals, for age and aphasia, a pathological reduction of processing speed and cognitive capacities is assumed.

5.4 Processing speed in hearing impairment

Already described in chapter 3.3.1, auditory sentence comprehension is regarded to require successful processing of all relevant information, and in order to achieve this, an accurate *timing* between acoustic stimuli presentation speed and linguistic processing speed is thought to be necessary. Chapter 5.3 described how increased perceptual and/or linguistic processing load in hearing impairment and age may result in longer processing times compared to those of normal-hearing and/or younger listeners. Moreover, slowed-down processing was argued to be able to affect interpretation of acoustically presented sentences, also described in chapters 3.3. and 4.4: In auditory processing, slower-than normal processing may lead to delays in processing the rapid on-going auditory signal: While still processing the first signals, other items are already presented; and this timing deficit owed to delayed processing might result in deficient or even missed perception of elements (Shinn-Cummingham & Best, 2008). As a consequence, delayed perceptual processing may result in delayed lexical, syntactic and/or semantic processing. Thus, if processing is much slower than the presentation rate, some of the crucial linguistic operations may not take place because of the time- limited auditory presentation. And even if these operations can be executed, they may be too late increasing the risk of neglect, decay or forgetting of other stimuli, and/or operations in as such that processing may become shallow, and a non-canonical structure may be interpreted as a canonical one (Miyake, Carpenter, & Just, 1994).

In chapter 3.3.1. it was suggested that increased processing load may slow down processing speed especially in older adults. In hearing loss on the other hand, longer processing times have been interpreted to reflect reductions in normally unimpaired processing speed, caused by an increased processing load (e.g., Wingfield *et al.*, 2003, 2006). Prolonged processing times have been seen to be even more evident in fast speech tasks, which are thought to reflect general perceptual or cognitive processing speed (e.g., Janse, 2009; Wingfield *et al.*, 1989, 1995; Wingfield, Wayland, & Stine, 1992). Here, processing times were even longer for hearing-impaired adults compared to normal-hearing adults, indicating decreased processing speed arising from the hearing loss-induced higher perceptual processing load (Wingfield *et al.*, 2003, 2006a). However, as most studies tested older hearing-impaired listeners, slowed-down processing of fast speech in hearing impairment might be difficult to distinguish from a rather general age-related cognitive slowing (Janse, van der Werff, & Quené, 2007; Vaughan & Letowski, 1997; van der Werff, 2007; Wingfield *et al.*, 2006a).

Older adults have also demonstrated longer processing times in speech perception and comprehension tasks than younger controls, reported in chapter 5.2. This does not seem to be restricted to language stimuli, as older adults have been noted with lower performance in processing speed tasks, such as digit-symbol substitution compared to younger adults (e.g., Janse, 2009; van der Werff, 2007). What is more, a high degree of the age-related variance in cognitive task performance may be explained by variances in processing speed (Tun, 1998; Vaughan *et al.*, 2006; Vaughan & Letowski, 1997; Wingfield *et al.*, 2006, 2006a)**.** Even stronger, some researchers assume the general reduction of processing speed in older adults as primary source of all age-related cognitive deficits (Salthouse, 1992, 1996, 2000; Kail & Salthouse, 1994).

The combination of hearing impairment and age has been seen to exacerbate reductions in processing speed (Lin *et al.*, 2013), and therefore, hearing-impaired older adults might just be doubly handicapped by the decline in fast information processing due to a generalized or specific age-related slowing, and an impaired ability to process rapidly changing acoustic information, caused by the slowing-down (perceptual) processing speed in hearing loss (Gordon-Salant, 2005). For sentence processing, the combination of hearing impairment and age might evolve into an aggravated effect on processing speed, affecting comprehension performance in general, and of non-canonical sentences in particular (Stewart & Wingfield, 2009; Wingfield *et al.*, 2005, 2006a; Wingfield & Tun, 2007). Still, the degree of slowing may not be equal in all older adults, and observed variability may depend on individual factors, age and the task at hand: Language-related tasks may produce faster results than tasks that do not involve language (McCoy, Tun, Cox, Colangelo, Stewart, & Wingfield, 2005).

5.5 Cognitive processes in hearing impairment

Not only processing speed and timing, but also cognitive abilities or their capacities were noticed to be impacted upon by hearing loss. Hearing impairment has been associated with *straining* several cognitive abilities, such as working memory and attention. Because of the degradation of the signal, a higher amount of cognitive capacity, such as working memory, is thought to be invested in order to decode the signal and to encode it linguistically (cf. Rönnberg *et al.*, 2013). Moreover, especially the decoding of morphosyntactic features is associated with higher cognitive effort, which may impact on working memory and other cognitive capacities (cf. Carroll, 2013). Perceptual decoding processes of degraded input may also claim more attentional resources, which might otherwise aid encoding (e.g., McCoy *et al.*, 2005; Tun *et al.*, 2009; Wingfield *et al.*, 2005). This higher degree of capacity recruitment may take its toll in language processing in hearing impairment: Lower verbal working memory performance (van Boxtel *et al.*, 2000) or lower recall scores (Tun *et al.*, 2009) have been measured in hearing-impaired listeners compared to normal-hearing adults. High WM capacity, often measured by recall spans, as in the reading span task (Daneman & Carpenter, 1980), was observed to correlate positively with speech perception and auditory language performance in hearing impairment, in particular in noise conditions (Rudner *et al.*, 2011), because some researchers consider a high WM capacity to allow a more efficient simultaneous storing and processing of stimuli while inhibiting irrelevant stimuli (cf. Rönnberg's *et al.*, 2013 Ease of Language Understanding (ELU) model). On top of that, hearing-impaired listeners have also been noted to encounter difficulties shifting their attention rapidly from source to source, which suggests an increased demand on selective attentional resources (cf. Shinn-Cummingham & Best, 2008).

In contrast to age (see below), cognitive functions in hearing-impaired listeners do not seem to be *impaired*, but rather stretched to the limit by the double load of perceptual and linguistic/cognitive processing. Again, these observations have to be taken with caution because much research on the relationship between hearing impairment cognitive reductions is mainly based on older hearing-impaired adults, making it difficult to disentangle the effect of age from the effect of hearing impairment on cognitive functions.

Besides slowed-down processing speed, aging has been considered to pathologically decrease cognitive abilities and/or capacities. General cognitive reductions are well documented, whereby not all cognitive functions have to be affected to the same degree (e.g., Albinet *et al.*, 2012; Bugaiska *et al.*, 2007). Older adults demonstrated deficits in short-term and working memory functions, like shorter forward or backward digit spans, or lesser recall scores than younger controls (Gordon-Salant & Fitzgibbons, 1997; Grossman *et al.*, 2002; Stine-Morrow *et al.*, 2000; Vaughan *et al.*, 2006, Waters & Caplan, 2005), which are associated with affected language comprehension, especially in low-context environments. Moreover, reduced working memory capacities or deficient resource allocation are also held -at least partly- responsible for canonicity effects (Angwin, Chenery, Copland, Cardell, Murdoch, & Ingram, 2006; Stine-Morrow *et al.*, 2000). In addition, cognitive control abilities can be reduced or impaired in age (e.g., Manard *et al.*, 2014; Tun, O'Kane, & Wingfield, 2002), which may lead to deficits in conflict resolution, reflected by misinterpretations of non-canonical sentences. Deficits in cognitive control are associated with attentional problems, which are also often present in older adults, either as generally reduced attentional resources or selective deficits in selective or divided attention (e.g., Stewart & Wingfield, 2009; Tun *et al.*, 2002, 2009). Inhibitory problems also appear to be very common: Older adults seem to have more problems to sustain their attention to one stimulus and ignore another than younger adults (Hasher & Zacks, 1988; Pettigrew & Martin, 2014; Wingfield *et al.*, 2005). This deficit in inhibitory control seems most obvious in their distractibility by background noise, which does not only affect performance in language tasks, but communication in normal listening environments (Gordon-Salant & Fitzgibbons, 2004; Tun, 1998).

Impaired sensory processes may aggravate age-related cognitive reductions (Pichora-Fuller & Singh, 2006; Schneider & Pichora-Fuller, 2001; Wingfield *et al.*, 2005; 2006): Hearing loss was noted to account for a large percentage of variance in cognitive decline (e.g., Cervera, Soler, Dasi, & Ruiz, 2009; Levitt, Fugelsang, & Crossley, 2006). More, as a recent study by Lin *et al.* (2013) showed, older adults with hearing impairment may even have an increased risk of cognitive impairment compared to normal-hearing older adults, due to constant straining of already reduced cognitive capacities for auditory language processing.

In summary, hearing impairment seems to strain intact cognitive capacities in younger hearing-impaired listeners, and increased perceptual processing load (for decoding) has been seen to prolong processing time in particular for non-canonical sentences. Traces may not be noticed because perceptual decoding of elements prior to the trace may not be completed. Alternatively, morphosyntactic markers signalling case and thus movement in object-first sentences may not be perceived. The assumed perceptual processing load may even decrease normal speed of processing. In age, prolonged processing times for general and in particular for non-canonical sentence processing have been associated with a pathological reduction of general processing speed and/or reduced cognitive capacities, which may delay trace recognition and/or object integration and/or impair reanalysis processes. Older hearing-impaired listeners may thus face a double challenge on account of an accumulation of perceptual and cognitive impairments.

5.6 Effects of slower speech on comprehension in hearing impairment

Similar to the impact on comprehension in aphasia, slower speech also may have a facilitating effect on the comprehension performance of hearing-impaired and/or older non-brain-damaged adults, and prolonged presentation may compensate for the timing deficit by providing more time to decode the perceptual signal and to encode the linguistic information. And similar to aphasia, speaking slowly is a common recommendation to aid comprehension for hearing-impaired listeners, especially in a noisy background (Adams & Moore, 2009; The Hearing Loss Association of America). Oddly enough, although it is known that hearing-impaired adults profit from slower speech in their comprehension performance (e.g., Picheny, Durlach, & Braida, 1989; Rawool, 2007), not many studies have made this a topic to investigate. Usage of *clear speech* was noted to result in an intelligibility increase up to 17% for hearing-impaired listeners (Picheny *et al.*, 1989; Shaw & Krause, 2007). Due to the accentuated and careful articulation, clear speech consists of several characteristics to enhance the overall salience of the speech signal, such as a higher volume, an expanded pitch range, an increased burst releases of plosives, as well as increased spectral energy in the 1000-3000 Hz range and increased low frequency modulations, and more importantly, a reduction of the speech rate by a general slowing of articulation, and longer and more frequent pauses (cf. Krause & Braida, 2002; Shaw & Braida, 2007). Furthermore, research demonstrated that lengthening temporal cues, such as prolonged VOT or formant transitions improve perceptual abilities (Digiovanni & Stover, 2008; Gordon-Salant, 1986; Gordon-Salant *et al.*, 2007; 2008). While selective lengthening of phonemes, or parts of phonemes, such as VOT has been seen to facilitate word identification (Digiovanni & Stover, 2008; Gordon-Salant *et al.*, 2007, 2008), the effect of uniform expansion on sentence comprehension has not been tested extensively on hearing-impaired listeners. Adams & Moore (2009) simulated hearing loss by younger listeners and tested their recall score in different speech rates, and their results tentatively imply that moderate slowing of speech may facilitate comprehension in hearing impairment, reflected by higher recall scores in the slower speech rates. In a self-paced listening design by another study, young hearing-impaired listeners' ability of recall of passages resembled that of the normal-hearing group when the former group was allowed to make as many pauses as they wanted, i.e., had more time to process (Piquado; Benichov, Brownwell, & Wingfield, 2012; see also Wingfield & Stine, 1986). However, the benefit might have not have been solely brought about by more time for perceptual or linguistic processing, but also because there was more time given for rehearsal.

The facilitating effect of slower speech has been better documented for older adults. In a narrative passages recall task, older adults with normal hearing had the best performance at the slowest rate of presentation, equalling 140 wpm (compared to 174 wpm for conversational speech) (Wingfield & Ducharme, 1999). Older adults also improved their performance on the Token Task, when the rate was expanded to 125% (Tomoeda, Bayles, Boone, Kaszniak, & Slauson, 1990). Self-motivated increase of pause duration after syntactic boundaries aided comprehension of text passages for older adults, too (Wingfield *et al.*, 1999, 2006a). Similarly, older adults improved their recall accuracy when the intervals between syntactic boundaries of relative clauses were prolonged (Fallon, Peelle, & Wingfield, 2006). Selective slowing of speech may also facilitate comprehension in older normal-hearing adults: Gordon-Salant and colleagues (2007) found that while slowing the whole speech signal already aided comprehension, the benefit was even better for selective slowing of temporal features, such as expanded VOT, formant transitions and vowel duration, which facilitated discrimination of phonemes and thus intelligibility of the whole stimulus (Gordon-Salant *et al.*, 2006, 2007, 2008). Wingfield & Ducharme (1989) noted recall improvement with a slower speech rate. Last, but not least, for hearing-impaired older adults, a higher degree of inter-stimulus interval expansion (than that implemented for normal-hearing older adults) facilitated perception abilities (Gordon-Salant *et al.*, 2008). In contrast, another study demonstrated that for older adults with hearing impairment, expanded presentation time of sentences aided performance only in noise, but not in a quiet background (Vaughan, Furukawa, Balasingam, Mortz, & Fausti, 2002). However, a decrease of the speech rate speech may not always facilitate comprehension in older hearing-impaired adults: Adams, Gordon-Hickey, Morlas, & Moore (2012) showed that sentence recall did not improve in slower speech rates when presented in noise to older adults with uncorrected hearing loss. This result implies that older hearing-impaired adults without hearing aids may not be able to benefit from the additional processing time (see chapter 5.6 for a possible explanation for the lacking benefit).

5.7 Correcting hearing loss

Already mentioned, delayed processing, whether perceptual and/or cognitive, cannot be -fully- compensated for by hearing aids. This lack of compensation might be one of the reasons why many hearing-impaired adults are not fitted with a hearing aid, or own one but do not *adopt* it, i.e., use it regularly. Although hearing loss is so common, especially in older adults, only a small percentage of them is equipped with a hearing aid (Wingfield *et al.*, 2005). On top of that, in Germany, only roughly a quarter of hearing aid owners actually adopt their aids (Hougaard & Ruf, 2011). What is more, adults with a unilateral hearing loss may not be aware that their hearing loss needs correction, and that they are entitled to a hearing aid. Aside from that, physicians may not recognize hearing loss in their patients and thus not start treatment. One survey demonstrated that up to 50% of physicians did not recognise hearing loss, in particular in older adults (MacPhee, Crowther, & Mc Alpine, 1988). Because the progression is often slow, adults with presbyacusis may consider their deficits as consequences of normal aging.

Hearing aids cannot fully restore hearing acuity (cf. Leuwer & Müller, 2005; Sarampalis *et al.*, 2009). Spectral correction does not help to overcome temporal deficits: "I can hear but I cannot understand" has been noted to be a frequent complaint of hearing-impaired listeners (Schneider & Pichora-Fuller, 2001; Tremblay *et al.*, 2003). Also, hearing aids cannot compensate for cognitive reductions (Rönnberg *et al.*, 2010; Stach, 2000). In addition, owners of a hearing aid reported do not use it regularly because of the low benefit in noisy surroundings, such as in public places or in groups of people (Gopinath, Schneider, Rochtchina, Leeder, & Mitchell, 2011; Gordon-Salant, 2005; Kochkin, 2000). But is this regular and daily usage, which seems to aid corrected speech perception (Hougaard & Ruf, 2011; Kochkin, 2010; Wendt *et al.*, 2015): Trained hearing aid users have been seen to benefit from slower speech (Gordon-Salant *et al.*, 2008), and have been suggested to be able to relearn acoustic cues (Uslar, 2014). In order to fit a hearing aid, a speech audiometry is administered. This assessment includes speech material, which often consist of words or sentences. In Germany, different sentence tests are in usage, such as the GÖSA (Göttinger Satztest; Kollmeier & Wesselkamp, 1994), the OLSA (Oldenburger Satztest; Wagener, Kühnel, & Kollmeier, 1999; Wagener, Brand, & Kollmeier, 1999a) or the Marburger Satzverständnistest with or without background noise (Niemeyer, 1967). Hearing level assessment is based on recall performance, i.e. measured by the percentage of correctly repeated items, and a percentage of 80% presented in a certain volume is taken as threshold for the setting of the hearing aid (cf. Uslar, 2014).

Summary

Hearing impairment is common, and the prevalence increases significantly in age. Hearing loss does not only result in impairments perceiving spectral features, but has been seen to lead to problems discriminating and identifying phonemes and other sounds differing in temporal cues. Adverse listening situation, such as background noise, can increase these impairments. Especially auditory processing of non-canonical sentences has been seen to be affected by hearing impairment and age-related reductions of processing speed and cognitive capacities. Slowed-down perceptual processing due to hearing loss and/or age might aggravate the risk of information loss, and in particular that of less salient morphosyntactic cues and closed-class words, which may affect in particular the interpretation of non-canonical sentences presented without a restraining context. Slowed-down perceptual processing may also lead to successive delays in sentence processing, which in turn increases especially the risk of neglecting traces. Strained cognitive abilities through hearing loss and/or reduced cognitive capacities or reduced cognitive abilities through age may also affect in particular object integration. The postulated timing deficit may be improved by selective or uniform slowing of the auditory signal. Hearing aids on the other hand may restore hearing acuity partially and have been seen to improve perception, especially, when the usage is regular, and the user has no cognitive deficits. But while hearing aids can restore spectral perception deficits, they may not be able to compensate fully for temporal processing impairments, which may affect sentence intelligibility and thus comprehension.

6 Hearing impairment and speech perception in aphasia

In this chapter, the potential relationship between non-canonical sentence comprehension deficits in aphasia and in hearing impairment is introduced. While so far there has been no research comparing normal-hearing and hearing-impaired PWA on auditory sentence comprehension, effects of hearing loss seen on non-brain-damaged listeners' sentence comprehension might be aggravated in hearing-impaired PWA. It is assumed that a high number of PWA also present with a hearing impairment, but the potential effect of hearing loss on perceptual abilities has not been considered in many studies on speech perception and auditory sentence comprehension in aphasia. While speech perception and word recognition deficits are common impairments in aphasia, these problems may not be caused solely by the language impairment, but can also be a at least partly a consequence of -undetected- hearing loss in PWA.

The previous chapters demonstrated that hearing loss is quite common, especially in age, that both hearing loss and age may result in speech perception and in lexical and sentential comprehension deficits, which in particular may affect non-canonical sentence comprehension, and that the combination of hearing loss and age can aggravate these deficits. Non-canonical sentence processing in aphasia, and in particular agrammatic aphasia, is assumed to be affected by slowed-down linguistic processing, which, similar to age-related decreases, has been argued to result from a pathological reduction of processing speed and/or reductions of cognitive capacities. Following these lines, older PWA might be even more prone to non-canonical sentence misinterpretations than younger PWA, because age-related reductions may aggravate the brain-damaged induced deficits. Older PWA with a hearing impairment may therefore suffer not only from a higher degree of processing speed reduction, but also a constant straining of already reduced cognitive abilities and/or capacities.

Canonicity effects in hearing impairment and age resembles those of agrammatic and other PWA, but the extent of this effect might be higher in PWA, reflected e.g., by lower accuracy and longer response times than those of age-matched non-brain-damaged controls. Unfortunately, like hearing loss, cerebrovascular diseases and aphasia are also quite common in age, and most PWA are above the age of 60, and may therefore suffer from additional age-related deficits. More, many older PWA may present with presbyacusis or another type of hearing loss, which may aggravate their aphasic comprehension impairment.

A potential relationship between hearing loss and aphasia has already been pointed out in the 1970s by Swisher & Hirsh (1972), because damage to the auditory cortex has been noted to result in aphasia and/or neural hearing loss (cf. Bungert, 2004). Although other early studies by Schubert & Panse (1953) and Schunicht, Esser, Moerman, & Ammon (1974) found associations between aphasic speech perception deficits and hearing impairment, the incidence of hearing loss in aphasia has only been assessed by some researchers: Böhme (1984) studied a sample of 100 German PWA and reported that 41 of them presented with a hearing loss in need of correction. Another study by Kreter, Nospes, Cichoroswski, & Keilmann (2010) found that 24% of the 72 German PWA assessed were entitled to hearing aids, but as 16 other PWA could not be assessed with a PTA because of the presence of cerumen, infections or lacking cooperation, the percentage might have been even higher. More, studies screening hearing thresholds of stroke patients with or without aphasia noted a high incidence of hearing loss with 61.7% among the 243 patients tested (Formby, Phillips, & Thomas, 1987); a more recent study by O'Halloran *et al.* (2009) even observed that 79% of their subjects were hearing-impaired. The incidence of hearing loss in stroke victims in general has been seen to be higher than that of the non-stroke population (Agrawal *et al.*, 2008; Gopinath *et al.*, 2009), because cerebrovascular diseases may degenerate auditory pathways (Böhme, 1984; Hausler & Levine, 2000; Torre *et al.*, 2005), and this risk is even higher for older adults (Hariri, Lakhsmi, Larner, & Conolly, 1994).

It might thus be safe to assume that the prevalence of hearing loss in aphasia resembles at least the prevalence of hearing loss of the whole population, and that the incidence might be higher. Most of them might have not been fitted with a hearing aid before the brain damage: Böhme (1984) found that only 20% of his assessed hearing-impaired PWA were fitted with a hearing aid, and in Kreter *et al.* (2010) study, only 10% of the hearing-impaired PWA had corrected hearing acuity, compared to 31.8% of the non-brain-damaged hearing-impaired German population (Hougaard & Ruf, 2011). Similar to the non-brain-damaged group of adults with presbyacusis, many older PWA may not have been diagnosed with hearing loss, and are thus not fitted with hearing aids before the onset of aphasia (Läßig *et al.*, 2013). Also, in more chronic stages of stroke, PWA with a prior normal hearing status might acquire a hearing loss, such as the sloping presbyacusis, which may go undiagnosed because it might be not detected, similar to sloping hearing loss in non-brain-damaged older adults. On top of that, hearing loss as a consequence of the stroke or acquired after the stroke may be misinterpreted as aphasic symptom by the PWA, their relatives and/or the physicians (Rankin, Newton, Parker, & Bruce, 2014). But even if a hearing loss is noticed, fitting of a hearing aid might come as a challenge because assessment involves repetition abilities, which are often impaired in aphasia. Therefore, the hearing level assessment may only be based on a PTA, which is regarded to be not precise enough in order to detect speech intelligibility thresholds. For the same reasons, refitting the hearing aid of aphasic hearing aid users post-stroke often poses a problem. Additionally, as hearing aids cannot compensate for central auditory processing deficits, which are very often present in aphasia (Schunicht *et al.*, 1974; Sidoropolus, Ackermann, Wannke, & Hertrich, 2010), many PWA might not be satisfied with only the spectral improvement, which may prevent them from adopting the aid. Because most PWA are not able to express their needs precisely, a hearing aid might not be fitted or adjusted to fully meet their individual demands. For these reasons, the percentage of hearing aid possession and usage may be higher in PWA than in non-brain-damaged hearing-impaired listeners. For stroke patients in general, the risk of not being fitted with a hearing aid was observed to be 88% higher than that for non-brain-damaged adults (Gopinath *et al*, 2011).

But uncorrected hearing loss may have even more drastic consequences for PWA than for non-brain-damaged hearing-impaired adults: Comparisons of hearing-impaired PWA and hearing-impaired controls display that in the presence of the same hearing sensitivity loss, PWA are much more affected in their peripheral and central processing, reflected in lower accuracy scores on speech perception and auditory comprehension tasks compared to those of non-brain-damaged adults (Pratt *et al.*, 2007; Rankin *et al.*, 2014). One possible reason might be that PWA are unable to compensate for their deficient linguistic and/or cognitive processing with effective sensory mechanisms (Rankin *et al*, 2014). Also, noise seems to affect aphasic comprehension abilities more than that of than non-brain-damaged controls (Pratt *et al.*, 2007; Rankin *et al.*, 2014; Smith, 2011).

While aphasic speech perception and language comprehension deficits are very well studied and documented, only a few studies have controlled for a potential relationship between hearing loss and aphasic deficits. Despite the known impact of hearing loss on speech perception performance (e.g., indicated by their selection criteria for non-brain-damaged controls), many studies on speech perception, word recognition, and sentence comprehension in aphasia did not assess or check the hearing status of their participating PWA. Out of the 84 studies reviewed for this research, only 282, i.e., 33%, mentioned the hearing status of their aphasic participants (e.g., Bates *et al.*, 1987; Blumstein, Baker, & Goodglass, 1977; Dickey *et al.*, 2007; Wilson & Saygin, 2004; see for a comprehensive listing table 13.12 in section 13.4), or just assumed their hearing to be normal by relying on medical reports, PWAs' own statements or auditory language tests (e.g., Blumstein *et al*, 1994; Hanne *et al.*, 2011; Wassenaar & Hagoort, 2007). The majority of the studies did not take the hearing status of their PWA into account (e.g., Blumstein *et al.*, 1985; Burchert *et al.*, 2003; Caplan *et al.*, 1985; Grodzinsky, 1999; Love *et al.*, 2008),

For these studies, there is a risk that a potential hearing impairment confounded the results of the speech perception or auditory comprehension tasks. What is more, neglecting the hearing status of PWA while assessing them may affect the diagnosis of aphasia in terms of symptoms, syndromes and/or severity (cf. Böhme, 1984). Moreover, even if assessed with normal hearing according to PTA-4, subtle hearing loss, such as HFHI, may affect perception performance in aphasia, similar to that of non-brain-damaged adults. Therefore, in order to interpret the results of speech perception deficits in aphasia, the potential neglect of hearing loss has to be taken into consideration, especially as many studies found deficits resembling those of non-brain-damaged older adults and non-brain-damaged adults with hearing loss.

6.1 Speech perception and auditory word recognition in aphasia

Similar to non-brain-damaged hearing-impaired adults, perception of spectral characteristics is regarded to be largely spared in aphasia, but temporal processing deficits on the segmental and sub-segmental level were noted to manifest in impaired discrimination and identification of VOT (Aydelott Utman, Blumstein, & Sullivan, 2001; Baum, 2001; Blumstein *et al.*, 1994; Boyzcuk & Baum, 1999; Caplan & Aydelott-Utman, 1994; Gaven, 2011; Heide & Stadie, 2007; Hessler, Jonkers, & Bastiaanse, 2010), and/or POA (Blumstein *et al.*, 1977; Caplan & Aydelott-Utman, 1994; Gaven, 2011).

Impaired temporal processing, reflected in phonetic perception deficits, such as in VOT discrimination, may result into lexical processing deficiencies. Word recognition has been seen to be affected in PWA; such as in lexical decision or minimal pair discrimination tasks (e.g., Blumstein *et al.*, 1994; Fink *et al.*, 2006; Milberg *et al.*, 1988; Mirman, Yee, Blumstein, & Magnuson, 2011; Utman *et al.*, 2001). Discrimination between non-words was observed to even more affected (Caplan & Aydelott Utman, 1994; Hessler *et al.*, 2010), and performance becomes worse when target and distractor only differ in a single phonetic contrast (Hessler *et al.*, 2010)[28]. On the other hand, not all PWA with phonetic perception deficits may encounter lexical difficulties, and vice versa, not all PWA with auditory word comprehension problems display speech sound perception deficits (e.g., Becker & Reinvang, 2007; Caplan & Aydelott Utman, 1994; Fink *et al.*, 2006).

Still, while some of the deficits in speech perception an auditory word recognition might be confounded by -undetected, unchecked- hearing loss, speech perception and/or word recognition in aphasia is generally much more affected than that of non-brain-damaged older and/or hearing-impaired adults, and these disorders cannot be explained solely in terms of defective auditory temporal processing (cf. Studdert-Kennedy, 2002).

Summary

The prevalence of hearing loss in aphasia resembles at least this of non-brain-damaged adults and may be even higher because of the risk of cortical pathway degeneration caused by stroke and/or age. Because most PWA are above the age of 60, the incidence of hearing loss is a factor, which should not be neglected in aphasia assessment and research. What is more, the number of uncorrected hearing loss was noted to be high in PWA, and many PWA do not own or use hearing aids because of the difficulties of assessing their speech-related hearing thresholds and/or fitting appropriate hearing aids. The quality of their temporal processing and word recognition deficits seems to be similar to those of adults with hearing impairment and older normal-hearing adults, but probably presents to a much higher degree. The underlying cause may be -at least partially-a timing deficit between stimulus presentation and perceptual processing, also assumed in hearing impairment and age. Due to a neglect of hearing status in many studies focussing on auditory processing in aphasia, those results cannot distinguish pure aphasic deficits from those as consequence of hearing loss. Uncontrolled presence of hearing loss in aphasia may even lead to wrong diagnoses of the language impairment.

[28] Some researchers assume the underlying cause of the rapid temporal feature processing deficit in aphasia to be a timing deficit (e.g., Bungert, 2004; Sidiropoulus *et al.*, 2010), which might be caused by slowed *perceptual* processing speed (cf. Efron, 1963; Ingram, 2007). Even when PWA show a similar performance in phoneme discrimination, their response latencies are longer than those of unimpaired controls (Becker & Reinvang, 2007), indicating pathologically slowed-down processing speed.

7 Hypotheses

So far, no research has studied the impact on hearing loss on (non-canonical) sentence comprehension in aphasia, nor the impact on slower speech on processing non-canonical structures in aphasic native speakers of German. Likewise, to my knowledge, this study is the first to measure the potential benefit of slower, time-expanded speech on hearing-impaired non-brain-damaged adults' comprehension of non-canonical sentences in German.

The German language allows a more flexible word order than English on account of its relatively rich morphosyntactic system for case and agreement. Therefore, it is possible to construct syntactic minimal pairs of verb-second and centre-embedded relative clauses only differing in the word order of syntactic subject and object, which are systematically controlled for in terms of overt case and agreement markers. General comprehension performance and comprehension differences between the canonical and the non-canonical item of each minimal pair across different speech rates may give further evidence on the nature of the deficit(s) believed to cause the canonicity effect in aphasia and hearing impairment.

According to the Slowed Processing Hypothesis, in agrammatic aphasia, timing of either lexical or syntactic processes is deficient, leading to delayed lexical, morphosyntactic and/or syntactic parsing. While many supporters of the lexical accounts base their claim mainly on agrammatic performance on English sentence items with covert case and agreement markings, the (morpho)syntactic accounts backs its assumptions with findings from agrammatic PWA's performance in other languages with a richer morphosyntactic system for case and agreement than that of English. Furthermore, two recent studies by Dickey *et al.* (2007) and Love *et al.* (2008) on the impact of slower speech on agrammatic non-canonical sentence comprehension also contained English items without overt case and agreement markers, thus a potential slower-than-normal processing of morphosyntactic features cannot be distinguished from too-slow lexical processing. Studying the effect of slower speech on comprehension of German -non-canonical- sentences with overt case and agreement markers might contribute to shed further light on potential underlying cause(s) of the agrammatic canonicity effect.

PWA with other types of aphasia have also been seen to have difficulties interpreting non-canonical sentences. According to a number of researchers, for German PWA this difficulty might also arise from deficits integrating morphosyntactic features within the time course of the presentation. Slower speech on the other hand might compensate for their suggested timing insufficiency by allowing more time to recognize and/or integrate morphosyntactic cues.

Similarly, the canonicity effect in hearing-impaired non-brain-damaged individuals is assumed by some researchers to result from an increased perceptual processing load induced by the degraded acoustic stimulus in general, and by degraded non-accentuated morphosyntactic markers in particular. Perceptual processing might thus demand more time with the risks of a timing deficit in processing. A prolonged acoustic presentation may therefore decrease this risk by allowing more time for perceptual decoding. Perceptual processing deficits were also observed in many PWA. Hearing-impaired PWA might face a double processing load due to slowed-down perceptual and linguistic processing, which may affect their comprehension of non-canonical sentences to a higher degree than that of normal-hearing PWA. The presence of age might aggravate the canonicity effect to an even higher degree.

The aims of this research are twofold. First, the combination of aphasia and hearing impairment are expected to affect non-canonical sentence comprehension to a higher degree than those of normal-hearing PWA or non-brain-damaged adults. Presence of older age may aggravate deficits. Slower speech on the other hand is predicted to improve performance on non-canonical sentences for all PWA, and in particular for the subgroup of agrammatic PWA, where research has shown a benefit of slower speech on their assumed delayed linguistic processing abilities. If proven correct, the results may not only contribute to theories on sentence processing in general, but also to a better understanding of syntactic processing in agrammatic and other types of aphasia. Second, I assume that hearing impairment is present to a higher degree in aphasia, and that a higher percentage of hearing-impaired PWA is left with uncorrected hearing loss, compared to non-brain-damaged hearing-impaired adults. The findings of this study would thus enable to differentiate between syntactic processing of aphasic listeners with hearing impairment compared to non-brain-damaged listeners.

My hypotheses are thus the following:

1 With regard to former studies on sentence processing and comprehension in aphasia, I assume that slowed-down processing is responsible for the canonicity effect in aphasia in general, and in particular for agrammatic aphasia. Lexical and/or syntactic processing is assumed to be prone to delays

because the time course of the unfolding acoustic event might be too fast for agrammatic and other PWA to compute the syntactic representations in the normal time course. Delayed processing of especially morphosyntactic features might affect comprehension of non-canonical structures to a higher degree because it may result in deficits in object integration and therefore thematic role assignment. Hearing-impaired PWA are assumed to face a double challenge comprehending non-canonical sentences, and the presence of age might aggravate this risk. Hearing-impaired PWA are expected to show a higher degree of the canonicity effect than their normal-hearing counterparts.

2. Prolonged presentation time is suggested to result in better performances for the whole group of PWA, and in particular for the agrammatic sub group for all syntactic structures, and notably for non-canonical verb-second and centre-embedded object-relative clauses, compared to performance at the conversational speech rate. Improvement should be reflected in higher accuracy rates compared to those at the conversational speech rate. Slower speech is hypothesized to aid general, and in particular non-canonical sentence comprehension to a higher degree for hearing-impaired PWA compared to normal-hearing PWA.

3. Slower (perceptual) processing compared to normal-hearing adults has been claimed to affect speech perception in hearing-impaired adults, and might result into delayed processing and even into neglect or loss of grammatical elements signifying case and agreement. This loss might especially affect comprehension of non-canonical sentences. A prolonged presentation time by slower speech is expected to compensate for the longer processing times induced by the higher perceptual processing load. Older hearing-impaired participants, who have been seen with slowed-down processing associated with an age-related reduction in processing speed, are expected to benefit from slower speech for comprehension of both canonical and non-canonical sentences.

8 Methods

The method section starts with an introduction of the participants of the actual experiments and the selectional criteria for participation. The actual participants of the experiments are described with regard to relevant data for the research. Then results of the hearing screening and language assessment are presented. The material section describes the stimuli and the time manipulation of the auditorily presented items. A third part of the chapter lays out the design and the procedure of the chosen sentence-picture matching task. The last section of this chapter explains the statistical analyses with regard to the variables and statistical models used, as well as how descriptive results were treated.

8.1 Participants

The initial hearing assessment included 50 PWA, among those were 20 PWA with hearing impairment (4 female and 16 male) and 30 PWA with normal hearing (17 female, 11 male) (see table 6.1. for an overview). The hearing-impaired group presented with sensineural post-lingual hearing losses from mild to moderate degrees on the better ear. For these PWA, it was not possible to obtain information if and in how far the hearing impairment got worse after the stroke because pre-stroke audiometric testing did not exist or were too old, and post-stroke audiometry was not performed shortly after the stroke. All PWA were native speakers of German, raised monolingually and came from various parts of Northern Germany.

Of the 50 PWA, 10 were excluded because the severity of the comprehension deficit prevented them from understanding the instructions for the experimental task or resulted in an overall accuracy score below 50% on the experimental SVO sentences[29]. Three other PWA could not finish the task on account of health reasons (see chapter 8.1.3 for more details). Thirty-seven PWA (19 female, 18 male) were left for the analyses: 25 were within normal hearing levels (14 female, 8 male), and 12 of them presented with hearing loss (5 female, 7 male), and (see also table 8.1 for an overview, and table 13.1 in the appendices for individual data).

[29] Performance of the experimental SVO items was taken as an indication of auditory sentence comprehension abilities. A score below 50% might have implied that the PWA had lexical comprehension deficits because otherwise he/she could have used a heuristic strategy in order to interpret the sentence. While I could not rule out completely speech perception and/or word recognition deficits in the tested PWA, a performance on SVO at or lower than chance value was set to exclude PWA with a potential severe auditory comprehension deficit.

All PWA consisted of persons who were interested in participating in this study. They were either recruited via an acute neurological rehabilitation hospital, self-help groups, or on recommendation of their speech and language therapists (SLT). PWA had a broad range of clinical diagnoses, such as classified in *syndromes* via the Aachener Aphasie Test (AAT) (Huber, Poeck, Weniger, & Willmes, 1983) as Broca's aphasia, Wernicke's aphasia, amnestic aphasia, Conduction aphasia, residual aphasia or unclassifiable aphasia, or were categorized in *symptoms* as agrammatic, paragrammatic or anomic, or as fluent vs. non-fluent aphasics. For some patients, I could not obtain an AAT diagnosis, as the treating SLT did not administer the AAT (four cases), was not willing to provide one (one case), or the patients did not attend therapy anymore (three cases). For these patients, my own clinical experience and subtests of the AAT (see subsection 8.1.4) was used to categorize their deficits and competences into symptoms rather than syndromes[30]. For the sake of homogeneity in terminology, all patients were thus grouped according to their prominent aphasic deficit (i.e., agrammatic, anomic or paragrammatic), rather than according to syndromes. Of the whole group of 37 PWA, 15 PWA were found with predominantly agrammatic symptoms, and two agrammatic PWA presented with a hearing loss, one classified as mild and one as moderate. Because there were only two, and latter exclusion of their results on the current study did not change the overall group results significantly, (see chapters 9.4 and 10.4), I did not form sub groups within the agrammatic group.

Table 8.1. Overview of persons with aphasia with normal hearing or hearing impairment (listing according to PTA-4 value). Code C), gender (G), age (in years), years of education (YoE), main aphasic symptom, aphasia state, severity of the auditory sentence comprehension deficit according to the score on the SVO sentences (in %; higher percentages signal better comprehension), BEHL PTA-4 score and PTA-6 score in dB, BE (better ear, R = right ear, L = left ear), presence of hearing aid (HA) and usage (NU = present, but not using the HA), score on the Token Test (TT; maximum: 50 error points).

C	G	Age	YoE	Main symptom[31]	Aphasia state	Severity	PTA-4	PTA-6	BE	HA	TT
Normal-hearing											
209	f	62	15	agrammatic	chronic	83.89	-1.25	1.67	L	-	5

[30] There is a range of aphasia tests used in Germany. Participating PWA were diagnosed with aphasia by standardized aphasia tests, such as the AAT (Huber *et al.*, 1983), Aphasie Check Liste (ACL; Kalbe, Reinhold, Ender, & Kessler, 2002), Aphasie Schnell Test (AST; Kroker, 2006) or by individual clinical tests and screenings.

31 Due to the problems of classifying or categorizing PWA in syndromes (see chapter 4.1.1), and because for some PWA a full AAT protocol was not obtained, all PWA in this study were categorized via their dominant main aphasic symptom.

C	G	Age	YoE	Main symptom[31]	Aphasia state	Severity	PTA-4	PTA-6	BE	HA	TT
212	m	35	10	anomic	chronic	57.78	0.00	0.00	R	-	38
217	m	74	12	agrammatic	chronic	75.56	1.25	1.67	L	-	26
208	f	59	12	agrammatic	chronic	47.22	2.50	3.33	L	-	16
211	m	75	15	paragrammatic	chronic	47.78	2.50	0.83	R	-	37
233	f	61	13	paragrammatic	chronic	64.44	2.50	4.17	L	-	33
234	f	62	12	agrammatic	chronic	48.89	3.75	5.83	L	-	20
242	f	57	11	anomic	chronic	45.56	3.75	9.17	L	-	4
240	f	59	13	agrammatic	chronic	72.22	5.00	6.67	L	-	28
215	f	71	13	anomic	chronic	92.78	7.05	8.33	R	-	0
210	m	22	19	agrammatic	chronic	80.56	10.00	11.67	L	-	1
239	m	82	13	anomic	chronic	77.22	10.00	20.00	R	-	3
206	m	55	13	agrammatic	chronic	50.56	11.25	14.17	L	-	33
213	f	59	15	anomic	chronic	48.89	12.50	16.67	L	-	33
230	m	46	12	agrammatic	chronic	68.89	12.50	10.83	R	-	16
223	m	47	19	agrammatic	acute	52.78	13.75	18.33	L	-	36
231	f	52	13	anomic	chronic	73.89	13.75	15.00	L	-	4
237	f	75	11	paragrammatic	chronic	55.56	13.75	17.50	L	no	26
238	f	54	13	agrammatic	chronic	52.22	13.75	14.17	R	-	15
222	m	43	12	paragrammatic	acute	58.33	15.00	16.67	L	-	18
227	m	52	14	agrammatic	acute	73.33	15.00	20.00	R	-	39
235	f	56	10	agrammatic	chronic	77.78	15.00	16.67	L	-	19
243	f	64	12	anomic	chronic	77.22	15.00	15.83	L	-	0
236	f	59	16	agrammatic	chronic	58.89	16.25	19.17	R	-	44
232	f	75	8	anomic	chronic	55.00	17.50	20.00	R	-	35
Hearing-impaired											
245	m	56	11	anomic	chronic	51.67	21.25	31.67	R	no	6
203	m	77	13	agrammatic	acute	52.22	26.25	31.67	R	no	26
218	f	44	9	paragrammatic	chronic	68.89	30.00	32.50	R	NU	9
229	m	49	22	anomic	chronic	61.11	33.75	38.33	L	NU	16
225	m	54	25	paragrammatic	acute	75.00	35.00	39.17	L	no	10
244	m	48	16	anomic	chronic	83.33	35.00	35.00	L	NU	6
216	m	56	12	anomic	chronic	85.00	36.25	36.67	L	yes	16
207	f	57	12	anomic	acute	61.11	37.50	36.67	L	no	22
214	f	54	9	anomic	chronic	66.67	53.75	53.33	L	yes	5
204	f	66	8	paragrammatic	acute	63.33	57.50	58.33	R	yes	25
226	f	64	8	anomic	acute	57.22	60.00	61.67	L	yes	16
202	m	71	13	agrammatic	acute	56.11	62.50	63.33	R	yes	21

The non-brain-damaged group (NBD) consisted of 50 non-brain-damaged adults, 26 NBD with (15 female, 11 male), and24 NBD without hearing impairment (13 female, 11 male). The hearing-impaired group all had mild to moderate sensineural hearing losses on the better ear. This group comprised of native speakers of German who were reimbursed for their participation.

In order to validate the test, 38 normal-hearing young controls (YC) (22 females, 16 males) were assessed. All young controls were students of the University of Oldenburg, native speakers of German, raised monolingually, and right-handed, and were also reimbursed for their participation.

For all participants, visual acuity was controlled for, and if needed, corrected. All NBD had no reported history of pre-morbid speech, language, learning or neurological disorders. Table 8.1 gives an overview of the demographic data of all groups.

Table 8.2. Overview of all groups of the experimental task: Persons with aphasia (PWA), agrammatic PWA (PWAA), non-brain-damaged persons (NBD) and young controls (YC), number of participants per group (N) with normal hearing (NH) and hearing impairment (HI), age and years of education (YoE) including range in years, mean hearing threshold and range for both PTA-4 and PTA-6 scores in dB, and in case of HI, usage of a necessary hearing aid (HA)[32].

Group	**N**	**Mean age (range)**	**Mean YoE (range)**	**Mean hearing threshold (range)**		**HA usage**
				PTA-4	**PTA-6**	
PWA NH	25	53.28 (22-75)	13.04 (10-20)	9.29 (-1.25-17.50)	11.70 (0.00-19.83)	0/1
PWA HI	12	68.33 (55-82)	13.17 (8-25)	40.79 (21.25-62.50)	43.18 (20.25-63.33)	5/12[33]
PWAA	15	57.6 (43-77)	88.2 (1-235)	13.9 (-1.25-62.5)	15.95 (1.67-63.33)	1/1
NBD NH	23	40.75 (23-74)	15.17 (10-20)	7.45 (-1.25- 20.00)	10.29 (0.00-25.00)	none
NBD HI	27	60.88 (35-75)	15.56 (11-23)	39.57 (21.25-57.50)	40.22 (25.17-60.83)	21/24
YC	38	24.05 (20-30)	15.00 (12-18)	0.00 (-5.00- 6.25)	2.39 (-3.33-14.17)	none

[32] In Germany, bilateral hearing aids are prescribed by the audiologist when the hearing loss level of the better ear for one of the frequencies between 500 and 4000 Hz equals 30 dB or more, and the intelligibility threshold of 80% for the better ear is not reached by 65 dB. Unilateral hearing aids are prescribed if the hearing loss of the worse ear equals 30 dB and more for 2000 Hz, or if at least two frequencies between 500 and 4000 Hz equal 30 dB or more for the worse ear (HilfsM-RL, 2012).

[33] Of the PWA entitled to a HA, eight had uni- or bilateral aids, but only five PWA adopted them. Out of these five, four had fluent aphasias (anomic and paragrammatic) with relatively mild production deficits.

8.1.1 Hearing status assessment

All participants were screened with the digital PC audiometer Ear 2.0 (Auritec) with a Sennheiser HDA200 headphone. Assessment was done exclusively for air conduction in a silent room. For each ear, air-conduction thresholds were measured using a pure tone audiometry (PTA) with 11 intermittent tones from 125 to 8000 Hertz. Participants were categorized according to the European Commission guidelines, which define hearing levels from 0-20 dB as normal, from 21-39 dB as mildly, from 40-69 dB as moderately, and from 70-94 dB as severely impaired, using the measured values for 500, 1000, 2000 and 4000 Hz (cf. Heger & Holube, 2010; Martini, 1996). All participants were rated on this PTA-4 scale[34]. What is more, all participants were rated on PTA-6, including the frequencies of 250 Hz and 8000 Hz, which covered the frequency areas of all phonemes. This second analysis was implemented in order not to miss potential high-frequency hearing loss effects on speech perception (see chapter 5.1.4).

Measures were taken for the better ear (Better Ear Hearing Loss; BEHL). Young controls were allowed to have two frequencies at 20 dB to be still considered as having otologically normal hearing. For this group, presentation volume was fixed at 65 dB. All hearing-impaired participants (PWA and NBD) had hearing impairments from mild to moderate levels (ranging from 21.25 to 62.50 dB for BEHL PTA-4, respectively from 20.25 to 63.33 dB for BEHL PTA-6). Because not all participants with hearing losses had a hearing aid, and because there was no information regarding quality and fitting of the existing hearing aids, a hearing aid was simulated by filtering all auditory stimuli according to the BEHL for 125, 500, 750, 1000, 2000, 3000, 4000 and 6000 Hz via the NAL-R procedure (Byrne & Dillon, 1986), calculated by using a MATLAB (Mathworks, Natick, MA) script. The NAL-R formula is considered to be sufficient to equalize loudness for up to 60 dB hearing losses. Application of this formula ensured that all participants perceived roughly the same spectral information, but the algorithm is argued to be able to restore all information and not to enable hearing-impaired listeners to perceive the speech stimuli in a way normal-hearing listeners do

[34] Described in chapter 5.2, the WHO defines normal hearing with hearing thresholds until 25 dB, mild hearing loss between 26 and 40 dB, moderate hearing loss between 41 and 60 dB, severe hearing loss between 61 and 80 dB and profound hearing loss from 91 dB upwards, measured over the same four frequencies as the EU guidelines do. In contrast, AMCLASS defines hearing loss using 6 frequencies (PTA-6) from 250 to 8000 Hz (250, 500, 1000, 2000, 4000, 8000). Their scale defines normal hearing with hearing thresholds under 20 dB, mild hearing loss with thresholds between 20 and 39 dB, moderate hearing loss between 40 and 59 dB, severe hearing loss between 61 and 89 dB and profound hearing loss from 90 dB upwards (cf. Margolis & Saly, 2007).

(cf. Wendt *et al.*, 2015). For all PWA, older (60+) and hearing-impaired NBD, the presentation volume was individually adapted, with the exception that the sound pressure level (SPL) was not being than 85 dB, controlled by the setting on the Echo Indigo sound card I0x (Echo Digital Audio Corporation, Santa Barbara, CA).

8.1.2 Results of the hearing screening

The hearing screening posed no difficulties for the PWA. However, results showed that a number of PWA suffered from hearing loss and were not fitted with hearing aids. As seen in table 8.3, of the 20 PWA diagnosed with hearing impairment, 17 were entitled to a hearing aid, but only eight PWA were fitted with a device, and only five out of these actually adopted and used their device (see also table 13.1. in the appendices for individual data). Ten of the remaining 12 hearing-impaired PWA did not even know they had a hearing impairment (neither did the medical team or relatives know). According to the prescription rules of the German Hilfsmittelrichtlinien (2012), even three normal-hearing PWA were entitled to a hearing aid for the worse ear (code numbers 237, 241, 248).

Hearing aid ownership was much more prominent for the 27 NBD with hearing loss; 24 were entitled, and 21 were already fitted with a HA, all of them with bilateral hearing loss (see table 13.10 in section 13.3.4 for individual data). For the three participants who were entitled to but not fitted with a device, their unilateral (2 NBD) or bilateral (1 NBD) hearing loss diagnose came as a surprise.

Table 8.3. Overview of all groups of the hearing screening: PWA, non-brain-damaged group (NBD) and young controls (YC) with normal hearing (NH) and hearing impairment (HI) for age and years of education (YoE) including range in years, mean hearing threshold in dB for both BEHL PTA-4 and PTA-6, and in case of HI, usage of a necessary hearing aid (HA).

Group	**N**	**Mean age (range)**	**Mean YoE (range)**	**Mean hearing threshold (range)**		**HA usage**
				PTA-4	**PTA-6**	
PWA NH	30	54.90 (22-75)	13.02 (8-19)	10.08 (-1.25-18.75)	12.64 (0.00-21.67)	0/3
PWA HI	20	71.40 (55-84)	13.20 (8-25)	37.43 (21.25-62.50)	40.40 (25.83-63.33)	5/18
NBD NH	23	40.75 (23-74)	15.17 (10-20)	7.45 (-1.25- 20.00)	10.29 (0.00-25.00)	None
NBD HI	27	60.88 (35-75)	15.56 (11-23)	39.57 (21.25-57.50)	40.22 (25.17-60.83)	21/24
YC	38	24.05 (20-30)	15.00 (12-18)	0.00 (-5.00- 6.25)	2.39 (-3.33-14.17)	None

8.1.3 Excluded PWA

Mentioned in section 8.1, 13 PWA had to be excluded, whereby six PWA presented with a bilateral and two PWA with a unilateral hearing loss, while five PWA possessed normal hearing levels. Of the eight hearing-impaired PWA, six were entitled to a hearing aid but none owned one. Furthermore, all of those eight hearing-impaired PWA were older than 60 years (ranging from 64 to 84 years). Exclusion reasons included lack of understanding of test instructions (code numbers 248, 249) or a SVO score below 50% (code numbers 205, 219, 220, 221, 224, 241). In contrast, only five of the normal-hearing PWA had to be excluded. Of those five normal-hearing PWA, four were below the age of 60 (ranging from 50 to 71 years). Reasons for exclusion included termination of the task because of health problems (code numbers 201, 246, 250), lack of understanding the test instructions (code number 247), or a score below 50% on SVO items (code number 228).

8.1.4 Language assessment

All PWA, whose AAT results were older than 6 months or did not exist, were assessed on the Token Test (TT) and the auditory word and sentence comprehension tasks (AC) from the AAT (Huber *et al.*, 1983). The Token Test was implemented because it has been used traditionally to assess *presence* as well as *severity* of aphasia (e.g., Huber *et al*., 1983; de Renz & Vignolo, 1962). The spontaneous speech (SS) was assessed for each PWA, using the AAT protocol and scales (see table 13.1 for a full report of all assessments and results of each PWA).

Although cognitive deficits have been observed to be common in aphasia, neither PWA nor NBD were tested on WM capacity, attentional abilities or measures of processing speed, because it would have involved too much pressure for the PWA.

8.2 Material

8.2.1 Sentence stimuli

Material consisted of items from the OLACS corpus (Oldenburger Linguistically and Audiologically Controlled Sentences, Uslar *et al.*, 2013), evaluated and tested on different methods and designs (e.g., Carroll, 2013; Carroll & Ruigendijk, 2013; Uslar, 2014; Wendt *et al.*, 2015). The corpus has been controlled for frequency of verbs, nouns and adjectives (cf. Carroll, 2013). OLACS contains seven semantically reversible active syntactic structures;

three verb-second (V2) sentence types -unambiguous SVO and OVS, and ambiguous OVS-, and four centre-embedded relative clause (RC) sentence types -unambiguous SR and OR, and ambiguous SR and OR. The verbs chosen for the verb-second- and the relative clauses are all active transitive verbs demanding a subject in nominative case with the thematic role of agent and a direct object in accusative case with the patient role. All sentences are controlled for predictability in terms argument structures of the verb in order to avoid context effects. All structures are controlled for an unmarked, i.e., SVO, prosody, which is in the case of OVS relevant, as German OVS sentences are assumed to be spoken with a different prosody, which accentuates the topicalised object (e.g., Burchert *et al.*, 2003; de Bleser *et al.*, 2005). This control ensures that especially the V2 sentences cannot be distinguished by intonational cues, but have to be interpreted by the respective morphosyntactic features (see Carroll, 2013 for a detailed description).

With these test items, canonicity effects have not only been found for young normal-hearing controls in terms of reaction time differences, but also for hearing-impaired non-brain-damaged listeners, who demonstrated longer reaction times, lower accuracy and/or different eye fixation latencies than normal-hearing non-brain-damaged controls (see chapters 3 and 5.4).

For this study, the four unambiguous syntactic structures from the OLACS were chosen. Of the transitive V2 structures, one structure -SVO- was considered canonical, the second -OVS- non-canonical with a topicalised object. Those two structures have been argued to be syntactic minimal pairs because the only difference between them is the word order of subject and object (cf. Carroll, 2013). More, these items resemble those of Burchert *et al.* (2003) and Hanne *et al.* (2011, 2015) (with the exception of two additional adjectives in the OLACS items), which enables a comparison of results of this research with their data.

The transitive centre-embedded RC structures contained canonical SR and non-canonical OR, and can also be regarded as syntactic minimal pairs, although besides word order, also agreement features are different (see below). Table 8.4 displays an example for each V2 and RC sentence type.

Table 8.4. Examples for V2 and RC items used in the study.

SVO	Der kleine	Junge	umarmt	den	dicken	Nikolaus.
	The$_{NOM\ SM}$small$_{NOM}$	boy$_{NOM}$	hugs	the$_{ACC}$	fat$_{ACC}$	Santa Claus
	'The small boy hugs the fat Santa Claus.'					
OVS	Den dicken	Nikolaus	umarmt	der	kleine	Junge.
	The$_{ACC}$ fat$_{ACC}$	Santa Claus	hugs	the$_{NOM}$	small$_{NOM}$	boy$_{NOM}$
	'It is the fat Santa Claus whom the small boy hugs.'					
SR	Der	Mönch,	der die	Astronauten	erschiesst,	lacht.
	The$_{NOM.SG}$	monk$_{NOMSG}$	who$_{NOM}$the$_{ACC.PL}$	astronauts$_{AMB.PL}$	shoots$_{SG}$	laughs$_{SG}$
	'The monk who shoots the astronauts laughs'.					
OR	Der	Mönch,	den die	Astronauten	erschiessen	lacht.
	The$_{NOM.SG}$	monk$_{NOMSG}$	whom$_{ACC}$ the$_{NOM.PL}$	astronauts$_{AMB.PL}$	shoot$_{PL}$	laughs$_{SG}$
	'The monk whom the astronauts shoot laughs'.					

The determiners in the V2 and the relative pronouns in the RC structures differed overtly in case. Incidentally, both the determiner "der" (*the*, masculine) respectively the pronoun "der" (*who*, masculine) marked for nominative case, and the determiner "den" (*the*, masculine,) respectively the pronoun "den" (*whom*, masculine) marked for accusative case, had the same morphological word form. Accusative (ACC) case of the determiner and pronoun was phonologically distinguished from nominative (NOM) case by vowel change and presence of nasality (NOM /deɐ/ vs. ACC /de:n/).

All structures were semantically reversible, and semantic agent and patient were only depicted by animate human participants in order to control for animacy effects (cf. Mak *et al.*, 2002). Fifteen reversible sentences of each of the structures were chosen. For the V2 sentences, 10 formed semantic minimal pairs with the thematic roles agent and patient of SVO being reversed in OVS, such as the subject-first sentence *Der fiese Pirat erschiesst den braven Soldaten* (*The evil pirate shoots the good soldier*) and the thematically reversed OVS *Den fiesen Piraten erschiesst der gute Soldat* (*It is the evil pirate whom the good soldier shoots*). In the remaining five sentences both agent and patient stayed the same for SVO and OVS (as seen in the examples in table 8.4). Thematic roles in all SR structures were reversed in the OR structures (see table 13.2 in section 13.2.1 for a list of all items). For the RC items, agents of the OR and patients of the SR of the embedded clause could be masculine (N = 8) or feminine (N = 7), and were always in plural[35].

In SVO and OVS both thematic roles were occupied by single masculine participants, and the verb showed agreement for the 3rd person singular. Case features overtly marked determiner and adjectives and weak nouns of syntactic subject and object. The relative verb in SR was in singular agreement, while in OR, the relative verb was marked for plural agreement. In SR, the syntactic subject of the relative clause was overtly marked for nominative case on the relative pronoun and by agreement cues, in OR, the subject was only marked by agreement cues, because the determiner “die” can either signal nominative or accusative case.

Besides different numbers of case and agreement markers, V2 and RC items also show other structural differences (which were described in chapter 1, and are for repeated here for easier reading): V2 and RC items both contained different numbers of verbs, with one verb in the V2, and two verbs in the RC structures (one matrix- and one relative verb). Both relative and matrix verb of the embedding condition were clause final. Furthermore, the embedded relative clause condition contains two clauses with two semantic/thematic propositions. In contrast to the V2 sentences, the relative clauses also contain an antecedent pronoun dependency. Last but not least, V2 and RC structures could also be distinguished by their respective prosodic structure: While SVO and OVS items contained one major Intonational Phrase (IPh), which covered the whole sentence, the RC structures on the other hand consisted of two major IPh, which boundaries were at the end of the embedded clause, and at the end of the matrix clause. In addition, all RC items contained a silent interval between the relative and the matrix verb, i.e., after the syntactic and intonational boundary (see Carroll, 2013, for a detailed analysis of the intonational structures of the OLACS items).

The absolute frequencies (per million) of the adjectives, nouns and verbs were checked with WEBCELEX (http://celex.mpi.nl), dlexdb (http://dlexdb.de/query/kern/typposlem/) and Clearpond (http://clearpond.northwestern.edu/germanpond.html) (see table 13.3 in section 13.2.2).

---

[35] All seven feminine and six masculine nouns had one or two overt plural affixes; only three masculine nouns („Metzger“, „Bäcker“, and „Astronauten“) were covertly marked for plural (in the case of “Astronauten” the suffix “-en” may also mark accusative case of the singlular form “Astronaut”).

8.2.2 Time manipulation

All stimuli were recorded by a female semi-professional speaker in a slow to normal speaking rate, here signified as "slow"[36]. The original rate resembled clear speech with its accentuated articulation, but was controlled for normal intonation and prosody. Stimuli were uniformly time-expanded to 125% in order to obtain a very slow rate, and time-compressed to 85% of the original speech rate in order to use a conversational, normal speech rate. Two different slow speech rates were implemented in order to compare results to findings from the literature using a similar expansion, and also, because a speech rate resembling that of clear speech might not be slow enough in order to facilitate aphasic sentence processing.

In relation to the defined conversational rate, the slow rate was time-expanded to ca. 125%, the very slow rate to ca. 140%. Time manipulation was accomplished by using PRAAT software (Boersma & Weenink, 2014). For compression, the Pitch-Synchronous Overlap Add (PSOLA) algorithm was used, which deletes every n^{th} portion of a segment while maintaining the original pitch contour. For a 50% compression, every second 10 ms sample of the sound signal is removed without regard to the informational content, and the remaining segments are abutted resulting in a linear, uniform compression of the sound signal and the silent intervals. For expansion, every nth segment is lengthened and the stimulus is modified in the same manner as for the compression. This method is widely used in time manipulation research (e.g., Wingfield *et al.*, 2003, 2006; Janse 2004).

Differences in durations (measured in ms) across speech rates between SVO and OVS items were not significant (analysed by paired t-tests: All three comparisons demonstrated $p = .385$), but were significant in-between SR and OR (all three comparisons: $p = .012$). Also, differences in syllables per second (sps) between the relative clause structures proved to be significant for all speech rates (dependent t-tests; $p < .001$ for all pairs). These differences were produced by the overall difference in syllables caused by the verb (two syllables for singular agreement in SR, three syllables for plural agreement in OR). More, the average speaking rate of the RC sentences differed from the V2 sentences because both SR and OR contained one longer silent interval at the second embedding border. Table 8.5 shows the average duration in ms, and the average ratios for words per minute (wpm) and sps per

---

[36] The OLACS corpus was recorded in a slightly slower-than-normal average German speaking rate, which normally may be between 5.34 sps (Schelten-Cornish, 2007) and 5.97 sps (Pellegrino, Coupe & Marsico, 2010), because the corpus is used for both audiometric and linguistic research. Cross-linguistically, German seems to be one of the slower languages compared to English (6.19 sps) or French (7.18 sps) (Pellegrino *et al.*, 2010).

syntactic structure for each speech rate, while table 13.4 in section 13.2.3 displays this information for each item.

Table 8.5. Average number of syllables and words, durations (dur, in ms), words per minute (wpm) and syllables per second (sps) for each syntactic structure per speech rate.

Syntactic structure	N of syllables	N of words	conversational rate			slow rate			very slow rate		
			dur	wpm	sps	dur	wpm	sps	dur	wpm	sps
SVO	12.4	7	2583	162.59	4.80	3039	139.17	4.09	3799	111.3	3.27
OVS	12.2	7	2598	161.68	4.77	3056	138.49	4.01	3820	110.8	3.21
total	12.3	7	2590	162.14	4.79	3047	138.83	4.05	3809	111.1	3.24
SR	11.1	7	2757	152.32	4.50	3243	130.24	3.43	4055	104.20	2.74
OR	11.7	7	2773	151.46	4.47	3262	129.47	3.63	4078	103.58	2.90
total	11.4	7	2765	151.89	4.48	3253	129.86	3.53	4066	103.89	2.82

8.2.3 Picture stimuli

All pictures were black and white drawings depicting agent, action and patient, and were pretested and validated (Uslar *et al.*, 2014; Wendt *et al.*, 2014; see more examples in the appendices 13.2.4). Figure 8.1 depicts the target and foil for either an SVO and OVS item, figure 8.2 target and foil for an SR respectively OR test item.

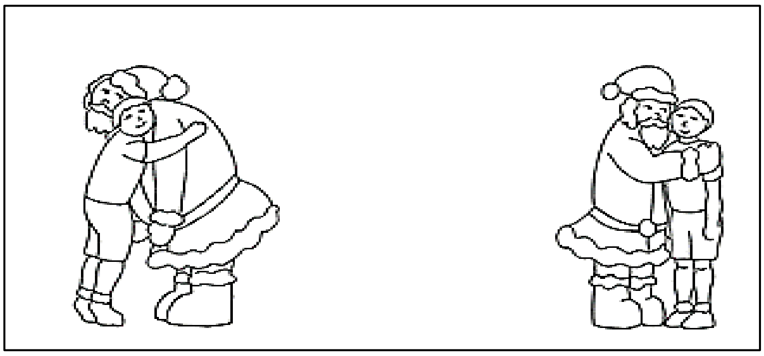

Figure 8.1. Examples of pictures for the V2 target sentences of table 8.4: SVO *Der kleine Junge umarmt den dicken Nikolaus* (left picture correct) and OVS *Den dicken Nikolaus umarmt der kleine Junge* (left picture correct).

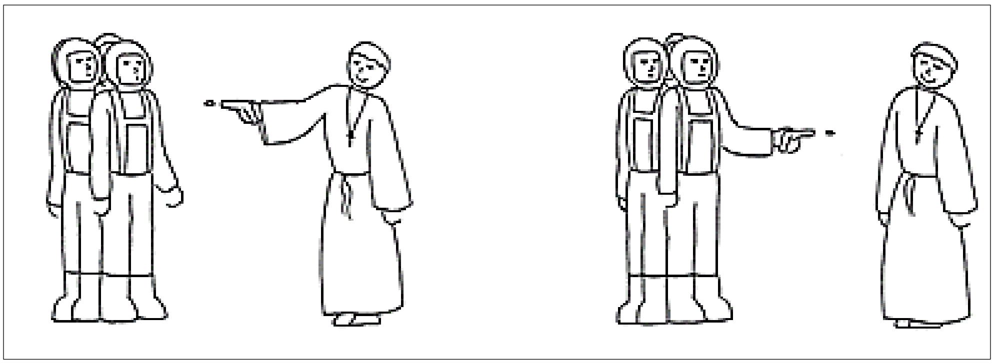

Figure 8.2. Examples of pictures for the RC target sentences of table 8.4: SR *Der Mönch, der die Astronauten erschiesst, lacht* (left picture correct) and OR *Der Mönch, den die Astronauten erschiessen, lacht* (right picture correct).

8.3 Design and Procedure

A total of 180 stimuli, consisting of 15 items per sentence type converted in three different speech rates, was presented. These were implemented in a sentence picture matching (SPM) task with two black and white pictures per sentence. One sentence always displayed the correct distribution of action and thematic roles of the participants, the distractor or foil the reverse distribution of thematic roles. For all groups, accuracy in terms of correct decision was measured. Although an offline measure does not allow interpretations about actual processing, it is less demanding: Reaction times measuring could have put too much stress on PWA, increasing the risk of lesser accuracy. Response latencies were only measured for the young control group by counting the reaction time from the offset of the auditorily presented stimulus until button hit (see chapter 8.4).

Testing procedures were far from real-life communicative situations with respect to loudness, background noise and directional hearing: All hearing-impaired participants were allowed to choose their own comfortable volume level, stimuli were presented via headphones, and invitations for breaks occurred often. This listening situation was kept as optimal as possible in order to keep listening effort as minimal as possible.

The test was administered on a Dell laptop; stimuli were presented electronically using the E-Prime software (Psychology Software Tools, Pittsburgh, PA). The sentence stimuli were presented via headphones. The display of the pictures was followed after 1000 ms by the presentation of the sentence, displayed by figure 8.3. Participants answered via a button box, pressing the left button when they chose the left picture and the right button for the right picture. The button box consisted of a customized device with just two buttons. As soon as the choice was made, a new pair of pictures appeared on the screen. A training session with feedback on the reaction containing eight (for the NBD) or 12 items (for the PWA) ensured that participants understood the procedure.

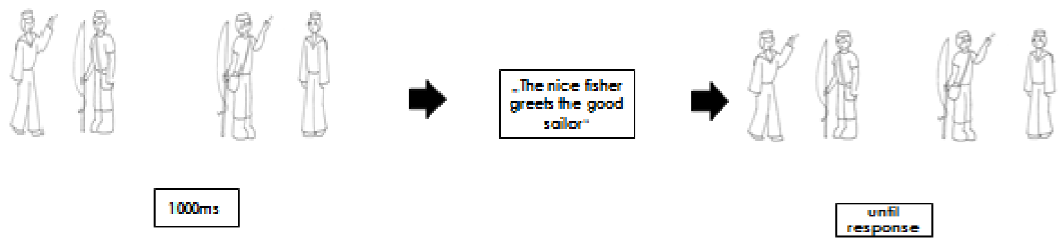

Figure 8.3. Procedure of the sentence-picture matching task. A visual presentation of the pictures was followed after 1000 ms by the auditory presentation of the sentence. Participants were asked to press a button on a two-choice button box whereby the left button corresponded to the left picture, and the right button to the right picture.

Whereas the actual experiment contained 12 blocks with each 15 sentences with the same speech rate, within the training session the speech rates were distributed randomly. Each experimental block consisted of a quasi-equal distribution of sentence structures (e.g., each three SVO, OVS and SR, and four OR), and a quasi-equal distribution of answers to the left or right picture (e.g., seven left and eight right responses). Distribution of sentence structures did not exceed more than two items of the same structure, distribution of answers not more than three responses for the same button side. All blocks started with an SVO sentence. For some PWA, the training session consisted of a paper test in order to familiarize the participants with the material and the procedure, and to control whether sentence comprehension deficits were not due to auditory word comprehension difficulties. The paper version enabled me as the instructor to give comments and to highlight specific aspects without having the timing restrictions of the actual task.

In order to compensate for effort and fatigue the participants might encounter[37], which may affect their sentence processing abilities, precautions in terms of material and procedure

[37] Increased effort as well as temporarily insufficient cognitive resources may be one reason why PWA suffer from intermittent deficiencies in syntactic processing (cf. Burchert *et al.*, 2013). Moreover, increased effort and fatigue are symptoms often occurring in aphasia (cf. Christensen & Wright, 2014; McNeil *et al.*, 1991), and also in hearing impairment (cf. Bess & Hornsby, 2014; van Boxtel *et al.*, 2000).

were taken. Sentence stimuli did only consist of seven words, to prevent storage and manipulation overload of verbal short-term memory and working memory. The quiet setting and headphones ensured the absence of background noise, to which PWA, hearing-impaired and older adults have been seen to show an increased susceptibility. The experimental setting contained blocks of no more than 15 sentences, and each block was followed by a self-paced pause setting. Experimental lists for PWA included either three or six blocks. The acute PWA received four lists with each three blocks in three to four sessions, the chronic PWA were tested on two lists with each six blocks. For the non-brain-damaged groups, one list with 12 blocks was presented, and all participants were instructed to choose their own durations of breaks in-between the blocks. While the non-brain-damaged group and the PWA were allowed to press buttons as soon as they decided on the picture, the YC were instructed to press only after offset of the speech stimulus in order to measure response latencies (see chapter 8.4. for more details on YC).

For the YC and the NBD a single session with an average duration of ca. 45 minutes including the initial audiometry was sufficient. PWA were administered 2-5 sessions including the hearing screening, whereby the sessions were at least one day and at most 7 days apart from each other. The short lists for the acute PWA did not take them longer than 12 minutes, the longer lists with 90 items, only presented for the chronic PWA, not longer than 25 minutes, including breaks. The AAT sub tests were administered at the end of the last session.

8.4 Statistical analyses

Statistical analyses for accuracy data were made of a mixed effect analysis with fixed and random effects and random slopes using the glmer (*lme4*, Bates, Maechler, Bolker, & Walker, 2014) function in *R studio* (version 0.98.1091, R Studio, 2014). All models consisted of a generalized linear mixed model fit by maximum likelihood (Laplace Approximation).

Accuracy was measured by analysing the number of correct responses. Accuracy of each participant was then centred-on the mean of each specific group. Log-transformed response latencies (RL) from the young controls (time from offset of the auditory stimulus until button press) were analysed using the lmer function (*lme4*) in R Studio. These linear mixed models were fitted by restricted maximum likelihood (REML), for *t*-tests Satterthwaite approximations for degrees of freedom were used. The final model was trimmed and screened for outliers by implementing the limit of 2.5 SD. While all 38 participating young controls were included in the accuracy analysis, for the analysis of response latencies five participants had to be excluded because their overall response latencies were below 150 ms; a time too short for actual reactions, as motor planning time has to be accounted for as well (cf. Miller & Low, 2001)[38].

Fixed effects included canonicity, speech rate and hearing level (for the young controls hearing level as factor was excluded by selecting only normal-hearing participants). Hearing level consisted of either the traditional BEHL PTA-4 values, or of BEHL PTA-6 values, in order to see whether hearing level of a low frequency (between 250 and 500 Hz) and/or a high frequency (between 4000 and 8000 Hz) had an impact on sentence comprehension. The values of each hearing level was also centred on their respective means. Age as fixed factor was added for the analyses of the non-brain-damaged and aphasic groups before random slopes were implemented. While accuracy was treated as ordinal, and syntactic structures and speech rates as nominal data, both age in years and hearing level- either BEHL PTA-4 or BEHL PTA-6- were analysed as continuous data. The random effects of participants and items were implemented to account for the fact that participants and items may vary in terms of accuracy. After obtaining the model with the best fit, random slopes were included in order to see whether fixed effects generalized across participants and/or items, and to prevent that one or more fixed effects were steered by the results of single participants and/or items. In other words, random slopes were identified to reduce the risk of a type 1 error (cf. Barr, Levy, Scheepers, & Tily, 2013).

Models were compared with and without a factor as main effect or interaction term by using the Akaike Information Criterion (AIC in) order to measure the relative quality of the statistical model and to define the goodness of the model. The model with the lower AIC value, showing the best fit, was retained. The best model was then tested by entering random slopes. If the effect of a fixed factor vanished after the implementation of the slopes, it was excluded, and a backward analysis started. Often, for both NBD and PWA, the AIC value for the best model only differed minimally from the other model (in terms of one or two values), and therefore random slopes lost their effects by a margin, which resulted consecutively in the

[38] The remaining 33 students consisted of 22 females and 11 males, with a mean age of 23.76 yrs. (ranging from 20 to 27 yrs.), mean length of education of 14.70 yrs. (ranging from 12 to 18 yrs.), and a mean hearing level of 0.80 dB, ranging from -5.00 to 10.00 dB.

loss of effects of fixed factors, such as hearing state and/or speech rate in the best model. For PWA for example, the AIC differences between the best and the second-best model for the V2 analysis was minimal, but choosing the better AIC value included losing speech rate as factor.

Analyses started with a hypothesis-driven model consisting of an interaction or three-way interaction term. Canonicity effects consisted of comparing accuracy on the canonical with that on the non-canonical structure, speech rate effects of an accuracy comparison of the slow and very slow speech rate with the conversational one. Hearing and age effects on the other hand were seen by gradual differences towards the end of one continuum.

A visual inspection of all residual plots did not show any obvious deviations from homoscedasticity or from normality. Correlations from each final model confirmed that there were no deviations from homoscedasticity and that there was no multicollinearity.

Result sections started with observational descriptions of the findings of each group. Means of accuracy were reported in percentages, and response latencies in ms. For the aphasic main group and the agrammatic subgroup, the result section also included a descriptive analysis of comprehension performance on each sentence type per each speech rate according to the chance performance criterion postulated by the TDH. While graphs depicting accuracy (and RL for the young controls) had the zero line at 50% accuracy for the non-brain-damaged groups, the bottom line started at 40% for the group of PWA order to show the range of the standard error (SE). Tables in the appendix section 13.3 complemented the descriptive results by containing all group results on accuracy performance and the respective SD, and also for each individual participant, in order to demonstrate comprehension performance ranges and variance on each syntactic structure.

Both PTA-4 and PTA-6 values were entered as hearing status levels in different analyses. Different sub sections reported the results, headed PTA-4 (for the BEHL PTA-4 values entered as hearing level factor) and PTA-6 (for the BEHL PTA-6 values). For illustration, hearing level was divided into groups of hearing-impaired versus normal-hearing participants according to PTA-4 classification. The statistical results of the final model contained fixed and random factors as well as random slopes. For all outcomes of the fixed effects, estimate (Est), SE, z-scores and p-value were reported (and in case of response latencies, the t-scores and degrees of freedom). Non-significant main effects were reported from the last model that included the respective factor. For the random effects and random slopes, the variance, the SD, the correlation and the direction of the correlation were reported. Because it was not clear at the moment of writing how to calculate the variance proportion accounted for by the random slope model, I could not give a measure of the explained variance by the random effects and slopes (cf. Neger, Janse, & Rietveld, 2015).

Described in chapter 4.5, individual performance of PWA may vary across days of testing or duration of testing. This might be attributed to the state of aphasia, the severity and/or the presence of cognitive deficits. Many of the PWA in this study were diagnosed/suspected with and/or reported about problems with working memory or attention. For these reasons, effects of severity- measured by error scores on the Token Test-, and state of aphasia -acute versus chronic- were tested as by-items random slopes.

I divided V2 and the RC items into two separate experiments and analysed them separately because I did not want to compare these structures with each other statistically. Carroll (2013), using the same item structures in some of her experiments, noted that comparing verb- second with relative clause structures is difficult because of several factors, such as the verb position, the prosodic properties or the informational structure (see chapter 8.2.1): For the two structure types, i.e., the verb-second- and the embedded relative clause, the verb is in different positions, which may affect processing differently (see Weyerts *et al.*, 2002).

After validating the experiment by analysing the performance of the young controls, I performed a group comparison between the NBD and the PWA in order to establish the expected higher canonicity effect in the PWA, and to see whether slower speech exerted a general effect on comprehension. Also, the group comparison was performed in order to see whether one group profited more from slower speech. Here, hearing level was not implemented as a factor because I was not interested in analysing whether hearing-impaired NBD has a better performance than hearing-impaired PWA. Age was neither included as a factor because inter-group matching with respect to this factor did not fit anymore after exclusion of 13 PWA. I then analysed the impact of hearing level and the effect of slower speech on general comprehension and comprehension of the non-canonical structures for the 37 PWA as a whole group. Because the agrammatic group only contained two hearing-impaired participants, only the effect of slower speech was analysed[39]. Last, I examined the impact of hearing level and the effect of slower speech on general comprehension and comprehension of the non-canonical structures of the NBD. Details of each model were reported in the respective result sections.

Putting PWA in one group, even if their main symptom is the same, might result in a loss of significant results due to their individual and intraindividual heterogeneity (cf. Burchert *et al.*, 2013; Caramazza *et al.*, 2001; Wilson & Saygin, 2004), therefore the p-value of < .1 was included in the significance levels in order to show trends of the data (also implemented by e.g., Bates *et al.*, 1987; Blumstein *et al.*, 1985; Burkhardt *et al.*, 2008; Ferrill *et al.*, 2012; Love *et al.*, 2008).

In order to compare results of the agrammatic PWA with those of the literature and their categorization (cf. chapter 4.3), I conducted a post hoc analysis implementing the chance performance criterion of the TDH, the "within-1.74 SD-of normal" criterion of Caplan *et al.* (2007) and the "2 SD-within-normal" criterion of Burchert *et al.* (2003), using either raw means (number of correct answers *n*) for the latter, or percentages correct for the former criterion. With this descriptive analysis, I was able to categorize agrammatic PWA performance as either below chance, within or above chance according to the TDH, "normal" (within 1.74 SD), or "abnormal" (below 1.74 SD) according to Caplan *et al.* (2007), or "normal" (within 2 SD), "partially impaired" (below 2 SD but still above change), "at chance" (within-chance performance) or "below chance" (below chance level) according to Burchert *et al.* (2003). In order to group patients according to the TDH parameter, the chance level and the chance range was computed, using the 15 items of each sentence type per speech rate, computed by a one-sampled two tailed test with a CI of 95%. Chance value was at 50%, i.e., $n = 7.5$ (8) correct answers. Chance performance was defined by calculating the range between 10 incorrect (below chance) and 10 correct answers (above chance), resulting in a within chance range of $n = 5$-10, a below-chance range of $n < 5$, and an above-chance range of $n >$ 10, corresponding to a range between 33% and 67% accuracy for the within-change level. For the within-1.74 SD criterion, the SD of comprehension performance on each sentence type of the normal-hearing NBD was used. In order to apply the 2 SD-within-normal criterion, the

[39] I performed two analyses with either the two hearing-impaired PWA included or excluded. For the results on V2, neither significance values for the main effects condition and age as well as for the interaction condition*age changed significantly as controlled by a pairwise comparison with a t-test.

number of correct answers and the corresponding SD of the normal-hearing group of NBD were calculated.

9 Results of experiment 1: Verb second (V2) structures

This chapter contains the result of the analyses on comprehension performance on SVO and OVS sentences in different speech rates. First, the performance the group of young controls is presented. Second, the effects of canonicity and slower speech are investigated by a group comparison between the non-brain-damaged and the aphasic group. This is followed by the results of the group of PWA, where the effect of aphasia, hearing loss and slower speech on comprehension performance are analysed. Thereafter, the impact of slower speech on agrammatic PWA's sentence comprehension is examined. Last, in order to see the impact of hearing impairment and slower speech on non-brain-damaged sentence comprehension, results of the group of non-brain-damaged persons are shown. Tables in appendix 13.3 complement group and individual results on comprehension accuracy (table 13.5 in section 13.3.1 for an overview on group results, tables 13.6 and 13.8 in section 13.3.2 for results of individual PWA and symptom groups, table 13.9 in section 13.3.3 for results of individual young controls, table 13.10 in section 13.3.4 for results of individual NBD, and table 13.11 in section 13.3.5 for accuracy on each item per group). A short summary of the results is followed by an interim discussion concerning the results with regard to findings from the literature. In particular, agrammatic findings are discussed, and performance of each individual agrammatic PWA is analysed with regard to the performance patterns postulated by the TDH, and with regard to two other performance patterns proposed by supporters of procedural accounts.

9.1 Validation of the experiment: Young Controls

For the young controls, the hypothesis-driven model consisted of the fixed factors canonicity and speech rate as interaction term and of the random factors of participants and items for both accuracy and response latencies analyses. Effects of canonicity and speech rate were also entered as by-participants' random slopes.

9.1.1 Accuracy

Figure 9.1 shows that accuracy on both SVO and OVS items was at ceiling performance. Comprehension scores for the conversational, slow and very slow rate were very similar, and the variance, reflected by the standard error, was low (see also table 13.5 in section 13.3.1 for variance signified by SD, and table 13.9 in section 13.3.3 for individual results).

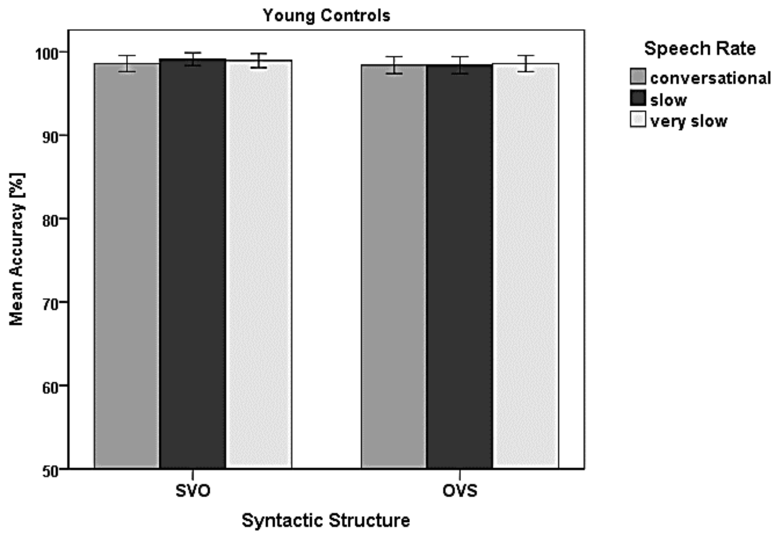

Figure 9.1. Comprehension accuracy in % correct for canonical SVO and non-canonical OVS per speech rate for the young control group (N = 38).

The best fitting and thus final model included canonicity as fixed factor, the random factors participants and items, and the effect of canonicity as by-participants random slope.

Table 9.1 demonstrates the expected lacking effects of canonicity and speech rates. The random slope structure included the effect of canonicity on participants, indicating that the degree of accuracy differences between SVO and OVS differed slightly among the 38 participants, in as such that some participants had lower accuracy on OVS compared to SVO, while others had the same accuracy level for both sentence types. Still, these differences did not result in a significant canonicity effect.

Table 9.1. Statistical results of the final model for the young control group.

Fixed effects	***β***	***SE***	***z***	***p***
Intercept	5.67	.61	9.25	< .001
Canonicity	-	-	-	.513
Speech Rate slow	-	-	-	1.00
Speech Rate very	-	-	-	.800
Random effects		**Variance**	**SD**	**Corr.**
Participants	Intercept	2.21	1.49	
	Canonicity	.50	.71	-.1.00-
Items	Intercept	.98	.99	

9.1.2 Response latencies

Figure 9.2 illustrates that the overall RL for SVO appeared to be shorter than those for OVS, but both SE were high. For speech rate, unexpected findings turned up: RL for the slow speech rate seemed longer than for the conversational speech rate and for the very slow rate. The effect of canonicity was most visible at the slow speech rate: For OVS, participants appeared to have longer RL on the slow speech rate than for SVO. This finding was less notable for the other two speech rates, but both RL for OVS at the conversational rate and the very slow rate looked also longer than for SVO at the same rates. Variances was high in all conditions, and in particular for processing of OVS, reflecting that at least some of the participants reacted very fast, while others had longer response times.

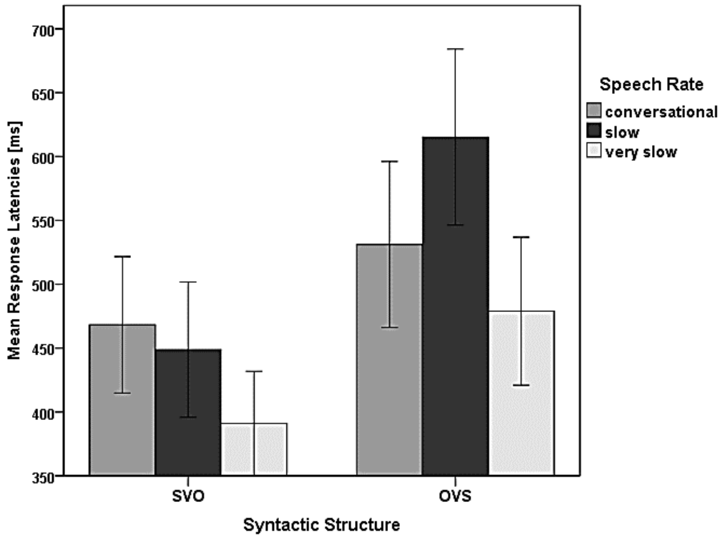

Figure 9.2. Mean response latencies in ms for canonical SVO and non-canonical OVS per speech rate for the young control group (*N* = 33).

In the best fitting model, canonicity and speech rate were entered as fixed factors with an interaction term. Participants and items had random effects, and there were by-participants' random slopes for the effects of canonicity and speech rate. Outliers, defined by values outside 2.5 SD, summed up to 61 values, which was not more than 2% of the total data.

As shown in table 9.2, canonicity did not prove to be significant. Speech rate on the other hand had an effect, and RL at the slow speech rate in general and particularly for OVS were significantly longer compared to those at the conversational rate. This difference was astonishing because I expected a gradual decrease of RL with slower speech rates. The random slope structure signalled the effect of canonicity and the slower speech rates on participants, implying that for some participants, the difference between mean response times between SVO and OVS or between different speech rates was longer than those of other participants, which did explain part of the variance among the participants' RL.

Table 9.2. Statistical results of the final model of response latencies for the young controls.

Fixed effects	***β***	***SE***	***dF***	***t***	***p***
Intercept	628.80	65.55	54.20	10.42	< .001
Canonicity	-	-	-	-	.467
Speech rate slow	83.90	23.82	180.70	3.522	< .001
Speech rate very slow	-	-	-	-	.253
Canonicity*speech rate slow	-95.33	32.18	2840.00	-2.96	.003
Canonicity*speech rate very slow	-	-	-	-	.850
Random effects		**Variance**	**SD**	**Corr.**	
Participants	Intercept	93058	305.05		
	Canonicity	3982	63.10	-.36-	
	Speech rate slow	1644	40.55	-.43 -.30	
	Speech rate very slow	16278	127.58	-.37 -.61 -.49	
Items	Intercept	18271	135.17		
Residual		128114	357.93		

9.2 Group comparison

With the group comparison, it was sought to establish the expected higher degree of a canonicity effect in the group of PWA, reflected in a lower accuracy rate on OVS compared to that of the NBD. Also, the effect on slower speech rates on comprehension was assessed, where accuracy on the slower speech rates was expected to be higher than that on the conversational speech rate, and this in particular for OVS. In this comparison, neither age nor hearing level was implemented as a factor because comparisons between older NBD and older PWA was not possible due to an insufficient age-matching after exclusion of 13 PWA. Furthermore, comparing performance of hearing-impaired NBD with hearing-impaired PWA was not part of the questions, which I seeked to answer with the study.

Figure 9.3 illustrates that accuracy on both SVO and OVS seemed to be better for the NBD than for the group of PWA. While the slower speech rates appeared only to slightly improve performance on OVS for both groups, they seemed to aid comprehension to a higher degree for SVO for the aphasic group (see also table 13.5 in section 13.3.1).

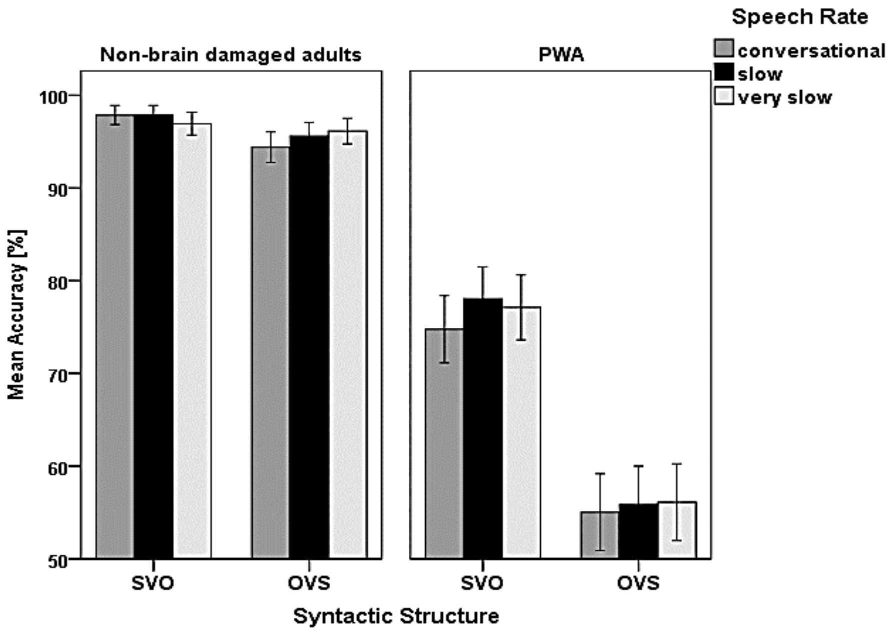

Figure 9.3. Comprehension accuracy in % correct for canonical SVO and non-canonical OVS per speech rate for the non-brain-damaged group ($N = 50$) and the group of PWA ($N = 37$).

The model for the comparison between all PWA and the non-brain-damaged group involved group, canonicity and speech rate as fixed factors with a three-way interaction term, and participants and items as random factors; random slopes included testing the effects of canonicity and speech rate on participants. The best fitting model included the fixed effects of group, canonicity and speech rate as a three-way interaction term, with participants and items as random factors, and an effect of canonicity as by-participants random slope.

The group of PWA demonstrated a significant lower comprehension accuracy than the NBD, clarified in table 9.3. Canonicity had an effect among groups, and comprehension of OVS was lower than that of SVO. Nevertheless is the direction of the main effect of this three-way interaction not entirely clear, because it may have occured in one group to a high degree while not necessarily occuring in the other groupfor SVO at the conversational speech rate (see also table 13.6). Out of these, 21 PWA were above-chance performance ($n > 10$), 16 PWA were within-chance performance (*n* = 5-10), and none below-chance performance (*n* < 5). At the slow speech rate, 34 PWA displayed accuracy rates of 50% or higher. 25 PWA were above chance, nine PWA score within chance, and three PWA were below chance. At the very slow rate, 35 PWA scored at or higher than 50% accuracy, 29 demonstrated above-chance performance, eight PWA were within-chance performance, while two PWA scored below chance.

For non-canonical OVS at the conversational speech rate, 22 PWA displayed an accuracy rate of 50% or higher, and eight of these 22 PWA had an above-chance performance. 24 PWA had an accuracy rate corresponding to within-chance performance ranges, while five PWA had comprehension levels below chance. At the slow speech rate, 21 PWA demonstrated a performance at or higher than 50% accuracy. 10 PWA showed above-chance performance, 23 PWA were within-chance performance, and four PWA scored below chance. At the very slow speech rate, 21 PWA were at-50% accuracy or higher. 10 PWA performed above chance, 23 were within-chance performance and four PWA demonstrated below-chance performance.

Hearing level seemed to have an influence, but surprisingly, the hearing-impaired group appeared to have a marginal better overall performance than the normal hearing PWA. This might be explained through the higher accuracy score of the hearing-impaired group on OVS compared to that of normal-hearing group. For SVO, the pattern was the other way around; comprehension performance of the normal-hearing group suggested a higher score than that of the hearing-impaired group. Accuracy on SVO across all speech rates ranged between 60%-91% for the hearing-impaired, and 51%-98% for the normal-hearing group). The range for OVS was even broader with 4% to 87% (hearing-impaired: 24%-87%; normal-hearing: 4%-84%). Similar ranges and a high variance also occurred for each of the different speech rates. A closer look on performance at the different speech rates displayed that accuracy on the slow rate and on the very slow rate appeared slightly better than that on the conversational rate, and that the slower speech rates seemed to aid comprehension of SVO more than comprehension of OVS. Furthermore, the hearing-impaired group seemed to benefit slightly more from the slow speech rate compared to their performance at the very slow and the conversational rate. The performance differences of the normal-hearing group on the different speech rates was less pronounced; comprehension was almost the same at the slow, the very slow or the conversational rate. A closer look on the different sentence structures per speech rate, shown also in table 13.6 in section 13.3.1, revealed that for the hearing-impaired group, the very slow speech rate seemed to improve comprehension slightly for OVS, and the slow speech rate comprehension for SVO. The normal-hearing group in contrast seemed to profit from the very slow rate for both OVS and SVO. A high variance on general comprehension, reflected by the SE, was seen for both groups, indicated also by the ranges in accuracy on both SVO and OVS (see also table 13.5 in section 13.3.1 for SD).

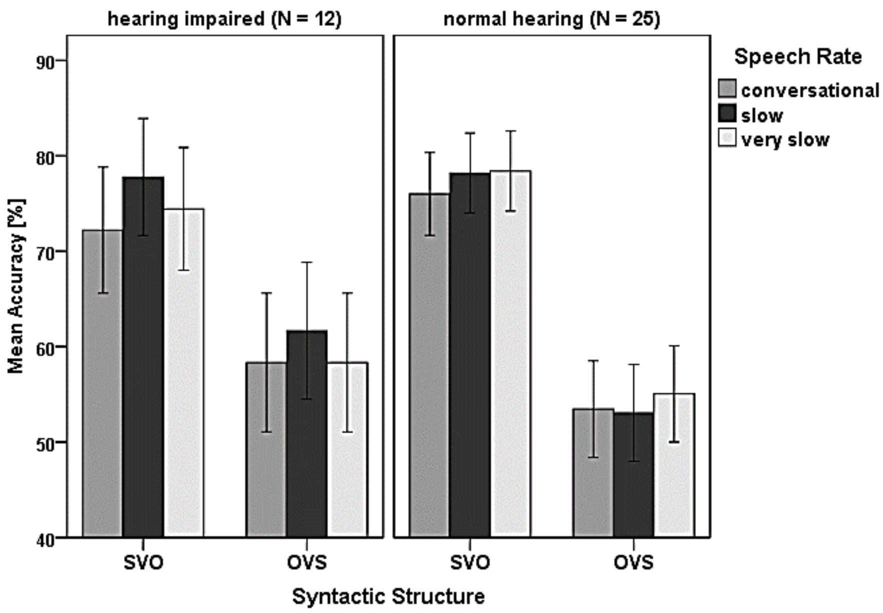

Figure 9.4. Comprehension accuracy in % correct for canonical SVO and non-canonical OVS per speech rate for the group of PWA (*N* =37) with (*N* = 12) and without (*N* = 25) hearing impairment. (Note that the scale starts with 40% in order to show the error bars.)

The hypothesis-driven statistical analysis included the fixed factors canonicity, speech rate, and hearing level -in terms of both BEHL PTA-4 values and BEHL PTA-6 values- as three- way interaction. Age as fixed factor was added before the final model was tested on random slopes. Participants and items were included as random factors, and by-participants' random slopes were tested for the effects of canonicity and speech rate. By-items random slopes included the effects of hearing level, age, error points on the Token Test and state of aphasia.

9.3.1 PTA-4

The final model contained canonicity and hearing level as fixed factors with an interaction, participants and items as random factors, and a by-participants random slope for canonicity.

There was a significant expected effect of canonicity, but slower speech rates did not aid comprehension, exemplified in table 9.4. Hearing level had a significant effect, but other than expected: The hearing-impaired PWA demonstrated a general (i.e. on both SVO and OVS) better comprehension performance than the normal-hearing PWA, and the hearing-impaired PWA also displayed significantly higher accuracy rate on OVS than the normal-hearing PWA. The random slope structure included the effect of canonicity on participants, indicating that the degree of accuracy differences between SVO and OVS might have been distinct among the participants; while some PWA showed high accuracy on SVO and low accuracy on OVS, others displayed higher accuracy on OVS, too, and other PWA demonstrated equal accuracy rates on both SVO and OVS. The performance variance across items was insignificant, as seen in the random slopes for items, and neither severity nor state of aphasia could explain any degree of variability among the participants' comprehension performance.

Table 9.4. Statistical results of the final model for the group of PWA with PTA-4 as factor.

Fixed effects	***β***	***SE***	***z***	***p***
Intercept	.26	.15	1.68	.093
Canonicity	1.09	.19	5.78	< .001
Speech rate slow	-	19-	-	.834
Speech rate very slow	-	-	-	.785
Hearing level PTA-4	.28	.14	2.08	.037
Age	-	-	-	.814
Canonicity*PTA-4	-.45	.17	-2.62	.009
Random effects		**Variance**	**SD**	**Corr.**
Participants	Intercept	.68	.82	
	Canonicity	.88	.94	-.67-
Items	Intercept	.10	.32	

9.3.2 PTA-6

The final model contained canonicity and age as fixed factors with an interaction, participants and items as random factors, and a by-participants random slope for the effect of canonicity.

Table 9.5 demonstrates that comprehension of OVS was significantly more deficient than that of SVO. Speech rate had no effect, and age as main effect neither, but there was a significant interaction between canonicity and age. Figure 9.5 illustrates the higher canonicity effect for the younger PWA until the age of 49 years and the decrease of the effect for the PWA of 52+ years. This effect was surprising because it turned my expectation around: Older PWA were predicted to have more difficulties with OVS than SVO sentences, but results showed that younger PWA were more impaired in OVS comprehension than the older ones. The random slope structure explained some of the inter-individual variance and indicated that the canonicity effect differed among the 37 participants, indicating that some PWA might had a higher difference between accuracy on SVO and OVS than other PWA (see chapter 9.3.1). The random effect items displayed only a small variance, which neither severity nor state of aphasia could explain.

Table 9.5. Statistical results of the final model for the group of PWA with PTA-6 as factor.

Fixed effects	***β***	***SE***	***z***	***p***
Intercept	.26	.15	1.68	.093
Canonicity	1.09	.19	5.89	< .001
Speech rate slow	-	19-	-	.853
Speech rate very slow	-	-	-	.800
Hearing level PTA-6	-	-	-	.119
Age	-	-	-	.259
Canonicity*age	-.42	.17	-2.47	.014
Random effects		**Variance**	**SD**	**Corr.**
Participants	Intercept	.68	.83	
	Canonicity	.83	.91	-.69
Items	Intercept	.10	.32	

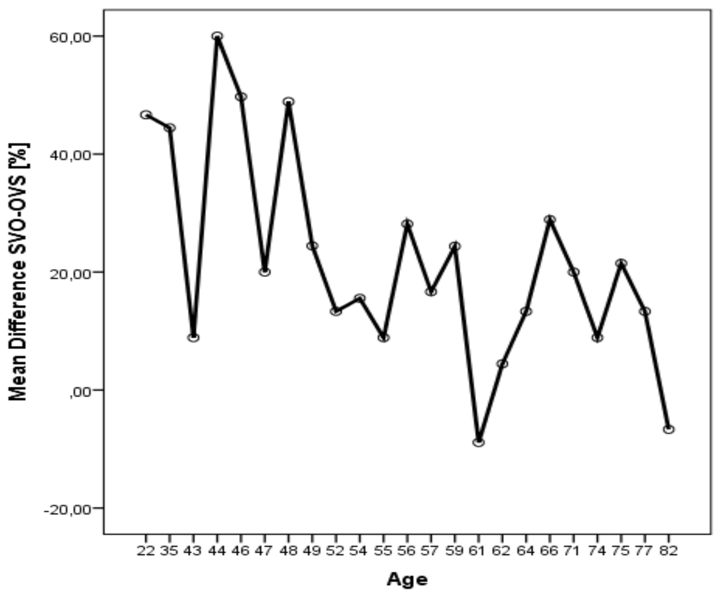

Figure 9.5. Mean comprehension accuracy difference in % between canonical SVO and non-canonical OVS per age (in years) for the group of PWA (*N* =37).

9.4 Agrammatic PWA

The first two research questions concerned also in particular agrammatic comprehension performance, and it was assumed that general comprehension and especially deficient comprehension for OVS improved in slower speech. With only two hearing-impaired participants, hearing level was excluded as factor for the agrammatic group[40]. As seen in figure 9.6, and also clarified in table 13.8 in section 13.3.1.1, general performance on SVO appeared better than on OVS. Variance was high, and accuracy displayed a range of 51%-93% for SVO, and 27%-84% for OVS. Similar variance was also seen for performances on the different speech rates, reflected by the SE in the graphs.

A look at the different speech rates suggested that accuracy on the slower speech rates was a bit higher than that on the conversational one. Comprehension of SVO seemed slightly better at the slower rates compared to the conversational speech rate. A closer look at the accuracy rates of the individual agrammatic PWA (seen in table 9.9 and also in table 13.8 in chapter 13.3.2) displays that comprehension accuracy for SVO at the conversational rate ranged between 27% and 93% (*M* = 75%), which corresponded to between 4 and 14 (*M* = 11

[40] Exclusion of the two hearing-impaired PWA resulted in significant levels *p* = .085 for condition, *p* = .29 for age, and *p* = .011 for the interaction. Using a pairwise comparison with a t-test, these levels were not significantly different from those of the results including the hearing-impaired PWA, seen in table 9.7.

correct answers*;* i.e., above chance performance) correct answers. At the slow rate, accuracy ranged between 33% and 93% (*M* = 73%), which corresponded to 5-14 correct answers (*M* = 11; i.e., above-chance performance). For SVO at the very slow speech rate, comprehension ranged between 47% and 100% (*M* = 74%), corresponding to 7-15 correct answers (*M* = 11, i.e., above-chance performance).

For OVS at the conversational rate, performance ranged from 13% to 93% (*M* = 56%), which corresponded to 2-14 (*M* = 8, within-chance performance) correct answers. At the slow speech rate, accuracy ranged between 27% and 87% (corresponding to 4-13 correct answers), with a mean of 56% (*M* = 8; i.e., within-chance performance). For OVS at the very slow speech rate, agrammatic performance ranged between 33% and 93% (*M* = 62%), which corresponded to a range of 5-14 correct answers (*M* = 9; i.e. within-chance performance).

With regard to the chance performance criterion of the TDH, comprehension accuracy for SVO at the conversational rate showed that 14 PWA had accuracy rates at 50% accuracy (*n* = 8) orand higher. Six PWA displayed within-chance performance (*n* = 5-10), and nine PWA above-chance performance (*n* > 10). None scored below chance (n < 5). At the slow rate, 13 agrammatic PWA demonstrated an accuracy rate of 50% or higher. Nine PWA showed above-chance performance, while six PWA were within-chance range. At the very slow rate, comprehension accuracy of 14 PWA was at or higher than 50% accuracy. Six agrammatic PWA showed within-chance performance, while nine demonstrated above-chance performance in their comprehension.

For OVS at the conversational speech rate, comprehension of eight PWA was at or higher than 50% accuracy. Three PWA had accuracy levels equalling above-chance performance, and only one agrammatic PWA displayed below-chance performance, while 11 PWA were in the within-chance performance range. At the slow rate, eight PWA were at or above an accuracy rate of 50%. Five PWA demonstrated above-chance performance, seven PWA were within-chance range, and three PWA scored below-chance. At the very slow rate, 11 agrammatic PWA scored at 50% accuracy or higher. Five PWA demonstrated accuracy above-chance performance, and no PWA performed below-chance, while the residual 10 PWA were within-chance performance range.

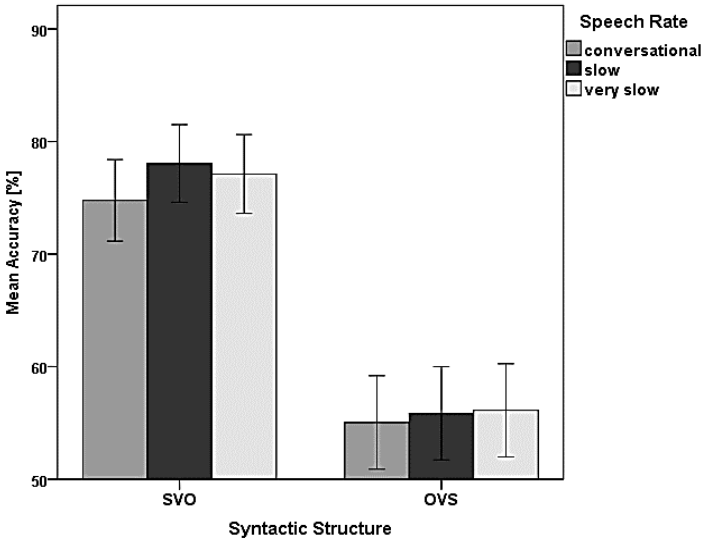

Figure 9.6. Mean comprehension accuracy in % correct for canonical SVO and non- canonical OVS per speech rate for the agrammatic group (*N* = 15).

The hypothesis-driven statistical analysis included canonicity and speech rate as fixed factors in an interaction. As a fixed factor, age was added before testing the random slopes. Intercepts for the random factors participants and items were obtained. By-participants' random slopes were tested for the effects of canonicity and speech rate. The effects of age, error points on the Token Test and state of aphasia were analysed as by-items random slopes. The final model included canonicity and age as fixed factors in an interaction, participants and items as random factors, and a by-participants random slope for the effect of canonicity.

While slower speech rates did not improve comprehension significantly, canonicity did have the predicted significant effect; accuracy on SVO was higher than on OVS, seen in table 9.6. Age as single factor did not prove to be significant, but the interaction between canonicity and age was. Figure 9.7 illustrates that the canonicity effect was higher for the younger agrammatic PWA, in as such that the older agrammatic PWA had a better comprehension of OVS. This result was similar to this of the whole group of PWA, and the age effect of the whole group of PWA might have been at least partially provoked by the agrammatic group. The random slope model showed that the canonicity effect differed across the participants, and indicated that some agrammatic PWA had more problems than other comprehending OVS, while performance on SVO might have also differed among them, in as such that some agrammatic PWA were impaired in comprehension of both SVO and OVS, while other PWA were more impaired in comprehension of OVS compared to that of SVO, and others had a high degree of accuracy for both SVO and OVS (see table 10.9 and chapter 9.7 for a detailed discussion). This variance was not affected by the items themselves, indicated by the low variance of the random intercept. Moreover, similar to the results of the whole group of PWA, neither severity nor state of aphasia as random slopes could explain the small variance in comprehension performance on the items.

Table 9.6. Statistical results of the final model for the agrammatic group.

Fixed effects	***β***	***SE***	***z***	***p***
Intercept	.39	.23	1.68	.094
Canonicity	.82	.25	3.27	.001
Speech rate slow	-	-	-	.925
Speech rate very slow	-	-	-	.259
Age	-	-	-	.596
Canonicity*age	-.54	.123	-2.30	.021
Random effects		**Variance**	**SD**	**Corr.**
Participants	Intercept	.64	.80	
	Canonicity	.60	.77	-.67-
Items	Intercept	.14	.37	

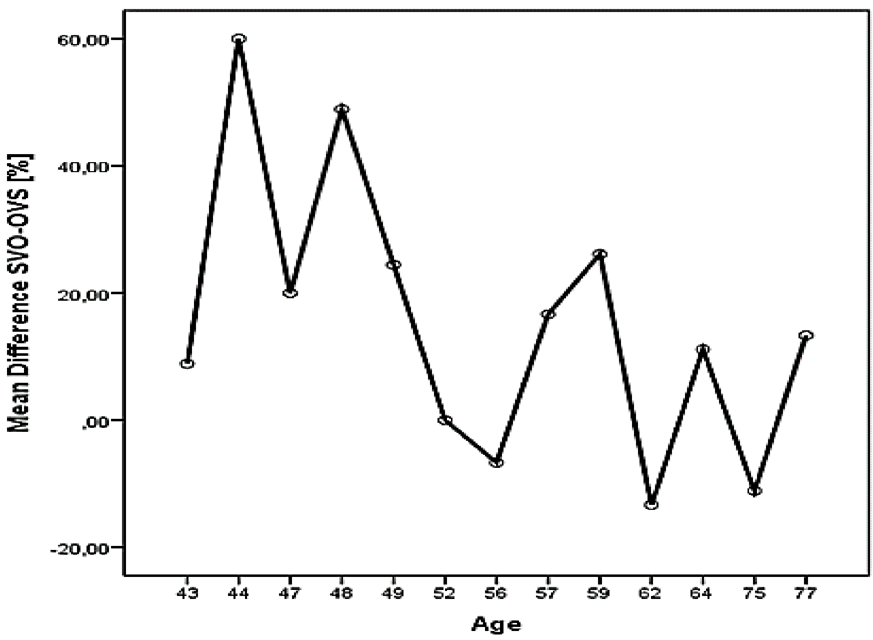

Figure 9.7. Mean difference in comprehension accuracy in % between SVO and OVS per speech rate and age in years for the agrammatic group (*N* = 15).

9.5 The effect of hearing impairment and slower speech on non-brain-damaged comprehension

The third research question concerned the negative impact hearing impairment was expected to exert in particular on non-canonical structures in non-brain-damaged adults. Also, it was hypothesized that slower speech facilitated comprehension, especially for non-canonical OVS for the hearing-impaired NBD to a higher extent than for the normal-hearing group.

Figure 9.8 illustrates that across groups, accuracy on SVO seemed higher than that on OVS. Variability of performance was high, as reflected in the SE, and both SE and accuracy ranges were higher for the hearing-impaired NBD compared to the normal-hearing NBD, seen also in table 13.5 in section 13.3.1 and table 13.10 in section 13.3.4. Accuracy ranged from 63% to 100% (hearing-impaired: 62%-100%, normal-hearing: 96%-100%) for SVO, and from 56%-100% on OVS (hearing-impaired: 56%-100% normal-hearing: 91%-100%). There appeared no visible speech rate effect on overall comprehension performance, but for OVS, accuracy seemed slightly higher on the very slow rate compared to the other rates. The broader variance of the hearing-impaired group was also reflected in the higher SE.

Moreover, the hearing-impaired group appeared to have a slightly lower accuracy on overall comprehension than the normal-hearing group. For both groups, accuracy scores for OVS looked slightly lower than for SVO. Both groups, and notably the normal-hearing group, seemed to benefit from the very slow speech rate for comprehension of OVS.

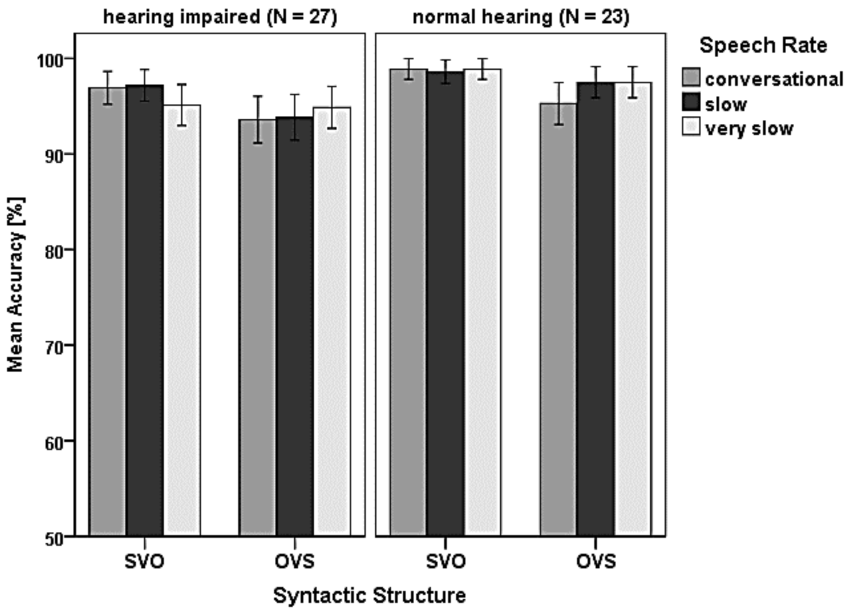

Figure 9.8. Comprehension accuracy in % correct for canonical SVO and non-canonical OVS per speech rate for the non-brain-damaged group with (*N* =27) and without (*N* = 23) hearing impairment.

The statistical analysis included canonicity, speech rate, and hearing level -in terms of both BEHL PTA-4 values or BEHL PTA-6 values- as fixed factors with a three way-interaction. Age was added as a fixed factor in an interaction before random slope testing was integrated in the final model. Participants and items were entered as random effects. By-participants' random slopes were tested for the effects of canonicity and speech rate, and by-items random slopes for the effects of hearing level and age.

9.5.1 PTA-4

Using the standard audiometric classification of the better ear hearing level by four frequency levels, the best fitting model comprised only age as fixed factor, participants and items as random factors, and a by-participants random slope for the effect of canonicity, signifying a degree of comprehension differences between SVO and OVS among some participants. Still, while some NBD seemed to have more difficulties comprehending OVS than others, these difficulties did not end in a canonicity effect. Table 9.7 demonstrates that there were neither effects of canonicity, speech rates nor hearing level. In fact, the only marginal significant effect was the one of age. Figure 9.9 shows that overall performance decreased from the age of 66, but increased again from the age of 73+, thus there was only a non-straightforward tendency of older age having a negative impact on overall comprehension (see also table 13.10 in section 13.3.4. for individual results).

Table 9.7. Statistical results of the final model for the non-brain-damaged group with PTA-4 as fixed factor.

Fixed effects	***β***	***SE***	***z***	***p***
Intercept	4.33	.23	18.49	< .001
Canonicity	-	-	-	.118
Speech rate slow	-	-	-	.369
Speech rate very slow	-	-	-	.171
Hearing level PTA-4				.760
Age	-.31	.17	-1.84	.066
Random effects		**Variance**	**SD**	**Corr.**
Participants	Intercept	1.82	1.35	
	Canonicity	1.02	1.35	-.71-
Items	Intercept	.54	.73	

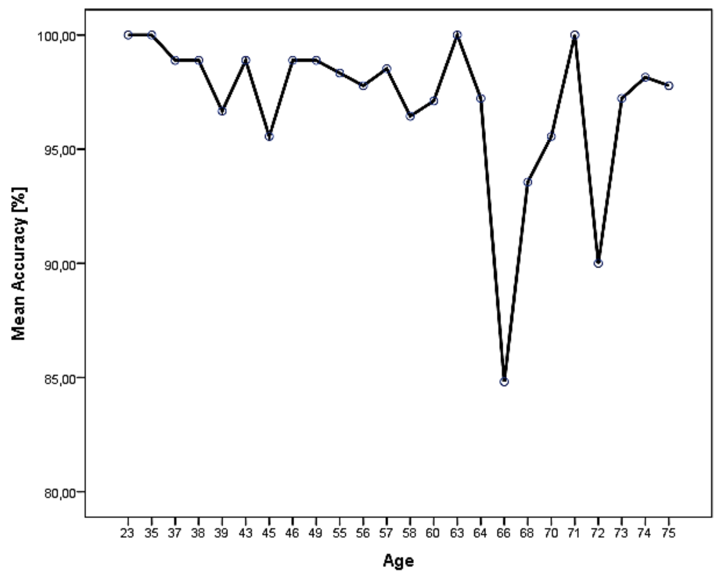

Figure 9.9. Overall comprehension accuracy in % correct for V2 per age (in years) for the non-brain-damaged group (*N* = 50).

9.5.2 PTA-6

By implementing the better ear hearing level assessed by the mean of six audiometric values including the high frequency of 8000 Hz, the best fitting model comprised canonicity and age as fixed effects, participants and items as random factors, and canonicity was entered as by-participants random slope. Table 9.8 demonstrates that again there were no effects of canonicity, speech rates or hearing level. The only marginal significant effect was the one of age, which was very similar to the one of the PTA-4 analysis. For an illustration and description, see thus section 9.2.1.

Table 9.8. Statistical results of the final model for the non-brain-damaged group with PTA-6 as factor.

Fixed effects	***β***	***SE***	***z***	***p***
Intercept	4.33	.23	18.49	< .001
Canonicity	-	-	-	.118
Speech rate slow	-	-	-	.369
Speech rate very slow	-	-	-	.172
Hearing level PTA-6				.102
Age	-.39	.20	-1.95	.052
Random effects		**Variance**	**SD**	**Corr.**
Participants	Intercept	1.82	1.35	
	Canonicity	1.02	1.35	-.71-
Items	Intercept	.54	.73	

9.6 Summary of all results

Validation of the task by the young control group showed that accuracy rates reflected the expected ceiling comprehension performance on both SVO and OVS. RL for SVO also exhibited the expected pattern, with decreasing processing times in slower speech rates. For OVS, the pattern was different; RL increased for the slow speech rate compared to the conversational one, but decreased again in the very slow rate. Still, as only accuracy should be measured for an analysis of effects on the other groups, these results showed that the test was valid. For this reason, their results are not discussed.

Effects of hearing impairment

Contrary to the hypothesis, hearing impairment had no significant negative effect on non-canonical sentence comprehension for the group of NBD, while for the group of PWA, the PTA-4 analysis demonstrated a small negative impact of hearing loss on general comprehension. In contrast, hearing-impaired PWA had a better performance on non-canonical sentence comprehension than their normal-hearing counterparts.

Effects of slower speech

When analysed separately, for neither NBD, PWA nor agrammatic PWA did slower speech exercise a significant positive influence on comprehension, although the graphs indicated an impact. But when statistical power was increased by analysing the data of all participants (NBD and PWA), the very slow speech showed a marginally significant effect on general, and in particular on non-canonical sentence comprehension among groups.

Effects of age

For the whole group of PWA at the PTA-6 analysis, as well as for the agrammatic PWA, the predicted canonicity effect stood in contrast to a reversed age effect, and older PWA had a better performance on non-canonical sentences than the younger ones. For NBD, both analyses only displayed a marginal effect of age, showing that some older adults had difficulties in general sentence comprehension.

9.7 Interim discussion

In this section, the performance of individual PWA, and in particular those of the agrammatic PWA at the conversational and at the very slow speech rate (the slow speech rate was left out because it did not yield any remarkable differences from the other two rates) are related to performance patterns postulated by the concept of chance performance, and in the case of the agrammatic data, also to two categorizations suggested by other accounts. Further, the effects of hearing impairment and age are discussed. Because the direction of the effect of the very slow speech rate found in the three-way interaction at the group comparison cannot be established securely (e.g., whether the effect was caused by both groups or only by one group), the effect will not be discussed.

9.7.1 Performance patterns in aphasia

The results demonstrated that variability of performance was very high in the group of all PWA and in the agrammatic group, as e.g., reflected by the random slopes for canonicity and by the SE and SD. Neither state nor severity of aphasia could explain the variances in general performance and in the canonicity effect, which might have been at least partly caused by inter-and intraindividual factors, such as e.g., cognitive deficits, the high variation in age and age of education, and the diversity of aphasic main symptoms.

Described in the result section, for non-canonical OVS at the conversational speech rate, 22 PWA displayed an accuracy rate of 50% (n = 8) or higher, which has been associated with awareness of the reversed word order (see chapter 4.2.1. .Eight PWA scored above chance ($n > 10$) on OVS, indicating that they were able to process the morphosyntactic case markers in order to integrate the object. On the other hand, five PWA seemed to suffer from a syntactic processing breakdown, reflected by below-chance performance ($n < 5$). At the very slow speech rate, ten PWA showed above-chance performance, and four PWA demonstrated below-chance performance.

Following the lines of the chance performance calculations, Burchert *et al*. (2003) formulated several performance patterns of agrammatic PWA: Above-chance performance in canonical and below-chance performance in non-canonical sentences would result in a *consistent* agent-first interpretation. Guessing due to the assignment of two possible agents should be reflected by above-chance performance on canonical and within-chance performance on non-canonical sentences, a behaviour termed a *preferred* agent-first strategy (the pattern predicted by the TDH; see also chapter 4.3.1). A total breakdown of syntactic parsing on the other hand should be displayed by within-chance performance at both structures, while unimpaired syntactic processing is considered to be reflected by above-chance comprehension in both canonical and non-canonical structures (cf. Burchert *et al.*, 2003). Although the TDH is restricted to agrammatic performance, postulated performance patterns by the chance performance criterion has been used on other aphasias as well (e.g., Burchert *et al.*, 2003).

With regard to these patterns, following patterns emerged: Four PWA (code number 212, 213, 234, 245, out of which 234 was agrammatic) showed above-chance performance on SVO at the conversational rate with below-chance performance on OVS (below 33%, indicating a consistent application of the agent-first strategy.[41]. Also, comparisons revealed that for 11 PWA (code numbers 206, 207, 209, 215, 217, 230, 231, 233, 235, 236, 243 out of which 206, 209, 217, 230, 235 and 236 were agrammatic), comprehension accuracy of SVO was above chance, while for OVS it was within-chance performance signifying the TDH-postulated preferred agent-first strategy, i.e., when experiencing a conflict by being faced with two potential agents, those PWA had to guess the agent and favoured the sentence-initial noun. Five PWA (code numbers 210, 216, 218, 239, 244, out of which 210 was agrammatic) presented with above-chance performance on both SVO and OVS, which according to the TDH implies unimpaired syntactic knowledge. 14 PWA (code numbers 202, 203, 204, 208, 211, 214, 222, 223, 226, 229, 232, 237, 238, 242, out of which 202, 203, 208, 223 and 238 were agrammatic) were within-chance for both conditions, signalling a syntactic breakdown, one PWA (237) was within-chance for SVO and below chance for OVS, and two PWA (code numbers 225 and agrammatic 227) demonstrated above-chance performance for OVS and within-chance performance for SVO.

The numbers of PWA fitting specific pattern changes slightly at the very slow rate: Here, four PWA (code numbers 212, 213, 233 and 245) demonstrated a consistent agent-first strategy with above-chance performance on SVO and below-chance performance on OVS. 17

[41]Note that in extreme cases, a pure consistent agent-first strategy would result in 100% accuracy in subject-first-, and 0% accuracy in object-first sentences, supposing PWA have no lexical comprehension deficits.

PWA seemed to rely on guessing, reflected in a preference for an agent-first interpretation (code numbers 204, 207, 209, 211, 214, 218, 222, 229, 230, 232, 234, 236, 237, 238, 239, 243, 244, out of which 209, 230, 234, 236 and 238 were agrammatic), while nine PWA showed above-chance performance on SVO and OVS (code numbers 210, 215, 217, 225, 227, 231, 235, 239, 240, out of which 210, 217, 227, 235 and 240 were agrammatic). Six PWA (code numbers 202, 203, 208, 223, 226, 242, out of which 202, 203, 208 and 226 were agrammatic) displayed a syntactic breakdown. One PWA (216) demonstrated above-chance performance for OVS and within-chance performance for SVO.

Following the lines of the Potsdam group (e.g., Burchert *et al.*, 2013; Hanne *et al.*, 2011, see also Caplan *et al.*, 2007; Patil *et al.*, 2015), these findings imply that for many PWA, the two or three overt case markings of the first NP in OVS signalled that there was a reversed word order and thus an object in first position, indicated by preserved sensitivity, but integration could not be executed correctly. Deficient processing of overt case cues in anomic, paragrammatic or residual PWA were also in seen in other researches (Bates *et al*., 1987; Hanne *et al*., 2015; MacWhinney *et al*., 1991; Schumacher *et al*., 2015). Furthermore, accuracy on SVO at both speech rates was far from ceiling (compared to that of the young controls), which gives further evidence to the assumption that many PWA did not apply a heuristic strategy but tried to process the sentences linguistically. These results are similar to those of other studies on SVO processing in PWA (e.g., Burchert *et al.*, 2003; Hanne *et al.*, 2011), and support the assumption that the deficit in canonical sentence comprehension is rather caused by an insufficient processing of morphosyntactic case markers, which distinguish syntactic subject and thematic agent from object and thematic patient, than by a lexical comprehension deficit, which prevents to match nouns to pictures depicting their meaning[42].

9.7.2 Agrammatic performance patterns

While the criterion of chance performance according to the TDH does not show group and individual differences between agrammatic and normal performance (and is not intended to), with the 2 SD-within-normal performance criterion by Burchert *et al.* (2003) and the

[42] Note, that all PWA below 50% accuracy on SVO across speech rates were excluded due the potential deficit in lexical processing. While some PWA benefitted in their accuracy from slower speech for comprehension of SVO, which might indicate improved lexical processing, he offline character as well as lacking significant results do not allow a detailed exploration of possible underlying causes.

within-1.74 SD criterion by Caplan *et al*. (2007), it is possible to compare actual agrammatic performance with those of an unimpaired control group on the same items. Rather than analysing agrammatic performance based on hypothetical means (see chapter 4.3), both criteria regard the variability of normal-like comprehension, which for OVS at the conversational and the very slow speech was relatively high in the group of NBD. Also, it enables to compare changes between individual results on each speech rate, as shown in table 9.9.

Mentioned also in the result section, none of the 15 agrammatic PWA scored below-chance at SVO at the conversarional rate. 14 PWA displayed accuracy rates at 50% accuracy (*n* = 8) and higher. Six PWA had an accuracy rate corresponding to within-chance performance (*n* = 5-10), and nine PWA a rate corresponding to above-chance performance (*n* > 10), while none demonstrated below-chance performance (*n* < 5). This pattern does not fit with the expectations of the TDH, where an agent-first application should result in all agrammatic PWA displaying above-chance performance on canonical sentences. For SVO, the within- 2 SD criterion categorized three PWA within normal range. According to the within 1.74 SD parameter, only one PWA reached a normal-like comprehension level, all others were partially impaired. Mentioned above, these findings might reflect that most of the agrammatic PWA processed the sentences syntactically rather than using a heuristic approach. These results are in line with findings from other studies (Burchert *et al*., 2003), Hanne *et al.*, 2011, 2015; Schumacher *et al*., 2015) where a number of German agrammatic PWA neither performed normal-like on SVO items.

For OVS at the conversational rate, three agrammatic PWA displayed accuracy levels equalling above-chance performance, and only one agrammatic PWA displayed below-chance performance, while 11 PWA were in the within-chance performance range. Similar inter-group variance on German OVS comprehension performance was also noted by Burchert *et al.* (2003) and Hanne *et al.* (2011, 2015) studies, where accuracy ranged from 35%-85% (Hanne *et al.*, 2015), or 50%-95% (Burchert *et al.*, 2003) for sentences comparable to the ones used here (see chapter 4.2.1. for examples of their items).

Pattern according to the chance performance notion were as follows: One PWA (code number 210) demonstrated above-chance performance at both SVO and OVS, one PWA (code number 234) seemed to have relied on a consistent agent-first preference, while six PWA (code numbers 206, 209, 217, 230, 235, 236) seemed to have preferred an agent-first or guessing strategy for OVS (see bold markings in table 9.9). One PWA (code number 227) showed a reverse pattern, with above-chance performance on OVS and within-chance performance on SV. The remaining five PWA (code numbers 202, 203, 208, 223, and 238) were within-chance performance for both SVO and OVS, which was interpreted as syntactic breakdown.

Application of the 2 SD-within-normal criterion suggests that three agrammatic PWA had a normal-like performance on OVS at the conversational speech rate, while the other 12 PWA were partially impaired. With Caplan *et al.*'s (2007) criterion, seven agrammatic PWA were within normal-like performance, but only three of those also for SVO. According to Burchert *et al.* (2003, 2013) and also to Caplan *et al.* (2007), these categorizations indicate that none of the agrammatic PWA had a complete syntactic breakdown because they all still showed at least partial comprehension of OVS, i.e., interpreted a higher number of items correctly than would be expected by an agent-first assumption. The results also reflect that also for a number of the normal-hearing control participants, comprehension of OVS was difficult, reflected by the high SD.

A possible explanation for the canonicity effect in agrammatic aphasia might be that PWA noticed the reversed word order signified by accusative case in at the first DP in OVS but could not always integrate the object. This insufficient integration could have been caused by a morphosyntactic integration timing deficit, suggested by e.g., the Potsdam group: PWA might have not always been able to integrate the case marking in the normal time course in order to assign thematic roles, which they seemed to be aware of. Insufficient integration of case features would explain why accuracy in both SVO and OVS was lower than that for the NBD. If an agent-first interpretation only takes over after syntactic processing failed, as observed in German agrammatic PWA by (Hanne *et al*, 2011), lexical and/or morphosyntactic information might have decayed, and would provoke PWA to guess which of the DP contained the agent and which the patient. However, in this study, the offline character of the task does allow to compare the results with the observations by Hanne *et al*. (2011). A syntactic parsing timing deficiency, as proposed by e.g., Burkhardt *et al*. (2003) would not explain the lower accuracy on SVO. Also, a lexical access delay, suggested e.g., by Love *et al*. (2008) or a lexical integration delay (e.g., Dickey *et al*., 2007), should not affect comprehension on SVO to the degree found in this study, due to the possibility of a -rapid- agent-first route kicking in, when too slow lexical or syntactic parsing jeopardizes the construction of a sentence representation. Alternatively, lexical comprehension deficits could have produce both low accuracy in SVO and OVS, despite the control for this, in as such all PWA with a mean accuracy of 50% or less on SVO items were excluded.

So far, the results of the current study do not give evidence against the representational approach of Grodzinsky (1999), and may also indicate that many agrammatic PWA (e.g., all PWA demonstrating within-chance performance) did delete the trace, were then faced with a conflict and retreated to a heuristic strategy.

Table 9.9. Accuracy rates of agrammatic PWA on SVO and OVS at the conversational (con) and very slow (v slow) speech rate (SRa) for either number of correct responses (N) or in % correct, related to the chance performance criterion of the TDH, the 2 SD-within-normal criterion of Burchert *et al*. (2003)

(part.imp. = partially impaired), and the within-1.74 SD criterion of Caplan *et al.* (2007). For a better overview, only full percentages are shown.

		SVO					OVS				
	SRa	**correct**		**TDH**	**2 SD**	**1.74 SD**	**correct**		**TDH**	**2 SD**	**1.74 SD**
Code		**n**	**%**				***n***	***%***			
202	con	8	53	within	part.imp.	abnormal	6	40	within	part.imp.	abnormal
	v.slow	7	47	within	part.imp.	abnormal	8	53	within	part.imp.	abnormal
203	con	9	60	within	part.imp.	abnormal	8	53	within	part.imp.	abnormal
	v.slow	9	60	within	part.imp.	abnormal	9	60	within	part.imp.	abnormal
206	con	14	93	within	normal.	normal	7	47	within	part.imp.	abnormal
	v.slow	8	53	within	part.imp.	abnormal	6	40	within	part.imp.	abnormal
208	con	9	60	within	part.imp.	abnormal	6	40	within	part.imp.	abnormal
	v.slow	9	60	within	part.imp.	abnormal	9	60	within	part.imp.	abnormal
209	con	12	80	above	part.imp.	normal	10	67	within	part.imp.	normal
	v.slow	13	87	above	part.imp.	normal	10	67	within	part.imp.	abnormal
210	con	12	80	above	part.imp.	normal	14	93	above	normal	normal
	v.slow	12	80	above	part.imp.	normal	11	73	above	part.imp.	normal
217	con	15	100	above	normal.	normal	9	60	within	part.imp.	normal
	v.slow	15	100	above	normal	normal	12	80	above	part.imp.	normal
223	con	7	47	within	part.imp.	abnormal	10	67	within	part.imp.	normal
	v.slow	8	53	within	part.imp.	abnormal	9	60	within	part.imp.	abnormal
227	con	9	60	within	part.imp.	abnormal	13	87	above	normal	normal
	v.slow	14	93	above	normal	normal	12	80	above	part.imp.	normal
230	con	14	93	above	normal.	normal	6	40	within	part.imp.	abnormal
	v.slow	14	93	above	normal	normal	5	33	within	part.imp.	abnormal
234	con	12	80	above	part.imp.	normal	2	13	below	part.imp.	abnormal
	v.slow	11	73	above	part.imp.	abnormal	6	40	within	part.imp.	abnormal
235	con	14	93	above	normal.	normal	10	67	within	part.imp.	normal
	v.slow	12	80	above	part.imp.	abnormal	14	93	above	normal	normal
236	con	11	73	above	part.imp.	abnormal	7	47	within	part.imp.	abnormal
	v.slow	11	73	above	part.imp.	abnormal	5	33	within	part.imp.	abnormal
238	con	9	60	within	part.imp.	abnormal	6	38	within	part.imp.	abnormal
	v.slow	12	80	above	part.imp.	abnormal	10	67	within	part.imp.	abnormal
240	con	11	73	above	part.imp.	abnormal	13	87	above	part.imp	normal
	v.slow	11	73	above	part.imp.	abnormal	13	87	above	part.imp.	normal

50% accuracy: n = 8; chance range: n = 5-10.
Means of the normal-hearing NBD on SVO (number of correct responses: M = 14.76, SD = 0.38; range 14-15; % correct: M = 98.98%; SD = 10.48 for the conversational, resp. number of correct responses: M = 14.76, SD = 0.38; range 14-15; % correct: M = 98.98%; SD = 10.48 for the very slow speech rate) compared to means on OVS (number of correct responses: M = 14.22, SD = 0.95, range 12-15; % correct: M = 95.28%, SD = 21.21 für the conversational, resp. number of correct responses: M = 14.55, SD = 0.71, range 12-15; % correct: M = 97.5%, SD = 15.61 für the very slow speech rate). All performances of the NBD were above chance.

Comprehension accuracy of 14 PWA for SVO at the conversational rate was at or higher than 50% accuracy. Six agrammatic PWA showed within-chance performance, while nine showed above-chance performance in their comprehension. Similar to the results on the conversational rate, the majority of PWA demonstrated comprehension accuracy far from ceiling, therefore seemed to have processed the sentences syntactically rather than applying a heuristic strategy. The 2 SD-within-normal criterion defined 12 agrammatic PWA with a partial impairment while three PWA had a normal-like comprehension. Caplan *et al.*'s (2007) parameter defined five agrammatic PWA within a normal-like performance[43].

For OVS at the very slow speech rate,11 PWA scored at 50% accuracy or higher. Five PWA demonstrated accuracy above-chance performance, and no PWA performed below-chance, while the residual 10 PWA were within-chance range.

Five PWA (code numbers 210, 217, 227, 235, 240) demonstrated an above-chance performance on both SVO and OVS, which according to the TDH could be categorized with intact syntactic processing. Five PWA (code numbers 209, 230, 234, 236, 238) seemed to have preferred an agent-first interpretation, but none did it consistently (although 230's performance pattern looked very close to this). One PWA (code 227) demonstrated a reverse pattern of an agent-first strategy (accuracy on OVS with above-chance-, and on SVO with within-chance performance), and the remaining four PWA (code numbers 202, 203, 208, 226) demonstrated a syntactic breakdown by within-chance performance for both SVO and OVS.

Application of the 2 SD- within-normal criterion for performance on the other hand categorized 14 agrammatic PWA with partial impairment and one PWA with normal-like comprehension. With Caplan *et al.*'s (2007) parameter, five agrammatic PWA seemed to be within a normal-like performance, whereby two of them also had normal-like comprehension of SVO.

Similar to that of the conversational speech rate, the assumptions of the TDH cannot be contradicted with the data of the performance on OVS at the very slow speech rate, but only a third of the PWA showed the pattern postulated by the TDH, while five PWA seemed to have an unimpaired parser, compared to only two PWA at the conversational rate. While with the two other criteria normal-like performance was also found, both criteria seem to be

[43] The discrepancy of numbers of agrammatic PWA within normal-like comprehension ranges between the two speech rates can be explained by the fact the variability of performance of the control group decreased at the very slow speech rate.

stronger than the TDH, as they only recognized two PWA (code numbers 217 and 235) with unimpaired, normal parsing abilities.

Although slower speech did not have a significant statistical effect, the categorization of 14 agrammatic PWA with partial impairment of non-canonical comprehension (according to the 2 SD-within-normal criterion), or of five PWA (according to the within-1.74 SD criterion indicate that a representational deficit of syntactic knowledge assumed by the TDH might not be tenable for all German agrammatic PWA (see chapter 11.1), because the performance patterns rather indicate that for a number of items, many PWA seemed to have been able to recognize the reversed word order signalled by the overt morphosyntactic case markers, and to integrate the object. On the other hand, delayed syntactic parsing, suggested by the Slow Syntax Hypothesis, should have resulted in a higher accuracy score for SVO than the one observed. A delay in lexical access and/or integration might also be likely, just as lexical comprehension deficits cannot be out ruled. Alternatively, the finding that none of the PWA was below-chance performance, and many of them comprehended a high number of OVS items correctly, could be interpreted in the way that their syntactic processing abilities were intact but temporarily disturbed, as postulated by the Potsdam group and other researchers. Those authors assume that while processing in agrammatic aphasia is generally slower than those of non-brain-damaged adults, syntactic parsing might be also impaired by intermittently deficient linguistic operations, leaving PWA to rely more on non-syntactic, heuristic strategies during the time of insufficiency. Slower speech might have helped to overcome these intermittent deficiencies. Unfortunately, on account of the offline character of the task, this assumption is not verifiable in this study and cannot give evidence against a pure guessing strategy postulated by the TDH.

A last note concerns the heterogeneity of the agrammatic group might have confounded results to a certain degree, as there was a high degree of variability in terms of severity and duration of aphasia, age and years of education. This was also true for the whole group of PWA, where the factors of hearing level and main symptom respectively diagnosis might have provoked an even higher variability of comprehension performance.

9.7.3 Effect of hearing impairment and age

While hearing impairment affected general comprehension in aphasia, hearing-impaired PWA demonstrated a higher degree of accuracy on OVS than the normal-hearing PWA. I can only speculate about reasons in order to explain this reverse effect of hearing impairment on non-canonical sentence comprehension. One of the reasons might be that the two groups were not matches with regard to several factors: Means and ranges of severity of aphasia measured by the Token Test (NH 21. 8 (range 1-44), HI = 15.8 (3-26)), nor age or years of education (see also table 8.3) were different for both groups. What is more, the better performance of the hearing-impaired PWA may not have been based on the hearing status alone, but rather on the fact that almost all agrammatic PWA (13/15) belonged to the normal-hearing group (in contrast, the proportion of paragrammatic and anomic PWA was roughly equal for both groups, see table 13.8 in section 13.3.1.1). Furthermore, the optimal acoustic situation provided by modification of the stimuli, headphones and lack of background noise might have improved the perceptual abilities of the hearing-impaired participants with hearing aids. Those PWA might have relearned to rely on sensory cues due to regular usage of a hearing aid, as proposed by Uslar (2014) for non-brain-damaged hearing-impaired listeners (see chapter 5.6). In addition, a small degree of accuracy difference might have been caused by a therapy effect of auditory and/or syntactic training. Treatment of syntactic deficits might have heightened awareness and/or facilitated processing of object-first structures (see e.g., Breitenstein *et al.*, 2014; Thompson & Shapiro, 2007). All of the hearing-impaired PWA received regular speech and language therapy, in contrast to six normal-hearing PWA who were not into therapy anymore. In addition, age had also reverse effect on as well general comprehension and performance on OVS for the whole group of PWA as well as for the agrammatic group, with older PWA demonstrating a higher degree of accuracy on OVS than their younger counterparts. Again, there is a lot of room for speculations for the possible explanations for these effect, but as the age variation was high (ranging from 22 to 82 years in the aphasic group, and from 23 to 75 years in the non-brain-damaged group), age effects may have only added to the general heterogeneity.

While hearing loss in aphasia had a reverse effect on comprehension of OVS, it did not seem to have an impact on the NBD. Differences in accuracy of both SVO and OVS in general and between the two sub groups were there but too small to cause an effect. Similar differences were seen by Wendt *et al.* (2015), but in their study, differences for picture recognition rates were significant and showed a canonicity effect for the hearing-impaired group. This significant effect might have been arisen through the higher number of items they implemented (60 per structure), which might have increased statistical power (cf. Caramazza *et al.*, 2001).

On the other hand, older age, irrespective of hearing loss, affected general comprehension, and also (marginally) performance on OVS for some of the older NBD. So far, comprehension of OVS for older compared to younger adults has not been studied systematically, so a comparison with other data is not possible. The results, even when the latter one is only a tendency, fit with findings from the literature assuming that age-related deficits in processing may affect general and non-canonical sentence comprehension (e.g., Schneider *et al.*, 2005; Stine-Morrow *et al.*, 2000; Wingfield *et al.*, 2006a).

In summary, canonicity effects were seen for the whole group of PWA, the agrammatic group and marginally also for the hearing-impaired non-brain-damaged adults. These findings match with others from the respective literature

10 Results on experiment 2: Centre-embedded relative clause (RC) structures

This chapter follows the same structure as chapter 9, beginning by the results from the young control group, followed by analyses of the group comparison between NBD and PWA, and the results from the whole group of PWA and the agrammatic group. The last analysis contains the results of the NBD. Tables in appendix 13.3. complement statistical and observational results of each group and each participant per group, as well as per item (table 13.5 in section 13.3.1 for an overview on group results, tables 13.7 in section 13.3.2 for results of individual PWA, table 13.8 in section 13.3.2 for results per aphasic group, table 13.9 in section 13.3.3 for results of individual young controls, table 13.10 in section 13.3.4 for results of individual NBD, and table 13.11 in section 13.3.5 for accuracy on each item per group). Thereafter, the results are discussed with regard to findings in the literature, especially those of the agrammatic PWA, whose group and individual data is related to performance categorization suggested by either the TDH or two procedural accounts. The last section contains a summary on the results from both experiments.

10.1 Validation of the test: Young controls

For both accuracy and (logtransformed) response latencies, the hypothesis-driven model included canonicity and speech rate as fixed effects with an interaction term, and participants and items as random factors. The effects of canonicity and speech rate were also entered as by-participants' random slopes.

10.1.1 Accuracy

Accuracy on both SR and OR was at ceiling, illustrated in figure 10.1. Performance on the three speech rates did not seem to differ, also shown in table 13.5 in section 13.3.1 for means and table 13.9 in section 13.3.3 for individual results.

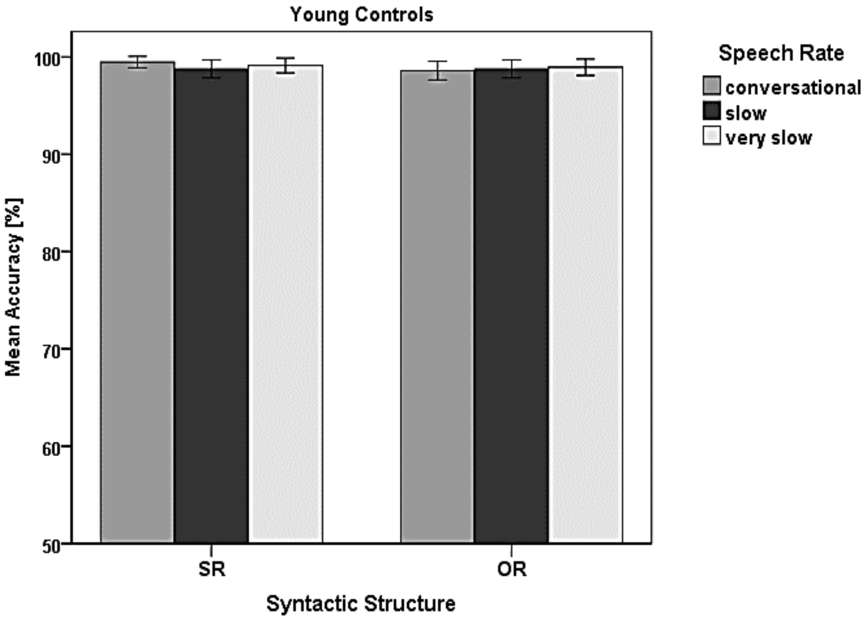

Figure 10.1. Mean accuracy in % correct for canonical SR and non-canonical OR per speech rate for the young control group (*N* = 38).

The final model only included canonicity as a fixed factor, participants and items as random factors, and there was a by-participant random slope for the effect of canonicity.

There was no main effect of canonicity, and neither of speech rates, shown in table 10.1. The random slope structure included the effect of canonicity on participants, indicating that the effect of canonicity, i.e., the difference in accuracy between SR and OR differed slightly among the 38 participants, and some participants seemed to be at ceiling at SR but not at OR.

Table 10.1. Statistical results of the final model for the young control group.

Fixed effects	***β***	***SE***	***z***	***p***
Intercept	4.76	.41	11.71	< .001
Canonicity	-	-	-	.413
Speech rate slow	-	-	-	.794
Speech rate very slow	-	-	-	.590
Random effects		**Variance**	**SD**	**Corr.**
Participants	Intercept	.42	.65	
	Canonicity	.26	.51	-.01-
Items	Intercept	.40	.63	

10.1.2 Response latencies

Illustrated in figure 10.2, RL for SR appeared to be generally shorter than for OR but again, comparable to the V2 results, both SE were high, indicating a high degree of variability among the 38 YC. A look at performance on speech rates revealed that RL at the slow speech rate seemed longer than those at the conversational and at the very slow rate, a pattern similar to that for the V2 structures. RL for the very slow rate nevertheless appeared to be shorter than for the conversational rate. The figure also reflects that at least for OR, similar to the OVS results, the slow speech rate had longer RL than for SR. This pattern was also visible for the conventional speech rate. The very slow speech rate on the other hand seemed to shorten response times for OR structures considerably.

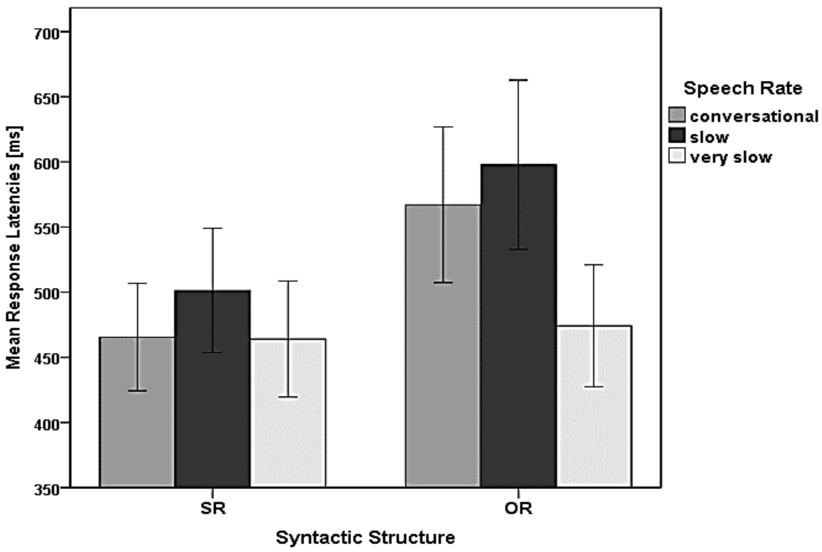

Figure 10.2. Mean response latencies in ms for canonical SR and non-canonical OR per speech rate for the young controls (*N* = 33).

The final model included canonicity and speech rate as fixed, and participants and items as random factors, and canonicity and speech rate were entered as by-participants' random slopes. Outliers summed up to 82 values, which was not more than 2% of the total data. Illustrated in table 10.2, canonicity did not prove to have an effect. Both slower speech rates had only marginal effects on comprehension, and, similar to the V2 results, RL at the slow speech rate were significantly longer than those at the conversational rate. RL for OR at the very slow speech rate just missed being significantly shorter compared to the conversational rate. The random slope structure had an effect of canonicity on participants, implying that there was some degree of difference in mean RL between SR and OR among the 33 participants, and some YC demonstrated much longer RL than other YC on SR compared to OR.

Table 10.2. Statistical results of the final model for response latencies of the young controls.

Fixed effects	***β***	***SE***	***dF***	***t***	***p***
Intercept	710.62	63.44	46.00	11.20	< .001
Canonicity	-	-	-	-	.261
Speech rate slow	35.99	21.78	2904.00	1.65	.099
Speech rate very slow	-39.44	21.78	2904.00	-1.81	.070
Canonicity*speech rate slow	-	-	-	-	.693
Canonicity*speech rate very slow	-	-	-	-	.107
Random effects		**Variance**	**SD**	**Corr.**	
Participants	Intercept	105683.00	325.09		
	Canonicity	72.58	8.52	1.00	
Items	Intercept	8766.99	93.63		
Residual		117403.74	342.64		

10.2 Group comparison

A visual inspection of figure 10.3 reveals that the NBD demonstrated a much higher degree of accuracy for both SR and OR than the PWA, also seen in table 13.5 in section 13.3.1. For both groups, comprehension performance of SR seemed better than for OR, and for the group of PWA, comprehension of OR looked much more deficient compared to that of the NBD. The very slow speech rate appeared to aid comprehension for SR and OR for both groups, and even more for the PWA. For this group, both slower speech rates also seemed to improve comprehension of OR.

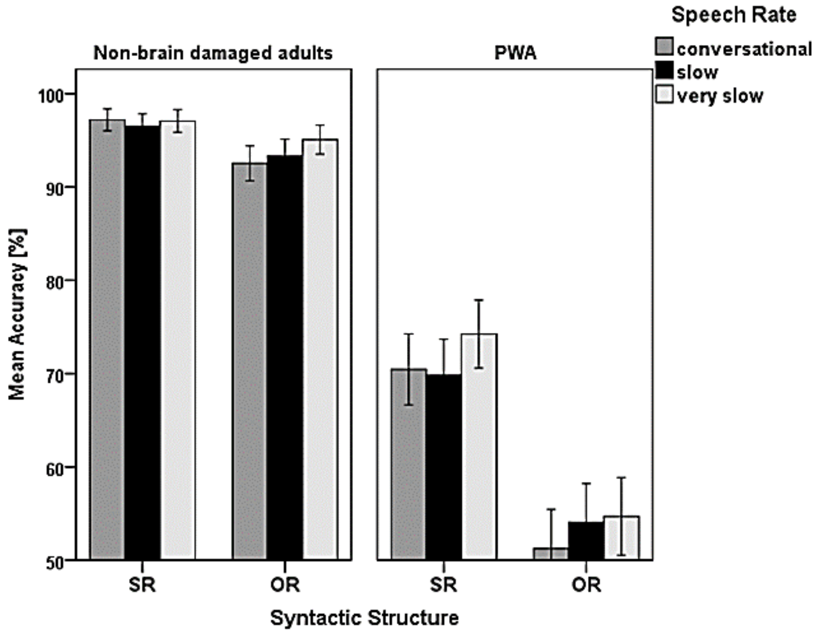

Figure 10.3. Mean comprehension accuracy in % correct for canonical SR and non-canonical OR per speech rate for the non-brain-damaged group (*N* = 50) and the group of PWA (*N* = 37).

The model for the comparison between all PWA and the NBD involved group, canonicity and speech rate as fixed factors with a three-way interaction term, participants and items as random factors, and random slopes included testing the effects of canonicity and speech rate for participants. Again, as for the experiment on V2 structures, neither age nor hearing level was implemented as a factor. The best fitting model included the fixed effects of group, canonicity and speech rate as a three-way interaction term, with participants and items as random factors, and an effect of canonicity as by-participant random slope.

The statistical comparison between the group of NBD and the group of PWA, as clarified in table 10.3, revealed that the group of PWA was significantly worse in their overall performance than the NBD. Among groups, there was a canonicity effect, which was provoked with a high probability by the group of PWA. The very slow speech rate aided overall comprehension performance among groups significantly compared to the conversational speech rate, and also facilitated comprehension of OR among groups. However, similar to the results of the V2 structures, the direction of the effect cannot be securely established.the main effects within a three-way interaction might have arisen because it occurs in one group to a high degree while it does not necessarily have to occur in the other group. For instance, the main effect of canonicity might have been produced mainly by the group of PWA. Also, while the very slow speech rate had a main effect on both groups, PWA seemed to have profited to higher degree from slower speech than NBD,. Comprehension accuracy on SR and OR differed among the 87 participants (see chapters 10.3 and 10.4 for the aphasic groups, and chapter 10.5 for the NBD), as well as the degrees of accuracy differences in between SR and OR among the individual participants. This variability was seen in the random slopes for canonicity, which explained much of the variance on comprehension performance on OR: While some participants had a high accuracy score on SR and a low one on OR (which was a pattern seen in many PWA), other participants demonstrated high accuracy rates for both sentence types (which appeared more often for the NBD) (see chapter 10.7 for a more detailed exploration of the different degrees of the canonicity effect within the whole group of PWA and the agrammatic PWA).

Table 10.3. Statistical results of the final model of the comparison between the non-brain-damaged group and the group of PWA.

Fixed effects	***β***	***SE***	***z***	***p***
Intercept	3.50	.27	13.03	< .001
Group	-3.27	.32	-10.29	< .001
Canonicity	.93	.40	2.31	.021
Speech rate slow	-	-	-	.247
Speech rate very slow	.45	.27	1.69	.091
Group*canonicity	-	-	-	.815
Canonicity*speech rate very slow	-.86	.44	-1.96	.049
Group*canonicity* speech rate very slow	.95	.48	1.98	.048
Random effects		**Variance**	**SD**	**Corr.**
Participants	Intercept	1.10	1.05	
	Canonicity	1.01	1.00	-.63-
Items	Intercept	.14	.38	

10.3 The effect of hearing impairment and slower speech on aphasic comprehension

The first and second research hypotheses predicted that the whole group of PWA benefitted from slower speech for general comprehension, and in particular for non-canonical OR. This positive effect of slower speech was hypothesized to be higher for the hearing-impaired compared to the normal-hearing group.

Illustrated in figure 10.4, PWA appeared to have a better comprehension for SR than for OR. Still, variability within the group was broad, indexed by the SE, and seen in accuracy scores, which ranged from 38%-100% for SR (hearing-impaired: 49%-96%; normal-hearing: 38%-100%), and from 13%-91% (hearing-impaired: 22%-91%; normal-hearing: 13%-91%) for OR, displayed in table 13.7 in section 13.3.2 in the appendices.

There were tendencies that the very slow speech rate slightly improved overall performance, and in particular for performance on SR compared to the slow speech rate and the conversational one. Again, variance depicted by the SE was broad.

Comprehension accuracy of SR at the conversational speech rate, as seen in table 13.7 in chapter 13.3.2, ranged for the whole group of PWA between 33% and 100% (M = 70%), corresponding to 5-15 correct answers (M = 11 correct answers; i.e. above-chance performance). At the slow speech rate, accuracy ranged between 27% and 100% (corresponding to 4-15 correct answers) with a mean of 70% (M = 10, i.e. within-chance performance). At the very slow speech rate, accuracy ranged between 40% and 100% (M = 74%), corresponding to 6-15 correct answers (M = 12; i.e. above-chance performance).

Comprehension accuracy for OR at the conversational speech rate ranged from 13% to 93% (M = 51%), corresponding to 2-14 correct answers (M = 8; i.e., within-chance performance). At the slow speech rate, comprehension accuracy showed a range between 13% and 100% (corresponding to 2-15 correct answers), with a mean of 54% (M = 8; i.e., within-chance performance). At the very slow speech rate, accuracy ranged between 27% and 100% (M = 55%), corresponding to 4-15 correct answers (M = 9; i.e., within-chance performance).

With regard to the chance performance criterion postulated by the TDH, 32 PWA demonstrated an accuracy rate at or higher than 50% accuracy (M = 8) for SR items at the conversational rate. 16 PWA showed above-chance performance (n > 10), one PWA was below chance (n < 5), and 19 PWA demonstrated within-chance performance (n = 5-10). At the slow rate, for 27 PWA comprehension accuracy was at 50% or higher. 19 PWA were above chance, 17 PWA displayed within-chance performance, and one PWA was below chance. At the very slow speech rate, 34 PWA displayed an accuracy rate at or higher than 50% accuracy. 17 PWA demonstrated above-chance performance, while the remaining 20 PWA were within-chance.

For OR at the conversational rate, 17 PWA were found with an accuracy rate at 50% or higher. Eight PWA showed above-chance performance, 26 PWA were within chance, and three PWA scored below chance. At the slow rate, 21 PWA displayed an accuracy rate at 50% or higher. Eight PWA scored above-chance, 25 within-chance, and four PWA below chance. At the very slow speech rate, 21 PWA showed an accuracy rate at 50% or higher. Eight PWA demonstrated above-chance performance, 23 were in the within-chance performance range, while six PWA were noted with below-chance performance.

Similar to the results on the V2 structures, the hearing-impaired group seemed to have a slightly higher accuracy rate for both SR and OR than the normal-hearing group. More, the hearing-impaired group appeared to have a better comprehension performance of OR than the normal-hearing group, while the normal-hearing PWA seemed to perform with higher accuracy on the canonical structure compared to their hearing-impaired counterparts. A closer look on comprehension accuracy per speech rates, shown in table 13.7 in section 13.3.2, revealed that especially for OR, the very slow speech rate seemed to improve comprehension for the hearing-impaired group, as compared to the other rates, but again, variability indicated by SE was high. Also, the hearing-impaired group seemed to benefit from the slowest speech rate for their comprehension of SR, a finding similar to this of the normal-hearing group.

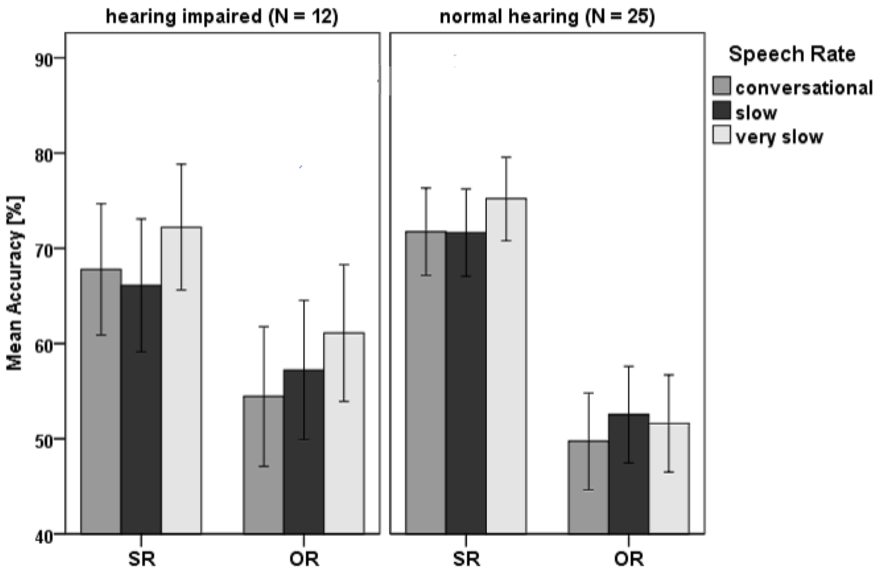

Figure 10.4. Mean comprehension accuracy in % correct for canonical SR and non-canonical OR for the group of PWA (*N* =37) with (*N* = 12) and without (*N* = 25) hearing impairment. (Note the scale starts with 40% in order to show the error bars.)

For the group of PWA, the hypothesis-driven model included canonicity, speech rate, and hearing level -in terms of both BEHL PTA-4 values or BEHL PTA-6 values- as fixed factors in a three-way interaction. Age as fixed factor (as interaction) was added before the final model was tested on random slopes. As random effects, intercepts for participants and items were obtained. By-participants' random slopes were tested for the effects of canonicity and speech rate. The effects of hearing level, age, severity of aphasia defined by error points on the Token Test and state of aphasia - acute vs chronic- were tested as by-items random slopes.

10.3.1 PTA-4

In the final model, canonicity and hearing level were fixed factors with an interaction, participants and items were random factors, and the effect of canonicity was entered as a by-participants random slope. As shown in table 10.4, the expected effect of canonicity occurred. Comparable to the results on the V2 structures, the hearing-impaired group had a higher accuracy rate for OR than the normal-hearing group. Speech rate did not change performance significantly, although there was a tendency that the very slow speech rate seemed to improve overall comprehension. Seen in the random slope for canonicity, the degree of which participants were affected in their comprehension of OR, varied, as well as the individual degrees of accuracy difference between SR and OR among PWA, with some PWA demonstrating a high degree of accuracy on SR and a low one on OR, while others had equal degrees. Again, severity and state of aphasia had no effect as random slopes and could not explain the low variance of differences on comprehension performance caused by the items used in the experiment.

Table 10.4. Statistical results of the final model for the group of PWA with PTA-4 as factor.

Fixed effects	***β***	***SE***	***z***	***p***
Intercept	.17	.15	1.15	.251
Canonicity	.97	.20	4.99	< .001
Speech rate slow	-	-	-	.676
Speech rate very slow	-	-	-	.152
PTA-4	-.44	.14	1.71	.087
Age	-	-	-	.180
Canonicity*PTA-4	-.44	.18	-2.44	.015
Random effects		**Variance**	**SD**	**Corr.**
Participants	Intercept	.68	.83	
	Canonicity	1.03	1.02	-.48-
Items	Intercept	.12	.35	

10.3.2 PTA-6

In the final model, canonicity and hearing level were fixed factors with an interaction term, participants and items had random effects, and canonicity had an effect as a by-participants random slope.

The same pattern of performance across speech rates as in the PTA-4 analysis was visible, displayed in table 10.5. Comprehension of SR was significantly better than of OR. While the effect of hearing level itself did not influence overall comprehension, hearing level did affect comprehension of OR marginally but with an unexpected pattern: The hearing-impaired group had a better comprehension of OR than the normal-hearing PWA, seen in figure 10.4. Nevertheless, seen on the random slopes for canonicity, the degree of comprehension accuracy difference between SR and OR differed across the 37 participants, which could explain some of the variance. Again, severity and state of aphasia did not explain the low variance caused by items.

Table 10.5. Statistical results of the final model for the group of PWA with PTA-6 as factor.

Fixed effects	***β***	***SE***	***z***	***p***
Intercept	.17	.15	1.12	.264
Canonicity	.97	.20	4.83	< .001
Speech rate slow	-	-	-	.671
Speech rate very slow	-	-	-	.154
PTA-6	-	-	-	.390
Age	-	-	-	.783
Canonicity*PTA-6	-.33	.19	-1.76	.079
Random effects		**Variance**	**SD**	**Corr.**
Participants	Intercept	.67	.82	
	Canonicity	1.03	1.02	-.44-
Items	Intercept	.12	.35	

10.4 Agrammatic PWA

In the first two hypotheses, agrammatic comprehension performance in general and in particular for OR was predicted to increase when presentation was prolonged. With only two hearing-impaired participants, hearing level was excluded in the findings and analyses[44]. A visual inspection of figure 10.5 demonstrates that overall performance on canonical SR seemed to be higher than that on non-canonical OR. The variance implied by the SE was high, and performance ranged from 38%-100% on SR, and from 36%-89% on OR, shown in table 13.8 in chapter 13.3.1.1.

Speech rate appeared to have an impact: Overall performance on the very slow speech rate looked marginally better than at the slow one and much better than at the conversational one, also demonstrated in table 13.8, but the variance reflected by the SE was again high. The figure implies that there was improved performance on OR at the slower speech rates.

[44] Exclusion of the two hearing-impaired PWA resulted in significant levels $p = .02$ for condition and $p = .46$ for the very slow speech rate. Using a pairwise comparison with a t-test, these levels were not significantly different from those of the results including the hearing-impaired PWA, seen in table 10.7

Comprehension performance of the agrammatic group (also displayed in table 10.9) shows that accuracy on SR at the conversational speech rate ranged between 27% and 93%, (*M* = 63%) which corresponded to a range of 4 to 14 correct answers (*M* = 10; i.e., within-chance performance). At the slow speech rate, accurancy ranged between 40% to 100% (corresponding to 6-15 correct answers), with a mean of 66% (*M* = 10; i.e., within-chance performance). At the very slow speech rate, comprehension of SR ranged between 47% and 100% (*M* = 70%), corresponding to 6-15 correct answers (*M* = 11, i.e., above-chance performance).

For OR, performance of the agrammatic group ranged from 25% to 80% (*M* = 51%) at the conversational speech rate, which corresponded to 4-12 correct answers (*M* = 8, i.e., within-chance performance). At the slow speech rate, accurancy rates ranged from 33% to 100% with a mean of 54%, corresponding to 5-15 correct answers (*M* = 8). For OR items at the very slow speech rate, agrammatic performance ranged between 27% to 87% (*M* = 57%), corresponding to the number of correct responses between 4 and 13 (*M* = 9, i.e., within chance performance).

With regard to the patterns of chance performance postulated by the TDH, 11 agrammatic PWA were at 50% accuracy (*n* = 8) or higher for Rat the conversational speech rate. Nine PWA performed within chance (*n* = 5-10), five above chance (*n* > 10), and one below chance. At the slow speech rate, 10 agrammatic PWA scored at or higher than 50%, seven PWA were above chance, while eight PWA displayed within-chance performance. At the very slow speech rate, 12 agrammatic PWA performed at 50% accuracy or higher. Seven PWA were noted with within-chance, and eight PWA with above-chance performance.

For OR at the conversational speech rate, eight PWA showed an accuracy rate of 50% or higher. Three PWA demonstrated above-chance performance, 11 PWA within-chance performance and one below-chance performance. At the slow speech rate, 10 agrammatic PWA scored at 50% accuracy or higher. Three PWA demonstrated above-chance performance, while 12 PWA were within-change performance. At the very slow rate, nine PWA scored at or higher than 50% accuracy. Three agrammatic PWA demonstrated above-chance performance, 11 were within chance and one was below chance.

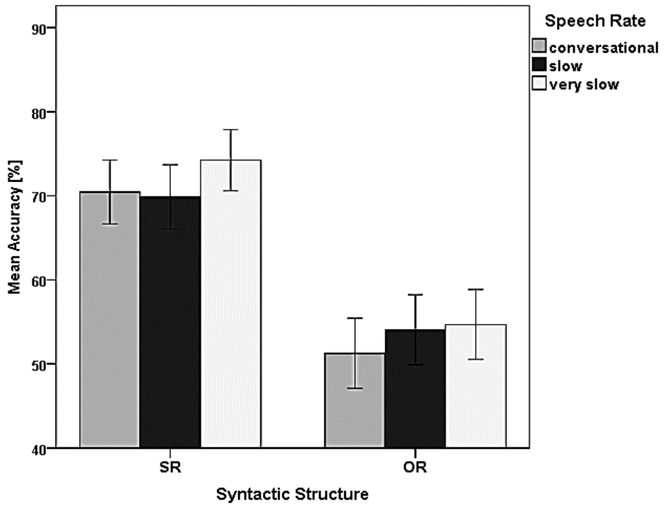

Figure 10.5. Mean comprehension accuracy in % correct for canonical SR and non-canonical OR per speech rate for the agrammatic group (*N* =15). (Note the scale starts with 40% in order to show the error bars.)

The hypothesis-driven model contained the fixed factors canonicity and speech rate as interaction. Age was added as a fixed factor. As random effects, intercepts for participants and items were analysed. By-participants' random slopes were tested for the effects of canonicity and speech rate, and the effects of age, error points on the Token Test and state of aphasia were entered as by-items random slopes. In the final model, canonicity and speech rate were fixed factors without interaction, participants and items proved valid as random effects, and canonicity had an effect as by-participants random slope.

While age had no effect on comprehension performance, the effect of canonicity was significant, and the degree of accuracy on OR was lower than that on SR. Finally, also seen in table 10.6, there was a significant speech rate effect: The very slow speech rate improved overall comprehension, compared to the conversational one. Seen by the random slope of canonicity on participants, there was a high degree of variability among the agrammatic PWA, with some PWA having almost equal accuracy scores on both SR and OR, while others had a high degree of accuracy on SR and a lower or very low one on OR (see table 10.9 for individual results and chapter 10.7 for a discussion). As there was no variance caused by the items used, neither severity nor state of aphasia had an effect as random slope.

Table 10.6. Statistical results of the final model for the group of agrammatic PWA.

Fixed effects	**β**	**SE**	**z**	**p**
Intercept	.06	.19	.30	.763
Canonicity	.62	.24	2.53	.011
Speech rate slow	-	-	-	.158
Speech rate very slow	.31	.14	2.16	.031
PTA-6	-	-	-	.390
Age	-	-	-	.145
Canonicity*speech rate slow				.712
Canonicity*speech rate very slow				.908
Random effects		**Variance**	**SD**	**Corr.**
Participants	Intercept	.31	.56	
	Canonicity	.65	.81	-.08-
Items	Intercept	.00	.04	

10.5 The effect of hearing impairment and slower speech on non-brain-damaged comprehension

In the third research question, it was predicted that hearing impairment had a negative impact on comprehension of especially non-canonical OR for non-brain-damaged adults. In addition, slower speech was expected to facilitate general and non-canonical comprehension for the hearing-impaired listeners compared to that of the normal-hearing group.

Figure 10.6 illustrates the findings of the NBD on the RC structures. Overall comprehension accuracy on SR appeared to be slightly better than that on OR. The hearing-impaired group seemed to have a lower degree of accuracy on both SR and OR than the normal-hearing group. Similar to the results on V2, the variance displayed by the SE in the figure was high for accuracy on OR, and accuracy ranged from 36% to 100% (hearing-impaired: 36%-100%, normal-hearing: 78%-100%), while accuracy on SR ranged from 69%-100% (hearing-impaired: 69%-100%; normal-hearing: 89%-100%), reported in table 13.10 in section 13.3.4.

An observation of performances per speech rates seemed to reveal a slight advantage for comprehension performance at the very slow speech rate compared to the slow and the conversational rate. More, for OR, comprehension looked slightly better at the very slow rate compared to the other two rates. This tendency could not be observed for SR, where accuracy on the very slow rate and the conversational rate appeared to be slightly higher than on the slow rate. The hearing-impaired group seemed to have a lower degree of accuracy on both SR and OR at each speech rate than the normal-hearing group. Likewise, accuracy on the different speech rates also showed a high degree of variability, indicated by the SE; which was even higher for the hearing-impaired group.

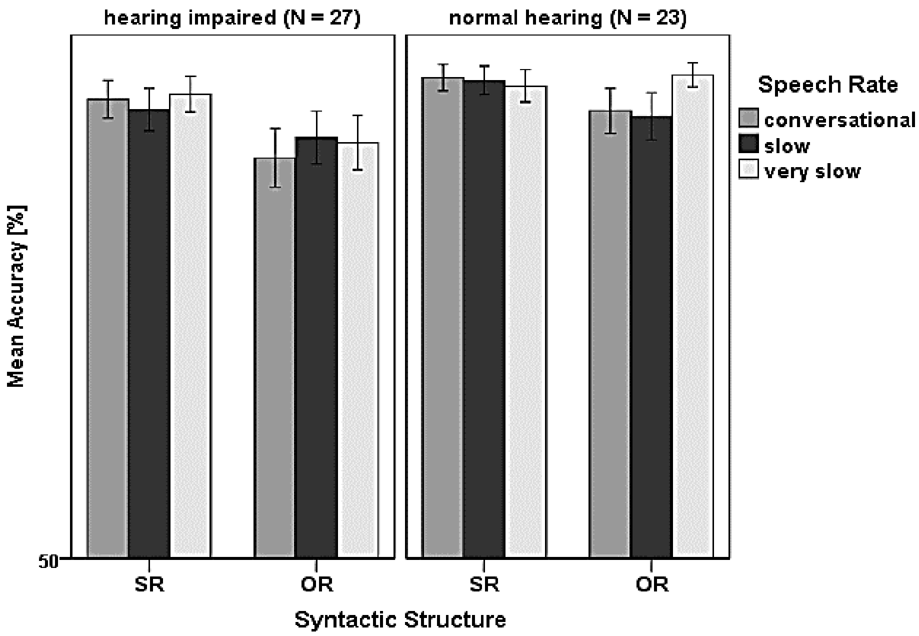

Figure 10.6. Mean comprehension accuracy in % correct for canonical SR and non-canonical OR for the non-brain-damaged group with (N =27) and without (N = 23) hearing impairment.

The hypothesis-driven model included the fixed factors canonicity, speech rate and hearing level- both PTA-4 and PTA-6 as separated analyses- as three-way interaction term. Age was added as a fixed factor in an interaction before random slope testing was executed. For random effects intercepts for participants and items were obtained. By-participants' random slopes were tested for the effects of canonicity and speech rate. The effects of hearing level and age were entered as by-items random slopes.

10.5.1 PTA-4

Same as for the V2 analysis, the final model only comprised age as fixed factor, participants and items as random factors, and a by-participants random slope for the effect of canonicity.

There were no significant differences in comprehension across structures and speech rates, exemplified in table 10.7. Age turned out to have a significant effect on comprehension. Similar to the age effect for the V2 structures, but more accentuated was a general tendency that in older age overall comprehension performance was reduced: It decreased from age 58 until 70 (24 NBD), increased for age 71 (one NBD), decreased again for age 72-73 (three NBD), and then increased for the four participants aged 74+, shown in figure 10.8. Random slopes included an effect of canonicity on participants, indicating that there was a substantial degree of variability on individual accuracy differences between SR and OR among the 50 NBD: While some NBD had ceiling performance for both SR and OR, others demonstrated a much lower degree of accuracy on OR compared to SR. This variance was so high (see table 13.5 in section 13.3.1. for SD and table 13.10 in 13.3.4 for individual results) that the main effect of canonicity vanished after its random slope for canonicity was implemented as by-participant factor.

Table 10.7. Statistical results of the final model for the non-brain-damaged group with PTA-4 as factor.

Fixed effects	***B***	***SE***	***z***	***p***
Intercept	4.22	.25	17.02	< .001
Canonicity	-	-	-	.429
Speech rate slow	-	-	-	.935
Speech rate very slow	-	-	-	.174
PTA-4	-	-	-	.302
Age	-.66	.23	-2.89	.004
Random effects		**Variance**	**SD**	**Corr.**
Participants	Intercept	3.20	1.79	
	Canonicity	1.63	1.28	-.84-
Items	Intercept	.34	.58	

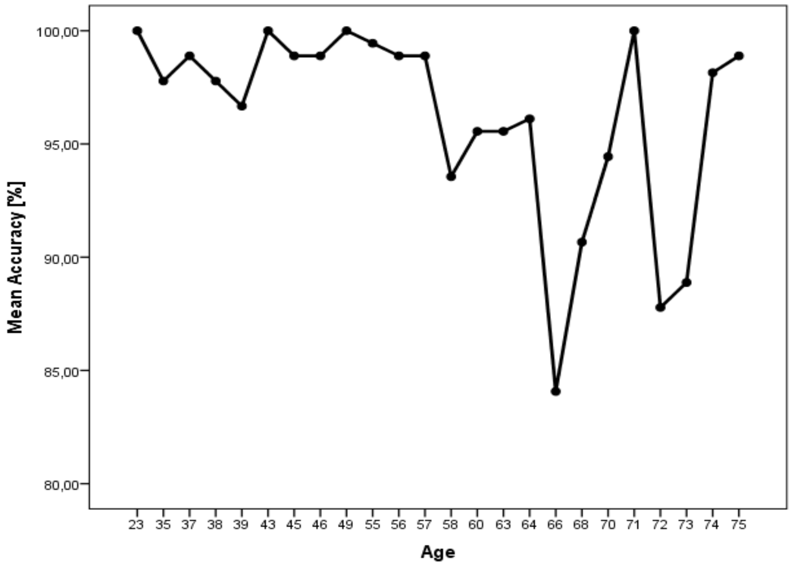

Figure 10.7. Overall comprehension accuracy in % correct for the relative clauses per age (in years) for the non-brain-damaged group (*N* = 50).

10.5.2 PTA-6

Unlike the V2 analysis, the best fitting model analysed canonicity, speech rate, hearing level and age as fixed factors, whereby canonicity and hearing level as well as speech rates and hearing level had interaction terms, and age as single effect was tested before random slopes were introduced. Participants and items had both random effects, and canonicity had an effect as a by-participants random slope, reducing the main effect of canonicity to a non-significant level.

Also in this analysis, similar to the analysis with PTA-4 as factor, canonicity and speech rates as main effects did not result into significant changes in comprehension, but older age, similar to the results on PTA-4, affected overall performance, clarified in table 10.8. Unlike the results of the PTA-4 analysis, hearing level measured by PTA-6 was significant, and hearing-impaired controls demonstrated a lower degree of accuracy on general comprehension than the normal-hearing controls. Also unlike the PTA-4 analysis, the interaction between speech rate and hearing level demonstrated that the lower the PTA-6 level and thus the better the hearing level, the more the very slow speech rate aided overall comprehension, as shown in figure 10.7. This result stood in contrast to the expectation that slower speech rates aided comprehension of hearing-impaired participants to a higher degree than that of normal-hearing participants. Only marginally significant, but still notable, was the effect on hearing level on comprehension of non-canonical OR: Lower PTA-6 levels corresponded with better comprehension of OR, implying that hearing-impaired participants were slightly more disadvantaged at comprehension of OR. Indicated by the random slope of canonicity on participants, the degree to which participants were affected by OR compared to SR varied, also seen in the PTA-4 analysis. Moreover, similar to the PTA-4 analysis, the degree of variance within individual canonicity effects among participants was high, suggested by the absence of the main effect when canonicity was entered as by-participant random slope.

Table 10.8. Statistical results of the final model for the non-brain-damaged group with PTA-6 as factor.

Fixed effects	***B***	***SE***	***z***	***P***
Intercept	3.97	.36	11.08	< .001
Canonicity	-	-	-	.377
Speech rate slow	-	-	-	.843
Speech rate very slow	-	-	-	.499
PTA-6	-.84	.30	-2.78	.006
Age	-.64	.23	-2.85	.004
Canonicity*PTA-6	.48	.27	1.81	.070
Speech rate slow*PTA-6	-	-	-	.388
Speech rate very slow*PTA-6	.51	.22	2.29	.022
Random effects		**Variance**	**SD**	**Corr.**
Participants	Intercept	2.39	.57	
	Canonicity	1.17	1.08	-.74-
Items	Intercept	.32	.57	

10.6 Summary

The young control group had a ceiling accuracy performance for both SR and OR, which was independent of speech rate. Their processing times were similar to the one on V2 sentences; the slow speech rate demanded longer RL compared to the other two rates.

Effects of hearing impairment

For PWA, both PTA-4 and PTA-6 analyses demonstrated that while hearing loss seemed to affect comprehension of SR, hearing loss had a reversed effect on comprehension of OR, and hearing-impaired PWA had a marginally significant higher degree of accuracy on OR than the normal-hearing PWA. Similar to the results for the V2 structures, hearing status did not have any impact on comprehension according to the PTA-4 analysis for NBD. But, in contrast to the V2 results, the PTA-6 analysis revealed that presence of hearing loss decreased overall performance, and there was even a marginal negative effect of hearing loss on comprehension of OR for the NBD.

Effects of slower speech

While slower speech did not facilitate comprehension for the whole group of PWA in the separate analysis, the very slow speech rate increased general sentence comprehension for the group of agrammatic PWA. In addition, the comparison between NBD and PWA also displayed a marginally significant positive impact of the very slow speech rate on general performance. Results on the PTA-6 analysis demonstrated a positive effect of the very slow speech rate on general comprehension for the normal-hearing NBD.

Other effects

There was no age effect for the group of PWA or the agrammatic group. But, similar to the results on V2 structures, older age had a negative effect on general comprehension for the NBD, seen in both PTA-4 and PTA-6 analyses. But unlike its impact on OVS, age did not particularly affect comprehension of OR.

10.7 Interim discussion

This section discusses individual aphasic, and in particular agrammatic accuracy performance at the conversational and the very slow speech rate (similar to the results on V2, the slow speech rate did not yield any remarkable differences) with regard to performance patterns postulated by the chance performance notion, and in the case of the agrammatic results, with regard to two other categorizations. In particular is the effect of slow speech on agrammatic comprehension performance discussed and possible causes are introduced. Also, the effects of hearing impairment and age are discussed. Again, as the direction of the effect of slower speech in the three-way interaction of the group comparison cannot be established securely, the effect will not be included in the discussion.

10.7.1. Performance patterns in aphasia

Again, similar to the results on V2, performance variability was high among PWA, as reflected in the random slopes. The random slopes for canonicity indicated that the actual degree of accuracy between SR and OR varied among the 37 PWA, in as such that some might have had a higher degree of the canonicity effect than others. And again, neither state nor severity of aphasia could explain the variance, which might have been at least partly due to inter-and intraindividual factors, already explained in chapter 9.6. Relating performance patterns of individual PWA of the whole group of PWA, and in particular of the agrammatic sub group to chance performance patterns and two other criteria may explain the variance seen in the results. Again, while the TDH is restricted to agrammatic performance, chance performance patterns may be applied to other PWA as well (cf. Burchert *et al.*, 2013).

Comprehension accuracy of SR at the conversational speech ratedisplayed that 32 PWA had an accuracy rate of 50% or higher. Also noted in the result section, 16 PWA demonstrated above-chance performance ($n > 10$), one PWA was below chance ($n < 5$), and 19 PWA demonstrated within-chance performance (n = 5-10). At the very slow speech rate, 34 PWA displayed an accuracy rate at or higher than 50% accuracy, 17 PWA demonstrated above-chance performance, while the remaining 20 PWA were within-chance. Similar to the results on SVO, this finding implies that instead of applying an agent-first strategy, many PWA actually seemed to have tried to process the sentences syntactically, otherwise comprehension would have centred around ceiling (i.e., at the accuracy level found for the young controls)[45]. This finding is similar to those of other German studies with branching SR, who neither found ceiling effects (e.g., Adelt *et al.*, 2017; Burchert *et al.*, 2003).

Contrary to performance on OVS, only 17 PWA demonstrated an accuracy rate at 50% ($n = 8$) or higher for the OR items at the conversational speech rate, which has been regarded

[45] Some PWA who had a low performance on SVO (lower than 50%) items at the conversational speech rate surprisingly did not demonstrate a similar performance at SR items, and vice versa, not all PWA with comprehension deficits of SR displayed a similar performance for SVO. This dissociation might be a tentative indication that lexical problems may not be the cause of the deficit in canonical sentence comprehension, but without statistical analyses, this finding has to be taken with extreme caution.

to reflect sensitivity for the reversed word order and/or the morphosyntactic markers on determiner, pronoun and/or verb. Eight out of these 15 PWA had an accuracy rate reflecting above-chance performance (*n* > 10), indicating that those seemed to have not only recognized a reversal of the word order in OR items, but were also most of the times able to integrate the morphosyntactic cues of case and/or agreement in order to integrate the object. In contrast, three PWA, (code numbers 213, 238, 245, out of which 238 was agrammatic) were below-chance performance (i.e., below 33% accuracy), signifying a syntactic processing breakdown. 26 PWA were within-chance performance for OR. At the very slow speech rate, 21 PWA scored above 50% accuracy for the OR items, and eight out of those PWA had an accuracy mean above 67%, reflecting above-chance performance (*n* > 10). In contrast six PWA (three more than at the conversational rate) demonstrated a below-chance performance, i.e. an accuracy rate of 33% or lower.

Individual performance patterns with regard to the chance performance calculation were the following: At the conversational speech rate, two PWA (code numbers 213, 245) appeared to have relied on a consistent agent-first strategy. Nine PWA (code numbers 204, 212, 217, 230, 231, 233, 237, 239 and 240, out of which 217, 230 and 240 were agrammatic), less than on V2, appeared to have preferred an agent-first interpretation, reflected in above-chance performance on SR compared to within-chance performance on OR. Five PWA (code numbers 209 (agrammatic), 215, 225, 243 and 244) demonstrated above-chance performance in both conditions, indicating unimpaired syntactic knowledge. 15 PWA (code numbers 202, 203, 206, 207, 211, 214, 218, 222, 223, 226, 227, 229, 232, 234, 236, out of which 202, 203, 206, 227, 234 and 236 were agrammatic) seemed to suffer from a syntactic breakdown, reflected by within-chance performance on both SR and OR. The remaining six PWA had either above-chance performance on OR and within-chance- or below-chance performance on SR.

At the very slow speech rate, five PWA (code numbers 206, 212, 213, 237, 242, out of which 206 was agrammatic) demonstrated a consistent agent-first strategy interpretation. Further, 11 PWA (code numbers 204, 214, 217, 225, 229, 230, 231, 235, 236, 239, 240, out of which 217, 230, 235, 236 and 240 were agrammatic) appeared to have preferred an agent-first strategy. On the other hand, seven PWA (code numbers 209, 210 (both agrammatic), 215, 216, 218, 243 and 244) were both above chance in SR and OR comprehension. 11 PWA (code numbers 202, 203, 207, 222, 223, 226, 227, 232, 234, 235, 238, out of which 202, 203, 223, 227, 234, 235 and 238 were agrammatic) demonstrated within-chance performance for both SR and OR. Three PWA had higher accuracy on OR than on SR.

Already reported in chapter 9.7, insufficient usage of morphosyntactic case markers have also been noted in agrammatic, paragrammatic and anomic PWA. The results of this study suggest that many PWA were sensitive to the accusative case of the relative pronoun and/or the agreement features in order to recognize a reversed word order. Still, object integration could not be executed correctly in most of the PWA. Similar to SVO, accuracy on SR was below ceiling, which indicates that many PWA did try to process the sentences syntactically instead of relying on an agent-first strategy, which would have resulted in close to 100% accuracy. Again, the findings rather suggest that misinterpretation of SR as well OR sentences might have been caused by impaired processing of morphosyntactic markers.

10.7.2 Agrammatic performance patterns

Comprehension performance of the agrammatic group, displayed in table 10.9 (see also table 13.8 in section 13.3.1.1) shows that for SR at the conversational speech rate, 11 agrammatic PWA were at 50% accuracy (n = 8) or higher. Nine PWA performed within-chance (n = 5-10), five above-chance (n > 10), and one below-chance level. These findings do not fit the expectations of the TDH, where reliance on an agent-first strategy should result in the majority of agrammatic PWA displaying above-chance performance in canonical sentences. The within-2 SD criterion categorized three PWA within normal comprehension range, while 12 PWA displayed a partial impairment. According to the within 1.74 SD parameter, only one PWA reached a normal-like comprehension level, all others had an abnormal performance. For ORaccuracy at the conversational speech rate displayed eight PWA with a rate at 50% or higher, three PWA demonstrated above-chance performance, 11 were within- and one below-chance performance, a pattern fitting the postulation of the TDH.

Application of the TDH criterion categorized three PWA (code numbers 217, 230 and 240) with a preferred agent-first interpretation when faced with a conflict. One PWA (code number 209) showed above performance on both SR and OR, signalling according to the TDH intact syntactic representational knowledge of antecedent-trace relations. Six agrammatic PWA (code numbers 202, 203, 223, 227, 234, 235) performed within-chance on both SR and OR. The remaining four PWA had above-chance or within-chance performance on OR and within- or below-chance performance on SR. Fitting these observations to the assumption of the TDH, the results imply that three agrammatic PWA seemed to have filled the antecedent correctly in the OR items, while the majority was guessing, respectively not being able to build a correct syntactic representation. Following Burchert *et al.*'s (2003) perspective in contrast, all agrammatic PWA seemed to have been aware of the reversed word order marked overtly by morphosyntactic cues, and while only one PWA displayed normal-like performance, the other 14 could be categorized suffering only from a partial impairment, implying at least recognition of the morphosyntactic features of case and/or agreement. According to Burchert *et al.* (2003, 2013), the results might indicate that none of the agrammatic PWA had a complete syntactic breakdown because they all still showed partial comprehension of OR. The criterion according to Caplan *et al.* (2007) categorized six agrammatic PWA within normal performance, because also for some normal-hearing NBD, comprehension of OR was far from ceiling, reflected in their high SD.

Similar to the results on SVO, mean accuracy for SR on the conversational speech rate seem to reflect that not all agrammatic PWA applied a heuristic strategy dominantly, because mean performance was far from ceiling. Rather, the results imply that the PWA tried to process the sentences syntactically. These results are again in line with findings from a recent study by Adelt *et al.* (2017), where German agrammatic PWA neither had normal-like accuracy on right-branching SR sentences (see chapter 10.7.4 for examples). Other studies also observed lower accuracy on subject-relative clauses for German agrammatic PWA (e.g, Burchert *et al*., 2003; de Bleser *et al*., 2005; Hanne *et al*., 2015). Following the lines of the morphosyntactic account, the results on both SR and OR indicate that many agrammatic PWA did seem to be sensitive to the case and/or agreement markers, which marked the relative object through accusative case of the relative pronoun, and the relative clause subject by plural agreement of the verb in OR, while in SR, the relative clause subject was morphosyntactically marked by nominative case of the pronoun and by singular agreement of the relative verb. However, it appeared that many PWA were not able to integrate the case and/or agreement marking in order to assign thematic roles, and had to rely on an agent-first interpretation, which could have confounded also accuracy on SR, if it was used as "last resort" (Hanne *et al*, 2011), i.e., *after* (morpho)syntactic processing failed, leading to potential decays of information and therefore to guessing. Considering the relatively low accuracy on SR (compared to this on SVO), deficient comprehension of the relative pronoun and/or deficits in processing of the antecedent-pronoun dependency might have led to this dissociation, but due to the offline character of the task, this speculation cannot be backed up.

Similar to the findings on SVO, both the Slowed Syntax Hypothesis and the slower-than normal lexical accounts cannot account for the low accuracy on SR, because a fast heuristic “kick-in” route (Love *et al*., 2008) should have resulted in a higher accuracy rate.

Table. 10.9. Performance of agrammatic PWA on SR and OR for the conversational (con) and very slow (v slow) speech rate (SRa) for either number of correct responses (n) or in % correct compared the chance performance criterion of the TDH, the 2 SD-within-normal criterion of number of correct responses of Burchert *et al*. (2003) (part.imp. = partially impaired), and the within-1.74 SD criterion of % correct of Caplan *et al*. (2007). For a better overview, only full percentages are shown.

		SR					OR				
	SRa	correct		TDH	2 SD	1.74 SD	correct		TDH	2 SD	1.74 SD
Code		*n*	*%*				*n*	*%*			
202	con	7	47	within	part.imp.	abnormal	9	60	within	part.imp.	normal
	v.slow	10	67	above	part.imp.	abnormal	8	53	within	part.imp.	abnormal
203	con	8	53	within	part.imp.	abnormal	5	33	within	part.imp.	abnormal
	v.slow	6	40	within	part.imp.	abnormal	7	47	within	part.imp.	abnormal
206	con	7	47	within	part.imp.	abnormal	6	40	within	part.imp.	abnormal
	v.slow	11	73	above	part.imp.	normal	4	27	below	part.imp.	abnormal
208	con	4	27	below	part.imp.	abnormal	6	40	within	part.imp.	abnormal
	v.slow	6	40	within	part.imp.	abnormal	12	80	above	part.imp.	normal
209	con	13	87	above	part.imp.	normal	12	80	above	normal	normal
	v.slow	15	100	above	normal	normal	13	87	above	part.imp.	normal
210	con	10	67	within	part.imp.	abnormal	12	80	above	normal	normal
	v.slow	11	73	above	part.imp.	normal	12	80	above	part.imp.	normal
217	con	14	93	above	part.imp.	normal	6	40	within	part.imp.	abnormal
	v.slow	14	93	above	normal	normal	7	47	within	part.imp.	abnormal
223	con	10	67	within	part.imp.	abnormal	5	33	within	part.imp.	abnormal
	v.slow	7	47	within	part.imp.	abnormal	9	60	within	part.imp.	abnormal
227	con	10	67	within	part.imp.	abnormal	9	60	within	part.imp.	normal
	v.slow	9	60	within	part.imp.	abnormal	10	67	within	part.imp.	abnormal
230	con	15	100	above	normal	normal	6	40	within	part.imp.	abnormal
	v.slow	15	100	above	normal	normal	8	53	within	part.imp.	abnormal
234	con	5	33	within	part.imp.	abnormal	10	67	within	part.imp.	normal
	v.slow	9	60	within	part.imp.	abnormal	7	47	within	part.imp.	abnormal
235	con	10	67	within	part.imp.	abnormal	12	80	above	normal	normal
	v.slow	11	73	above	part.imp.	normal	8	53	within	part.imp.	abnormal
236	con	9	60	within	part.imp.	abnormal	6	40	within	part.imp.	abnormal
	v.slow	11	73	above	part.imp.	normal	7	47	within	part.imp.	abnormal
238	con	10	67	within	part.imp.	abnormal	4	27	below	part.imp.	abnormal
	v.slow	10	67	within	part.imp.	abnormal	7	50	within	part.imp.	abnormal
240	con	11	73	above	part.imp.	abnormal	7	47	within	part.imp.	abnormal
	v.slow	13	87	above	part.imp.	normal	10	67	within	part.imp.	abnormal

50% accuracy: *n* = 8; chance range: *n* = 5-10.
Means of normal-hearing NBD on SR (number of correct responses: *M* = 14.67, *SD* = 0.45; range 14-15; % correct: *M* = 98.33%; *SD* = 12.8 for the conversational, resp. number of correct responses: *M* = 14.58, *SD* = 0.57, range 14-15; % correct: *M* = 95%; *SD* = 15.61 for the very slow speech rate) and OR (number of correct responses: *M* = 14.58, *SD* = 0.57, range 10-15; % correct: *M* = 95%, *SD* = 15.61 für the conversational, resp. number of correct responses: *M* = 14.71, *SD* = 0.42, range 12-15; % correct: *M* = 98.61%, *SD* = 11.70 für the very slow speech rate). For OR, even one normal-hearing NBD was within change range.

10.7.3 The effect of slower speech on agrammatic comprehension

At the very slow speech rate, 12 agrammatic PWA performed at 50% accuracy or higher on SR items, seven were within- and eight above-chance performance. According to Burchert *et al.*'s (2003) criterion, three PWA, and according to Caplan *et al.*'s (2007) criterion, eight PWA demonstrated normal performance.

For OR items at the very slow speech rate, nine PWA scored at or higher than 50% accuracy. Three PWA demonstrated above-chance performance, 11 were within-chance and one was below-chance level (compared to the conversational speech rate, one agrammatic PWA improved to above-chance performance, while another one formerly above-chance, degraded his performance to within-chance level). One PWA (code number 206) seemed to have applied a consistent agent-first strategy, while five PWA (code numbers 217, 230, 235, 236, 240) appeared to have preferred heuristic over syntactic processing. Two PWA (code numbers 209, 210) demonstrated above-chance comprehension performance on both SR and OR, signalling an intact syntactic knowledge, but none of these PWA reached the normal-like comprehension accuracy of the normal-hearing NBD. Seven PWA (code numbers 202, 203, 223, 227, 234, 235 and 238) appeared to have a syntactic breakdown. While with the 2 SD-within-normal criterion all PWA were categorized with a partial impairment, the within-1.47 SD parameter classified two PWA with normal-like performance.

Similar to accuracy on SR at the conversational rate, and similar to the findings for SVO, far-from ceiling performance on SR indicates that agrammatic PWA did seem to process the sentences syntactically and or/lexically and not heuristically, as proposed by the TDH, because comprehension was not at ceiling. Furthermore, categorization with the chance performance criterion does not reflect the significant improvement of comprehension of SR and OR at the very slow speech rate (shown in table 10.9), as it explains it with an accidentally better guessing rate.

While the Slow Syntax account cannot explain the low accuracy on SR, similar to that on SVO (because a fast subject-first processing route would have resulted in a higher degree of accuracy on SR), comprehension performance might have also been improved because the presentation of the lexical elements was prolonged, which could have counteracted delayed lexical access and/or integration. Still, also the lexical access account (e.g., Love *et al*., 2008) assumes a fast agent-first bypass route, which should have resulted in ceiling accuracy for

SVO and also for SR. But following the line of Burchert *et al.* (2003), the results reflect an improved integration of case and/or agreement features in both SR and OR, compared to that at the conversational rate. This improvement might have been caused by a more sufficient - perceptual saliency of the morphosyntactic cues effected by a prolonged presentation, which might acclaim for the observation that as well canonical as also non-canonical comprehension improved. Alternatively, the prolonged presentation might have provided more time for the integration of the morphosyntactic cues: Preserved sensitivity but impaired integration has been noted by Burchert *et al.* (2003) and (2005), and later online studies by Hanne *et al.* (2001) and (2015) interpreted eye movement patterns of their PWA to reflect preserved sensitivity to case and agreement features but delayed integration of those.

Two studies by (Hanne *et al*, 2015) and Adelt *et al*. (2017) demonstrated that agrammatic PWA's differentiation between object-first and subject-first sentences was better when word order was distinguishable only by agreement features compared to only by case cues. Hanne *et al* (2015), using SVO and OVS items, such as examples (10.1) and (10.2), which differed in case features, found a higher comprehension accuracy difference (SVO: 77%, OVS: 46%), than for SVO and OVS differing in agreement, such as examples (10.3) and (10.4), where the difference in accuracy was smaller (SVO: 78%, OVS: 64%)

(10.1) Der Arzt schubst den Dieb

The$_{\mathrm{NOM}}$ doctor pushes the$_{\mathrm{ACC}}$ thief.

'The doctor pushes the thief.'

(10.2) Den Arzt schubst der Dieb

The$_{\mathrm{ACC}}$ doctor pushes the$_{\mathrm{NOM}}$ thief.

'The doctor pushes the thief.'

(10.3) Das Kind fängt die Frauen.

The$_{AMB}$ child catches$_{\mathrm{SG}}$ the$_{AMB}$ women$_{\mathrm{PL.}}$

'The child catches the women. '

(10.4) Das Kind fangen die Frauen.

The$_{AMB}$ child catch$_{PL}$ the$_{AMB}$ women$_{PL.}$

'It is the child that the women catch.' (Hanne *et al*., 2015)

Even more distinctive were accuracy differences in right-branching subject-first and object-first relative clauses for German agrammatic PWA in Adelt *et al*.' (2017) study. While sentences differing only in case of the relative pronoun in (10.5) and (10.6) were generally better comprehended (SR: 76%, OR: 69%) than those differing in agreement (examples 10.7 for SR and 10.8 for OR) (SR: 60%, OR:59%), the accuracy difference between the latter ones was unremarkable. Moreover, in Adelt *et al*. (2017) experiment, PWA were seen to increase eye fixations to a picture after the offset of the sentence, indicating that they waited for an interpretation until they heard the verb and its agreement cues.

(10.5) Wo ist der Hamster, der den Frosch wäscht?
Where is the$_{NOM}$ hamster who$_{NOM}$ the$_{ACC}$ frog washes$_{SG}$?
'Where is the hamster who washes the frog?'

(10.6) Wo ist der Hamster, den der Frosch wäscht?
Where is the$_{NOM}$ hamster whom$_{ACC}$ the$_{NOM}$ frog washes$_{SG}$?
'Where is the hamster whom the frog washes?'

(10.7) Wo ist das Kamel das die Igel wäscht?
Where is the$_{NOM}$ camel$_{SG}$ that$_{AMB}$ the$_{AMB}$ hedgehogs washes$_{S?}$
'Where is the camel that washes the hedgehogs?'

(10.8) Wo ist das Kamel das die Igel waschen?
Where is the$_{NOM}$ camel$_{SG}$ that$_{AMB}$ the$_{AMB}$ hedgehog wash$_{PL}$?
'Where is the camel that the hedgehogs wash?' (Adelt *et al*., 2017

This dissociation implies that PWA actually tried to rely on the agreement features to assign thematic roles in case ambiguous sentences, which was indicated by eye fixations to the target after the agreement features occurred. For this research, these observations may help to explain the improved accuracy on as well SR and OR, which differed in both overt case and agreement cues, in as such a prolonged presentation time could have aided integration of either case or agreement, or of both features.

Another reason for the improvement could stem from the prolonged silent interval between the end of the relative clause and the verb of the matrix clause, which might have also given additional time for recognition and thus integration of the *agreement* features. Also, prolonged syntactic boundaries might have given more time to process the thematic propositions of both the relative clause and the matrix clause. Expanding pauses at major syntactic boundaries facilitated comprehension of right-branching SR and OR sentences in the research by Blumstein *et al.* (1985), but in contrast to the results of this research, more for paragrammatic PWA, and not significantly for agrammatic PWA, who were already at ceiling performance in the conversational speech rate condition. In addition, expansion of the first intonational phrase boundary after the relative verb might have also aided morphosyntactic or syntactic processing. IPhs in the OLACS items consist essentially of a change of the pitch at the boundary and a pause (cf. Carroll, 2013), and lengthening those features may have facilitated recognition of a syntactic boundary and thus processing[46].

While some studies used items with co-indexation of pronouns with matrix subjects (e.g., Adelt *et al.*, 2017, Burchert *et al.*, 2003, Zurif *et al.*, 1992), none of these studies has systematically investigated agrammatic processing of relative pronouns, and I can only speculate that slower speech might have also facilitated the resolution of this binding relation.

The latter suggested causes have in common that the improvement seemed to have been provoked by a decrease of the processing load induced by the double sentence structure of the centre-embedded relative clause type clause. Therefore, an elongation of duration and thus of processing time might have also decreased a higher working memory load induced by the

[46] Additionally, IPh may consist of a prefinal lengthening of the stressed last syllable before the boundary, which in the items in this research would only lengthen the singular verbs, and not the plural verbs, whose agreement features form an own, unstressed, syllable.

verb-final position of the relative clause and/or by the two thematic propositions of matrix and relative clause (cf. Gibson, 1998; Lewis & Vasishth, 2005). Related to that, slower speech might have decreased the strain on the already reduced working memory (and attentional) capacities in aphasia (e.g., Hillary *et al*., 2010; Neto & Santos, 2012).

Only two studies so far have found a positive impact of slower speech on performance on OR structures in agrammatic PWA, but a direct comparison of results is not without problems, because Love *et al.* (2008) measured priming effects and not accuracy in their long-distance antecedent-trace dependencies, while Dickey *et al.* (2007) measured accuracy to object-clefted *wh*-questions within text passages. Nevertheless, both studies found improved performance, indicating that expanded presentation aided processing and thus reduced the degree of neglect or decay and/or integration of traces caused by too slow processing. In contrast, Choy (2012) did not find note find a facilitating effect of slower speech on comprehension of OR.

Similar to the findings on the V2 structures, cognitive deficits might have interfered with processing. And again, these deficits might have been only temporary, otherwise accuracy of OR could have been much lower. In this manner, slower speech might have been able to compensate at least for some of the intermittent deficiencies. e.g., working memory, which are assumed by some researchers to impose processing reductions (Burchert *et al.*, 2003; Caplan *et al.*, 2004, 2007; Hanne *et al.*, 2011; see discussion on chapter 11.1.2).

On a last note, the heterogeneity of the agrammatic group might have confounded results to a certain degree, as there was a high degree of variability in terms of severity and duration of aphasia, age and years of education. This was also true for the whole group of PWA, where the factors of hearing level and main symptom respectively diagnosis might have provoked an even higher variability of comprehension performance.

10.7.4 Effects of slower speech on normal comprehension

Slower speech had an effect, but other than predicted: For general sentence comprehension, slower speech facilitated performance only for the normal-hearing group, indicating that expanding morphosyntactic features did not help perception and/or integration of morphosyntactic features for the hearing-impaired listeners as much as for the normal-hearing participants. Inconclusive facilitation through uniformly slowed sentences for hearing-impaired listeners has also been seen in the literature (e.g., Adams & Moore, 2009; Vaughan *et al.*, 2002). Still, similar to the results on the V2 structures, accuracy of the normal-hearing NBD at the conversational speech rate was close to ceiling performance, i.e., to that of the young controls. Performance of the hearing-impaired adults was also above 90% at the conversational speech rate, which did not leave much space for improvement.

10.7.5 Effects of hearing impairment and age

Similar to the findings on V2, both age and hearing impairment had effects, which were not predicted: Hearing-impaired as well as older PWA demonstrated a better non-canonical comprehension than the normal-hearing group, Therefore I refer to the discussion in chapter 9.7.3.

While hearing level measured by four frequencies as factor did not result into significant effects for the comprehension performance of NBD, analysing data of the NBD by including the hearing level of a lower and a higher frequency (at the PTA-6 analysis), a marginal canonicity effect was found for the hearing-impaired non-brain-damaged listeners, which fits with findings in the literature (e.g., Wingfield *et al.*, 2003; 2006). This effect might reflect that the perceptual properties of the relative pronoun as such or of its case cues, as well as of the agreement features were not always salient enough for the hearing-impaired group in order to differentiate between nominative and accusative case, and/or between singular and plural agreement, so that in case of doubt, they preferred a subject-first interpretation. Another possibility is that the hearing-impaired adults might have not always recognized the reversed word order because of the higher perceptual processing load, assumed to lead to slowed-down processing and thus to a potential risk of neglect of traces.

Age affected general comprehension of the NBD. This was also found for the verb-second items, and these finding matches those of other studies, where older adults were observed to be more impaired in auditory comprehension or object-relative clauses than younger listeners, which was attributed to an age-related slowing of perceptual and/or cognitive abilities (e.g., Schneider *et al.*, 2005; Schneider, Daneman, & Pichora-Fuller, 2002; Stine-Morrow *et al.*, 2002; Wingfield *et al.*, 2003; 2006).

In summary, canonicity effects were seen for the whole group of PWA, the agrammatic group and marginally also for the hearing-impaired non-brain-damaged adults. These findings match with others from the respective literature. In contrast to results on V2, agrammatic individuals improved general comprehension by slower speech, which might be owed to the prolonged morphosyntactic, syntactic and/or intonational markers, which might have facilitated object integration and/or reduced working memory load. With regard to agrammatic sentence processing theories, the effect of slower speech and the performance patterns within the agrammatic group suggest that a number of them do not seem to suffer from impaired syntactic knowledge, as postulated by the TDH. Although the mean accuracy of the agrammatic group was within-chance performance, the results are better explained by assuming procedural deficiencies within sentence processing, such as postulated by the Slowed Processing Hypothesis.

10.8 Overall summary

Before the results are discussed with regard to the literature and implications in the next chapter, a short summary of all results provides similarities and differences of performance of NBD and PWA on V2 and RC structures. While for PWA, shown in tables 13.6 and 13.7 in section 13.3.1, mean comprehension of OVS (55.67%) and OR (53.34%) was similar, SVO items (76.65%) seemed to be a bit easier to comprehend than SR the sentences (71.51%) sentences, indicating that SVO with the unmarked subject-verb-object order was preferred by German PWA. In contrast, NBD were at ceiling performance for both SVO (97.60%) and SR (96.87%), and close to ceiling performance at OVS (95.42%) and OR (93.65%), signalling no preference for a certain canonical structure.

Hearing impairment

For PWA, the expected canonicity effect of OVS and OR was smaller in the hearing-impaired compared to the normal-hearing group, while overall comprehension of V2 and RC sentences was worse for the first group compared to the normal-hearing PWA. While there was no impact of hearing impairment on V2 sentence comprehension for the NBD, comprehension of RC, especially of OR, was affected by hearing loss, reflected in the PTA-6 analysis.

Slower speech

The very slow speech rate facilitated overall comprehension of both relative clauses for agrammatic PWA. A comparison of performance between PWA and NBD displayed the facilitating effect of the very slow speech rate for both groups, in particular for non-canonical OVS and OR. While an interpretation of a three-way interaction is difficult, graphics show that NBD seemed to benefit more than PWA from the very slow speech rate in general and also tentatively on non-canonical sentence interpretation. Furthermore, seen in the PTA-6 analysis, the normal-hearing NBD profited more from the very slow speech rate for RC comprehension than their hearing-impaired counterparts.

Other effects

The separate analyses reflected that age seemed to affect general comprehension for the NBD on all structures, while older PWA, and especially older agrammatic PWA, had a better performance on OVS than the younger PWA.

11 General discussion

In the final chapter, first the results with regard to the hypotheses are discussed. Slower speech facilitated comprehension of centre-embedded relative clause structures for the agrammatic group of PWA, indicating that it could compensate partially for the hypothesized delayed processing. Surprisingly, hearing-impaired PWA had a higher accuracy rate at OR than the normal-hearing PWA, an effect, which might be due to lack of matching between these two groups. Also, slower speech did not have a differentiating effect on the hearing-impaired PWA compared to the normal-hearing PWA. Moreover, not reflected in the statistical analyses, the percentage of hearing-impaired PWA was higher than those of non-brain-damaged adults in Germany, and hearing aid ownership and adoption rates were very low. Normal-hearing NBD also profited from slower speech for comprehension of RC. On the other hand, impaired hearing of high frequencies seemed to affect perception of certain morphosyntactic features, which were reflected in a canonicity effect. Results also demonstrated that age as effect should not be under-estimated in sentence processing.

The results are discussed with regard to the two theories of sentence processing in aphasia, i.e., the TDH and the Slowed Processing Hypothesis. Also, the contribution of the results for accounts on sentence processing in hearing impairment is regarded. The latter will also include a comparison between the conventional PTA-4 and the more comprehensive PTA-6 audiometry. Finally, implications for as well aphasia therapy and audiological assessment are introduced.

11.1 Slower speech compensates partially for sentence comprehension deficits in agrammatic aphasia

The first hypothesis concerned the assumption that non-canonical sentence comprehension deficits in agrammatic aphasia are caused by slower-than-normal processing with the risk of processing delays, which may notably affect object integration. Therefore, a prolonged presentation time should compensate for the processing delay, and may aid specifically recognition and/or integration of morphosyntactic markers.

A facilitating effect of slower speech has been reported for agrammatic PWA on their performance on American English OR sentences (e.g., Dickey *et al.*, 2007; Love *et al.*, 2008). In the current study, comprehension of both OVS and OR was impaired for almost all agrammatic, paragrammatic and anomic PWA, resulting in a clear canonicity effect, which has been noted in many German aphasia studies (e.g., Bates *et al.*, 1987; Burchert *et al.*, 2003, Hanne *et al.*, 2011, 2015). This effect was assumed to be at least partly produced by deficient processing of case and/or agreement features marking thematic roles (cf. Bates *et al.*, 1987).

In the German test items used in this research, movement of the object in OVS was signalled by overt accusative case markings on the determiner, the adjective, and sometimes even on the noun in the first NP. In OR, the accusative case of the pronoun and the agreement feature of plurality in the relative clause signified that movement of the object had taken place. While there was no significant effect of slower speech on V2 comprehension, the very slow speech rate aided general comprehension of embedded SR and OR for the agrammatic group. Several possible reasons were named in chapter 10.7. In this section, the effect of slow speech is discussed with respect to the different accounts within the Slowed Processing Hypothesis.

While the TDH may regard the improvement as a higher score of accidental, correct guessing, the lexical account suggests that slower speech, which prolonged the presentation time of lexical elements, might have given more time to compensate either for delayed lexical access as proposed by e.g., Love *et al.* (2008) or for delayed lexical integration, assumed by e.g., Dickey *et al.* (2007), which as a consequence might have prevented the postulated trace site neglect, and aided object recognition and/or integration in non-canonical sentences. Delayed lexical access and/or integration would explain why accuracy on both SR and OR improved, because slower speech might have compensated also for a hypothesized delay in antecedent-pronoun resolution. Although the effect in this study was smaller, the results of the agrammatic group are similar to of those of Dickey *et al.* (2007) and Love *et al.* (2008), whose agrammatic participants profited from a slower speech rate for their comprehension of branching object relative clauses. Dickey's *et al.* (2007) online results showed eye movement patterns, which reflected a higher number of correct object integration at the occurrence of the trace compared to the conversational speech rate, implying that slower speech could compensate for the delays in processing. The Slow Syntax Hypothesis (SSH) suggests that slower-than-normal syntactic parsing would result in delays for in particular object integration in non-canonical sentences while canonical sentence comprehension should be less affected (e.g., Burkhardt *et al*., 2003, 2008). But it has difficulties to account for the low accuracy rate on SR because a postulated non-syntactic fast subject-first processing route should have led to a higher degree of accuracy (see Burchert *et al*., 2013). The morphosyntactic account on the other hand, postulated by e.g. Hanne *et al*. (2011) and Burchert *et al*. (2013), would explain the effect of slower speech as and/or improved integration of morphosyntactic markers. Recent German studies (Adelt *et al*., 2017; Hanne *et al*., 2011, 2015) demonstrated that German agrammatic and other PWA were able to recognize case and agreement markers in verb-second or relative clause structures. While overt case markers facilitated comprehension to a higher degree than overt agreement markers (Adelt *et al*; 2017; Hanne *et al*., 2015), Adelt *et al.* (2017) as well as Hanne *et al*. (2015) noted that their PWA increased eye fixations to a picture *after* the verb and its agreement features were presented, indicating attempted processing of the verb information. In addition, eye movement latency patterns implied a general delay in sentence processing, which was argued to lead sometimes to an impaired integration of these cues in order to interpret a sentence, and to force them to rely at an agent-first strategy in these times (Hanne *et al*., 2011, 2015). Prolonging the presentation time might have provided more time in order to process case and/or agreement cues to a higher degree within the time course of the presentation, which in turn may have aided general thematic role assignment. Also lengthening the silent interval between the end of the relative clause and the verb of the matrix clause, which also prolonged the intonational phrase boundary, could have given additional time for integration of the agreement features. Alternatively, a prolonged acoustic presentation might have improved perceptual processing by expanding lexical elements and particularly morphosyntactic features, which have been considered to be normally perceptually less salient. Another possibility is that slower speech might have decreased working memory load (e.g., Caplan *et al*., 2007), by e.g., giving more time to process the two thematic propositions of the centre-embedded structure. Last but not least, a combination of two or more of these potential facilitating factors could have aided comprehension in the German agrammatic PWA.

While the offline data as such cannot give evidence to whether lexical, syntactic, morphosyntactic or semantic processing was improved, a comparison of agrammatic group performance on OVS and OR might help to shed more light of the underlying cause(s) of the assumed timing deficit in German agrammatic PWA. Delayed lexical processes may result in a rather homogenous performance pattern across the two non-canonical sentence types, while slowed-down syntactic parsing, as suggested by the SSH, may increase the canonicity effect in sentences, which are regarded more complex than others. Morphosyntactic timing deficits may affect structures with less salient and/or ambiguous markers more than those with double and/or overt markers.

Let's recapitulate the differences between V2 structures (example 11.1 for SVO) and centre-embedded SR (example 11.2) described in chapter 3 with regard to their syntactic and thematic properties, such as number of DP, number and position of verbs, number of dependencies and number of thematic propositions. It was suggested that the higher number of DP and verbs in RC might increase processing load. Also, it was argued that processing of the two verbs in clause final positions increase working memory load compared to that of the single verb in verb-second position in main clause structures (e.g., Weyerts *et al*., 2002). Also, embedded relative clauses have been associated with a higher working memory load because the matrix sentence can only be interpreted after occurrence of the relative clause, which entails for RC that the matrix verb can only be processed after the occurrence of three DP and another verb (e.g., Gibson, 1998; Lewis & Vasishth, 2005). More, processing two thematic propositions in RC compared to the one proposition in V2 has been suggested to increase integration costs, too (Gibson, 1998; Lewis & Vasishth, 2005). In addition, RC contained a pronoun co-indexed with the matrix subject, which was also assumed to raise processing load.

Morphosyntactic differences also occurred: Subject and object in V2 had two or three overt case markers (marked boldly), while in RC, the relative pronoun had only one case marking, which can be considered to be phonologically and perceptually less salient, also because the pronoun as a monosyllabic grammatical element many be articulated with lesser accentuation than adjectives and nouns. In contrast to two overtly case-marked DP in V2, RC contained an ambiguously case-marked DP, which also was seen to increase processing load (e.g., Hanne *et al*., 2015; Adelt *et al*., 2017).

(11.1) D**er** klein**e** Junge umarmt d**en** dick**en** Nikolaus.
The$_{\mathrm{NOM}}$ small$_{\mathrm{NOM}}$ boy$_{\mathrm{NOM}}$ hugs the$_{\mathrm{ACC}}$ fat$_{\mathrm{ACC}}$ Santa Claus
'The small boy hugs the fat Santa Claus.'

(11.2) D**er** Maurer$_{j}$, d**er**$_{ij}$ die Metzger grüßt, errötet.
The$_{\mathrm{NOM}}$ mason$_{\mathrm{SG}}$ who$_{\mathrm{NOM}}$ the$_{\mathrm{AMB}}$ butchers$_{\mathrm{PL}}$ greets$_{\mathrm{SG}}$, blushes$_{\mathrm{SG}}$.
'The mason who greets the butchers blushes.' (Uslar *et al*., 2013)

Differences between OVS (example 11.3) and OR (example 11.4) concerned position and morphosyntactic marking of the object: The object in OVS occurred at the beginning of the sentence and was marked by two or three overt case markers, while the moved object in OR was realised as a relative pronoun at the initial position of the relative-clause after the matrix DP. Furthermore, the syntactic subject of the matrix clause transformed to the syntactic object in the relative clause in OR, which has also been noted also to increase processing load (MacWhinney & Pleh, 1988).

Because of these differences, OR can be considered more complex than OVS, and may be more difficult to process due to the higher degree of processing load induced by a higher demand on working memory. By extending the argumentation of the Slowed Processing Account, agrammatic PWA should thus be more impaired processing OR than OVS. Slower speech on the other hand might therefore have a greater effect on comprehension of OR compared to OVS by e.g., giving more time to process the dependencies, and the higher degree of information of the three DP, the two clause-final verbs and/or the morphosyntactic information.

(11.3) D**en** dick**en** Nikolaus$_{i}$ umarmt d**er** klein**e** Junge_$_{ti}$.
The$_{ACC}$ fat$_{ACC}$ Santa Claus hugs the$_{NOM}$ small$_{NOM}$ boy$_{NOM}$.
'It is the fat Santa Claus whom the small boy hugs'.

(11.4) D**er** Maurer$_{j}$, d**en**$_{ij}$ die Metzger grüßen_$_{ti}$, errötet.
The$_{NOM}$ mason$_{SG}$ whom$_{ACC}$ the$_{AMB}$ butchers$_{PL}$ greet$_{PL}$, blushes$_{SG}$.
'The mason whom the butchers greet blushes.' (Uslar *et al.*, 2013)

Shown in chapters 9.7 and 10.7, for the agrammatic group, mean accuracy on SVO was 75% and on SR 63%, indicating that SR was more difficult to process than SVO, which might be caused by one or more of the described differences in processing load. Mean accuracy on OVS was 56% and 51% on OR at the conversational speech rate. This difference also may reflect the higher processing load induced by OR compared to OVS, and could be explained by both the Slow Syntax and the slowed morphosyntactic account. Lower accuracy of SR compared to SVO may be explained by both syntactic and lexical accounts because processing of an additional antecedent-pronoun dependency may be regarded to delay further syntactic or lexical processes in SR as well. However, already mentioned, the low accuracy on SVO contradicts the assumption of the SSH, and also the lexical accounts have no sufficient explanation for a far- from ceiling comprehension performance on SVO, because both assume that a fast agent-first processing routes may replace a too slow lexical or syntactic processing (e.g., Burkhardt *et al*., 2008; Love *et al*., 2008).

At the very slow speech rate, mean accuracy on SVO was 74%, and on SR 70%, compared to 62% on OVS and 58% on OR. While accuracy on SVO and OVS did not change markedly, improved accuracy on both SR and OR was significant. However, the effect was small across the group of agrammatic patients, and accuracy was still within-chance performance level and might not be distinguishable from a higher degree of correct guessing, as the TDH might interpret the improvement.

Nevertheless, the positive speech rate effect has been tentatively attributed to a reduced processing load for either lexical, morphosyntactic, syntactic and/or thematic processing in chapter 10.7 and above, and was associated with a decrease in working memory load and/or a reduction of the strain on already reduced working memory (and attentional) capacities (e.g., Hillary *et al*., 2010; Neto & Santos, 2012), by e.g., allowing more time for processing the two verbs in final positions and/or providing additional time for the syntactic parsing of the embedded relative clause to be completed before the final constituent of the matrix clause turned up. For morphosyntactic processing, this would entail that morphosyntactic features could have been integrated more along the time course of the presentation, and lesser information had to be stored in working memory.

Decrease of working memory load by slower speech might be a possible explanation why agrammatic PWA improved comprehension of the embedded sentences but not for the verb-second structures, and still demonstrated lower accuracy on both SR and OR compared to SVO and OVS. As embedding has been claimed to increase integration and thus cognitive load, slower speech might have prevented the degree of the timing deficit.

This latter hypothesized effect of slower speech on working memory is more in line with the single resource theory suggesting that working memory capacity affects general processing (Just & Carpenter, see chapter 2.2). According to this account, decreasing processing load should facilitate complex sentence processing. Slower speech as a potential factor to decrease processing load by enhancing perceptual and/or linguistic processing would thus explain the improved performance of agrammatic PWA on relative clause comprehension. With the dual-resource theory on the other hand (Caplan & Waters, 1999,

2013) which postulates that syntactic processing would not be affected by a change of -perceptual- processing load, it is difficult to explain the positive effect of slower speech on sentence comprehension. Unfortunately, the PWA in this research were not tested on working memory capacity, attentional abilities and processing speed, but cognitive deficits have been seen to be present in almost all PWA (see chapters 4.3 and 4.5), so strained and/or impaired cognitive deficits may be to some extent responsible for the findings in this study.

Slower speech could have also contributed to prevent hypothesized processing resource reductions to some degree (e.g., Caplan *et al.*, 2007). Limitations in processing speed and/or cognitive functions may also impact on the degree of *access* to certain linguistic information or operations, which affect thematic role assignment for moved objects[47]. While object integration in reversed word order does not have to be lost in the syntactic knowledge in agrammatic aphasia, retrieving or implementing this knowledge might be dependent on the degree of general and/or linguistic processing speed: PWA with a higher degree of speed reduction may thus be more impaired in object integration in object-first structures, with a higher risk of trace deletion and consequential guessing behaviour as proposed by Grodzinsky (1995; 2000), as those PWA with a lower degree of speed reduction. Unfortunately, general processing speed was neither measured in the PWA in this research, so there is no evidence for this assumption.

11.1.2 A note on comparisons of studies on slower speech

While the slower speech rates in this research are different from the rates in the American studies, the rate of slowing reflects the differences of a general speech speed in both languages. The slow speech rate used here for OR (3.24 sps) is similar to the rate used in the two American studies (Dickey *et al.* (2007) with 3.3 sps, and Love *et al.* (2008) with 3.8.sps approximating 130-140% expansion rate of the original signal), but did not aid comprehension. Only the very slow speech rate (2.8 sps) did. German is a slower language than American English (cf. Pellegrino *et al.*, 2010; Schelten-Cornish, 2007), thus it might be possible that a proportionally slower speech rate is needed in order to facilitate comprehension in PWA. Because of this observation, effects of speech rate in the literature should be

---

[47] Burkhardt *et al.* (2008) interpret the postulated cause of the comprehension by the TDH as „[…] inability to access thematic role information contained in NP-/Wh-traces“ (Burkhardt *et al.*, 2008, p. 121), which indicates that there is no loss of syntactic knowledge but rather an inability to use it. This impaired ability might be partially caused by timing restrictions imposed by reductions in processing speed.

compared in the context of the conversational speech rate of the native language. Also, these results raise the question whether linguistic processing speed might be dependent on the speed of the native language(s).

11.1.2 Individual dissociations in performance between OVS and OR: Tentative evidence for intermittent deficiencies in agrammatic aphasia?

Possible dissociations in individual agrammatic performance on different sentence structures might help to distinguish between the potential causes of the hypothesized timing deficit. Along the lines of e.g., Berndt *et al*, 1996; Burchert *et al.* (2003), and Caplan *et al.* (2007), performance of each agrammatic PWA in this study was analysed according to his or her performance pattern at V2 and RC and between the two non-canonical conditions and speech rates (see chapters 9.7 and 10.7).

Within the concept of chance performance, four distinct performance patterns for agrammatic PWA have been proclaimed (cf. Burchert *et al*., 2003): A consistent agent-first strategy with above-chance performance on SVO and SR and below-chance performance on OVS and OR, a preferred agent-first strategy with above-chance performance on SVO and SR and within-chance accuracy on OVS and OR, above-chance performance on all structures signalling unimpaired syntactic knowledge, and within-chance performance on both canonical and non-canonical structures signifying a syntactic breakdown (cf. Burchert *et al*., 2003). In the current study, only roughly a third of the agrammatic PWA displayed a preferred agent-first strategy at V2 (seven PWA (code numbers 206, 209, 217, 230, 235, 236) at the conversational and five PWA (code numbers 209, 230, 234, 236, 238) at the very slow speech rate), and one PWA (code number 234) seemed to have relied on a consistent application at the conversational rate. For RC, rates for the preferred agent-first application were similar (with only three PWA (code numbers 217, 230, 240) at the conversational and five PWA (code numbers 217, 230, 235, 236, 240) at the very slow speech rate), while only one agrammatic participant (code number 206) seemed to have applied an agent-first strategy consistently[48]. In contrast, preservation of syntactic knowledge was seen for one agrammatic

[48] For these agrammatic PWA assumed with a preferred and/or consistent agent-first application, auditory comprehension, measured by the Token Test and the subtests of the AAT, did not seem to be substantially different than those of other agrammatic PWA who showed above-chance performance in non-canonical sentence comprehension (see table 13.1). Therefore, severity of a more general auditory comprehension deficit in aphasia did not seem to impact on processing of antecedent-trace relations, and might thus not account for potential trace deletions.

PWA (code number 210) at the conversational, and five agrammatic PWA (code numbers 210, 217, 227, 235, 240) at the very slow speech rate for V2 items. For the centre-embedded structures, one agrammatic PWA (code number 209) presented with intact syntactic knowledge for OR at the conversational, and two agrammatic PWA (code numbers 209, 210) at the very slow speech rate (out of which only one individual could be categorized as unimpaired at both speech rates). Interestingly, only one PWA (code number 210) seemed to be relatively unimpaired in comprehension of all structures, while four PWA with seemingly intact object integration behaviour in OVS were not among those with unimpaired comprehension in OR, and vice versa, PWA 209 with intact syntactic knowledge of RC did not show this for V2. Categorized with a syntactic breakdown were roughly a third of the agrammatic PWA: Within-chance performance for both SVO and OVS were seen for six PWA at the conversational speech rate (code numbers 202, 203, 206, 208, 223, 238) and for five PWA at the very slow speech rate (code numbers 202, 203, 206, 208, 223). For both SR and OR, seven PWA seemed to have a syntactic breakdown at the conversational speech rate (code numbers 202, 203, 206, 208, 223, 227, 234, 236) and five PWA at the very slow speech rate (code numbers 203, 223, 227, 234, 238). More, according to the THD criterion, across speech rates only three agrammatic PWA were below chance at either OVS (code number 234) or OR (code numbers 206, 238). This observation is similar to those of studies where below-chance performance in agrammatic PWA has seldom be noticed (e.g., in the two systematic reviews by Berndt *et al.*,1996 and Caplan *et al.*, 2007, encompassing several studies on agrammatic non-canonical comprehension data).

Relating agrammatic performance and its variance by comparing it to the variability in accuracy of normal controls' on the same items is another opportunity to categorize agrammatic comprehension: An application of the 2 SD-within-normal criterion by Burchert *et al.* (2003) showed that compared to normal performance (that of the normal-hearing NBD), almost all agrammatic PWA were only partially impaired in general comprehension, which was regarded as evidence for at least partially preserved sensitivity to morphosyntactic features. Following their line, two agrammatic PWA (code numbers 210, 227) could be categorized with unimpaired performance at the conversational speech rate for OVS, and one PWA (code number 235) at the very slow rate, and while three PWA (code numbers 209, 210, 235) seemed to be unimpaired in OR at the conversational rate, only one PWA (code number 235) had normal-like performance at the very slow speech rate.

According to Caplan *et al.*'s (2007) criterion, four PWA (code numbers 209, 210, 217, 235) had normal comprehension performance for V2 at the conversational rate, while three PWA (code numbers 210, 217, 227) were normal-like at the very slow rate. For RC, only one PWA (code number 209) had normal performance at the conversational rate, while two PWA (code numbers 209, 210) were normal-like at the very slow speech rate. More, normal comprehension was observed for OVS at the conversational speech rate for seven PWA (209, 210, 217, 223, 227, 235, 240), and at the very slow speech rate for five PWA (210, 217, 227, 235, 240). For OR, six PWA (code numbers 202, 209, 210, 227, 234, 235) had normal-like accuracy rates at the conversational speech rate, while three PWA (208, 209, 210) showed normal accuracy at the very slow rate. Taking this further, two PWA (code numbers 202, 234) at the conversational speech rate, and two PWA (code numbers 208, 209) at the very slow speech rate had a proclaimed normal-like performance at OR with abnormal performance on OVS, while three PWA (code numbers 217, 223, 240) at the conversational speech rate and four PWA (code numbers 217, 227, 235, 240) at the very slow speech rate had normal-like accuracy rates on OVS, but not on OR (see table 9.9 in chapter 9.7.2 and table 10.9 in chapter 10.7.2).

These dissociations between performance accuracy for OVS and OR within the same individual might be difficult to fit within the TDH, because in both structures, antecedents were referential NP, which are assumed to fill positions in Spec/CP (cf. Grodzinsky, 1995), and should thus be equally prone to trace deletion. A syntactic knowledge loss resulting in trace deletion in OVS with preserved comprehension of OR, as seen for four agrammatic participants, or preserved comprehension of OVS compared to trace deletion behaviour in OR for five other agrammatic PWA, might not be explained sufficiently by loss of syntactic knowledge or just a higher number of correct guessing. The finding that a high number of PWA were categorized with the chance performance criterion with within-chance performance does neither fit an assumption of guessing behaviour, but rather indicates failed approaches of general syntactic processing, and not only for antecedent-trace relations. Furthermore, it is not easy to explain the significant positive effect of slower speech on comprehension with a higher correct guessing score within the framework of the TDH. Also, most agrammatic PWA did not reach ceiling comprehension at the canonical items, and even more, mean accuracy of SR at the conversational speech rate was within-chance performance level, a finding, which neither fits the assumptions of a preference of heuristic processing induced by syntactic knowledge loss. Alternatively, this finding could be interpreted in as such that the majority of the tested PWA tried to parse the sentences syntactically.

While the offline results of this study cannot falsify the assumption of an impaired syntactic representation, these observations still indicate that traces might not have been deleted, as postulated by the TDH, in a number of the agrammatic PWA. Also, with regard to the degree of complexity, a pattern of comprehension of OR with impaired comprehension of OVS, seen by four agrammatic PWA, seems rather astonishing, regarding the higher degree of processing load assumed in OR compared to OVS.

The dissociations between comprehension accuracy on OVS and OR within the agrammatic group for some individuals, plus the positive effect of slower speech on comprehension, could be regarded as tentative evidence for the intermittent deficiency hypothesis by the Potsdam group and other researchers (e.g., Burchert *et al.*, 2013; Hanne *et al.*, 2011, see also Caplan *et al.*, 2007; Patil *et al.*, 2015), which suggest that (morpho)syntactic parsing might be impaired by intermittently deficient linguistic operations, leaving PWA to rely more on non-syntactic, heuristic strategies during the time of insufficiency. This assumption would not only help to explain the low accuracy rates on both SVO and SR, but also the divergent pattern of impaired and normal-like performance across conditions and speech rates within the same agrammatic individual.

The dissociations found in this study also suggest that the assumed intermittent deficiencies might have occurred within very short time spans, e.g., from stimulus to stimulus within the same block of presentation (all of which contained all four sentence types in a pseudorandomized order). Evidence for this rapid change in processing reductions comes from studies, which have found that PWA may display a “moment-to moment variability” (Petroi, 2011, p. 4), which may show as inconsistent performance within the same linguistic task (e.g., Hula & McNeil, 2008 (on general aphasia); McNeil & Pratt, 2001 (on general aphasia)); Petroi, 2011 (on Broca’s aphasia); Tseng *et al.*, 1993 (on general aphasia)). Insufficient attentional allocation has been suggested to be at least partly responsible for the impaired resolution of conflicts induced by a competition between two possible analyses, e.g., two competing syntactic representations (Hula & McNeil, 2008; McNeil *et al.*, 1991). The proposed intermittent deficiencies might also result from a -temporary- lack of cognitive control, in as such that PWA may not have the flexibility and/or inhibitory control to change their analysis (e.g., Glosser & Goodglass, 1990; Purdy, 2002). Cognitive capacity is regarded to be also dependent on vigilance, and reduced vigilance in terms of effort and fatigue seem to be very common problem in aphasia (e.g., Christensen, 2012; Christensen & Wright, 2014; McNeil *et al.*, 1991), which might also affect auditory sentence processing. Additionally, insufficient cognitive capacities might be even more reduced by slowed-down processing speed, which has been seen to impact on cognitive abilities (Arlinger *et al.*, 2009; McCoy *et al.*, 2005; Obleser *et al.*, 2012). What is more, reduction of processing resources might also follow from temporary insufficiencies of already reduced cognitive abilities and/or capacities in aphasia.

Intermittent deficiencies have been suggested to be caused by reductions in processing capacities, which in turn might be effected by reductions in the speed of lexical activation (Haarmann & Kolk, 1991) or by the speed of syntactic presentation activation respectively by an increase in the speed of decay for traces (Caplan *et al.*, 2007). The findings of this study rather fit the hypothesis of reductions in syntactic processing speed than in lexical activation speed, otherwise a facilitating effect of slower speech should have been found also for comprehension of SVO and OVS. Presence of intermittent reductions of syntactic abilities would enable to account for the observation why also in canonical sentences accuracy was far from ceiling for most agrammatic (and also non-agrammatic) PWA in this study: Potential intermittent deficiencies could have prevented them from processing SVO and SR syntactically and as a consequence left them to rely on a heuristic strategy *after* the failed syntactic approach (cf. Hanne *et al*., 2011). A late application of an agent-first strategy on the other hand might have led to guessing because information of lexical and/or morphosyntactic information could have been decayed (Patil *et al.*, 2015), which would explain the lower accuracy on SR compared to SVO, because SR contained more syntactic and/or thematic information than SVO.

On account of the offline character, the results of this study cannot contradict the postulations of the TDH for the V2 data. Still, the findings that comprehension accuracy on SVO was considerably low for agrammatic PWA compared to those of the NBD, speaks against a reliance on an agent-first strategy, but rather indicates a syntactic processing approach. Lower accuracy or longer response times (compared to those of unimpaired controls) on subject-first sentences (e.g., SVO, branching SR or centre-embedded SR) for agrammatic and other PWA were also noted in most other studies on agrammatic sentence processing (e.g., Burchert *et al*., 2003; Dickey *et al*., 2007; Love *et al*., 2008; Meyer *et al*., 2012; Sheppard *et al*., 2015), and recent German studies (e.g., Adelt *et al*., 2017; Hanne *et al*., 2011, 2015; Schumacher *et al*., 2017), also observed aphasic eye movement patterns reflecting syntactic processing of subject-first structures.

The positive effect of slower speech on RC comprehensions tentatively conforms to the assumption of the Slowed Processing Account. Individual dissociations of performance between OVS and OR and/or between the different speech rates might hint that for many of the 15 tested agrammatic PWA, syntactic knowledge was not impaired per se, but that the timing between intact processing and sentence presentation was disturbed. For some PWA (were dissociations between accuracy on SVO and OVS were found), the degree of this timing deficit may have been temporarily raised either by temporary reduction in processing resources (Caplan *et al.*, 2007), or more specifically by intermittently deficient linguistic operations, leading to misinterpretations. Those temporal shortcomings might have affected morphosyntactic cue integration and/or revision or reanalysis of initial incorrect interpretations (Burchert *et al.*, 2003; Hanne *et al.*, 2011), and left those agrammatic PWA to rely more on heuristic strategies or on guessing during the period of distortion. For other PWA, the degree of the slower-than normal processing might have been so high that it disturbed general sentence processing, and suggested intermittent deficiencies might have also affected processing of canonical sentences.

11.1.3 The problems with group studies

While a number of studies carefully controlled for syntactic comprehension performance of their agrammatic PWA prior to selection, (e.g., Hanne *et al.*, 2011, 2015; Sheppard *et al*, 2015), in this research, all PWA wanting to participate were tested, because canonicity effects have been seen not to be restricted to agrammatic aphasia (cf. Bates *et al.*, 1987; Caramazza *et al.*, 1981). While this finding was confirmed in my research, it also led to a high variability with regard to syndromes, symptoms, state of aphasia, duration of aphasia, hearing level, and age. This high inter- as well as intra-group variability (for the agrammatic, paragrammatic, and anomic sub groups) resulted into a high degree of variance within performance, as seen in the random slopes of the analyses, and might have led to extinctions of significance effects of certain variables, such as speech rate.

Intra-group variance has been noted in many studies, which might be at least partially associated with the *severity* degree of the aphasia. Severity of a receptive impairment has been shown to play an important role in sentence comprehension abilities (cf. Caplan, Baker, & Dehaut, 1985; Dick *et al.*, 2001; Ingram, 2007; Miyake *et al.*, 1994). Caramazza, Capitani, Rey, & Berndt (2001) also demonstrated that agrammatic sentence comprehension does not seem to follow a single and consistent pattern. This variability has not only led some researchers to look for different patterns of performances within the group and even within individual data, an analysis, which I followed, but also to associate Broca's aphasia with different patterns of comprehension performance (e.g., Burchert *et al.*, 2003; Caramazza *et al.*, 2001). Different patterns might be induced by presence or absence of cognitive deficiencies, as well as by age and hearing status. Within the Slowed Processing Hypothesis, cognitive deficits such as reduced working memory capacity and/or pathologically slowed-down processing speed are considered to be at least partly responsible for comprehension difficulties. Not only the number but also the degree of one or more cognitive impairments has been suggested to determine the degree of the agrammatic comprehension deficit (e.g., Caplan *et al.*, 2007), as well as age-related and hearing-loss induced deficiencies (e.g., Boehme, 1984). Also, in recent years, the supporters of the representational account have acknowledged the relevance of cognitive dysfunctions on language processing impairments (e.g., Grodzinsky, 2006; Grodzinsky & Santi, 2008).

11.2 The effect of hearing impairment on comprehension in aphasia

The second research question predicted a higher canonicity effect in hearing-impaired PWA caused by the extra perceptual processing load induced by sensory deficits, and therefore predicted also an increased effect of slower speech. Contrary to that, the 12 hearing-impaired PWA had a higher degree of accuracy on OVS and OR than the normal-hearing PWA, while comprehension accuracy on SVO and SR was lower than that for the normal-hearing group. Described in the interim discussions, the two subgroups were not matched with respect to age, education, severity of aphasia (seen in a comparison of error scores on the Token Test), and type of aphasia: Except for two PWA, all agrammatic PWA belonged to the normal-hearing group, which might have confounded results. Of the remaining10 hearing-impaired PWA, seven PWA presented with a predominantly anomic and three PWA with a paragrammatic deficit. What is more, the five hearing-impaired PWA with regular use of their hearing aid might have had improved perceptual abilities due former audiometric auditory training (cf. Uslar, 2014) compared to the normal-hearing PWA, which could have enabled them to perceive morphosyntactic cues to a higher degree than the normal-hearing PWA, who might have paid more attention to the open-class elements of the sentence.

Not seen in the statistical analyses is the finding that of the 10 PWA who were excluded because of insufficient comprehension of SVO items or instructions, six were bilaterally hearing-impaired, and two had a unilateral impairment (see table 13.1 in the appendix). This outcome was rather striking, and a potential influence of hearing loss on their auditory comprehension performance cannot be ruled out. Not comprehending SVO might imply that their perception was too inadequate in order to understand the nouns and the verb, and thus to apply a heuristic strategy. This might be at least partly induced by insufficient sensory abilities: None of those participants was fitted with a hearing aid, which might have improved at least a proportion of their performance on subject-first structures by ameliorating at least spectral abilities. Furthermore, all hearing-impaired excluded PWA were older than 60 years, which might indicate that the combination of hearing impairment and age could be at least partly responsible for affected speech or spoken sentence comprehension in aphasia. However, this is only speculation, and does not answer the findings that hearing-impaired PWA in this study behaved different to the hypothesis.

Nevertheless, the percentage of hearing-impaired PWA in this study summed up to 40% (20 out of 50), and was higher than the percentage for the non-brain-damaged population, which was assessed maximally with 26.8% (Stackelberg, 1986; see chapter 5.1.1). Moreover, the percentage of hearing-impaired PWA above the age of 60 was with 55% (11 out of 20) also higher than that for the older non-brain-damaged population in Germany, estimated at 28.5 % (Hougaard & Ruf, 2011) up to 40%-45% (Heger & Holube, 2010). 2013). This finding agrees with those of other studies observing a higher incidence of hearing loss in the aphasic population (e.g., Läßig *et al.*, 2013; Rankin *et al.*, 2014). For many PWA, i.e., 12, their hearing loss came as a surprise, which also fits with findings from the literature showing that hearing loss may go undetected in aphasia because of misinterpreting sensory problems with aphasic symptoms (cf. Rankin *et al.*, 2014), and/or due to the sloping progress in presbyacusis (Läßig *et al.*, 2013). For the PWA with no prior knowledge of hearing loss, participation in this study was beneficial, because their hearing loss was identified, and most of them were referred to an ear specialist to receive audiological care. Moreover, relatives and therapists were informed and could adjust their communication or therapy.

11.2 Slower speech does not improve non-canonical sentence comprehension in hearing-impaired non-brain-damaged adults

The third hypothesis considered the impact of slowed-down perceptual processing effected by hearing loss, which was assumed to lead to delayed processing with the risk of neglect of morphosyntactic elements affecting specifically the interpretation of non-canonical sentences. An expanded presentation time was supposed to compensate for the assumed timing deficit.

Slower speech had an effect on comprehension of the embedded relative-clause, but the degree of improvement was higher for the normal-hearing NBD compared to the hearing-impaired NBD. Looking at accuracy scores, both normal-hearing and hearing-impaired NBD had rates above 90% for both OVS and OR in the conversational rates, leaving not much space for improvement through slower speech. The close-to-ceiling performance (when compared to those of the young control group) might be at least partially explained through the acoustic situation the participants were placed in. All participants were seated in a quiet room, and auditory stimuli were presented via headphones. For the hearing-impaired listeners, sentence stimuli were modified in order to compensate for their hearing loss. The absence of time pressure on responses and the presence of self-paced pauses between the experimental presentation blocks prevented potential effects of effort. Also, the absence of background noise ensured that no proportion of the speech signal was masked. These acoustically optimal conditions might have provided NBD with sufficient information to perceive case and/or agreement features, especially those of the hypothesized less salient ones of the RC sentences. Probably due to these reasons, I could not find a convincing facilitating effect of slow speech on non-canonical sentence comprehension in hearing-impaired non-aphasic adults. These findings are similar to those of Adams & Moore (2009) and Vaughan *et al*. (2002) who neither found clear evidence for benefits of slow speech on auditory sentence comprehension in quite surroundings.

11.3.1 The impact of high frequencies

There was a striking difference between the PTA-4 and the PTA-6 analyses for comprehension of centre-embedded relative clause performance. While hearing level measured by PTA-4 only resulted in an age effect, the addition of a lower and a higher frequency value comprising the whole speech spectrum did not only lead to the same age effect, but also displayed that hearing impairment affected general comprehension negatively. More, hearing loss measured with six frequencies also reflected the tendency of affected comprehension of non-canonical OR. These differences, arising from different hearing level values, were not seen for NBDs performance on V2 sentences, and neither for the PWA in all analyses. Already discussed in chapter 10.7.5, this effect was assumed to be caused by a lesser perceptual saliency of the relative pronoun, and/or the agreement features in order to differentiate between nominative and accusative case, and/or between singular and plural agreement, making it difficult for hearing-impaired NBD to perceive them. Alternatively, it was suggested that due to a higher perceptual processing load, assumed to result in slowed down processing, hearing-impaired ND might have not always recognized the reversed word order.

High-frequency loss has been seen to affect speech perception, as described in chapter 5.1.4, in particular for POA (place of articulation). POA was not an issue for perception and comprehension of the relative pronoun and determiner, because the only perceptual difference between SR and OR were the vowels (and the presence of nasality in the OR pronoun) between “der” and “den”. This difference of nasality also appears in the V2 items for the determiners, but for these items, no hearing effect was found, so impaired perception and/or discrimination might not be held responsible for the canonicity effect found for the RC items. In contrast, there was a difference between the singular agreement feature [t] and the plural agreement feature [Ṇ][49]: Both features did not only differ in manner, but also in place of articulation. Due to their final syllable positions, these fine differences are normally not accentuated and thus articulated with a lower volume. This could be the reason why the NBD with a high-frequency hearing loss might have not been able to discriminate between them, and interpreted a non-canonical OR item occasionally as a canonical SR. Following this line, PTA-6 assessment thus seems to detect subtle perceptual deficits, which may cause impairments perceiving non-accentuated morphosyntactic features, and consecutively result in canonicity effects, in particular for unpredictable and/or low-context sentences.

Canonicity effects for branching or centre-embedded OR were also found in other research (Stewart & Wingfield, 2009; Wingfield *et al.*, 2006, Wendt *et al*, 2015), so the result

[49]Note that in German, inflections of the morphological form /-en/ are pronounced as without the /e/, as the nasal nuclearizes the weak vowel.

of this study, even when it was only a marginal effect, gives further evidence to the assumption that hearing loss may in particular affect non-canonical sentence comprehension.

Because of this finding, a hearing screening with PTA-6, as proposed by Margolis & Saly (2007), seems to give a better indication of speech perception difficulties in hearing loss, as well as detecting otherwise not recognized high-frequency hearing loss, while not changing the degree of severity: Values on PTA-6 compared to PTA-4 for the better ear for all aphasic and non-brain-damaged participants did not result in different severity degrees according to the EU guidelines (except for one PWA, who was excluded in the later analyses by reason of his inability to understand the test instructions).

11.4 Implications

11.4.1 Implication for aphasia therapy and research

All PWA in this experiment, regardless of main symptom and/or syndrome, had difficulties with non-canonical sentences, even the PWA diagnosed with residual aphasia. This finding is concordant with those in the literature (e.g., Bates & Goodman, 1997; Caramazza *et al.*, 1981; Dick *et al.*, 2001; Wilson & Saygin, 2004), and has implications for speech and language therapy: A German-speaking PWA with amnestic aphasia, whose main symptom is anomia, might not be treated on sentence comprehension deficits, and or specifically trained on morphosyntactic features, because the syntactic problem might not be recognized. The findings from this and other research imply that non-canonical sentence comprehension should be screened in all PWA, regardless of their diagnosis based on the AAT or other tests.

The findings that a considerable number of PWA, as well as some NBD, presented with formerly undetected hearing loss supports the argument that hearing screening should be performed regularly for PWA (and older non-brain-damaged adults), especially because “[…] hearing problems may have a disproportionate effect on individuals with aphasia who rely on sensory input to compensate for some of their language and cognitive difficulties. “(Rankin *et al.*, 2014, p.589). Furthermore, lack of body movement and certain antibiotics has been seen to increase the risk of cerumen: Many acute PWA and stroke patients still in clinics and rehabilitative centres may have a conductive hearing loss produced by blockage of the outer ear. In order to prevent faulty diagnoses in terms of severity or even syndrome/symptom classification (cf. Böhme, 1984), and to provide optimal treatment, a hearing screening and/or a check by an ear specialist seems necessary, and is highly recommended (cf. Läßig *et al.*, 2013). More, even if PWA present only with a unilateral hearing loss, and might still be classified with normal hearing, a hearing aid should be fitted for the worse ear in order to provide PWA with as optimal hearing abilities as possible, in order to prevent hearing loss of the worse ear compromising intelligibility and comprehension.

Last but not least, not only studies on aphasia, but also research focussing on speech perception, auditory word recognition and/or sentence comprehension in non-brain-damaged adults should implement a hearing screening for their participants in order to ensure that sensory deficits may not confound results.

11.4.2 Implications for audiology practice and research

Assessment with PTA-6 has been seen to reveal a more detailed result on effects of hearing loss on auditory sentence comprehension by highlighting the impact of high frequencies on speech perception and comprehension. Therefore, inclusion of high-frequency values into measurements of hearing status for research on effects of hearing loss is highly recommended.

Speech audiometry measures for PWA are recommended to be modified in terms of the response mode. Instead of repetition, a word- or sentence-picture matching task would allow PWA to be assessed with more precise hearing levels. Stimuli from conventional speech audiometry could be presented with one picture asked if it matches the sentence (whereby nouns and verbs of wrong targets should be phonologically controlled to those of the target), in order to gain a first insight into speech hearing levels. Decision based on two pictures might reveal discrimination abilities based on audiometric and/or perceptual criteria. While speech perception tests are similar, changing the speech reception threshhold in speech audiometry tasks would allow to distinguish whether the nature of the deficit is primarily sensory or linguistic, i.e., perceptual or phonetic/phonological, by implementing minimal pair items: If discrimination and/or identification improves with a higher volume, the underlying cause might be a hearing loss rather than a phonetic-phonological impairment, such as deficits in distinguishing VOT or other temporal features. Also, by implementing a slower mode, potential facilitation of slower speech on hearing and perception abilities could be measured, and, if the effect is positive, an algorithm could be implemented into the device, which can lenghthen auditory signals or features of the signal to a certain degree.

11.5 Future research

An online observation of agrammatic sentence processing in slower speech could give more insight on the speculated causes of as well the agrammatic deficit and the facilitating effect of slower speech. By e.g., using the visual world paradigm, shorter eye fixations latencies, faster decision moments, and/or fixations to the target more within the time course of the occurrence of overt morphosyntactic markers, such as seen for non-brain-damaged listeners, might reflect that in German agrammatic and other PWA, the canonicity effect is induced by slower-than normal morphosyntactic processing. So far, only one study by Choy (2012) has investigated the effect of slower speech with the eye-tracking method, but her English items did not contain overt morphosyntactic markers, so lexical or syntactic parsing deficits could not be distinguished from morphosyntactic feature parsing. Also, it would be interesting to investigate the effects of slower speech on non-brain-damaged and aphasic hearing-impaired adults in more detail. While slower speech does not seem to improve already good comprehension of non-canonical sentences in a quiet background in this research, it might improve comprehension in adverse listening situations, thus future research could include studying the effect of prolonged presentation in background noise.

In addition, agrammatic and other aphasic processing of relative pronouns is worth to be studied more extensively. To my knowledge, although many studies in English and also German implemented items containing relative pronouns, the impact of resolving an antecedent-pronoun dependency has not been studied systematically. An investigation could include branching and centre-embedded relative clauses with overtly and covertly case-marked relative pronouns compared to main clauses with the same number of lexical elements.

11.6 Limitations of the study

First, besides the often mentioned heterogeneity of the 37 PWA in terms of diagnosis, severity, state of aphasia, and age, which might have added to weakening the expected effects, there was also a variability of the education level, not being taken into consideration as factor. A higher education level or status, often measured as years of education in studies, may have an impact on (non-canonical sentence) comprehension, by reason of a suggested higher degree of experience with non-canonical sentence structures (cf. Federmeier, McLennan, de Ochoa, & Kutas, 2002; Goral, 2011), e.g., through a higher degree of exposure to written sentences (Payne, Gao, Noh, Anderson, & Stine-Morrow, 2012). While object-first structures in general do not seem to occur often in spoken language (e.g., Bastiaanse, Bouma, & Post, 2009; Dick *et al.*, 2001), and German OVS and OR are rather infrequent when presented without context (Weskott *et al*., 2011), they seem to have a higher frequency in written language (Heyler, 2003; Weber & Müller, 2004). Second, none of the participants was assessed on working memory capacity, attentional abilities and/or processing speed, so effects of potential cognitive deficits could not be related to the results. Third, the research included 15 items per sentence structure, and therefore comparisons between performances on different speech rates might have been confounded by a too low number of items. It is a known fact that test power depends on the number of trials, and that a sufficient number of items lowers the probability of chance performance (cf. Caramazza *et al.*, 2001). However, a higher number of items would have meant a higher number of sessions and a higher risk of training effects. Nevertheless, the increased amount of data of both NBD and PWA, showed significant effects of speech rates compared to the separate analyses with lesser data, indicating that more data helped to out-balance the small number of items.

11.7 Conclusion

This study demonstrated that not only agrammatic but also paragrammatic and anomic PWA were impaired in the comprehension of non-canonical OVS and/or OR. Furthermore, it was shown that slower speech may have a facilitating effect on sentence comprehension, especially for agrammatic PWA's comprehension of centre-embedded relative clauses, presumably induced by improved recognition and/or integration of morphosyntactic agreement features and/or by reduced working memory load. This finding implies that syntactic knowledge of antecedent-trace relations may not be lost in agrammatic aphasia, but rather that processing seems to be slowed down, resulting in a timing deficit between presentation and processing rate, which may impair timely integration of postulated moved objects. While hearing loss did not affect general and non-canonical sentence comprehension in the aphasic group in this study, the potential negative impact of especially high-frequency hearing loss on non-canonical sentence comprehension, seen in the non-brain-damaged group, should not only be considered in aphasia therapy and in aphasia research, but also in research studying the impact on hearing loss on non-brain-damaged auditory sentence comprehension.

12 References

Abel, S. M., Sass-Kortsak, A., & Naugler, J. J. (2000): The role of high-frequency hearing in age-related speech understanding deficits. *Scandinavian Audiology*, 29(3), 131–138.

Ackerman, P. L., Beier, M. E., & Boyle, M. O. (2002). Individual differences in working memory within a nomological network of cognitive and perceptual speed abilities. *Journal of Experimental Psychology-General*, *131*(4), 567–589.

Adams, E. M., Gordon-Hickey, S., Morlas, H., & Moore, R. (2012). Effect of rate-alteration on speech perception in noise in older adults with normal hearing and hearing impairment. *American Journal of Audiology*, 21, 22–32.

Adams, E. M., & Moore, R. E. (2009). Effects of speech rate, background noise, and simulated hearing loss on speech rate judgment and speech intelligibility in young listeners. *Journal of the American Academy of Audiology*, 20(1), 28–39.

Adelt, A., Lassotta, R., Adani, F., Stadie, N., & Burchert, F. (2015). What causes the processing advantage in the comprehension of German object relative clauses? *Frontiers in Psychology Conference Abstract: Academy of Aphasia 53rd Annual Meeting.*

Agrawal, Y., Platz, E. A., & Niparko, J. K. (2008). Prevalence of hearing loss and differences by demographic characteristics among US adults: Data from the national health and nutrition examination survey, 1999–2004. *Archives of Internal Medicine*, 168(14), 1–10.

Akeroyd, M. A. (2008). Are individual differences in speech reception related to individual differences in cognitive ability? A survey of twenty experimental studies with normal and hearing-impaired adults. *International Journal of Audiology*, 47(Suppl. 2), 53–71.

Albert, M. L., & Bear, D. (1957). Time to understand. A case study of word deafness with reference to the role of time in auditory comprehension. *Brain*, 97, 373–384.

Albinet, C. T., Boucard, G., Bouquet, C. A., & Audiffren, M. (2012). Processing speed and executive functions in cognitive aging: How to disentangle their mutual relationship? *Brain and Cognition*, 79, 1–11.

Allen, C. M., Martin, R. C., & Martin, N. (2012). Relations between short-term memory deficits, semantic processing, and executive function. *Aphasiology*, 26(3–4), 428–461.

Altmann, L. J. P., *&* Kemper, S. (2006). Effects of age, animacy and activation order on sentence production. *Language and Cognitive Processes*, 21(1/2/3), 322–354.

Altmann, G. T. M., van Nice, K., Garnham, A., & Henstra, J. A. (1998). Late closure in context. *Journal of Memory and Language*, 38, 459-484.

Anderson, K., & Matkin, N. (2007). *Relationship of degree of long term hearing loss to psychosocial impact and educational needs*. Educational Audiology Association. www.successforkidswithhearingloss.com

Anderson, S. R. (1993), Wackernagel's revenge: Clitics, morphology, and the syntax of second position. *Language* 69. 68-95.

Andersson, U., & Lyxell, B. (1998). Phonological deterioration in adults with an acquired severe hearing impairment. *Scandinavian Audiology*, *27*(4), 93–100.

Angwin, A. J., Chenery, H. J., Copland, D. A., Cardell, E. A., Murdoch, B. E., & Ingram, J. C. L. (2006). Searching for the trace: The influence of age, lexical activation and working memory on sentence processing. *Journal of Psycholinguistic Research*, 35(1), 101–117.

Arlinger, S., Lunner, T., Lyxell, B., & Pichora-Fuller, M. (2009). The emergence of Cognitive Hearing Science. *Scandinavian Journal of Psychology*, 50, 371–384.

Arlinger, S. (2003). Negative consequences of uncorrected hearing loss-a review. *International Journal of Audiology*, 42, 2 S17–2 S20.

Awh, E., Vogel, E. K., & Oh, S.-H. (2006). Interactions between attention and working memory. *Neuroscience*, *139*, 201–206.

Aydelott, J., Leech, R., & Crinion, J. (2011). Normal adult aging and the contextual influences affecting speech and meaningful sound perception. *Trends in Amplification*, 14(4), 218–232.

Baddeley, A.D. (2003). Working memory and language: An overview. *Journal of Communication Disorders*, 36, 189–208.

Baddeley, A.D. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences*, 4(11), 417–423.

Bader, M., & Häussler, J. (2010). Word order in German: A corpus study. *Lingua*, 120, 717–762.

Bader, M., & Bayer, J. (2006). Case and linking in language comprehension: Evidence from German. Berlin: Springer.

Bader, M., *&* Frazier, L. (2005). Interpretation of leftward-moved constituents: Processing topicalizations in German. *Linguistics*, 43(1), 49–87.

Bader, M, Meng, M., & Bayer, J. (2000). Case and reanalysis 1. *Journal of Psycholinguistic Research*, 29(1), 37–52.

Barker-Collo, S., Feigin, V. L., Parag, V., Lawes, C. M. M., & Senior, H. (2010). Auckland Stroke Outcomes Study. Part 2: Cognition and functional outcomes 5 years poststroke. *Neurology 75*(18), 1608–1616.

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, 68(3), 255–278.

Bastiaanse, R., Bouma, G., & Post, W. (2009). Linguistic complexity and frequency in agrammatic speech production. *Brain and Language*, 109, 18–28.

Bastiaanse, R., & van Zonneveld, R. (2006). Comprehension of passives in Broca's aphasia. *Brain and Language*, 96, 135–142.

Bastiaanse, R., Jonkers, R., Ruigendijk, E., & van Zonneveld, R. (2003). Gender and case in agrammatic production. *Cortex*, 39(3), 405–417.

Bastiaanse, R. (1995). Broca’s aphasia: A syntactic and/or morphological disorder? A case study. *Brain and Language*, 48, 1–32.

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2014). *lme4: Linear mixed-effects models using Eigen and S4*. R package version 1.1–7. http://CRAN.R–project.org/package=lme4

Bates, E., & Goodman, E. B. J. C. (1997). On the inseparability of grammar and the lexicon: Evidence from acquisition, aphasia and real-time processing. *Language and Cognitive Processes*, *12*(5–6), 507–584.

Bates, E., Wulfeck, B., & MacWhinney, B. (1991): Cross-linguistic research in aphasia: An overview. *Brain and Language*, 41, 123–148.

Bates, E., Friederici, A., & Wulfeck, B. (1987). Comprehension in aphasia: A cross-linguistic study. *Brain and Language*, 32, 19–67.

Bates, E., Friederici, A., & Wulfeck, B. (1987a). Grammatical morphology in aphasia: Evidence from three languages. *Cortex*, 23, 545–574.

Bates, E., McNew, S., MacWhinney, B., Devescovi, A., & Smith, S. (1982). Functional constraints on sentence processing: A cross-linguistic study. *Cognition, 11*, 245–299.

Bayer, J. (2008). *What is verb second?* Manuscript, University of Konstanz.

Bayer, J., de Bleser, R., & Dronsek, C. (1987). Form und Funktion von Kasus bei Agrammatismus. *Linguistische Berichte/Sonderheft*, 1, 81–117.

Baudouin, A., Clarys, D., Vanneste, S., & Isingrini, M. (2009). Executive functioning and processing speed in age-related differences in memory: Contribution of a coding task. *Brain and Cognition,* 71, 240–245.

Baum, S. R. (2001). Contextual influences on phonetic identification in aphasia: The effects of speaking rate and semantic bias. *Brain and Language, 76*, 266–281.

Baum, S. R. (1996). The processing of morphology and syntax in aphasia: A test of the fast decay and slow activation hypothesis. *Aphasiology*, 10(8), 783–800.

Becker, F., & Reinvang, I. (2007). Successful syllable detection in aphasia despite processing impairments as revealed by event–related potentials. *Behavioral and Brain Functions*, 3(6), 1–16.

Benichov, J., Clarke Cox, L., Tun, P. A., & Wingfield, A. (2012). Word recognition within a linguistic context: Effects of age, hearing acuity, verbal ability and cognitive function. *Ear and Hearing,* 32(2), 250–256.

Berndt, R. S., Mitchum, C. C., & Haedinges, A. N. (1996). Comprehension of reversible sentences in ‘‘agrammatism’’: A meta-analysis. *Cognition*, 58, 289–308.

Berndt, R., & Caramazza, A. 1980. A redefinition of the syndrome of Broca’s aphasia: Implications for a neuropsychological model of language. *Applied Psycholinguistics*, 1, 225–278.

Blackburn, H. L., & Benton, A. L. (1955). Simple and choice reaction time in cerebral disease. *Confinia Neurologica, 15, 321–338.*

Blanchard, S. L., & Prescott, T. E. (1983). The effects of temporal expansion upon auditory comprehension in aphasic adults. *British Journal of Disorders of Communication*, 15(2), 115–127.

Blumstein, S. E., Burton, M., Baum, S., Waldstein, R., & Katz, D. (1994). The role of lexical status on the phonetic categorization of speech in aphasia. *Brain and Language*, 46, 181–197.

Blumstein, S. E., Katz, B., Goodglass, H., Shrier, R., & Dworetsky, B. (1985). The effects of slowed speech on auditory comprehension in aphasia. *Brain and Language*, 24, 246–265.

Blumstein, S. E.; Baker, E.; & Goodglass, H. (1977). Phonological factors in auditory comprehension in aphasia. *Neuropsychologia*, 15, 19–30.

Böhme, G. (1984). Aphasie: Ursachen, Altersverteilung und Hörfunktion. *Laryngo-Rhino-Otology*, 63, 79–81.

Boersma, P., & Weenink, D. (2014). *Praat: Doing phonetics by computer* [Computer program]. Version 5.3.62, retrieved 2 January 2013 from http://www.praat.org

Boothroyd, A., & Nittrouer, S. (1988). Mathematical treatment of context effects in phoneme and word recognition. *Journal of the Acoustic Society of America*, 84(1), 101–114.

Bornkessel-Schlesewsky, I., & Schlesewsky, M. (2013). Reconciling time, space and function: A new dorsal-ventral stream model of sentence comprehension. *Brain and Language*, 125(1), 60–76.

Bornkessel-Schlesewsky, I., & Schlesewsky, M. (2009). The role of prominence information in the real time comprehension of transitive constructions: A cross-linguistic approach. *Language and Linguistics Compass*, *3*, 19–58.

Bornkessel, I., & Schlesewsky, M. (2006). The Extended Argument Dependency Model: A neurocognitive approach to sentence comprehension across languages. *Psychological Review,* 113(4), 787–821.

Bornkessel, I., Zysset, S., Friederici, A. D., von Cramon, Y. D., & Schlesewsky, M. (2005). Who did what to whom? The neural basis of argument hierarchies during language comprehension. *NeuroImage*, 26, 221–233.

Bornkessel, I., Schlesewsky, M. & Friederici, A. D. (2003). Eliciting thematic reanalysis effects: The role of syntax-independent information during parsing. *Language and Cognitive Processes* 18(3), 269-298.

Bornkessel, I., Schlesewsky, M., & Friederici, A. D. (2002). Grammar overrides frequency: Evidence from the online processing of flexible word order. *Cognition* 85, B21–B30.

Bosman, A. J., & Smoorenburg, G. F. (1995). Intelligibility of Dutch CVC syllables and sentences for listeners with normal hearing and with three types of hearing impairment. *International Journal of Audiology*, *34*(5), 260–284.

Boyzcuk, J. P., & Baum, S. R. (1999). The influence of neighborhood density on phonetic categorization in aphasia. *Brain and Language,* 67, 46–70.

Brand, T., Uslar, V., Wendt, D., & Kollmeier, B. (2012). Recognition rate and linguistic processing: Do we need new measures of speech perception? In T. Dau, M. L. Jespen, T. Paulsen, & J. C. Dalsgaard, (Eds.), *Speech perception and auditory disorders* (pp. 45–56). Proceedings of the 3rd International symposium on Auditory and Audiological Research (ISAAR).

Breitenstein, C., Grewe, T., Flöel, A., Ziegler, W., Springer, L., Martus, W., & Baumgärtner, A. (2014). Wie wirksam ist intensive Aphasietherapie unter regulären klinischen Bedingungen? Die deutschlandweite Aphasieversorgungsstudie FCET2EC. *Sprache, Stimme, Gehör*, 38, 14–19.

Britz, J. (2006). Electrophysiological insights into timing aspects of discourse processing in aphasic patients. Doctoral dissertation, Universität Konstanz.

Brookshire, R. H., & Nicholas, L. E. (1986). Consistency of effects of rate of speech on brain–damaged adults 'comprehension of information in narrative discourse. *Journal of Speech and Hearing Research,* 29, 462–470.

Bugaiska, A., Clarys, D., Jarry, C., Taconnat, L., Tapia, G., Vanneste, S., & Isingrini, M. (2007). The effect of aging in recollective experience: The processing speed and executive functioning hypothesis. *Consciousness and Cognition,* 16, 797–808.

Bungert, P. (2004). Zentralnervöse Verarbeitung akustischer Informationen. Signalidentifikation, Signallateralisation und zeitgebundene Informationsverarbeitung bei Patienten mit erworbenen Hirnschädigungen. Leipzig: Max Planck Insitute for Human Cognitive and Brain Sciences.

Burchert, F., Hanne, S., & Vasishth, S. (2013). Sentence comprehension disorders in aphasia: The concept of chance performance revisited. *Aphasiology*, 27(1), 112–125.

Burchert, F., Swoboda-Moll, M., & de Bleser, R. (2005). Tense and agreement dissociations in German agrammatic speakers: Underspecification vs. hierarchy. *Brain and Language,* 94, 188–199.

Burchert, F., & de Bleser, R. (2004). Passives in agrammatic sentence comprehension. A German study. *Aphasiology,* 18(1), 29–45.

Burchert, F., de Bleser, R., & Sonntag, K. (2003). Does morphology make the difference? Agrammatic sentence comprehension in German. *Brain and Language*, 87, 323–342.

Burchert, F., Friedmann, N., & de Bleser, R. (2003a). Morphology does not help comprehension in agrammatism: A study of German and Hebrew. *Brain and Language,* 87, 52.

Burkhardt, P., Avrutin, S., Piñango, M. M., & Ruigendijk, E. (2008). Slower-than-normal syntactic processing in Broca's aphasia: Evidence from Dutch. *Journal of Neurolinguistics* 21, 120–137.

Burkhardt, P., Piñango, M. M., & Wong, K. (2003). The role of the anterior left hemisphere in real-time sentence comprehension: Evidence from split intransitivity. *Brain and Language,* 86(1), 9–22.

Byrne, D., & Dillon, H. (1986). The National Acoustic Laboratories' (NAL) new procedure for selecting the gain and frequency response of a hearing aid. *Ear and Hearing* 7, 257– 265.

Caplan, D., Michaud, J., & Hufford, R. (2013). Dissociations and associations of performance in syntactic comprehension in aphasia and their implications for the nature of aphasic deficits. *Brain and language, 127*(1), 21-33.

Caplan, D., & Waters, G. (2013). Memory mechanisms supporting syntactic comprehension. *Psychonomic Bulletin & Review*, 20, 243–26.

Caplan, D., DeDe, G., Waters, G. S., Michaud, J., & Tripodis, Y. (2011). Effects of age, speed of processing, and working memory on comprehension of sentences with relative clauses. *Psychology and Aging* 26(2), 439–450.

Caplan, D., Waters, G. S., DeDe, G., Michaud, J., & Reddy, A. (2007). A study of syntactic processing in aphasia I: Behavioral (psycholinguistic) aspects. *Brain and Language,* 91, 64–65.

Caplan, D., Waters, G. S., & Alpert, N. (2003). Effects of age and speed of processing on rCBF correlates of syntactic processing in sentence comprehension. *Human Brain Mapping,* 19, 112–131.

Caplan, D. (2001). The measurement of chance performance in aphasia, with specific reference to the comprehension of semantically reversible passive sentences: A note on issues raised by Caramazza, Capitani, Rey, and Berndt (2001) and Drai, Grodzinsky, and Zurif (2001). *Brain and Language,* 76, 193–201.

Caplan, D., & Waters, G. (1999). Verbal working memory and sentence comprehension. *Brain Behavioral Sciences,* 22, 77–126.

Caplan, D., Alpert, N., & Waters, G. (1998). Effects of syntactic structure and propositional number on patterns of regional cerebral blood flow. *Journal of Cognitive Neuroscience*, *10*(4), 541–-552.

Caplan, D., & Aydelott-Utman, J. (1994). Selective acoustic-phonetic impairment and lexical access in an aphasic patient. *Journal of the Acoustical Society of America,* 95, 512–517.

Caplan, D., Baker, C., & Dehaut, F. (1985). Syntactic determinants of sentence comprehension in aphasia. *Cognition,* 21, 117–175.

Caramazza, A., Capasso, R., Capitani, E., & Miceli, G. (2005). Patterns of comprehension performance in agrammatic Broca's aphasia: A test of the Trace Deletion Hypothesis. *Brain and Language,* 94, 43–53.

Caramazza, A., Capitani, E., Rey, A., & Berndt, R. S. (2001). Agrammatic Brocas's aphasia is not associated with a single pattern of comprehension performance. *Brain and Language*, 76, 158–184.

Caramazza, A., Berndt, R. S., Basili, A. G., & Keller, J. J. (1981). Syntactic processing deficits in aphasia. *Cortex*, 17, 333–348.

Carroll, R. (2013). Effects of syntactic complexity and prosody on sentence processing and comprehension in noise. Aachen: Shaker.

Carroll, R., & Ruigendijk, E. (2013). The effects of syntactic complexity on processing sentences in noise. *Journal of Psycholinguistic Research, 42(2),* 139–159.

Caspari, I., Parkinson, S. R., LaPointe, L. L., & Katz, R. C. (1998). Working memory and aphasia. *Brain and Cognition,* 37, 205–223.

Cervera, T. C., Soler, M.J., Dasi, C., & Ruiz, J. C. (2009). Speech recognition and working memory capacity in young-elderly listeners: Effects of hearing sensitivity. *Canadian Journal of Experimental Psychology,* 63(3), 216–226.

Chomsky, N. (1982). Some concepts and consequences of the theory of government and binding (Vol. 6). MIT Press.

Chomsky, N. (1977) On Wh-movement. In P.W. Culicover, T. Wasw, & A. Akmajian, (Eds.), *Formal syntax.* San Francisco, London: Academic Press.

Choy, J. J. (2012). Effects of lexical processing deficits on sentence comprehension in agrammatic Broca's aphasia. Ann Arbor: Proquest.

Choy, J. J., & Thompson, C. (2010). How lexical processing deficits affect sentence comprehension in agrammatic Broca's aphasia. *Procedia Social and Behavioral Sciences,* 6, 198–199.

Christensen, S.C., & Wright, H. H. (2014). Quantifying the effort individuals with aphasia invest in working memory tasks through heart rate variability. *American Journal of Speech–Language Pathology,* 23, supplement, S361–S371.

Christensen, S. C. (2012). Working memory in adults with aphasia: Considering effort invested to verbal and spatial tasks through a physiological measure-heart rate variability. Doctoral dissertation. Arizona State University.

Clahsen, H., & Ali, M. (2009). Formal features in aphasia: Tense, agreement, and mood in English agrammatism. *Journal of Neurolinguistics,* 22, 436–450.

Clahsen, H., & Felser, C. (1995). Continuity and shallow structures in language processing: A reply to our commentators. *Applied Psycholinguistics, 27*, 107-126.

Clifton, C., & Frazier, L. (1989). Comprehending sentences with long-distance dependencies. In G. N. Carlson & M. K. Tanenhaus (Eds.), *Linguistic structure in language processing* (pp. 273–317). Dordrecht: Kluwer Academic Publishers.

Cooper, J. C., & Gates, G. A. (1991). Hearing in the elderly- The Framingham Cohort, 1983-1985: Part II. Prevalence of central auditory processing disorders. *Ear and Hearing,* 12(5), 304–311.

Cumming, T. B., Marshall, R. S, & Lazar, R. M. (2013). Stroke, cognitive deficits, and rehabilitation: still an incomplete picture. *International Journal of Stroke*; 8, 38–45.
Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of verbal learning and verbal behavior*, *19*(4), 450–466.
Davis, A., Smith, P., Ferguson, M., Stephens, D., & Gianopoulos, I. (2007). Acceptability, benefit and costs of early screening for hearing disability: A study of potential screening tests and models. *Health Technology Assessment*, 11(42), 1–293.
Davis, J. M., Elfenbein, J., Schum, R., & Bentler, R. A. (1986). Effects of mild and moderate hearing impairments on language, educational, and psychosocial behavior of children. *Journal of speech and hearing disorders*, *51*(1), 53–62.
Davis, A. C. (1995). *Hearing in Adults*. London: Whurr.
Davis, A. C. (1989). The prevalence of hearing impairment and reported hearing disability among adults in Great Britain. *International Journal of Epidemiology*, *18*(4), 911–917.
Davis, G. A., & Ball, H. E. (1989). Effects of age on comprehension of complex sentences in adulthood. *Journal of Speech and Hearing Research*, *32*, 143–150.
de Bleser, R., Burchert, F., & Rausch, P. (2005). Breakdown at the morphological level in agrammatism. *Stem-, Spraak- en Taalpathologie*, 13(1), 37–48.
De Renzi, E., & Vignolo, L. A. (1962). The Token Test: A sensitive test to detect receptive disturbances in aphasics *Brain 85, 556–678.*
Dick, F., Bates, E., Wulfeck, B., Utman, J., Dronkers, N., & Gernsbacher, M. (2001) Language deficits, localization and grammar: Evidence for a distributed model of language breakdown in aphasics and normals. *Psychological Review*, 108, 759–788.
Dickey, M. W., & Thompson, C. K. (2009). Automatic processing of wh-and NP-movement in agrammatic aphasia: Evidence from eyetracking. *Journal of Neurolinguistics,* 22(6), 563–583.
Dickey, M. W., Choy, J. J., & Thompson, C. K. (2007). Real-time comprehension of wh-movement in aphasia: Evidence from eyetracking while listening. *Brain and Language*, 100(1), 1–22.
Dickey, M. W., &Thompson, C. K. (2004). The resolution and recovery of filler-gap dependencies in aphasia: Evidence from on-line anomaly detection. *Brain and Language*, 88, 108–127.
Digiovanni, J. J., & Stover, A. K. (2008). The role of consonant duration and amplitude processing on speech intelligibility in noise. *Proceedings of Meetings on Acoustics,* 4, 1–5.
Dobie, R. A. (2001). Medical-legal evaluation of hearing loss. *Ear and Hearing*, *22*(6), 548.
Dorman, M. F., Marton, K., & Hannley, M.T. (1984). Phoneme identification by elderly normal and hearing impaired listeners. *Journal of the Acoustic Society of America*, 77(2), 664–670.
Dowty, D. (1991). Thematic proto-roles and argument selection. *Language*, 67(3), 547–619.
Drai, D., & Grodzinsky, Y. (2006). A new empirical angle on the variability debate: Quantitative neurosyntactic analyses of a large data set from Broca’s Aphasia. *Brain & Language*, 76(2), 117–128.
Drai, D., & Grodzinsky, Y. (1999). Syntactic regularity in Broca's aphasia: there's more of it than you ever imagined. *Brain & Language,* 70, 139–143.
Dreschler, W. A., & Plomp, R. (1985). Relations between psychophysical data and speech perception for hearing-impaired subjects. II. *The Journal of the Acoustical Society of America*, *78*(4), 1261–1270.
Dubno, J. R., Dirks, D. D., & Schaefer, A. B. (1989). Stop-consonant recognition for normal-hearing listeners and listeners with high-frequency hearing loss. II: Articulation index predictions. *The Journal of the Acoustical Society of America*, *85*(1), 355–364.
Dubno, J. R., Dirks, D., & Morgan, D. (1984). Effects of age and mild hearing loss on speech recognition in noise. *Journal of the Acoustical Society of America*, *76(1),* 87–96.
Erickson, R. J., Goldinger, S. D., & LaPointe, L. L. (1996). Auditory vigilance in aphasic individuals: Detecting nonlinguistic stimuli with full or divided attention. *Brain & Cognition*, 30, 244–253.
Fallon, M. Peelle, J. E., & Wingfield, A. (2006). Spoken sentence processing in young and older adults modulated by task demands: Evidence from self-paced listening. *Journal of Gerontology*: *Psychological Sciences*, 61B, (1), P10–P17.
Fanselow, G., & Lenertova, D. (2011). Left peripheral focus: Mismatches between syntax and information structure. *Natural Language & Linguistic Theory,* 29, 169–209.
Federmeier, K, D., McClennan, B. D., De Ochoa, E., & Kutas, M. (2002). The impact of semantic memory organization and sentence context information on spoken language processing by younger and older adults: An ERP study. *Psychophysiology,* 39, 133–146.
Feier, C. D., & Gerstman, L. J. (1980). Sentence comprehension abilities throughout the adult life span. *Journal of Gerontology, 35*, 722–728.

Felser, C., Clahsen, H., & Münte, T. F. (2003). Storage and integration in the processing of filler-gap dependencies: An ERP study of topicalization and wh-movement in German. *Brain and Language,* 87, 345–354.

Ferreira, F. (2003). The misinterpretation of noncanonical sentences. *Cognitive Psychology,* 47, 164–203.

Ferreira, F., Bailey, K. G. D., & Ferraro, V. (2002). Good-enough representations in language comprehension. *Current Directions in Psychological Science*, 11, 11–15.

Ferrill, M., Love, T., Walenski, M., & Shapiro, L. P. (2012). The time-course of lexical activation during sentence comprehension in people with aphasia. *American Journal of Speech and Language Pathology,* 21(2), S179–S189.

Festen, J. M., & Plomp, R. (1990). Effects of fluctuating noise and interfering speech on the speech-reception threshold for impaired and normal hearing. *The Journal of the Acoustical Society of America,* 88(4), 1725–1736.

Fink, M., Churan, J., & Wittmann, M. (2006). Temporal processing and context dependency of phoneme discrimination in patients with aphasia. *Brain and Language,* 98, 1–11.

Formby, C., Phillips, D. E., & Thomas, R. G. (1987). Hearing loss among stroke patients. *Ear and Hearing,* 8(6), 326–332.

Frazier, L. (1993). Processing Dutch sentence structure. *Journal of Psycholinguistic Research,* 22(2), 85-108.

Frazier, L., Clifton, C., & Randall. J. (1983). Filling gaps: Decision principles and structure in sentence comprehension. *Cognition*; 13(2), 187–222.

Frazier, L., & Rayner, K. (1982). Making and correcting errors during sentence comprehension: Eye movements in the analysis of structurally ambiguous sentences. *Cognitive Psychology, 14,* 178–210.

Frazier, L., & Fodor, J. D. (1978). The sausage machine: A new two-stage parsing model. *Cognition*, 6, 291–325.

Friederici, A. D., Fiebach, C. J., Schlesewsky, M., Bornkessel, I. D., & von Cramon, Y. D. (2006). Processing linguistic complexity and grammaticality in the left frontal cortex. *Cerebral Cortex,* 16, 1709–1717.

Friederici, A. D., & Kilborn, K. (1989). Temporal constraints on language processing: Syntactic priming in Broca’s aphasia. *Journal of Cognitive Neuroscience,* 1(3), 262–272.

Friedmann, N., & Gvion, A. (2012). Intervention and locality in agrammatic aphasia. Internet celebration for Luigi Rizzi’s 60th birthday. *CISCL, Siena.*

Friedmann, N., Reznick, J., Dolinski-Nuger, D., & Soboleva, K. (2010). Comprehension and production of movement-derived sentences by Russian speakers with agrammatic aphasia. *Journal of Neurolinguistics,* 23, 44–65.

Friedmann, N., & Gvion, A. (2003). Sentence comprehension and working memory limitation in aphasia: A dissociation between semantic-syntactic and phonological reactivation. *Brain and Language,* 86, 23–39.

Friedmann, N., & Shapiro, L. P. (2003). Agrammatic comprehension of simple active sentences with moved constituents: Hebrew OSV and OVS structures. *Journal of Speech, Language, and Hearing Research,* 46, 288–297.

Friedmann, N. & Grodzinsky, Y. (1997). Tense and agreement in agrammatic production: Pruning in the syntactic tree. *Brain and Language*, 56, 397–425.

Fry, A. F., & Hale, S. (2000). Relationships among processing speed, working memory, and fluid intelligence in children. *Biological Psychology*, 54, 1–34.

Garaffa, M., & Grillo, N. (2007). Canonicity effects as grammatical phenomena. *Journal of Neurolinguistics,* 21(2), 177–197.

Gaven, J. M. (2011). The effects of high-frequency hearing loss on speech perception in people with aphasia. Unpublished master thesis. University of North Carolina.

Gibson, E. (2000). *The dependency locality theory: a distance-based theory of linguistic complexity*. In Image, language, brain: Papers from the first mind articulation project symposium, 95–126.

Gibson, E. (1998). Linguistic complexity: locality of syntactic dependencies. *Cognition,* 68, 1–76.

Glosser, G., & Goodglass, H. (1990). Disorders in executive control functions among aphasic and other brain–damaged patients. *Journal of Clinical and experimental Neuropsychology*, *12*(4), 485–501.

Gopinath, B., Schneider, J., Hartley, D., Teber, E., McMahon, C. M., Leeder, S. R., & Mitchell, P. (2011). Incidence and predictors of hearing aid use and ownership among older adults with hearing loss. *Annals of epidemiology, 21*(7), 497–506.

Gopinath, B., Schneider, J., Rochtchina, E., Leeder, S., & Mitchell, P. (2009). Association between age-related hearing loss and stroke in an older population. *Stroke, 40*: 1496–1498.

Gordon-Salant, S., & Friedman, S. A. (2011). Recognition of rapid speech by blind and sighted older adults. *Journal of Speech, Language and Hearing Research,* 54, 622–631.

Gordon-Salant, S., Yeni-Komshian, G., & Fitzgibbons, P. J. (2008). The role of temporal cues in word identification by younger and older adults: Effects of sentence context. *Journal of the Acoustic Society of America,* 124(5), 3249–3260.

Gordon-Salant, S., & Fitzgibbons, P. J. (2007). *Aging and auditory temporal processing: implications for speech communication*. PowerPoint presentation, University of Maryland.

Gordon-Salant, S., Fitzgibbons, P. J., & Friedman, S. A. (2007). Recognition of time-compressed and natural speech with selective temporal enhancements by young and elderly listeners. *Journal of Speech, Language, and Hearing Research*, 50, 1181–1193.

Gordon-Salant, S., Yeni-Komshian, G., Fitzgibbons, P. J., & Barrett, J. (2006). Age-related differences in identification and discrimination of temporal cues in speech segments. *Journal of the Acoustic Society of America,* 119(4), 2455–2466.

Gordon-Salant, S., (2005). Hearing loss and aging: New research findings and clinical implications. *Journal of Rehabilitation Research & Development,* 42(4), 9–24.

Gordon-Salant, S., & Fitzgibbons, P. J. (2004). Effects of stimulus and noise rate variability on speech perception by younger and older adults. *Journal of the Acoustic Society of America,* 115(4), 1808–1817.

Gordon-Salant, S., & Fitzgibbons, P. J. (2001). Sources of age-related recognition difficulty for time-compressed speech. *Journal of Speech, Language, and Hearing Research,* 44, 709–719.

Gordon-Salant S., & Fitzgibbons, P. J. (1997). Selected cognitive factors and speech recognition performance among young and elderly listeners. *Journal of Speech Language and Hearing Research,* 40, 423–431.

Gordon-Salant, S. (1986). Recognition of natural and time/intensity altered CVs by young and elderly subjects with normal hearing. *Journal of the Acoustical Society of America*, 80(6), 1599–1607.

Gordon-Salant, S. (1985). Phoneme feature perception in noise by normal-hearing and hearing-impaired subjects. *Journal of Speech, Language, and Hearing Research*, *28*(1), 87–95.

Grodzinsky, Y., & Santi, A. (2008). The battle for Broca's region. *Trends in Cognitive Sciences*, 12, 474–480.

Grodzinsky, Y. (2006). The language faculty, Broca's region and the mirror system. Special Issue: Position paper. *Cortex*, 42, 464–468.

Grodzinsky, Y. (2000). Overarching agrammatism. In Y. Grodzinsky, L. Shapiro, & D. Swinney (Eds.), *Language and the Brain: Representation and processing - Studies presented to Edgar Zurif on his 60th birthday* (pp. 73-86). San Diego: Academic Press.

Grodzinsky, Y. (1999). Agrammatic comprehension of relative clauses. *Brain and Language,* 37, 480–499.

Grodzinsky, Y. (1995). Trace deletion, theta roles and cognitive strategies. *Brain and Language*, 51, 469–497.

Grossman, M., Zurif, E., Lee, C., Prather, P., Kalmanson, J., Stern, M. B., & Hurtig. H. I. (2002). Information processing speed and sentence comprehension in Parkinson's disease. *Neuropsychology,* 16(2), 174–181.

Haarmann, H. J., & Kolk, H. H. J. (1991). Syntactic priming in Broca's aphasics: Evidence for slow activation. *Aphasiolog*y, 5(3), 247–263.

Hällgren, M., Larsby, B., Lyxell, B., & Arlinger, S. (2001). Evaluation of a cognitive test battery in young and elderly normal-hearing and hearing-impaired persons. *Journal of the Americal Academay of Audiology*, 12, 357–370.

Haider, H. (2010). *The syntax of German*. Cambridge: Cambridge University Press.

Haider, H. (1985). *The case of German.* In J. Toman (Ed.), Studies in German grammar (pp. 65–101). Dordrecht: Foris.

Hanne, S., Burchert, F., de Bleser, R., & Vasishth, S. (2015). Sentence comprehension and morphological cues in aphasia: What eye-tracking reveals about integration and prediction. *Journal of Neurolinguistics, 34*, 83–111.

Hanne, S., Sekerina, I. A., Vasishth, S., Burchert, F., & de Bleser, R. (2011). Chance in agrammatic sentence comprehension - What does it really mean? Evidence from eye movements of German agrammatic aphasic patients. *Aphasiology,* 25(2), 221–244.

Hasher, L., & Zacks, R. T. (1988). *Working memory, comprehension, and aging: A review and a new view*. In Bower, G. H. (Ed.), The Psychology of Learning and Motivation: Advances in Research and Theory, 22 (193–225). San Diego: Academic Press, Inc.

Hashimoto, N., & Thompson, C. K. (2001). Time course of semantic and phonological activation in aphasic individuals. *Brain and Language*, 79(1), 161–164.

Hausler, R. & Levine, R.A. (2000). Auditory dysfunction in stroke. *Acta Otolaryngologica, 120,* 689–703.

Hawkins, J. (1983). *Word order universals.* New York: Academic Press.

Heger, D., & Holube, I. (2010). Wie viele Menschen sind schwerhörig? *Zeitschrift für Audiologie,* 49(2), 61–70.

Heide, J., & Stadie, N. (2007). Die kategorielle Wahrnehmung von Phonemen bei Aphasie: Eine Einzelfallstudie. *Bulletin Aphasie und verwandte Gebiete*, 21(3), 17–31.

Helm-Estabrooks, N. (2002): Aphasia and cognition: A discussion and a study. *Journal of Communication Disorders*, 35, 171–186.

Herbst, K.G., & Humphrey, C. (1980). Hearing impairment and mental state in the elderly living at home. *British Medical Journal*, 281, 903–905.

Hessler, D., Jonkers, R., & Bastiaanse, R. (2010). The influence of phonetic dimensions on aphasic speech perception. *Clinical Linguistics & Phonetics*, 24(12), 980–996.

Heuer, S. (2009). New eye-tracking method to assess attention allocation in individuals with and without aphasia using a dual-task paradigm. Ann Arbor: Proquest.

Heylen, K. (2005). A quantitative corpus of German word order variation. In: S. Kepser & M. Reis (Eds.), *Linguistic Evidence. Empirical, theoretical and computational perspectives* (pp. 241–263). Berlin: Mouton de Gruyter.

Hickock, G. (2009). The functional neuroanatomy of language. *Physics of Life Reviews,* 6, 121–143.

Hickok, G, & Avrutin, S. (1995). Representation, referentiality, and processing in agrammatic comprehension: two case studies. *Brain and Language*, 5, 10–26.

HilfsM-RL (2012). Richtlinie des Gemeinsamen Bundesauschusses über die Verordnung von Hilfsmitteln in der vertragsärztlichen Versorgung. *Bundesanzeiger*.

Hillary, F. G., Genova, H. M., Medaglia, J. D., Fitzpatrick, N. M., Chiou, K. S., Wardecker, B. M., Franklin, R. G. Jr., Wang, J., & DeLuca, J. (2010). The nature of processing speed deficits in traumatic brain injury: is less brain more? *Brain Imaging and Behavior,* 4, 141–154.

Hoffman, P., Jefferies, E., Ehsan, S., Jones, R. W., & Ralph, M. A. L. (2012). How does linguistic knowledge contribute to short-term memory? Contrasting effects of impaired semantic knowledge and executive control. *Aphasiology,* 26(3-4), 383–403.

Holube, I., & von Gablenz, P. (2012). *Epidemiological research: How good do German adults hear?* Presentation at the Adult Hearing Screening, Italy, Cernobbio.

Hosom, J. P. (2009). Speaker-independent phoneme alignment using transition-dependent states. *Speech Communication*, *51*(4), 352–368.

Hougaard, S. & Ruf, S. (2011). EuroTrak I: A consumer survey about hearing aids in Germany, France and the UK. *Hearing Review*, 18(2), 12–28.

Huber, W., Poeck, K., Weniger, D., & Willmes, K. (1983). *Aachener Aphasie Test.* Göttingen: Hogrefe.

Hüttig, F., & Janse, E. (2016). Individual differences in working memory and processing speed predict anticipatory spoken language processing in the visual world. *Language, Cognition and Neuroscience*, 31(1), 80–93.

Hula, W. D., & McNeil, M. R. (2008). Models of attention and dual-task performance as explanatory constructs in aphasia. *Seminars in Speech and Language*, 29, 169–187.

Humes, L. E., Dubno, J. R., Gordon-Salant, S., Lister, J. J., Cacace, A. T., Cruickshanks, K. J., & Wingfield, A. (2012). Central presbycusis: A review and evaluation of the evidence. *Journal of the American Academy of Audiology*, *23*(8), 635–666.

Humes, L. E., Burk, M. H., Coughlin, M. P., Busey, T. A., & Strauser, L. E. (2007). Auditory speech recognition and visual text recognition in younger and older adults: Similarities and differences between modalities and the effects of presentation rate. *Journal of Speech, Language, and Hearing Research,* 50, 283–303.

Humes, L. E. (2003). Modeling and predicting hearing aid outcome. *Trends in Amplification*, *7*(2), 41–75.

Ingram, J. C. (2007). Neurolinguistics: An introduction to spoken language processing and its disorders. Cambridge, New York: Cambridge University Press.

Ivanova, M., & Hallowell, B. (2012). Validity of an eye-tracking method to index working memory in people with and without aphasia. *Aphasiology, 26, 556–578.*

Janse, E. (2009). Processing of fast speech by elderly listeners. *Journal of the Acoustic Society of America,* 125(4), 2361–2373.

Janse, E., van der Werff, M., & Quené, R. (2007). Listening to fast speech: Aging and sentence context. In J. Trouvain, & W. J. Barry (Eds.), *Proceedings of the 16th International Congress of Phonetic Sciences* (ICPhS 2007) (pp. 681–684). Dudweiler: Pirrot.

Janse, E. (2004). Word perception in fast speech: Artificially time-compressed vs. naturally produced fast speech. *Speech Communication, 42, 155–173.*

Ji, C., Galvin, III, J. J., Xu, A., & Fu, Q. (2013). Effect of speaking rate on recognition of synthetic and natural speech by normal-hearing and cochlear implant listeners. *Ear and Hearing*, 34(4), 313-323.

Jongman, A., Wayland, R., & Wong, S. (2000). Acoustic characteristics of English fricatives. *The Journal of the Acoustical Society of America*, *108*(3), 1252–1263.

Just, M. A., & Carpenter, P. A. (1992). A capacity theory of comprehension: Individual differences in working memory. *Psychological Review,* 98, 122–149.

Kaan, E., & Swaab, T. Y. (2002). The brain circuitry of syntactic comprehension. *TRENDS in Cognitive Sciences,* 6(8), 350–356.

Kail, R., & Salthouse, T.A. (1994). Processing speed as a mental capacity. *Acta Psychologica*, 86, 199–225.

Kalbe, E., Reinhold, N., Ender., U., & Kessler, J. (2002). *Die Aphasie-Check-Liste (ACL): Ein neues Instrument zur Aphasiediagnostik.* Köln: ProLog, Therapie– und Lernmittel GmbH.

Kalinyak-Fliszar, M., Kohen, F., & Martin, N. (2011). Remediation of language processing in aphasia: Improving activation and maintenance of linguistic representations in (verbal) short-term memory. *Aphasiology*, 25(10), 1095–1131.

Kalikow, D. N., Stevens, K. N., & Elliott, L. L. (1977). Development of a test of speech intelligibility in noise using sentence materials with controlled word predictability. *Journal of the Acoustic Society of America*, 61, 1337–1351.

Kamide, Y. (2008). Anticipatory processes in sentence processing. *Language and Linguistics Compass*, 2/4, 647–670.

Kamide, Y., Scheepers, C., & Altmann, G. T. M. (2003). Integration of syntactic and semantic information in predictive processing: Cross-linguistic evidence from German and English. *Journal of Psycholinguistic Research*, 32(1), 37–55.

Kamide, Y, Altmann, G. T. M., & Haywood, S. L. (2003a). The time-course of prediction in incremental sentence processing: Evidence from anticipatory eye movements. *Journal of Memory and Language*, 49, 133–156.

Kemper, S. (1987). Life-span changes in syntactic complexity. *Journal of Gerontology*, 42(3), 323–328.

Kirk, K. I., Pisoni, D. B., & Miyamoto, R. C. (1997). Effects of stimulus variability on speech perception in listeners with hearing impairment. *Journal of Speech, Language, and Hearing Research*, 40(6), 1395–1405.

Knöferle, P. (2007). Comparing the time-course of processing initially ambiguous and unambiguous German SVO/OVS sentences in depicted events. In R. van Gompel, M. Fischer, W. Murray, W., & R. Hill (Eds.), *Eye Movement Research*. *A Window on Mind and Brain.* (pp. 517–531). Oxford-Amsterdam: Elsevier.

Knöferle, P., Crocker, M. W., Scheepers, C., & Pickering, M. J. (2005). The influence of the immediate visual context on incremental thematic role-assignment: Evidence from eye movements in depicted events. *Cognition*, 95, 95–127.

Kochkin, S. (2010). MarkeTrak VIII: Consumer satisfaction with hearing aids is slowly increasing. *The Hearing Journal*, *63*(1), 19–20.

Kochkin, S. (2000). MarkeTrak V:" Why my hearing aids are in the drawer": The consumers' perspective. *The Hearing Journal*, *53*(2), 34–36.

Kochkin, S. (1998). MarkeTrak IV: Correlates of hearing aid purchase intent. *Hearing Journal*, *51*, 30–33.

Kollmeier, B. & Wesselkamp, M. (1997). Development and evaluation of a German sentence test for objective and subjective speech intelligibility assessment. *Journal of the Acoustical Society of America*, *102*(4), 2412–2421.

Korda, R. J. & Douglas, J. M. (1997) Attention deficits in stroke patients with aphasia. *Journal of Clinical and Experimental Neuropsychology*, 19(4), 525–542.

Krause, J. C. & Braida, L. D. (2004) Acoustic properties of naturally produced clear speech at normal speaking rates. *Journal of the Acoustic Society of America*, 115, 362–378.

Kreter, S., Nospes, S., Cichorowski, M., & Keilmann, A. (2010). *Schwerhörigkeit und Aphasie.* Presentation held at the 27. Wissenschaftliche Jahrestagung der Deutschen Gesellschaft für Phoniatrie und Pädaudiologie (DGPP). Germany, Aachen, 17.-19.09.

Kroker, C. (2006). Aphasie Schnell Test (AST). Ein standardisierter Test für die Differenzialdiagnose Aphasie - keine Aphasie - Dysarthrie in der Akutphase. 3rd edition. Büsingen: K2 Verlag.

Kuehnast, M. (2011). Processing negative imperatives in Bulgarian-Evidence from normal, aphasic and child language. Doctoral dissertation. University of Potsdam.

Läßig, A. K., Kreter, S., Nospes, S., & Keilmann, A. (2013). Hörstörungen bei Aphasie. *Laryngo-Rhino-Otologie*, 92(8), 531–535.

LaPointe, L. L., & Erickson, R. J. (1991). Auditory vigilance during divided task attention in aphasic individuals. *Aphasiology*, *5*(6), 511–520.

Lasky, E. Z., Weidner, W. E., & Johnson, J. P. (1976). Influence of linguistic complexity, rate of presentation, and interphrase pause time on auditory-verbal comprehension of adult aphasic patients. *Brain and Language*, 3, 386–395.

Laures-Gore, J., Shisler Marshall, R., & Verner, E. (2011). Performance of individuals with left-hemisphere stroke and aphasia and individuals with right brain damage on forward and backward digit span tasks. *Aphasiology*, 14(25), 43–56.

Laures, J. S., Odell, K., & Coe, C. L. (2003). Arousal and auditory vigilance in individuals with aphasia during a linguistic and nonlinguistic task. *Aphasiology*, *17*(12), 1133–1152.

Lethbridge-Ceijku, M., Schiller, J. S., & Bernadel, L. (2004). Summary health statistics for U.S. adults: National Health Interview Survey. *Vital Health Statistics*, 10, 1–151.

Letowski, T. & Poch, N. (1995). Understanding of time-compressed speech by older adults: Effect of discard interval. *Journal of the American Academy of Audiology,* 6(6), 433–439.

Leuwer, R., & Müller, J. (2005). Restoration of hearing by hearing aids. *Current Topics in Otorhinolaryngology, Head and Neck Surgery*, 4, document 03.

Levitt, T., Fugelsang, J., & Crossley, M. (2006). Processing speed, attentional capacities, and age-related memory change. *Experimental Aging Research*, 32, 263–295.

Lewis, R. L., & Vasishth, S. (2005). An activation-based model of sentence processing as skilled memory retrieval. *Cognitive Science*, 29, 375–419.

Lewis, R. L. (2000). Specifying architectures for language processing: Process, control, and memory in parsing and interpretation. In M. W. Crocker, M. Pickering, & C. Clifton Jr. (Eds.), Architectures and mechanisms for language comprehension (pp. 56–89). Cambridge, England: Cambridge University Press.

Lin, F. R., Thorpe, R., Gordon-Salant, S., & Ferrucci, L. (2011). Hearing loss prevalence and risk factors among older adults in the United States. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, *66*(5), 582–590.

Lindholm, J. M., Dorman, M., Taylor, B. E., & Hannley, M. T. (1988). Stimulus factors influencing the identification of voiced stop consonants by normal-hearing and hearing-impaired adults. *The Journal of the Acoustical Society of America*, *83*(4), 1608–1614.

Love, T., Walenski, W., & Swinney, D. (2009). Slowed speech input has a differential impact on on-line and offline processing in children's comprehension of pronouns. *Journal of Psycholinguistic Research,* 38(3), 285–304.

Love, T., Swinney, D., Walenski, W., & Zurif, E. (2008). How left inferior frontal cortex participates in syntactic processing: evidence from aphasia. *Brain and Language*, 107, 203–219.

Love, T., Swinney, D., & Zurif, E. (2001). Aphasia and the time-course of processing long distance dependencies. *Brain and Language*, *79*(1), 169–170.

Lukatela, K., Crain, S., & Shankweiler, D. (1988). Sensitivity to inflectional morphology in agrammatism: Investigation of a highly inflected language. *Brain and Language*, *33*, 1–15.

Lukatela, K., Shankweiler, D., & Crain, S. (1995). Syntactic processing in agrammatic aphasia by speakers of a Slavic language. *Heskins Laboratory Status Report on Speech Research*, SR 119/120, 95–115.

Lyxell, B., Andersson, U., Borg, E., & Ohlsson, I. S. (2003). Working-memory capacity and phonological processing in deafened adults and individuals with a severe hearing impairment. *International Journal of Audiology*, *42*, S86–S89.

MacPhee, G. J. A., Crowther, J. A., & McAlpine, C. H. (1988). A simple screening test for hearing impairment in elderly patients. *Age and Ageing*, 347–351.

MacWhinney, B., Osmán-Sági, J., & Slobin, D. I. (1991). Sentence comprehension in aphasia in two clear case-marking languages. *Brain and Language*, *41*(2), 234–249.

MacWhinney, B. & Pleh, C. (1988). The processing of restrictive relative clauses in Hungarian. *Cognition*, 29(2), 95–141.

Majerus, S., van der Kaa, M.-A., Renard, C., van der Linden, M., & Poncelet, M. (2005). Treating verbal short-term memory deficits by increasing the duration of phonological representations: A case study. *Brain and Language*, 95(1), 174–175.

Mak, W. M., Vonk, W., & Schriefers, H. (2006). Animacy in processing relative clauses: The hikers that rocks crush. *Journal of Memory and Language,* 54, 466–490.

Mak, W. M., Vonk, W., & Schriefers, H. (2002). The influence of animacy on relative clause processing. *Journal of Memory and Language,* 47, 50–68.

Manard, M., Carabin, D., Jaspar, M., & Collette, F. (2014). Age-related decline in cognitive control: The role of fluid intelligence and processing speed. *BMC Neuroscience*, 15(7), 1–16.

Margolis, R. H., & Salys, G. L. (2007). Toward a standard description of hearing loss. *International Journal of Audiology*, 46, 746–758.

Marantz, A. (2013). Verbal argument structure: Events and participants. *Lingua*, 130, 152–168.

Marshall, R. C. (2004). Functional strategies to enhance auditory comprehension of persons with aphasia for neurological physical therapists. *Journal of Neurological Physical Therapy,* 28(3), 138–144.

Martin, N., Kohen, F., Kalinyak-Fliszar, M., Soveri, A., & Laine, M. (2012). Effects of working memory load on processing of sounds and meanings of words in aphasia. *Aphasiology,* 26(3–4), 462–493.

Martin, N., & Reilly. J. (2012): Short-term/working memory impairments in aphasia: Data, models, and their application to aphasia rehabilitation. *Aphasiology*, 26(3-4), 253–257.

Martin, J. S., & Jerger, J. F. (2005). Some effects of aging on central auditory processing. *Journal of Rehabilitation Research & Development,* 42(4), 25–44.

Martin, N., & Saffran, E. M. (1999). Effects of word processing and short-term memory deficits on verbal learning: Evidence from aphasia. *International Journal of Psychology*, 34(5/6), 339–346.

Martini, A. E. (1996). *European Working Group on genetics of hearing impairment*. European Commission Directorate, Biomedical and Health Research Programme (HEAR), Infoletter 2, 8.

Mattys, S. L., Brooks J., & Cooke, M. (2009). Recognizing speech under a processing load: Dissociating energetic from informational factors. *Cognitive Psychology*, 59(3), 203–243.

Mattys, S. L., Melhorn, J. F., & White, L. (2007). Effects of syntactic expectations on speech segmentation. *Journal of Experimental Psychology: Human Perception and Performance*, *33*(4), 960–977.

McCoy, S., Tun, P. A., Cox, C., Colangelo, M., Stewart, R. A., & Wingfield, A. (2005) Hearing loss and perceptual effort: Downstream effects on older adults' memory for speech. *Quarterly Journal of Experimental Psychology,* 58A (1), 22–33.

McElree, B., Foraker, S., & Dyer, L. (2003). Memory structures that subserve sentence comprehension. *Journal of Memory and Language, 48*, 67–91.

McElree, B., & Griffith, T. (1995). Syntactic and thematic processing in sentence comprehension: Evidence for a temporal dissociation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *21*(1), 134–156.

McNeil, M. R., Doyle, P. J., Hula, W. D., & Rubinsky, H. J. (2004). Using resource allocation theory and dual task methodology to increase the sensitivity of assessment in aphasia. *Aphasiology, 18,* 521–542.

McNeil, M. R., & Pratt, S. R. (2001). Defining aphasia: Some theoretical and clinical implications of operating from a formal definition. *Aphasiology*, 15(10–11), 901–911.

McNeil, M. R., Odel, K., & Tseng, C.-H. (1991). Toward the integration of resource allocation into a general theory of aphasia. *Clinical Aphasiology, 20*, 21–39.

Mecklinger, A., Schriefers, H., Steinhauer, K., & Friederici, A. D. (1995). Processing relative clauses varying on syntactic and semantic dimensions: An analysis with event-related potentials. *Memory & Cognition*, *23*(4), 477–494.

Meltzer, J. A., McArdle, J. J., Schafer, R. J., & Braun, A. R. (2010). Neural aspects of sentence comprehension: Syntactic complexity, reversibility, and reanalysis. *Cerebral Cortex,* 20, 1853–1864.

Meng, M., & Bader, M. (1997). *Syntax and morphology in sentence parsing: A new look at German subject-object ambiguities*. Written version of the talk at the Conference on Architectures and Mechanisms for Language Processing, Torino, September 1996. http://ling.uni–konstanz.de/pages/home/bader/DownLoads/mm–AMLAP.pdf

Meyer, A. M., Mack, J. E., &. Thompson, C. K. (2012). Tracking passive sentence comprehension in agrammatic aphasia. *Journal of Neurolinguistics,* 25, 31–43.

Miceli, G., & Caramazza, A. (1988). Dissociation of inflectional and derivational morphology. *Brain and Language*, 35, 24–65.

Miceli, G., Mazzuchi, A., Menn, L., & Goodglass, H. 1983. Contrasting cases of Italian agrammatic aphasia without comprehension disorder. *Brain and Language*, 19, 65–97.

Miller, J. O., & Low, K. (2001). Motor processes in simple, go/no-go, and choice reaction time tasks: a psychophysiological analysis. *Journal of Experimental Psychology: Human Perception and Performance*, 27(2), 266–289.

Milberg, W., Blumstein, S. E., & Dvoretzky, B. (1988). Phonological processing and lexical access in aphasia. *Brain and Language*, 34(2), 279–293.

Milekic, S., Boskovic, Z., Crain, S., & Shankweiler, D. (1995). Comprehension of nonlexical categories in agrammatism. *Journal of Psycholinguistic Research, 24* (4), 299–311.

Mirman, D., Yee. E., Blumstein, S. E., & Magnuson, J. S. (2011). Theories of spoken word recognition deficits in aphasia: Evidence from eye-tracking and computational modeling. *Brain and Language,* 117(2), 53–68.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology*, *41*, 49–100.

Miyake, A., Carpenter, P. A., & Just, M. A. (1995). Reduced resources and specific impairment in normal and aphasic sentence comprehension. *Cognitive Neuropsychology, 12,* 651–679.

Miyake, A., Carpenter, P. A., & Just, M. A. (1994). A capacity approach to syntactic comprehension disorders: Making normal adults perform like aphasic patients. *Cognitive Neuropsychology,* 11(6) 671–717.

Monson, B. B., Hunter, E. J., Lotto, A. J., & Story, B. H. (2014). The perceptual significance of high-frequency energy in the human voice. *Frontiers in Psychology*, 5, article 587.

Monson, B. B., Lotto, A. J., & Story, B. H. (2012). Analysis of high-frequency energy in long-term average spectra of singing, speech, and voiceless fricatives. *Journal of the Acoustical Society of America,* 132, 1754–1764.

Moore, B. C. (2012). *An introduction to the psychology of hearing*. 6th edition. Boston: Brill Academic Publishers.

Moore, B. C. J., Fullgrabe, C., & Stone, M. A. (2010). Effect of spatial separation, extended bandwidth, and compression speed on intelligibility in a competing-speech task. *Journal of the Acoustical Society of America*, 128, 360–371.

Murray, L. L. (2000). The effects of varying attentional demands on the word retrieval skills of adults with aphasia, right hemisphere brain damage, or no brain damage. *Brain and Language,* 72, 40–72.

Murray, L. L. (1999). Review Attention and aphasia: Theory, research and clinical implications. *Aphasiology,* 13(2), 91–111.

Murray, L. L., Holland, A. L., & Beeson, P. M. (1997). Auditory processing in individuals with mild aphasia. *Journal of Speech, Language, and Hearing Research*, 40, 792–808.

Myers, E. B., & Blumstein, S. E. (2005). Selectional restriction and semantic priming effects in normals and Broca's aphasics. *Journal of Neurolinguistics,* 18, 277–296.

Neger, T., Janse, E., & Rietveld, T. (2015). Correlates of older adults' discrimination of acoustic properties in speech. *Speech, Language and Hearing,* 18(2), 102–115.

Nespoulous, J. L., Dordain, M., Perron, C., Ska, B., Bub, D., Caplan, D., Mehler, J., & Roch Lecours, A. (1988). Agrammatism in sentence production without comprehension deficits: Reduced availability of syntactic structures and/or of grammatical morphemes? A case study. *Brain and Language, 33*(2), 273–295.

Neto, B., & Santos, M. E. (2012). Language after aphasia: Only a matter of speed processing? *Aphasiology,* 26(11), 1352–1361.

Neuhaus, E. & Penke, M. () Production and comprehension of wh-questions in German Broca's aphasia. *Journal of Neurolinguistics* 21, 150–176.

Nicol, J. L., Jakubowicz, C., & Goldblum, M.-C. (1996). Sensitivity to grammatical marking in English-speaking and French-speaking non-fluent aphasics. *Aphasiology*, *10*(6), 593–622.

Nicol, J. L., & Swinney, D. (1989). The role of structure in coreference assignment during sentence comprehension. *Journal of Psycholinguistic Research* 18, 5–19.

Niemeyer, W. (1967). Sprachaudiometrie mit Sätzen. *Zeitschrift für Hals–Nasen–Ohrenkunde,* 15, 421–427.

Novick, J. M., Trueswell, J. C., & Thompson-Schill, S. L. (2005). Cognitive control and parsing: Reexamining the role of Broca's area in sentence comprehension. *Cognitive, Affective and Behavioral Neuroscience,* 5, 263–281.

Nys, G. M. S., Van Zandvoort, M. J. E., De Kort, P. L. M., Jansen, B. P. W., De Haan, E. H. F., & Kappelle, L. J. (2007). Cognitive disorders in acute stroke: prevalence and clinical determinants. *Cerebrovascular Diseases*, *23*(5–6), 408–416.

Obler, L. K., Fein, D., Nicholas, M., & Albert, M. L. (1991). Auditory comprehension and aging: Decline in syntactic processing. *Applied Psycholinguistics*, 12, 433–452.

Obleser, J., Woestmann, M., Hellbernd, N., Wilsch, A., & Maess, B. (2012) Adverse listening conditions and memory load drive a common alpha oscillatory network. *Journal of Neuroscience*, 32(36), 12376–12383.

O'Halloran, R., Worrall, L., & Hickson, L. (2009). The number of patients with communication related impairments in acute hospital stroke units. *International Journal of Speech–Language Pathology,* 11(6), 438–49.

Pado, U., Keller, F. F., & Crocker, M. (2006). Combining syntax and thematic fit in a probabilistic model of sentence processing. ***Proceedings of the 28th Annual Conference of the Cognitive Science*** **Society (pp. 657**–662).

Papagno, C., Bricolo, E., Mussi, D., Daini, R., & Cecchetto, C. (2012). (Eye) tracking short-term memory over time. *Aphasiology,* 26(3-4), 536–555.

Papagno, C., & Basso, A. (1996). Perseveration in two aphasic patients. *Cortex, 32*, 67–82.

Pashek, G. V., & Brookshire, R. H. (1982). Effects of rate of speech and linguistic stress on auditory paragraph comprehension of aphasic individuals. *Journal of Speech and Hearing Research,* 25, 377–383.

Patil, U., Hanne, S., Vasishth, S., Burchert, F., de Bleser, R., & Vasishth, S (2015). Computational evaluation of sentence processing deficits in aphasia. *Cognitive Science*, 1–44.

Payne, B. R., Gao, X., Noh, S. R., Anderson, C. J., & Stine-Morrow, E. A. L. (2012). The effects of print exposure on sentence processing in older adults: Evidence for efficiency and reserve. *Aging, Neuropsychology, and Cognition*, 19(1-2), 1221–49.

Pellegrino, F., Coupe, C., & Marsico, E. (2011). A cross-language perspective on speech information rate. *Language,* 87(3), 539–558.

Penke, M. (2013). Syntaktische Störungen bei Aphasie. *Spektrum Patholinguistik* 6, 47–86.

Peristeri, E., & Tsimpli, I. M. (2014). *Linguistic processing and executive control: Evidence for inhibition in Broca's aphasia*. In N. Lavidas, T. Alexiou, & A. M. Sougari (Eds,), Major Trends in Theoretical and Applied Linguistics 2 (455–470). Selected Papers from the 20th ISTAL.

Petroi, D. (2011). Investigation of resource allocation in persons with aphasia for AAC-related tasks. Doctoral dissertation. Texas Tech University.

Pettigrew, C., & Martin, R. C. (2014). Cognitive declines in healthy aging: Evidence from multiple aspects of interference resolution. *Psychology and Aging,* 29(2), 187–204.
Picheny, M. A., Durlach, N. I., & Braida, L. D. (1989). Speaking clearly for the hard of hearing I: Intelligibility differences between clear and conversational speech. *Journal of Speech and Hearing Research,* 28, 96–103.
Pichora-Fuller, M. K. (2008). Use of supportive context by younger and older adult listeners: Balancing bottom-up and top-down information processing. *International Journal of Audiology,* 47(Suppl. 2), S72–S82.
Pichora-Fuller, M. K. (2003). Processing speed and timing in aging adults: psychoacoustics, speech perception and comprehension. *International Journal of Audiology,* 42, 59–67.
Pichora-Fuller, M. K., & Singh, G. (2006). Effects of age on auditory and cognitive processing: Implications for hearing aid fitting and audiological rehabilitation. *Trends In Amplification,* 10(1), 29–59.
Pichora-Fuller, M. K., & Carson, A. J. (2000). Hearing health and the listening experiences of older communicators. In M. L. Hummert, & J. Nussbaum (Eds.). *Communication, Aging, and Health: Linking Research and Practice for Successful Aging* (pp. 161-202). New York: Lawrence Erlbaum Associates.
Pichora-Fuller. M. K., Schneider, B. A., & Daneman, M. (1995). How young and old adults listen to and remember speech in noise. *Journal of the Acoustic Society of America,* 97(1), 593–608.
Pickering, M. J., & Traxler, M. J. (1998). Plausibility and recovery of garden paths: an eye-tracking study. *Journal of Experimental Psychology: Learning, Memory and Language,* 24(4), 940–961.
Piñango, M. M., & Burkhardt, P. (2005). Pronominal interpretation and the syntax-discourse interface: Real-time comprehension and neurological properties. In A. Branco, T. McEnery, & T. Mitkov (Eds.), *Anaphora Processing: Linguistic, cognitive and computational modelling* (pp. 221–237). Amsterdam/Philadelphia: John Benjamins Publishing Company.
Piñango, M. M. (2000). *Canonicity in Broca's sentence comprehension: The case of psychological verbs*. In Y. Grodzinsky (Ed.), Language and the brain: Representation and processing (pp. 327–350). San Diego/London: Academic Press.
Piquado, T., Benichov, J. I., Brownell, H., & Wingfield, A. (2012). The hidden effect of hearing acuity on speech recall, and compensatory effects of self-paced listening. *International Journal of Audiology,* 51(8), 576–583.
Poeck, K., & Pietron, H.-P. (1981). The influence of stretched speech on token test performance of aphasic and rightbrain damaged patients. *Neuropsychologia,* 19, 133–136.
Poeppel, D. (2003). The analysis of speech in different temporal integration windows: Cerebral lateralization as "asymmetric sampling in time". *Speech Communication,* 41, 245–255.
Pollock, J.-Y. (1989). Verb movement, Universal Grammar, and the structure of IP. *Linguistic Inquiry,* 20, 365–424.
Prather, P. A., Zurif, E., Love, T., & Brownwell, H. (1997). Speed of lexical activation in nonfluent Broca's aphasia and fluent Wernicke's aphasia. *Brain and Language,* 59, 391–411.
Prather, P., Zurif, E., Stern, C., & Rosen, T. J. (1992). Slowed lexical access in non-fluent aphasia: A case study. *Brain and Language,* 43, 336–348.
Prather, P., Shapiro, L., Zurif, E., & Swinney, D. (1991). Real-time examinations of lexical processing in aphasics. *Journal of Psycholinguistic Research,* 20(3), 271–281.
Pratt, S., McNeil, M., Roxberg, J., Ortmann, A., Eberwein, C., Durrant, J., Szuminsky, N., & Doyle, P. (2007). *Effects of signal intensity level and noise-simulated hearing loss on auditory language processing persons with aphasia.* Clinical Aphasiology Conference, Scottsdale, AZ.
Purdy, M. (2002). Executive function ability in persons with aphasia. *Aphasiology, 16*(4-6), 549–557.
Raithel, V., & Wrede, B. (2003). Warum haben es Schnellsprecher schwerer? Untersuchungen zur automatischen Spracherkennung und zum aphasischen Sprachverständnis. Forschung an der Universität Bielefeld, 25.
Rankin, E., Newton, C., Parker, A., & Bruce, C. (2014). Hearing loss and auditory processing ability in people with aphasia. *Aphasiology,* 28(5), 576–595
Rawool, V. W. (2007). The aging auditory system, Part 2: Slower processing and speech recognition. *Hearing Review,* 14(8), 36–43.
Rayner, K., Carlson, M., & Frazier, L. (1983). The interaction of syntax and semantics during sentence processing. *Journal of Verbal Learning and Verbal Behavior,* 22, 358–74.
Riedel, K., & Studdert-Kennedy, M. (1985). Extending formant transitions may not improve aphasics' perception of stop consonant place of articulation. *Brain and Language,* 24, 223–232.
Riensche, L. L., Wohlert, A., *&* Porch, B. E. (1983). Aphasic comprehension and preference of rate-altered speech. *British Journal of Disorders of Communication,* 18(1), 39–48.
Rizzi, L. (2013). Locality. *Lingua,* 130, 169–186.

Rizzi, L. (1997). *The fine structure of the left periphery*. In L. Haegemann (Ed.), Elements of grammar (pp. 281–337). Dordrecht: Kluwer Academic Publishers.

Rizzi, L. (19909: *Relativized minimality*. Cambridge, MA: MIT Press.

Rönnberg, J., Lunner, T., Zekveld, A., Sörqvist, P., Danielsson, H., Lyxell, B., Dahlström, Ö., Signoret, C., Stenfelt, S., Pichora-Fuller, M. K., & Rudner, M. (2013). The Ease of Language Understanding (ELU) model: theoretical, empirical, and clinical advances. *Frontiers in Systems Neuroscience*, 7,1–17.

Rönnberg J., Rudner, M., Lunner, T., & Zekveld, A. A. (2010). When cognition kicks in: Working memory and speech understanding in noise. *Noise and Health*, 12, 263–269.

Rosen, S. (1992). Temporal information in speech: Acoustic, auditory and linguistic aspects. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *336*(1278), 367–373.

RStudio (2014). RStudio: Integrated development environment for R (Version 0.98.1091) [Computer software]. Boston, MA. Retrieved October, 20, 2014. Available from http://www.rstudio.org/

Rudner, M., Rönnberg, J., & Lunner, T. (2011). Working memory supports listening in noise for persons with hearing impairment. *Journal of the American Academy of Audiology*, *22*(3), 156–167.

Rudner, M., Foo, C., Rönnberg, J., & Lunner, T. (2009). Cognition and aided speech recognition in noise: Specific role for cognitive factors following nine-week experience with adjusted compression settings in hearing aids. *Scandinavian Journal of Psychology*, 50, 405–418.

Ruigendijk, E. (2002*). Case assignment in agrammatism: A cross-linguistic study*. Groningen: Groningen Dissertations in Linguistics.

Salis, C. (2011). Short-term memory training in aphasia: patterns of treatment-induced learning and their implications for sentence comprehension. *Procedia Social and Behavioral Sciences*, 23, 193–194.

Salthouse, T. A. (2000). Aging and measures of processing speed. *Biological Psychology*, 54, 35–54.

Salthouse, T. A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review*, 103(3), 403–428.

Salthouse, T. A. (1994). The aging of working memory. *Neuropsychology*, *8*(4), 535–543.

Salthouse, T. A. (1993). Speed mediation of adult age differences in cognition. *Developmental Psychology*, 29, 722–738.

Salthouse, T. (1992). Influence of processing speed on adult age differences in working memory. *Acta Psychologica*, 79, 155–170.

Santi, A., & Grodzinsky, Y. (2012). Broca's area and sentence comprehension: A relationship parasitic on dependency, Displacement or predictability? *Neuropsychologia*, 50(5), 821–832.

Sarampalis, A., Kalluri, S., Edwards, B., & Hafer, E. (2009). Objective measures of listening effort: Effects of background noise and noise reduction. *Journal of Speech, Language, and Hearing Research*, 52(5), 1230–1240.

Schaapmeerders, P., Maaijwee, N. A. W., van Dijk, E. J., Rutten-Jacobs, L. C. A., Arntz, R. M., Schoonderwaldt, H. C., Dorresteijn, L. D. A.; Kessels, R. P. C., & de Leeuw, F. (2013). Long-term cognitive impairment after first-ever ischemic stroke in young adults. *Stroke*, 44, 1621–1628.

Schelten-Cornish, S. (2007). Die Bedeutung der Sprachgeschwindigkeit für die Sprachtherapie. *Die Sprachheilarbeit*, 52(4), 136 –145.

Schmidt, R. F., & Thewes, G. (2013). *Einführung in die Physiologie des Menschen*. Berlin, Springer Verlag.

Schneider, B. A., Daneman, M., & Murphy, D. R. (2005). Speech comprehension difficulties in older adults: Cognitive slowing or age-related changes in hearing? *Psychology and Aging*, 20(2), 261–271.

Schneider, B. A., & Pichora-Fuller, M. K. (2001). Age-related changes in temporal processing: Implications for speech perception. *Seminars in Hearing*, 22, 227–240.

Schriefers, H., Friederici, A., & Kühn, K. (1995). The processing of locally ambiguous relative clauses in German. *Journal of Memory and Language, 34*, 499–520.

Schubert, K., & Panse, F. (1953). Audiologische Befunde bei sensorischer Aphasie. *Archiv für Ohr-, Nasen- und Kehlkopf-Heilkunde*, 164, 23–40.

Schumacher, R., Cazzoli, D., Eggenberger, N., Preisig, B., Nef, T., Nyffeler, T. *et al.* (2015) Cue recognition and integration – eye tracking evidence of processing differences in sentence comprehension in aphasia. *PLoS ONE*,10(11): e0142853. doi:10.1371/journal.pone.0142853

Schunicht, R., Esser, G., Moerman, C. & Ammon, K.-H. (1974). Audiologische Befunde bei Aphasikern. *Archiv für Ohr-, Nasen- und Kehlkopf-Heilkunde*, 207, 512–513.

Shallice, T. (1982). Specific impairments of planning. *Philosophical Transactions of the Royal Society of London*, *298*, 199–209.

Shankweiler, D., Crain, S., Gorrell, P., & Tuller, B. (1989). Reception of language in Broca's aphasia. *Language and Cognitive Processes*, *4*(1), 1–33.

Shaw, B. J., & Krause, J. C. (2007). *Clear speech at normal rates: Intelligibility for older hearing-impaired adults*. Poster at the ASHA convention, Miami Beach, November 2007.

Sheppard, S. M., Walenski, M., Love, T., & Shapiro, L. P. (2015). The auditory comprehension of wh-questions in aphasia: Support for the Intervener Hypothesis. *Journal of Speech, Language, and Hearing Research,* 1–17.

Shinn-Cummingham, B. G., & Best, V. (2008). Selective attention in normal and impaired hearing. *Trends in Amplification,* 12(4), 283–299.

Sidiropoulos, K., Ackermann, H., Wannke, M., & Hertrich, I. (2010). Temporal processing capabilities in repetition conduction aphasia. *Brain and Cognition,* 73, 194–202.

Silkes, J. P. (2012). Providing audiological services to individuals with aphasia: considerations, preliminary recommendations, and a call for research. *American Journal of Audiology* 21, 3–12.

Silkes, J. P., & Rogers, M. A. (2010). Perception of visually masked stimuli by individuals with aphasia: A methodological assessment and preliminary theoretical implications. *Aphasiology,* 24(6–8), 763–774.

Simon, H. A. (1975). The functional equivalence of problem solving skills. *Cognitive Psychology*,7, 268–288.

Smith, S. L., & Pichora-Fuller, M. K. (2015). Associations between speech understanding and auditory and visual tests of verbal working memory: effects of linguistic complexity, task, age, and hearing loss. *Frontiers in Psychology*, 6, article 1394.

Smith, P. A. (2011): Impact of distraction and memory on grammaticality judgment in a patient with aphasia. Clinical Aphasiology Conference, Fort Lauderdale, USA.

Smith, S., & Bates, E. (1987). Accessibility of case and gender contrasts for agent-object assignment in Broca's aphasics and fluent anomics. *Brain and Language, 30*, 8–32.

Smith, A. (1968). The Symbol Digit Modalities Test: A neuropsychological test for economic screening of learning and other cerebral disorders. *Learning Disorders, 36,* 83–91.

Sohn, W., & Jörgenshaus, W. (2001). Schwerhörigkeit in Deutschland. *Zeitschrift für Allgemeine Medizin*, 77, 143–147.

Sommers, M. S. (1997). Stimulus variability and spoken word recognition. II. The effects of age and hearing impairment. *Journal of the Acoustical Society of America,* 101(4), 2278–2288.

Spehar, B., Tye-Murray, N., & Sommers, M. (2004). Time-compressed visual speech and age: A first report. *Ear & Hearing,* 25, 565–572.

Spreen, O., & Risser, A. (2003). *Assessment of Aphasia*. Oxford: Oxford University Press.

Stach B. (2000). *Hearing aid amplification and central auditory disorders*. In R. E. Sandlin (Ed.), Textbook of hearing aid amplification - 2nd edition (pp. 607–641). San Diego: Singular Publishing Group.

Stackelberg, H. v. (1986). *Hörtest 1985*. Bonn, Deutsches Grünes Kreuz.

Stevenson, S. (1994). Competition and recency in a hybrid network model of syntactic disambiguation. *Journal of Psycholinguistic Research*, 23,295–322.

Stewart, R., & Wingfield, A. (2009). Hearing loss and cognitive effort in older adults' report accuracy for verbal materials. *Journal of the American Academy of Audiology*, 20(2), 147–154.

Sticht, T. C., & Gray, B. B. (1969)**.** The intelligibility of time compressed words as a function of age and hearing loss. *Journal of Speech and Hearing Research*, 12, 443–448.

Stine-Morrow, E. A. L., Ryan, S., & Leonard, J. S. (2000*).* Age differences in on-line syntactic processing. *Experimental Aging Research*, 26, 315–322.

Stroop, J. R., 1935. Studies of interference in serial verbal reactions. *Journal of Experimental Psychology,* 18, 643–662.

Swaab, T., Brown, C., & Hagoort, P. (1998). Understanding ambiguous words in sentence contexts: Electrophysiological evidence for delayed contextual selection in Broca's aphasia. *Neuropsychologia,* 25(7), 626–650.

Swaab, T., Brown, C., & Hagoort, P. (1997). Spoken sentence comprehension in aphasia: Event-related potential evidence for a lexical integration deficit. *Journal of Cognitive Neuroscience,* 9(1), 29–66.

Sweetow, R., & Palmer, C. V. (2005). Efficacy of individual auditory training in adults: A systematic review of the evidence. *Journal of the American Academy of Audiology*, *16*(7), 494–504.

Swinney, D., Zurif, E., Prather, P., & Love, T. (1996). Neurological distribution of processing resources underlying language comprehension. *Journal of Cognitive Neuroscience,* 8(2), 174–184.

Swinney, D., & Zurif, E. (1995). Syntactic processing in aphasia. *Brain and Language,* 50, 225–239.

Swisher, L. & Hirsh, I. J. (1972). Brain damage and the ordering of two temporally successive stimuli. *Neuropsychologia,* 10, 137–152.

Tartaglione, A., Bino, G., Manzino, M., Spadavecchia, L., & Favale, E. (1986). Simple reaction time changes in patients with unilateral brain damage. *Neuropsychologia*, 24, 649–658

Tatemichi, T. K., Desmond, D. W., Stern, Y., Paik, M., Sano, M., & Bagiella, E. (1994). Cognitive impairment after stroke: Frequency, patterns and relationship to functional abilities. *Journal of Neurology, Neurosurgery and Psychiatry*; 57, 202–207.

Thompson, C. K., & Shapiro, L. P. (2007). Complexity in treatment of syntactic deficits. *American Journal of Speech-Language Pathology*, 16, 30–42.

Tomlin, R. (1986). *Basic word order: Functional principles*. London: Croom Helm.

Tomoeda, C., Bayles, K. R., Boone, D. R., Kaszniak, A. W., & Slauson, T. J. (1990): Speech rate and syntactic complexity effects on the auditory comprehension of Alzheimer patients. *Journal of Communication Disorders,* 23, 151–161.

Torre, P., Cruickshanks, K. J., Klein, B. E. K., Klein, R., & Nondahl, D. M. (2005). The association between cardiovascular disease and cochlear function in older adults. *Journal of Speech, Language & Hearing Research, 48(2)*, 473–481.

Traxler, M., Morris, R. K., & Seely, R. E. (2002). Processing subject and object relative clauses: Evidence from eye movements. *Journal of Memory and Language* 47, 69–90.

Tremblay, K. L., Piskosz, M. A., & Souza, P. (2003). Effects of age and age-related hearing loss on the neural representation of speech cues. *Clinical Neurophysiology*, 114, 1332–1343.

Tseng, C.-H., McNeil, M. R., & Milenkovic, P. (1993). An investigation of attention allocation deficits in Aphasia. *Brain and Language*, 45, 276–296.

Tun, P.A., Benichov, J., & Wingfield, A. (2010). Response latencies in auditory sentence comprehension: Effects of linguistic versus perceptual challenge. *Psychology and Aging*, 25(3), 730–735.

Tun, P. A., McCoy, S., *&* Wingfield, A. (2009). Aging, hearing acuity, and the attentional costs of effortful listening. *Psychology and Aging*, 24(3), 761–766.

Tun, P. A., O'Kane, G., & Wingfield, A. (2002). Distraction by competing speech in young and older adult listeners. *Psychology and Aging*, 17(3), 453–467.

Tun, P. A. (1998). Fast noisy speech: Age differences in processing rapid speech with background noise. *Psychology and Aging*, 13, 424–434.

Turken, A., Whitfield-Gabrieli, S., Bammer, R., Baldo, J. V., Dronkers, N. F., & Gabrieli, J. D. (2008). Cognitive processing speed and the structure of white matter pathways: Convergent evidence from normal variation and lesion studies. *Neuroimage*; 42, 1032–1044.

Turner, C. W., & Cummings, K. J. (1999). Speech audibility for listeners with high-frequency hearing loss. *American Journal of Audiology*, *8*(1), 47–56.

Turner, C. W., Smith, S. J., Aldridge, P. L., & Stewart, S. L. (1997). Formant transition duration and speech recognition in normal and hearing-impaired listeners. *Journal of the Acoustical Society of America,* 101, 2822–2825.

Turner, C. W., Souza, P. E., & Forget, L. N. (1994). Use of temporal envelope cues in speech recognition by normal and hearing-impaired listeners. *Journal of the Acoustic Society of America*, 97(4), 2568–2576.

Tyler, R., Summerfield, A. Q., Wood, E., & Fernandes, M. (1982). Psychoacoustic and phonetic temporal processing in normal and hearing-impaired listeners. *Journal of the Acoustic Society of America*, 73, 740–752.

Uslar, V. N. (2014). Speech perception, age, and hearing loss: Methods to assess the balance between bottom-up and top-down processing. Berlin: Winter-Industries.

Uslar, V. N., Carroll, R., Hanke, M., Hamann, C., Ruigendijk, E., Brand, T., & Kollmeier, B. (2013). Development and evaluation of a linguistically and audiologically controlled sentence intelligibility test. *Journal of the Acoustic Society of America,* 134(4), 3039–3056.

Utman, J. A., Blumstein, S. E., & Sullivan, K. (2001). Mapping from sound to meaning: Reduced lexical activation in Broca's aphasics. *Brain and Language*, 79, 444–472.

Van Boxtel, M. P. J., van Beijsterveldt, C. E. M., Houx, P. J., Anteunis, L. J. C, Metsemakers, J. F. M., & Jolles, J. (2000). Mild hearing impairment can reduce verbal memory performance in a healthy adult population. *Journal of Clinical and Experimental Neuropsychology*, 22(1), 147–154.

Van der Werff, M. J. (2007). Processing of fast speech by older listeners. Benefit from semantic context and prosody? Unpublished master thesis. Utrecht University.

van Herten, M., Chwilla, D. J., & Kolk, H. H. (2006). When heuristics clash with parsing routines: ERP evidence for conflict monitoring in sentence perception. *Journal of Cognitive Neuroscience*, *18*(7), 1181–1197.

van Rooij, J. C. G. M., & Plomp, R. (1992). Auditive and cognitive factors in speech perception by elderly listeners. III. Additional data and final discussion. *Journal of the Acoustic Society of America,* 91(2), 1028–1033.

Varlokosta, S., Valeonti, N., Kakavoulia, M., Lazaridou, M., Economou, A., *&* Protopapas, A. (2006). The breakdown of functional categories in Greek aphasia: Evidence from agreement, tense, and aspect. *Aphasiology*, 20, 723–743.

Vaughan, N. E., Storzbach, D., & Furukawa, I. (2006). Sequencing versus nonsequencing working memory in understanding of rapid speech by older listeners. *Journal of the American Academy of Audiology,* 17(7), 506–518.

Vaughan, N. E., Furukawa, I., Balasingam, N., Mortz, M., & Fausti, S. A. (2002). Time-expanded speech and speech recognition in older adults. *Journal of Rehabilitation Research and Development,* 39(5), 559–566.

Vaughan, N. E., & Letowski, T. (1997). Effects of Age, Speech Rate, and Type of Test on Temporal Auditory Processing. *Journal of Speech and Hearing Research,* 40, 1192–1200.

Versfeld, N. J., & Dreschler, W. A. (2002). The relationship between the intelligibility of time-compressed speech and speech in noise in young and elderly listeners. *Journal of the Acoustic Society of America,* 111(1), 401–408.

Vitela, A. D., Monson, B. B., & Lotto, A. J. (2014). Phoneme categorization relying solely on high-frequency energy. *Journal of the Acoustic Society of America,* 137(1), EL65–EL70.

Vuong, L. C., & Martin, R. C. (2011). LIFG-based attentional control and the resolution of lexical ambiguities in sentence context. *Brain & Language*, *116*, 22–32.

Wagener, K., V. Kühnel, V., & Kollmeier, B. (1999). Entwicklung und Evaluation eines Satztests in deutscher Sprache I: Design des Oldenburger Satztests. *Zeitschrift für Audiologie/Audiological Acoustics***,** 38(1), 4–15.

Wagener, K., Brand, T., & Kollmeier, B. (1999a). Entwicklung und Evaluation eines Satztests in deutscher Sprache II: Optimierung des Oldenburger Satztests. *Zeitschrift für Audiologie/Audiological Acoustics* 38(2), 44–56.

Wassenaar, M., & Hagoort, P. (2007). Thematic role assignment in patients with Broca's aphasia: Sentence-picture matching electrified. *Neuropsychologia,* 45, 716–740.

Wassenaar, M., Brown, C., & Hagoort, P. (2004). ERP effects of subject-verb agreement violations in patients with Broca's aphasia. *Journal of Cognitive Neuroscience,* 16(4), 553–576.

Waters, G., & Caplan, D. (2005). The relationship between age, processing speed, working memory capacity, and language comprehension. *Memory,* 13(3–4), 403–413.

Waters, G., Caplan, D., Alpert, C. N., & Stanczak, L. (2003). Individual differences in rCBF correlates of syntactic processing in sentence comprehension: Effects of working memory and speed of processing. *NeuroImage*, 19, 101–112.

Weber, A. & Müller, K. (2004). Word order variation in German main clauses. A corpus analysis. In S. Hansen-Schirra, S. Oepen, & H. Uszkoreit (Eds.), *Workshop On Linguistically Interpreted Corpora* (pp. 71–77). Geneva, Coling.

Wechsler, D. (1958). *The measurement and appraisal of adult intelligence*. Baltimore, Md: Williams & Wilkens.

Weidner, W. E., & Lasky, E. Z. (1976). The interaction of rate and complexity of stimulus on the performance of adult aphasic subjects. *Brain and Language,* 3, 34–40.

Wendt, D., Kollmeier, B., & Brand, T. (2015). How hearing impairment affects sentence comprehension: Using eye fixations to investigate the duration of speech processing. *Trends in Hearing*, 19, 1–18.

Wendt, D., Brand, T., & Kollmeier, B. (2014). An eye-tracking paradigm for analyzing the processing time of sentences with different linguistic complexities. *PLoS ONE* 9(6), e100186.

Wendt, D., Brand, T., & Kollmeier, B. (2012). *The influence of linguistic complexity, noise and age on speech comprehension: Evidence from eye movements.* Poster presented at the Speech in Noise Workshop, Cardiff, UK, January 05–06.

Wenzlaff, M., & Clahsen, H. (2005). Finiteness and verb-second in German agrammatism. *Brain & Language,* 92, 33–44.

Weskott, T., Hörnig, R., Fanselow, G., & Kliegl, R. (2011). Contextual licensing of marked OVS word order in German. *Linguistische Berichte*, 225, 3-18.

Weyerts, H., Penke, M., Münte, T. F., Heinze, H.-J., & Clahsen, H. (2002). Word order in sentence processing: An experimental study of verb placement in German. *Journal of Psycholinguistic Research, 31*, 211-268.

Wiener, D., A., Tabor Connor, L., & Obler, L. (2004). Inhibition and auditory comprehension in Wernicke's aphasia. *Aphasiology*, 18(5-7), 599-609.

Wilson, S. M. & Saygin, A. P. (2004). Grammaticality judgment in aphasia: Deficits are not specific to syntactic structures, aphasic syndromes, or lesion sites. *Journal of Cognitive Neuroscience*, 16(2), 238–252.

Wingfield, A., & Tun, P. A. (2007) Cognitive supports and cognitive constraints on comprehension of spoken language. *Journal of the American Academy of Audiology,* 18, 567–577.

Wingfield, A., McCoy, S. M., Peelle, J. E., Tun, P. A., & Cox, C. (2006). Effects of adult aging and hearing loss on comprehension of rapid speech varying in syntactic complexity. *Journal of the American Academy of Audiology,* 17, 487–497.

Wingfield, A., Tun, P. A., McCoy, S. L., Stewart, R. A., & Cox, C. (2006a). Sensory and cognitive constraints in comprehension of spoken language in adult aging. *Seminars in Hearing,* 27, 273–283.

Wingfield, A., Tun, P. A., & McCoy, S. L. (2005). Hearing loss in older adulthood: What it is and how it interacts with cognitive performance. *Current Directions in Psychological Science,* 14, 144–148.

Wingfield, A., Peelle, J. E., & Grossman, M. (2003). Speech rate and syntactic complexity as multiplicative factors in speech comprehension by young and older adults. *Aging, Neuropsychology and Cognition,* 10, 310–322.
Wingfield, A., & Kahana, M. J. (2002). The dynamics of memory retrieval in older adulthood. *Canadian Journal of Experimental Psychology,* 56(3), 187–199.
Wingfield, A., & Ducharme, J. L. (1999). Effects of age and passage difficulty on listening-rate preferences for time-altered speech. *Psychological Sciences,* 54B, 199–202.
Wingfield, A., Tun, P. A., & Rosen, M. J. (1995). Age differences in veridical and reconstructive recall of syntactically and randomly segmented speech. *Journal of Gerontology: Psychological Sciences,* 50B(5), P257–P266.
Wingfield, A., Wayland, S. C., & Stine, E. A. L. (1992). Adult age differences in the use of prosody for syntactic parsing and recall of spoken sentences. *Journal of Gerontology: Psychological Sciences,* 47(5), P35O–P356.
Wingfield, A. Lahar, C. J., & Stine, E. A. (1989). Age and decision strategies in running memory for speech: Effects of prosody and linguistic structure. *Journal of Gerontology,* 44(4), 106–113.
Wingfield, A., & Stine, E. L. (1986). Organizational strategies in immediate recall of rapid speech by young and elderly adults. *Experimental Aging Research: An International Journal Devoted to the Scientific Study of the Aging Process,* 12(2), 79–83.
Winkens, I. (2009). *Mental slowness after stroke: Assessment and treatment.* Maastricht: Neuropsych Publishers.
World Health Organization (2012). Global estimates on prevalence of hearing loss. Geneva: World Health Organization. Available from: http://www.who.int/pbd/deafness/estimates
Wright, H. H., Downey, R. A., Gravier, M., Love, T., & Shapiro, L. P. (2007). Processing distinct linguistic information types in working memory in aphasia. *Aphasiology,* 21(6–8), 802–813.
Wulfeck, B., Bates, E., & Capasso, R. (1991). A crosslinguistic study of grammaticality judgments in Broca's aphasia. *Brain and Language*, 41, 311–336.
Yampolsky, S., Waters, G., Caplan, D., Matthies, M., *&* Chiu, P. (2002). Effects of acoustic degradation on syntactic processing: Implications for the nature of the resource system used in language processing. *Brain and Cognition 48(2-3)*, 617–625.
Yarbay Duman, T., Altinok, N., Özgirin, N., & Bastiaanse, R. (2011). Sentence comprehension in Turkish Broca's aphasia: An integration problem. *Aphasiology,* 25(8), 908–926.
Zahnert, T. (2011). Differenzialdiagnose der Schwerhörigkeit. *Deutsches Ärzteblatt,* 108(25), 433–445.
Zenker-Castro, F., Carballo Gonzalez, A. B., Rodriguez Jimenez, M., Olleta Lascarro, M I., Marro Cosials, S., & Barajas de Prat, J. J. (2012). Effects of sensineural hearing loss on the time-compressed speech test. *Journal of Hearing Science*, 2(1), 23–26.
Zurif, E., Swinney, D., Prather, P., Wingfield, A., & Brownell, H. (1995). The allocation of memory resources during sentence comprehension: Evidence from the elderly. *Journal of Psycholinguistic Research, 24,* 165–182.
Zurif, E., Swinney, D., Prather, P., Solomon, J., & Bushell, C. (1993). An on-line analysis of syntactic processing in Broca's and Wernicke's aphasia. *Brain and Language,* 45, 448–464.

13 Appendices

13.1 Demographic data of PWA

Table 13.1. Code, gender (G, M = male, F = female), age (in years), years of education (YoE), aphasia diagnosis (amnest = amnestic, cond = conduction, nc = non-classifiable; resid = residual), main symptom of production deficits(symptom, agram = agrammatic, para = paragrammatic, anom = anomic), cause of aphasia (Cause, IS = ischemic, HAE = haemorrhagic; CHI = closed head injury; l = left, b = bilateral), duration of aphasia (DA, in months), state of aphasia (SofA; A = acute, C = chronic), severity of the auditory sentence comprehension deficit (Sev, according to the score on the SVO sentences (in %)), PTA-4 score in dB, PTA-6 score in dB, Hearing status (HS, B = Bilateral, U = unilateral, N = normal), presence of needed hearing aid (HA, NU = present but no usage), scores on the Spontaneous Speech Protocol of the AAT (SSP; numbers refer to the 6 scales consisting of Communicative Behaviour, Articulation and Prosody, Formulaic Language, Semantics, Phonology, and Syntax, with higher numbers reflecting better performance), score on the Token Test (TT; maximum: 50 error points; higher numbers signify a higher degree of impairment), scores on the auditory comprehension tests of the AAT (AC; maximum: 60 points, higher numbers signify a higher degree of correct comprehension), and exclusion criteria (Ex, H = health reasons, I = lack of instructions comprehension; S = SVO score below 50%) for the group of PWA per participant (N = 50) for the selected (N = 37) and the excluded (N = 13) sub group.

Code	G	Age	YoE	Diagnosis	Symptom	Cause	DA	SoA	Sev	PTA_4	PTA-6	HS	HA	SSP[50]	TT	AC	Ex
Selected																	
202	M	71	13	Broca	agram	IS b	2	A	56.11	62.5	63.33	B	yes	234422	21	35	-
203	M	77	13	Broca	agram	re-IS l	1	A	52.22	26.25	31.67	B	no	111211	26	56	-
204	F	66	8	Wernicke	para	HAE l	3	A	63.33	57.5	58.33	B	yes	354334	25	35	-
206	M	55	13	agram	agram	IS l	27	C	50.56	11.25	14.17	N	-	254444	33	44	-
207	F	57	12	amnest	anom	HAE l	2	A	61.11	37.5	36.67	B	no	455444	22	57	-
208	F	59	12	agram	agram	HAE l	88	C	47.22	2.5	3.33	N	-	255451	16	56	-

[50] The spontaneous speech of PWA, containing answers to fixed questions was analysed via six areas defined by the SSP of the AAT: Communicative Behaviour, Articulation and Prosody, Formulaic Language, Semantics, Phonology, and Syntax. The utterances of the PWA are divided into phrases, type of errors are identified, and the frequency of the error occurrence is counted (e.g., automatisms in Communicative Behaviour, phonological paraphasias in Phonology, or semantic paraphasias in Semantics). For syntax, error types include omission or substitution of inflections and/or function words, sentence termination, omission of constituents, and symptoms of paragrammatism, such as doubling of sentence constituents or syntactic entanglements. Frequency of error occurrence defines the severity of the symptom within one area in terms of five different severity levels, ranging from no utterance (total impairment) to no impairment.

Code	G	Age	YoE	Diagnosis	Symptom	Cause	DA	SoA	Sev	PTA_4	PTA-6	HS	HA	SSP[50]	TT	AC	Ex
209	F	62	15	agram	agram	IS l	132	C	83.89	-1.25	1.67	N	-	445544	5	58	-
210	M	22	19	agram	agram	IS l	48	C	80.56	10	11.67	N	-	245342	1	50	-
211	M	75	15	para	para	IS l	43	C	47.78	2.5	0.83	N	-	354453	37	41	-
212	M	35	10	amnest	anom	IS l	7	C	57.78	0.00	0.00	N	-	454344	38	60	-
213	F	59	15	nc	anom	IS l	9	C	48.89	12.5	16.67	N	-	344443	33	52	-
214	F	54	9	amnest	anom	IS l	17	C	66.67	53.75	53.33	B	yes	344434	5	49	-
215	F	71	13	resid	anom	IS l	39	C	92.78	7.5	8.33	N	-	435445	0	60	-
216	M	56	12	resid	anom	IS l	42	C	85	36.25	36.67	B	yes	443454	16	57	-
217	M	74	12	agram	agram	IS l	45	C	75.56	1.25	1.67	N	-	232341	26	53	-
218	F	44	9	para	para	IS l	44	C	68.89	30.00	32.5	B	NU	333343	9	46	-
222	M	43	12	Wernicke	para	HAE l	3	A	58.33	15.00	16.67	U	-	443354	18	41	-
223	M	47	19	agram	agram	IS l	3	A	52.78	13.75	18.33	N	-	243222	36	30	-
225	M	54	25	Wernicke	para	CHI and HAE	5	A	75	35.00	39.17	B	no	445444	10	51	-
226	F	64	8	amnest	anom	IS l	1	A	57.22	60.00	61.67	B	yes	454444	16	47	-
227	M	52	14	Broca	agram	IS l	4	A	73.33	15.00	20.00	N	-	233222	39	50	-
229	M	49	22	nc	anom	IS l	25	C	61.11	33.75	38.33	B	NU	454444	16	46	-
230	M	46	12	Broca	agram	IS l	117	C	68.89	12.50	10.83	N	-	212432	16	57	-
231	F	52	13	resid	anom	HAE l	44	C	73.89	13.75	15.00	N	-	454444	4	54	-
232	F	75	8	Cond	anom	IS l	33	C	55	17.50	20.00	N	-	353323	35	41	-
233	F	61	13	Wernicke	para	IS l	24	C	64.44	2.50	4.17	N	-	455434	33	51	-
234	F	62	12	Broca	agram	IS l	195	C	48.89	3.75	5.83	N	-	253352	20	44	-
235	F	56	10	Broca	agram	IS l	235	C	77.78	15	16.67	U	-	243322	19	44	-
236	F	59	16	Broca	agram	HAE l	123	C	58.89	16.25	19.17	N	-	242342	44	47	-
237	F	75	11	nc	para	CHI and IS l	337	C	55.56	13.75	17.5	U	no	453433	26	56	-
238	F	54	13	Broca	agram	IS l	28	C	52.22	13.75	14.17	N	-	333333	15	90	-

Code	G	Age	YoE	Diagnosis	Symptom	Cause	DA	SoA	Sev	PTA_4	PTA-6	HS	HA	SSP[50]	TT	AC	Ex
239	M	82	13	resid	anom	IS l	39	C	77.22	10.00	20.00	N	-	444433	3	48	-
240	F	59	13	Broca	agram	IS l	275	C	72.22	5.00	6.67	N	-	234343	28	50	-
242	F	57	11	nc	anom	IS l	77	C	45.56	3.75	9.17	N	-	454444	4	53	-
243	F	64	12	resid	anom	HAE l	282	C	77.22	15.00	15.83	N	-	454454	0	47	-
244	M	48	16	amnest	anom	IS l	57	C	83.33	35.00	35.00	B	NU	454454	6	49	-
245	M	56	11	amnest	anom	CHI l	7	C	51.67	21.25	31.67	B	no	454444	64	49	-
Excluded																	
201	w	73	10	Broca	agram	IS l	1	A	NA	12.50	12.50	N	-	NA	NA	NA	H
205	m	84	12	global	agram	IS l	1	A	NA	33.75	35.83	B	no	NA	43	23	S
219	m	73	16	NA	agram	IS l	3	A	NA	32.50	39.17	B	no	NA	NA	NA	S
220	m	79	18	Wernicke	para	HAE l	65	C	NA	22.50	30.00	B	no	NA	NA	NA	S
221	m	74	12	agram	agram	IS l	3	A	NA	27.50	32.50	B	no	NA	NA	NA	S
224	m	64	13	global	agram	IS l	3,5	A	NA	21.25	25.83	B	no	NA	NA	NA	S
228	m	71	19	Jargon	Jargon	IS l	2	A	NA	10.00	17.50	N	-	NA	NA	NA	S
241	w	50	9	Broca	agram	HAE l	35	C	NA	17.50	21.67	U	no	333434	28	30	S
246	w	58	12	amnest	anom	IS l	2	C	NA	11.25	12.50	N	-	NA	NA	NA	H
247	m	56	NA	global?	agram	HAE l	1	C	NA	10.00	17.50	N	-	NA	NA	NA	I
248	m	65	NA	NA	agram	IS l	2	C	NA	18.75	21.67	U	no	NA	NA	NA	I
249	m	75	NA	NA	agram	IS l	2	C	NA	40	41.67	B	no	NA	NA	NA	I
250	w	56	11	nc	anom	IS l	65	C	NA	3.75	9.17	N	-	333444	34	41	H

13.2 Material

13.2.1 Sentence stimuli

Table 13.2. All experimental items and their translation per syntactic structure. Note that female plural nouns (fem) are marked in the translation

Code	Item per syntactic structure	Translation
SVO		
1054	Der fiese Pirat erschießt den braven Soldaten.	“The evil pirate shoots the good soldier.”
1062	Der grobe Riese ersticht den scheuen Piloten.	“The rough giant stabs the shy pilot.”
1063	Der wirre Astronaut ersticht den trägen Maler.	“The weird astronaut stabs the shy pilot.”
1071	Der böse Gärtner erwürgt den dreisten Postboten.	“The evil gardener chokes the brash postman.”
1084	Der gute Soldat fängt den frechen Cowboy.	“The good soldier catches the naughty cowboy.”
1122	Der brave Matrose grüßt den netten Angler.	“The good sailor greets the nice fisher.”
1124	Der kluge Pilot grüßt den alten Pfarrer.	“The clever pilot greets the old pastor.”
1132	Der sture Kellner interviewt den frechen Frisör.	“The stubborn waiter interviews the naughty hairdresser.”
1162	Der nette Papst küsst den guten Soldaten.	“The nice pope kisses the good soldier.”
1242	Der schlaue Kellner tadelt den dreisten Touristen.	“The clever waiter reprimands the brash tourist.”
1261	Der alte König tröstet den jungen Prinzen.	“The old king comforts the young prince.”
1273	Der kleine Junge umarmt den dicken Nikolaus.	“The small boy hugs the fat Santa Claus.”
1291	Der flinke Maler verfolgt den blassen Touristen.	“The swift painter chases the pale tourist.”
1294	Der rüde Punker verfolgt den starken Soldaten.	“The rude punker chases the strong soldier.”
1313	Der nasse Taucher verscheucht den stillen Angler.	“The wet diver shoos off the quiet fisher.”
OVS		
2054	Den fiesen Piraten erschießt der brave Soldat.	“It is the evil pirate whom the good soldier shoots.”
2062	Den scheuen Piloten ersticht der grobe Riese.	“It is the shy pilot whom the rough giant stabs.”
2063	Den wirren Astronauten ersticht der träge Maler.	“It is the weird astronaut whom the lazy painter stabs.”
2071	Den dreisten Postboten erwürgt der böse Gärtner.	“It is the brash postman whom the evil gardener chokes.”
2084	Den guten Soldaten fängt der freche Cowboy.	“It is the good soldier whom the naughty cowboy catches.”
2122	Den braven Matrosen grüßt der nette Angler.	“It is the good sailor whom the nice fisher greets.”
2124	Den alten Pfarrer grüßt der kluge Pilot.	“It is the old pastor whom the clever pilot greets.
2132	Den sturen Kellner interviewt der freche Frisör.	“It is the stubborn waiter whom the naughty hairdresser interviews.”
2162	Den netten Papst küsst der gute Soldat.	“It is the nice pope whom the good soldier greets.”
2242	Den schlauen Kellner tadelt der dreiste Tourist.	“It is the clever waiter whom the brash tourist interviews.”
2261	Den alten König tröstet der junge Prinz.	“It is the old king whom the young prince comforts.”
2273	Den dicken Nikolaus umarmt der kleine Junge.	“It is the fat Santa Claus whom the small boy hugs.”
2291	Den blassen Touristen verfolgt der flinke Maler.	“It is the pale tourist whom the swift painter chases.”
2294	Den rüden Punker verfolgt der starke Soldat.	“It is the rude punker whom the strong soldier chases.”
2313	Den nassen Taucher verscheucht der stille Angler.	“It is the wet diver whom the quiet fisher shoos off.”
SR		
4012	Der Papst, der die Detektive berührt, gähnt.	“The pope who touches the detectives yawns.”
4042	Der Lehrer, der die Models bestiehlt, zittert.	“The teacher who steals from the models shivers.”
4053	Der Frisör, der die Köchinnen erschießt, grinst.	“The hairdresser who shoots the cooks$_{\text{fem}}$ sneers.”
4054	Der Koch, der die Touristinnen erschießt, niest.	“The cook who shoots the tourists$_{\text{fem}}$ sneezes.”

Code	Item per syntactic structure	Translation
4062	Der Maler, der die Witwen ersticht, zittert.	“The painter who stabs the widows shivers.”
4063	Der Mönch, der die Astronauten ersticht, schwitzt.	“The monk who shoots the astronauts sweats.”
4071	Der Angler, der die Müllmänner erwürgt, grinst.	“The fisher who chokes the dustmen sneers.”
4074	Der Taucher, der die Bräute erwürgt, lächelt.	“The diver who chokes the brides smiles.”
4082	Der Bauer, der die Ärztinnen fängt, lächelt.	“The farmer who catches the doctors$_{\text{fem}}$ smiles.”
4121	Der Maurer, der die Metzger grüßt, errötet.	“The mason who greets the butchers blushes.”
4132	Der Dieb, der die Bäcker interviewt, weint.	“The thief who interviews the bakers cries.”
4133	Der Soldat, der die Köche interviewt, lacht.	“The soldier who interviews the cooks laughs.”
4164	Der Metzger, der die *Stewardessen* küsst, gähnt.	“The butcher who kisses the flight attendants$_{\text{fem}}$ yawns.”
4182	Der Frisör, der die Bäuerinnen massiert, weint.	“The hairdresser who massages the farmers$_{\text{fem}}$ cries.”
4243	Der Soldat, der die Köchinnen tadelt, niest.	“The soldier who reprimands the cooks$_{\text{fem}}$ sneezes.
OR		
5012	Der Papst, den die Detektive berühren, gähnt.	“The pope whom the detectives touch yawns.”
5042	Der Lehrer, den die Models bestehlen, zittert.	“The teacher whom the models steal from shivers.”
5053	Der Frisör, den die **Köchinnen** erschießen, grinst.	“The hairdresser whom the cooks$_{\text{fem}}$ shoot sneers.”
5054	Der Koch, den die **Touristinnen** erschießen, niest.	“The cook whom the tourists$_{\text{fem}}$ shoot sneezes.”
5062	Der Maler, den die **Witwen** erstechen, zittert.	“The painter whom the widows stab shivers.”
5063	Der Mönch, den die Astronauten erstechen, schwitzt.	“The monk whom the astronauts shoot sweats.”
5071	Der Angler, den die Müllmänner erwürgen, grinst.	“The fisher whom the dustmen choke sneers.”
5074	Der Taucher, den die **Bräute** erwürgen, lächelt.	“The diver whom the brides choke smiles.”
5082	Der Bauer, den die **Ärztinnen** fangen, lächelt.	“The farmer whom the doctors$_{\text{fem}}$ catch smiles.”
5121	Der Maurer, den die Metzger grüßen, errötet.	“The mason whom the butchers greet blushes.”
5132	Der Dieb, den die Bäcker interviewen, weint.	“The thief whom the bakers interview cries.”
5133	Der Soldat, den die Köche interviewen, lacht.	“The soldier whom the cooks interview laughs.”
5164	Der Metzger, den die **Stewardessen** küssen, gähnt.	“The butcher whom the flight attendants$_{\text{fem}}$ kiss yawns.”
5182	Der Frisör, den die **Bäuerinnen** massieren, weint.	“The hairdresser whom the farmers$_{\text{fem}}$ massage cries.”
5243	Der Soldat, den die **Köchinnen** tadeln, niest.	“The soldier whom the cooks$_{\text{fem}}$ reprimand sneezes.

13.2.2 Lemma frequencies

Table 1.3. Absolute frequency per million of the content words in the stimuli sentences, taken from the databases of dlexdb, WebCelex (MannSMln: Mannheimer Spoken Word Frequency; MannWMln: Mannheimer Written Word Frequency), and Clearpond. (NA: not found in database).

Word	Type	Lemma	dlexdb	Web Celex		Clearpond
				MannSMln	MannWMln	
alt	adjective	alt	6298	559	724	248.47
blass	adjective	blass	1190	NA	NA	6.34
böse	adjective	böse	2152	13	33	161.19
brav	adjective	brav	617	10	16	18.15
dick	adjective	dick	1634	10	12	31.69
dreist	adjective	dreist	197	0	2	2.01
fies	adjective	fies	18	NA	NA	5.24

Word	Type	Lemma	dlexdb	Web Celex		Clearpond
				MannSMln	MannWMln	
flink	adjective	flink	316	0	6	0.83
frech	adjective	frech	664	0	9	10.32
grob	adjective	grob	1019	31	22	9.09
gut	adjective	gut	42901	1838	1260	2960.63
jung	adjective	jung	2609	301	384	58.31
klein	adjective	klein	5010	528	580	70.87
klug	adjective	klug	1537	15	37	33.66
nass	adjective	nass	813	NA	NA	20.47
nett	adjective	nett	1318	65	32	194.47
rüde	adjective	rüde	32	NA	NA	1.18
scheu	adjective	scheu	673	10	10	1.54
schlau	adjective	schlau	428	3	6	30.79
stark	adjective	stark	15807	74	36	106.74
stur	adjective	stur	214	2	4	7.21
träge	adjective	träge	500	17	40	1.89
wirr	adjective	wirr	296	2	7	0.79
Angler	noun	Angler	136	0	1	NA
Ärztin	noun	Ärztin	432	NA	NA	NA
Astronaut	noun	Astronaut	14	24	18	3.19
Bäcker	noun	Bäcker	495	NA	NA	1.93
Bauer	noun	Bauer	2731	49	52	66.89
Bäuerin	noun	Bäuerin	606	NA	NA	NA
Braut	noun	Braut	2092	9	22	32.25
Cowboy	noun	Cowboy	47	NA	NA	13.07
Detektiv	noun	Detektiv	152	3	3	7.87
Dieb	noun	Dieb	593	NA	NA	28.54
Frisör	noun	Frisör	31	NA	NA	1.61
Gärtner	noun	Gärtner	715	NA	NA	3.66
Junge	noun	Junge	5323	44	68	326.98
Kellner	noun	Kellner	2157	0	12	9.21
Koch	noun	Koch	1362	0	12	24.13
Köchin	noun	Köchin	542	NA	NA	5.24
König	noun	König	14090	NA	NA	105.79
Lehrer	noun	Lehrer	8241	118	117	47.68
Maler	noun	Maler	5297	19	34	6.61
Matrose	noun	Matrose	344	0	4	2.05
Maurer	noun	Maurer	631	7	13	NA
Metzger	noun	Metzger	176	0	4	3.07
Model	noun	Model	86	0	4	5.79
Mönch	noun	Mönch	694	NA	NA	13.35
Müllmann	noun	Müllmann	1	NA	NA	1.61
Nikolaus	noun	Nikolaus	747	NA	NA	3.54
Pfarrer	noun	Pfarrer	3758	56	27	15.75

Word	Type	Lemma	dlexdb	Web Celex		Clearpond
				MannSMln	MannWMln	
Pilot	noun	Pilot	269	3	30	27.91
Pirat	noun	Pirat	26	2	1	4.61
Postbote	noun	Postbote	88	0	1	2.05
Prinz	noun	Prinz	2926	5	71	28.66
Punker	noun	Punker	15	NA	NA	NA
Riese	noun	Riese	429	2	4	2.68
Soldat	noun	Soldat	2767	73	122	42.4
Stewardess	noun	Stewardess	9	NA	NA	3.07
Taucher	noun	Taucher	103	3	21	1.54
Touristin	noun	Touristin	20	NA	NA	NA
Witwe	noun	Witwe	1439	3	21	11.14
berühren	verb	berühren	1369	NA	NA	18.62
bestehlen	verb	bestehlen	36	0	1	2.05
erröten	verb	erröten	86	NA	NA	NA
erschiessen	verb	erschiessen	104	NA	NA	NA
erstechen	verb	erstechen	25	0	2	2.48
erwürgen	verb	erwürgen	115	NA	NA	2.72
fangen	verb	fangen	420	121	66	74.45
gähnen	verb	gähnen	56	NA	NA	NA
grinsen	verb	grinsen	120	NA	NA	4.25
grüssen	verb	grüssen	546	NA	NA	NA
interviewen	verb	interviewen	35	0	1	2.17
küssen	verb	küssen	757	NA	NA	40.16
lächeln	verb	lächeln	365	NA	NA	45.26
lachen	verb	lachen	2627	61	114	80.51
massieren	verb	massieren	79	0	3	3.07
niesen	verb	niesen	65	0	0	2.24
schwitzen	verb	schwitzen	175	2	12	6.58
tadeln	verb	tadeln	226	2	5	0.98
trösten	verb	trösten	658	NA	NA	6.18
umarmen	verb	umarmen	252	0	7	10.98
verfolgen	verb	verfolgen	2310	87	78	35.58
verscheuchen	verb	verscheuchen	170	2	1	0.94
weinen	verb	weinen	1333	10	54	61.58
zittern	verb	zittern	523	9	30	8.03

13.2.3 Duration of sentences

Table 1.4. Number of syllables (NofS), duration (dur, in ms), syllables per second (sps), words per minute (wpm) per item per sentence type and speech rate.

Syntactic structure/ Code	**NofS**	**Speech Rate**								
		conversational			**slow**			**very slow**		
		dur	wpm	sps	dur	wpm	sps	dur	wpm	sps
SVO										
1054	13	2824	276.23	4.60	3322	126.43	3.91	4153	101.14	3.13
1062	13	2440	319.74	5.33	2870	146.34	4.53	3588	117.07	3.62
1063	13	2661	293.18	4.89	3130	134.19	4.15	3913	107.35	3.32
1071	13	2831	275.49	4.59	3331	126.09	3.90	4164	100.87	3.12
1084	11	2374	278.01	4.63	2793	150.38	3.94	3491	120.30	3.15
1122	12	2630	273.77	4.56	3094	135.75	3.88	3868	108.60	3.10
1124	11	2113	312.34	5.21	2486	168.95	4.42	3108	135.16	3.54
1132	13	2811	277.49	4.62	3307	127.00	3.93	4134	101.60	3.14
1162	11	2499	264.11	4.40	2940	142.86	3.74	3675	114.29	2.99
1242	13	2806	277.99	4.63	3301	127.23	3.94	4126	101.79	3.15
1261	12	2353	306.02	5.10	2768	151.73	4.34	3460	121.39	3.47
1273	13	2651	294.21	4.90	3119	134.66	4.17	3899	107.73	3.33
1291	13	2715	287.30	4.79	3194	131.50	4.07	3993	105.20	3.26
1294	13	2687	290.30	4.84	3161	132.87	4.11	3951	106.30	3.29
1313	12	2355	305.80	5.10	2770	151.62	4.33	3463	121.30	3.47
OVS										
2054	13	2666	292.52	4.88	3137	133.89	4.14	3921	107.11	3.32
2062	13	2552	305.68	5.09	3002	139.91	4.33	3753	111.93	3.46
2063	13	2751	283.49	4.72	3237	129.75	4.02	4046	103.80	3.21
2071	13	2779	280.71	4.68	3269	128.48	3.98	4086	102.78	3.18
2084	12	2462	292.49	4.87	2896	145.03	4.14	3620	116.02	3.31
2122	12	2402	299.74	5.00	2826	148.62	4.25	3533	118.90	3.40
2124	11	2445	269.89	4.50	2877	145.99	3.82	3596	116.79	3.06
2132	13	3001	259.88	4.33	3531	118.95	3.68	4414	95.16	2.95
2162	10	2301	260.76	4.35	2707	155.15	3.69	3384	124.12	2.96
2242	12	2472	291.29	4.85	2908	144.43	4.13	3635	115.54	3.30
2261	11	3171	208.17	3.47	3730	112.60	2.95	4663	90.08	2.36
2273	13	2449	318.52	5.31	2881	145.78	4.51	3601	116.63	3.61
2291	13	2598	300.28	5.00	3056	137.43	4.25	3820	109.95	3.40
2294	12	2592	277.82	4.63	3049	137.75	3.94	3811	110.20	3.15
2313	12	2325	309.71	5.16	2735	153.56	4.39	3419	122.85	3.51
SR										
4012	11	2812	234.73	3.91	3308	126.96	3.33	4135	101.57	2.66
4042	11	2661	248.07	4.13	3130	134.19	3.51	3913	107.35	2.81
4053	11	2887	228.58	3.81	3397	123.64	3.24	4246	98.91	2.59
4054	11	2938	224.67	3.74	3456	121.53	3.18	4320	97.22	2.55
4062	11	2569	256.94	4.28	3022	138.98	3.64	3778	111.18	2.91

Syntactic structure/ Code	**NofS**	**Speech Rate**								
		conversational			**slow**			**very slow**		
		dur	wpm	sps	dur	wpm	sps	dur	wpm	sps
4063	11	3093	213.37	3.56	3639	115.42	3.02	4549	92.33	2.42
4071	11	2913	226.57	3.78	3427	122.56	3.21	4284	98.04	2.57
4074	11	2655	248.63	4.14	3123	134.49	3.52	3904	107.59	2.82
4082	11	2439	270.64	4.51	2869	146.39	3.83	3586	117.11	3.07
4121	11	2433	271.30	4.52	2862	146.75	3.84	3578	117.40	3.07
4132	11	2549	258.91	4.32	2999	140.05	3.67	3749	112.04	2.93
4133	11	2722	242.50	4.04	3202	131.17	3.44	4003	104.93	2.75
4164	11	2692	245.18	4.09	3167	132.62	3.47	3959	106.09	2.78
4182	12	3184	226.12	3.77	3746	112.12	3.20	4683	89.70	2.56
4243	11	2815	234.44	3.91	3312	126.81	3.32	4140	101.45	2.66
OR										
5012	12	2628	273.95	4.57	3092	135.83	3.88	3865	108.67	3.10
5042	11	2455	268.86	4.48	2888	145.43	3.81	3610	116.34	3.05
5053	12	3152	228.44	3.81	3708	113.27	3.24	4635	90.61	2.59
5054	12	2665	270.19	4.50	3135	133.97	3.83	3919	107.18	3.06
5062	12	2722	264.54	4.41	3202	131.17	3.75	4003	104.93	3.00
5063	12	3173	226.91	3.78	3733	112.51	3.21	4666	90.01	2.57
5071	12	2744	262.41	4.37	3228	130.11	3.72	4035	104.09	2.97
5074	12	2564	280.76	4.68	3017	139.21	3.98	3771	111.37	3.18
5082	11	2712	243.33	4.06	3191	131.62	3.45	3989	105.30	2.76
5121	12	2760	260.87	4.35	3247	129.35	3.70	4059	103.48	2.96
5132	11	2585	255.33	4.26	3041	138.11	3.62	3801	110.49	2.89
5133	12	2812	256.06	4.27	3308	126.96	3.63	4135	101.57	2.90
5164	12	2804	256.76	4.28	3299	127.31	3.64	4124	101.85	2.91
5182	13	3165	246.48	4.11	3723	112.81	3.49	4654	90.25	2.79
5243	11	2656	248.47	4.14	3125	134.40	3.52	3906	107.52	2.82

13.2.4 Examples of pictures

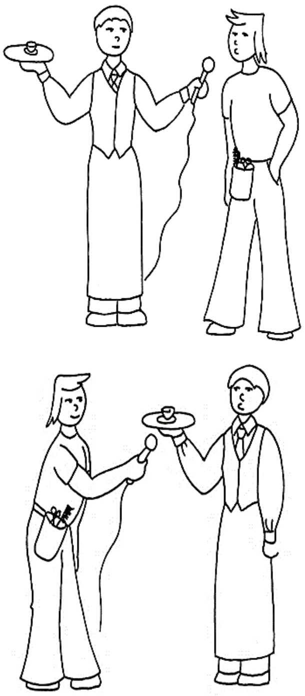

Figure 1.1. Example of V2 structures (left: code 1132, right: code 2132).

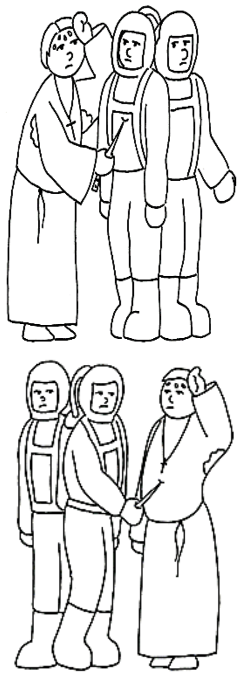

Figure 13.2. Example of RC structures (left: code 4063, right: code 5063).

13.3 Results

13.3.1 Results of all groups

Table 13.5. Mean accuracy in % correct (Mean) and standard deviation (SD) per speech rate for the groups of young controls, normal-hearing and hearing-impaired NBD, and normal-hearing and hearing-impaired PWA.

	Speech rate							
Syntactic structure/Group	**conversational**		**slow**		**very slow**		**Total**	
Hearing level	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
SVO								
Young Controls	98.60	11.76	99.12	9.32	98.95	10.21	98.89	10.48
Hearing-impaired NBD	96.92	17.27	97.18	16.56	95.13	21.53	96.41	18.60
Normal-hearing NBD	98.89	10.48	98.61	11.70	98.89	10.48	98.80	10.91
Hearing-impaired PWA	72.22	44.79	77.78	41.57	74.44	43.62	74.81	43.41
Normal-hearing PWA	76.00	42.71	78.19	41.29	78.40	41.15	77.53	41.74
Agrammatic PWA	75.00	43.40	73.45	44.26	73.66	44.15	74.04	43.88
OVS								
Young Controls	98.42	12.47	98.42	12.47	98.60	11.76	98.48	12.24
Hearing-impaired NBD	93.59	24.49	93.85	24.03	94.87	22.06	94.10	23.56
Normal-hearing NBD	95.28	21.21	97.50	15.61	97.50	15.61	96.76	17.71
Hearing-impaired PWA	58.33	49.30	61.67	48.62	58.33	49.30	59.44	49.10
Normal-hearing PWA	53.46	49.88	53.07	49.91	55.05	49.74	53.86	49.85
Agrammatic PWA	56.19	49.72	55.80	49.77	61.95	48.66	57.99	49.39
SR								
Young Controls	99.47	7.24	98.77	11.01	99.12	9.32	99.12	9.32
Hearing-impaired NBD	96.15	19.23	95.13	21.53	96.67	17.95	95.98	19.64
Normal-hearing NBD	98.33	12.80	98.06	13.81	97.50	15.61	97.96	14.13
Hearing-impaired PWA	67.78	46.73	66.11	47.33	72.22	44.79	68.70	46.37
Normal-hearing PWA	71.73	45.03	71.66	45.07	75.20	43.19	72.86	44.47
Agrammatic PWA	63.39	48.28	66.37	47.35	70.09	45.89	66.62	47.19
OR								
Young Controls	98.60	11.76	98.77	11.01	98.95	10.21	98.77	11.01
Hearing-impaired NBD	90.26	29.66	92.31	26.65	91.79	27.44	91.45	27.96
Normal-hearing NBD	95.00	21.79	94.44	22.91	98.61	11.70	96.02	19.55
Hearing-impaired PWA	54.44	49.80	57.22	49.48	61.11	48.75	57.59	49.42
Normal-hearing PWA	49.73	50.00	52.53	49.94	51.60	49.97	51.29	49.98
Agrammatic PWA	50.88	50.10	56.70	49.66	57.52	49.54	55.03	49.78

13.3.2 PWA

Table 1.6. Accuracy in raw numbers correct (*n*) and % correct (*%*) (without decimals) on SVO (*N* = 45) and OVS (*N* = 45) for the conversational (con) (*N* = 15), slow (*N* = 15), and very slow (v slow) (*N* = 15) speech rate for the selected group of PWA per participant (*N* = 37).

	SVO correct								OVS correct							
	con		**slow**		**v slow**		**total**		**con**		**slow**		**v slow**		**total**	
Code	***n***	***%***	***n***	***%***	***n***	***%***	***n***	***%***	***n***	***%***	***n***	***%***	***n***	***%***	***n***	***%***
202	7	47	11	73	7	47	29	64	6	40	9	60	8	53	23	51
203	9	60	10	67	9	60	28	62	8	53	6	40	9	60	23	51
204	10	67	13	87	11	73	34	76	7	47	8	53	6	40	21	47
206	14	93	9	60	8	53	31	69	7	47	7	47	6	40	20	44
207	13	87	12	80	12	80	37	82	6	40	11	73	7	47	24	53
208	9	60	5	33	9	60	23	51	6	40	4	27	9	60	19	42
209	12	80	14	93	13	87	39	87	10	67	10	67	10	67	30	67
210	12	80	14	93	12	80	38	84	14	93	13	87	11	73	38	84
211	9	60	7	47	12	80	28	62	8	53	7	47	7	47	22	49
212	11	73	12	80	11	73	34	76	4	27	6	40	4	27	14	31
213	12	80	14	93	11	73	37	82	1	7	1	7	0	0	2	4
214	10	67	10	67	12	80	32	71	9	60	11	73	9	60	29	64
215	14	93	15	100	15	100	44	98	10	67	13	87	14	93	37	82
216	12	80	13	87	10	67	35	78	12	80	14	93	13	87	39	87
217	15	100	14	93	15	100	44	98	9	60	12	80	12	80	33	73
218	12	80	11	73	11	73	34	76	11	73	9	60	10	67	30	67
222	10	67	11	73	11	73	32	71	8	53	7	47	9	60	24	53
223	7	47	8	53	8	53	23	51	10	67	9	60	9	60	28	62
225	10	67	13	87	14	93	37	82	11	73	10	67	11	73	32	71
226	10	67	9	60	8	53	27	60	9	60	10	67	11	73	30	67
227	9	60	12	80	14	93	35	78	13	87	13	87	12	80	38	84
229	9	60	10	67	11	73	30	67	9	60	8	53	9	60	26	58
230	14	93	14	93	14	93	42	93	6	40	4	27	5	33	15	33
231	14	93	15	100	11	73	40	89	8	53	9	60	11	73	28	62
232	6	40	9	60	12	80	27	60	9	60	7	47	7	47	23	51
233	12	80	14	93	14	93	40	89	7	47	10	67	2	13	19	42
234	12	80	11	73	11	73	34	76	2	13	4	27	6	40	12	27
235	14	93	13	87	12	80	39	87	10	67	11	73	14	93	35	78

	SVO correct								OVS correct							
	con		**slow**		**v slow**		**total**		**con**		**slow**		**v slow**		**total**	
Code	***n***	***%***	***n***	***%***	***n***	***%***	***n***	***%***	***n***	***%***	***n***	***%***	***n***	***%***	***n***	***%***
236	11	73	14	93	11	73	36	80	7	47	6	40	5	33	18	40
237	10	69	13	87	14	94	38	83	3	20	7	47	5	33	15	33
238	9	57	7	50	12	79	28	61	6	40	6	43	10	69	23	50
239	15	100	14	93	14	93	43	96	12	80	11	73	10	67	33	73
240	11	73	9	60	11	73	31	69	13	87	11	73	13	87	37	82
242	10	67	10	67	5	33	25	56	8	53	5	33	6	40	19	42
243	13	87	15	100	14	93	42	93	10	67	6	40	9	60	25	54
244	11	73	14	93	15	100	40	89	13	87	10	67	10	67	33	73
245	13	87	14	93	14	93	41	91	4	27	5	33	2	13	11	24

Table 1.7. Accuracy in raw numbers correct (*n*) and % correct (*%*) (without decimals) on SR (*N* = 45) and OR (*N* = 45) for the conversational (con) (*N* = 15), slow (*N* = 15), and very slow (v slow) (*N* = 15) speech rate for the selected group of PWA per participant (*N* = 37).

	SR correct								OR correct							
	con		**slow**		**v slow**		**total**		**con**		**slow**		**v slow**		**total**	
Code	***n***	***%***	***n***	***%***	***n***	***%***	***n***	***%***	***n***	***%***	***n***	***%***	***n***	***%***	***n***	***%***
202	7	47	10	67	10	67	27	60	9	60	5	33	8	53	22	49
203	8	53	8	53	6	40	22	49	5	33	9	60	7	47	21	47
204	11	73	12	80	11	73	34	76	8	53	7	47	10	67	25	56
206	7	47	6	40	11	73	24	53	6	40	6	40	4	27	16	36
207	10	67	7	47	8	53	25	56	8	53	9	60	7	47	24	53
208	4	27	7	47	6	40	17	38	6	40	8	53	12	80	26	58
209	13	87	14	93	15	100	42	93	12	80	15	100	13	87	40	89
210	10	67	14	93	11	73	35	78	12	80	10	67	12	80	34	76
211	5	33	4	27	8	53	17	38	5	33	10	67	4	27	19	42
212	15	100	13	87	14	93	42	93	5	33	5	33	4	27	14	31
213	15	100	14	93	14	93	43	96	3	20	2	13	1	7	6	13
214	10	67	9	60	13	87	32	71	8	53	11	73	8	53	27	60
215	15	100	15	100	15	100	45	100	12	80	14	93	15	100	41	91
216	10	67	13	87	15	100	38	84	14	93	13	87	14	93	41	91
217	14	93	11	73	14	93	39	87	6	40	7	47	7	47	20	44
218	10	67	10	67	12	80	32	71	6	40	10	67	12	80	28	62

	SR correct								OR correct							
	con		slow		v slow		total		con		slow		v slow		total	
Code	***n***	***%***	***n***	***%***	***n***	***%***	***n***	***%***	***n***	***%***	***n***	***%***	***n***	***%***	***n***	***%***
222	10	67	12	80	8	53	30	67	5	33	6	40	8	53	19	42
223	10	67	6	40	7	47	23	51	5	33	7	47	9	60	21	47
225	13	87	11	73	11	73	35	78	11	73	10	67	10	67	31	69
226	9	60	7	47	9	60	25	56	6	40	6	40	9	60	21	47
227	10	67	13	87	9	60	32	71	9	60	8	53	10	67	27	60
229	8	53	8	53	11	73	27	60	8	53	9	60	10	67	27	60
230	15	100	15	100	15	100	45	100	6	40	8	53	8	53	22	49
231	12	80	14	93	13	87	39	87	10	67	9	60	7	47	26	58
232	10	67	10	67	8	53	28	62	9	60	5	33	7	47	21	47
233	12	80	14	93	9	60	35	78	7	47	8	53	7	47	22	49
234	5	33	6	40	9	60	20	44	10	67	5	33	7	47	22	49
235	10	67	12	80	11	73	33	73	12	80	13	87	8	53	33	73
236	9	60	11	73	11	73	31	69	6	40	8	53	7	47	21	47
237	12	80	12	80	12	80	36	80	5	33	2	13	4	27	11	25
238	10	67	7	47	10	64	27	59	4	25	6	43	7	50	18	39
239	14	93	14	93	14	93	42	93	7	47	6	40	8	53	21	47
240	11	73	9	60	13	87	33	73	7	47	12	80	10	67	29	64
242	9	60	6	40	11	73	26	58	5	33	4	27	3	20	12	27
243	12	80	10	64	14	93	36	80	13	86	13	87	11	71	37	81
244	15	100	14	93	14	93	43	96	11	73	11	73	12	80	34	76
245	11	73	10	67	10	67	31	69	4	27	3	20	3	20	10	22

13.1.1.1 Aphasic symptom groups

Table 1.8. Performance per PWA in % correct (with code, age in years, duration of aphasia (dur) in months) per symptom group and hearing status (HI = hearing impaired, NH = normal hearing) on SVO, OVS, SR, and OR across all speech rates (N = 45).

Code	**Age**	**dur**	**Symptom**	**Hearing**	**SVO**	**OVS**	**SR**	**OR**
202	71	2	agrammatic	HI	64.44	51.11	60.00	48.89
203	77	1	agrammatic	HI	62.22	51.11	48.89	46.67
206	55	27	agrammatic	NH	68.89	44.44	53.33	35.56
208	59	88	agrammatic	NH	51.11	42.22	37.78	57.78
209	62	132	agrammatic	NH	86.67	66.67	93.33	88.89
210	22	48	agrammatic	NH	84.44	84.44	77.78	75.56
217	74	45	agrammatic	NH	97.78	73.33	86.67	44.44

Code	Age	dur	Symptom	Hearing	SVO	OVS	SR	OR
223	47	3	agrammatic	NH	51.11	62.22	51.11	46.67
227	52	4	agrammatic	NH	77.78	84.44	71.11	60.00
230	46	117	agrammatic	NH	93.33	33.33	100.00	48.89
234	62	195	agrammatic	NH	75.56	26.67	44.44	48.89
235	56	235	agrammatic	NH	86.67	77.78	73.33	73.33
236	59	123	agrammatic	NH	80.00	40.00	68.89	46.67
238	54	28	agrammatic	NH	61.36	50.00	59.09	39.13
240	59	275	agrammatic	NH	68.89	82.22	73.33	64.44
total	**57**	**88.2**	**agrammatic**		**74.04**	**57.99**	**66.61**	**55.05**
207	57	2	anomic	HI	82.22	53.33	55.56	53.33
212	35	7	anomic	NH	75.56	31.11	93.33	31.11
213	59	9	anomic	NH	82.22	4.44	95.56	13.33
214	54	17	anomic	HI	71.11	64.44	71.11	60.00
215	71	39	anomic	NH	97.78	82.22	100.00	91.11
216	56	42	anomic	HI	77.78	86.67	84.44	91.11
226	64	1	anomic	HI	60.00	66.67	55.56	46.67
229	49	25	anomic	HI	66.67	57.78	60.00	60.00
231	52	44	anomic	NH	88.89	62.22	86.67	57.78
232	75	33	anomic	NH	60.00	51.11	62.22	46.67
239	82	39	anomic	NH	95.56	73.33	93.33	46.67
242	57	77	anomic	NH	55.56	42.22	57.78	26.67
243	64	282	anomic	NH	93.33	54.35	80.43	81.40
244	48	57	anomic	HI	88.89	73.33	95.56	75.56
245	56	7	anomic	HI	91.11	24.44	68.89	22.22
total	**58.6**	**45.4**			**79.11**	**55.18**	**77.36**	**53.58**
204	66	3	paragrammatic	HI	75.56	46.67	75.56	55.56
211	75	43	paragrammatic	NH	62.22	48.89	37.78	42.22
218	44	44	paragrammatic	HI	75.56	66.67	71.11	62.22
222	43	3	paragrammatic	NH	71.11	53.33	66.67	42.22
225	54	5	paragrammatic	HI	82.22	71.11	77.78	68.89
233	61	24	paragrammatic	NH	88.89	42.22	77.78	48.89
237	75	337	paragrammatic	NH	82.98	33.33	79.55	25.00
total	**59.71**	**65.57**			**76.93**	**51.75**	**69.46**	**49.29**

13.3.3 Young Controls

Table 1.9. Code. gender (g). age in years. years of education (YoE). hearing level of BEHL PTA-4 and PTA-6 in dB. and accuracy in % correct on SVO,. OVS, SR and OR. and on the conversational (con). slow and very slow speech rate for the young controls per participant (N = 38).

Code	G	Age	YoE	PTA-4	PTA-6	Syntactic Structure				Speech Rate		
						SVO	OVS	SR	OR	con	slow	very slow
01	M	27	16	0	1.67	100.00	100.00	97.78	95.56	98.33	100.00	96.67
02	w	25	16	3.75	5.00	100.00	97.78	100.00	100.00	100.00	98.33	100.00
03	w	20	13	-1.25	-0.83	100.00	95.56	100.00	100.00	100.00	100.00	96.67

Code	G	Age	YoE	PTA-4	PTA-6	Syntactic Structure				Speech Rate		
						SVO	**OVS**	**SR**	**OR**	**con**	**slow**	**very slow**
04	w	24	16	1.25	3.33	100.00	100.00	100.00	100.00	100.00	100.00	100.00
05	w	24	16	-2.5	-2.50	97.78	97.78	100.00	100.00	100.00	98.33	98.33
06	w	22	13	-1.25	0.00	97.78	97.78	97.78	100.00	95.00	100.00	100.00
07	w	27	16	-1.25	0.83	100.00	100.00	97.78	97.78	100.00	100.00	96.67
08	w	21	13	1.25	1.67	97.78	100.00	100.00	100.00	100.00	98.33	100.00
09	w	25	16	-1.25	0.00	97.78	97.78	97.78	95.56	96.67	96.67	98.33
10	w	25	16	0	0.83	100.00	100.00	100.00	100.00	100.00	100.00	100.00
11	w	22	13	-2.5	2.50	100.00	100.00	100.00	95.56	98.33	100.00	98.33
12	w	23	16	-1.25	0.83	97.78	100.00	100.00	97.78	98.33	98.33	100.00
13	w	24	16	-1.25	0.83	97.78	100.00	100.00	100.00	98.33	100.00	100.00
14	w	21	13	-3.75	-3.33	100.00	100.00	100.00	100.00	100.00	100.00	100.00
15	w	22	13	-2.5	3.33	97.78	100.00	97.78	100.00	98.33	98.33	100.00
16	w	23	13	0	1.67	95.56	93.33	100.00	100.00	96.67	98.33	96.67
17	w	24	13	-1.25	-1.67	100.00	95.56	100.00	97.78	96.67	100.00	98.33
18	w	22	13	0	5.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
19	m	21	13	1.25	10.00	100.00	100.00	97.78	97.78	100.00	96.67	100.00
20	m	23	13	-3.75	-3.33	97.78	100.00	100.00	97.78	96.67	100.00	100.00
21	m	20	12	-5	3.33	100.00	95.56	100.00	100.00	100.00	100.00	96.67
22	m	24	16	0	0.00	100.00	100.00	97.78	100.00	100.00	98.33	100.00
23	m	23	13	1.25	1.67	100.00	97.78	93.33	100.00	98.33	96.67	98.33
24	m	30	18	1.25	7.50	100.00	100.00	100.00	100.00	100.00	100.00	100.00
25	m	26	16	0	1.67	100.00	100.00	97.78	100.00	100.00	100.00	98.33
26	m	29	17	-1.25	6.67	95.56	97.78	95.56	95.56	98.33	93.33	96.67
27	m	26	13	0	0.83	100.00	100.00	100.00	97.78	100.00	98.33	100.00
28	m	26	16	0	-0.83	100.00	97.78	100.00	93.33	96.67	98.33	98.33
29	m	27	16	1.25	2.50	97.78	100.00	100.00	97.78	100.00	100.00	96.67
30	m	25	15	1.25	7.50	97.78	100.00	97.78	97.78	100.00	96.67	98.33
31	m	27	16	0	0.83	100.00	100.00	100.00	100.00	100.00	100.00	100.00
32	m	27	18	3.75	4.17	100.00	100.00	100.00	100.00	100.00	100.00	100.00
33	m	26	16	1.25	14.17	95.56	97.78	100.00	100.00	100.00	98.33	96.67
34	w	23	16	6.25	9.17	100.00	100.00	100.00	100.00	100.00	100.00	100.00
35	w	23	15	-2.5	-1.67	93.33	80.00	97.78	97.78	88.33	90.00	98.33
36	w	22	15	1.25	0.83	100.00	100.00	100.00	100.00	100.00	100.00	100.00
37	w	22	13	5	4.17	100.00	100.00	100.00	97.78	98.33	100.00	100.00
38	w	23	13	2.5	2.50	100.00	100.00	100.00	100.00	100.00	100.00	100.00
total		24.05	14.76	0	2.39	98.89	98.48	99.12	98.77	98.77	98.77	98.90

13.3.4 NBD

Table 1.10. Gender, age in years, years of education (YoE), hearing level in BEHL PTA-4 and PTA-6. hearing status (HS; B= bilateral, U= unilateral. N= normal), presence of needed hearing aid (HA),

accuracy in percentage correct on SVO, OVS, SR, and OR, and on the conversational (con), slow and very slow speech rate for the non-brain-damaged group per participant (N = 50).

								Syntactic Structure				Speech Rate		
Code	**G**	**Age**	**YoE**	**PTA-4**	**PTA_6**	**HS**	**HA**	**SVO**	**OVS**	**SR**	**OR**	**con**	**slow**	**very slow**
101	m	64	18	26.25	30.00	B	-	97.78	100.00	97.78	100.00	100.00	98.33	98.33
102	w	63	18	22.50	29.17	B	-	100.00	100.00	95.56	95.56	100.00	93.33	100.00
103	m	43	18	20.00	22.50	B	-	100.00	97.78	100.00	100.00	100.00	100.00	98.33
104	m	64	18	7.50	11.67	N	-	97.78	100.00	95.56	93.33	96.67	96.67	96.67
105	m	60	13	21.25	24.17	B	no	97.78	97.78	97.78	100.00	98.33	100.00	96.67
106	m	56	20	23.75	28.33	B	-	97.78	97.78	95.56	100.00	98.33	95.00	100.00
107	w	57	18	11.25	13.33	B	-	97.78	100.00	97.78	100.00	100.00	100.00	96.67
108	m	68	23	31.25	36.67	B	yes	100.00	97.78	100.00	100.00	100.00	100.00	98.33
109	w	70	18	37.50	36.67	B	yes	97.78	93.33	95.56	93.33	96.67	95.00	93.33
110	m	56	18	10.00	15.83	U	-	100.00	95.56	100.00	100.00	96.67	100.00	100.00
111	m	73	15	50.00	49.17	B	yes	97.78	100.00	97.78	88.89	95.00	98.33	95.00
112	m	57	16	22.50	29.17	B	yes	100.00	100.00	97.78	100.00	100.00	100.00	98.33
113	w	60	13	3.75	5.83	N	-	100.00	100.00	100.00	100.00	100.00	100.00	100.00
114	w	57	13	7.50	9.17	N	-	97.78	95.56	100.00	97.78	98.33	98.33	96.67
115	w	68	18	40.00	45.83	B	no	100.00	100.00	97.78	100.00	100.00	98.33	100.00
116	m	66	19	43.75	45.83	B	yes	62.22	60.00	68.89	57.78	50.00	63.33	73.33
117	w	58	15	1.25	6.67	N	-	95.56	97.78	95.56	95.56	96.67	93.33	98.33
118	m	72	13	41.25	45.00	B	yes	95.56	84.44	91.11	84.44	86.67	91.67	88.33
119	w	68	11	57.50	60.83	B	yes	97.78	55.56	93.33	35.56	70.00	65.00	76.67
120	w	58	12	2.50	6.67	N	-	97.78	91.11	97.78	86.67	88.33	91.67	100.00
121	m	73	12	43.75	53.33	B	yes	95.56	95.56	82.22	86.67	90.00	93.33	86.67
122	w	55	15	3.75	9.17	N	-	97.78	100.00	100.00	97.78	98.33	98.33	100.00
123	w	58	16	-1.25	4.17	N	-	100.00	93.33	95.56	100.00	93.33	98.33	100.00
124	w	64	11	28.75	34.17	B	no	91.11	93.33	100.00	88.89	95.00	93.33	91.67
125	m	64	11	12.50	17.50	N	-	100.00	97.78	97.78	95.56	96.67	98.33	98.33
126	w	66	10	17.50	28.33	N	-	100.00	93.33	93.33	93.33	98.33	93.33	93.33
127	w	60	11	11.25	16.67	N	-	100.00	95.56	100.00	97.78	98.33	96.67	100.00
128	m	58	12	3.75	7.50	N	-	97.78	100.00	100.00	77.78	90.00	93.33	98.33
129	w	60	11	42.50	45.00	B	yes	91.11	88.89	93.33	66.67	81.67	90.00	83.33
130	m	71	16	45.00	54.17	B	yes	100.00	100.00	100.00	100.00	100.00	100.00	100.00
131	m	58	13	12.50	18.33	N	-	100.00	91.11	95.56	91.11	93.33	98.33	91.67
132	w	60	16	47.50	50.00	B	yes	100.00	100.00	100.00	100.00	100.00	100.00	100.00
133	w	55	15	37.50	37.50	B	yes	97.78	97.78	100.00	100.00	98.33	100.00	98.33
134	m	66	16	31.25	30.83	B	yes	95.56	97.78	100.00	91.11	96.67	95.00	96.67
135	w	75	12	33.75	38.33	B	yes	97.78	97.78	100.00	97.78	100.00	98.33	96.67
136	w	35	18	43.75	56.67	B	yes	100.00	100.00	100.00	95.56	98.33	100.00	98.33
137	w	46	20	53.75	58.33	B	yes	97.78	97.78	100.00	100.00	100.00	98.33	98.33
138	w	22	16	51.25	20.83	N	yes	100.00	100.00	100.00	100.00	100.00	100.00	100.00
139	w	49	14	47.50	47.50	B	yes	100.00	97.78	100.00	100.00	100.00	100.00	98.33
140	w	46	11	47.50	50.00	B	yes	97.78	100.00	93.33	100.00	95.00	100.00	98.33
141	w	46	18	36.25	45.00	B	yes	100.00	100.00	100.00	100.00	100.00	100.00	100.00
142	m	39	16	7.50	32.50	B	-	97.78	95.56	97.78	95.56	100.00	96.67	93.33
143	m	68	18	6.25	16.67	N	-	100.00	93.33	100.00	100.00	96.67	98.33	100.00

								Syntactic Structure				Speech Rate		
Code	**G**	**Age**	**YoE**	**PTA-4**	**PTA_6**	**HS**	**HA**	**SVO**	**OVS**	**SR**	**OR**	**con**	**slow**	**very slow**
144	w	68	13	5.00	7.50	N	-	97.78	93.33	88.89	91.11	95.00	90.00	93.33
145	m	74	20	0.00	15.00	N	-	97.78	100.00	97.78	100.00	98.33	98.33	100.00
147	m	74	20	3.75	6.67	N	-	100.00	100.00	100.00	100.00	100.00	100.00	100.00
148	m	45	16	3.75	7.27	N	-	100.00	93.33	97.78	95.56	96.67	95.00	98.33
149	w	38	16	3.75	4.17	U	-	100.00	97.78	97.78	100.00	100.00	96.67	100.00
150	w	74	12	43.75	45.83	B	yes	97.78	100.00	100.00	97.78	98.33	98.33	100.00
151	w	37	20	1.25	0.83	N	-	97.60	95.42	96.87	93.65	95.51	95.85	96.29
total		**58.8**	**15.4**	**24.13**	**28.25**		-	**97.60**	**95.42**	**96.87**	**93.65**	**95.51**	**95.85**	**96.29**

13.3.5 Item per group

Table 1.11. Accuracy in % correct per syntactic structure and stimulus item across all speech rates for the group of young controls (YC), the non-brain-damaged group (NBD), and the group of PWA (PWA).

Syntactic Item	YC	Group NBD	PWA
SVO	**98.81**	**97.56**	**76.65**
1054	94.44	96.67	80.73
1062	100.00	97.33	76.79
1063	98.89	96.00	82.57
1071	97.78	97.33	75.45
1084	95.56	98.00	75.68
1122	97.78	94.67	67.86
1124	97.78	98.67	73.87
1132	100.00	94.67	62.73
1162	100.00	98.67	79.65
1242	100.00	96.67	70.00
1261	100.00	98.67	80.53
1273	100.00	99.33	91.07
1291	100.00	98.00	76.99
1294	100.00	100.00	81.25
1313	100.00	98.67	74.31
OVS	**98.37**	**95.38**	**55.67**
2054	98.89	92.67	47.32
2062	96.67	96.00	52.29
2063	100.00	96.67	55.45
2071	98.89	98.67	54.13
2084	98.89	93.33	61.82
2122	92.22	86.67	39.45
2124	100.00	95.33	66.36
2132	97.78	91.33	52.21
2162	98.89	97.33	53.57
2242	97.78	92.67	46.90
2261	96.67	97.33	55.36
2273	100.00	98.00	68.14
2291	100.00	98.67	59.82

Syntactic Item	YC	Group NBD	PWA
SVO	**98.81**	**97.56**	**76.65**
2294	100.00	98.67	65.49
2313	98.89	97.33	56.36
SR	**99.11**	**96.93**	**71.51**
4012	94.44	90.00	57.80
4042	98.89	98.67	76.36
4053	98.89	99.33	75.23
4054	100.00	98.67	80.91
4062	100.00	98.00	73.39
4063	100.00	98.67	70.00
4071	98.89	97.33	82.57
4074	100.00	96.67	68.18
4082	100.00	99.33	76.11
4121	100.00	96.67	71.43
4132	98.89	98.67	64.60
4133	100.00	96.67	79.46
4164	100.00	95.33	61.06
4182	98.89	97.33	76.79
4243	97.78	92.67	59.29
OR	**98.67**	**93.64**	**53.34**
5012	95.56	96.00	55.36
5042	98.89	94.67	62.39
5053	100.00	94.00	49.11
5054	98.89	92.00	44.95
5062	98.89	95.33	56.36
5063	97.78	90.67	46.79
5071	98.89	94.67	39.09
5074	100.00	96.00	51.35
5082	100.00	94.67	56.36
5121	97.78	94.67	61.06
5132	97.78	89.33	62.73
5133	96.67	86.67	41.44
5164	100.00	94.00	56.25
5182	100.00	96.67	50.44
5243	98.89	95.33	66.07

13.4 Hearing status check in aphasia studies

Table 1.12. Overview on studies on speech perception. auditory word recognition or auditory sentence comprehension in aphasia and the presence of a hearing status check.

Author(s)	**Hearing status check**
Albert & Bear, 1957	present
Bastiaanse, 1995	present
Bates *et al.*, 1987	present
Baum, 2001	present

Author(s)	Hearing status check
Blanchard & Prescott, 1980	present
Blumstein *et al.*, 1977	present
Britz, 2006	present
Bunger, 2002	present
Choy, 2011	present
Choy & Thompson, 2010	present
Dickey *et al.*, 2007	present
Ferrill *et al.*, 2012	present
Meyer *et al.*, 2012	present
Milekic *et al.*, 1995	present
Mirman *et al.*, 2011	present
Riedel & Studdert Kennedy, 1985	present
Sidiropoulus *et al.*, 2010	resent
Thompson & Choy, 2010	present
Wilson & Saygin, 2004	present
Yarbay Duman *et al.*, 2011	present
Blumstein *et al.*, 1994	reliance on report
Hanne *et al.*,2015	reliance on report
Hanne *et al.*, 2011	reliance on report
Hessler *et al.*, 2010	reliance on report
Wassenaar & Hagoort, 2007	reliance on report
Wassenaar *et al.*, 2004	reliance on report
Baum, 1996	absent
Bayer *et al.*, 1987	absent
Becker & Reinvang, 2007	absent
Blumstein *et al.*, 1985	absent
Boyczuk & Baum, 1999	absent
Brookshire & Nicholas, 1986	absent
Burchert & de Bleser, 2004	absent
Burchert *et al.*, 2003	absent
Burchert *et al.*, 2003a	absent
Burkhardt *et al.*, 2003	absent
Burkhardt *et al.*, 2008	absent
Caplan & Aydelott-Utman, 1994	absent
Caplan *et al.*, 2007	absent
Caplan *et al.*, 2004	absent
Caplan *et al.*, 1985	absent
Caramazza *et al.*, 2005	absent
Caramazza *et al.*, 1981	absent
Clahsen & Ali, 2009	absent
de Bleser *et al.*, 2005	absent
Dickey & Thompson, 2009	absent
Dickey & Thompson, 2004	absent
Friederici & Kilborn, 1989	absent
Friedmann & Gvion, 2012	absent
Friedmann & Gvion, 2003	absent
Friedmann & Shapiro, 2003	absent

Author(s)	**Hearing status check**
Garaffa & Grillo, 2007	absent
Grodzinsky, 1999	absent
Haarmann & Kolk, 1991	absent
Kuehnast, 2011	absent
Lasky *et al.*, 1976	absent
Love *et al.*, 2008	absent
Love *et al.*, 2001	absent
Lukatela *et al.*, 1988	absent
Lukatela *et al.*, 1995	absent
MacWhinney *et al.*, 1991	absent
Myers & Blumstein, 2005	absent
Papagno *et al.*, 2012	absent
Pashek & Brookshire, 1981	absent
Piñango, 2000	absent
Piñango & Burkhardt, 2001	absent
Poeck & Pietron, 1981	absent
Potagas *et al.*, 2011	absent
Prather, 1997	absent
Prather *et al.*, 1992	absent
Prather *et al.*, 1991	absent
Raithel & Wrede, 2003	absent
Riensche *et al.*,1983	absent
Swaab *et al.*, 1998	absent
Swaab *et al.*, 1997	absent
Swinney & Zurif, 1995	absent
Swinney *et al.*, 1996	absent
Utman *et al.*, 2001	absent
Varlokosta *et al.*, 2006	absent
Wenzlaff & Clahsen, 2007	absent
Wulfeck *et al.*,1991	absent
Zurif *et al.*, 1993	absent

Curriculum Vitae

Personal details

Name:	Angela Jochmann
Date and place of birth:	10.10.1968 in Bremerhaven
Nationality:	German

Career

09/2016	defence of the PhD thesis, grade: Cum laude
2015	ongoing research and writing of PhD thesis. Topic: “The effect of slowed speech on comprehension of German non-canonical sentences in aphasia with and without hearing impairment”
03/2012-12/2014	research assistant and PhD student at the interdisciplinary project AULIN (Audiology and Psycholinguistics) at the University of Oldenburg; research topics: aphasia, hearing impairment, timing, neuro- and psycholinguistics, and syntactic complexity (comprehension of time-manipulated speech with varying syntactic structures); supervisor: Prof. Dr. Esther Ruigendijk
03/2009-10/2011	speech and language therapist at a private speech and language therapy clinic in Visbek/Germany, with fields of expertise in the diagnostics and treatment of adults and children with neurological, oncological and geriatrical communication and swallowing disorders
07/2010-08/2010	visiting lecturer for neuropsychology, cerebral palsy and practical training of therapy at UKM, Universiti Kebangsa’an Malaysia, Malaysia
01/2010	visiting lecturer for dysphagia at UKM, Universiti Kebangsa’an Malaysia, Malaysia; volunteer speech and language therapist for Normah Medical Specialist Centre, Kuching/Sarawak, Malaysia
11/2009-12/2009 and 01 – 02/2010	volunteer speech and language therapist and trainer for NASAM (National Association for Stroke Rehabilitation of Malaysia)
11/2008 and 01/2009	voluntary speech and language therapist and lecturer at Normah Medical Specialist Centre and Lions Nursing Home, Kuching/Malaysia
05/2008-09/2008	head of a school for speech and language therapy; financial and staff management and lecturer for linguistics, aphasia, dysphagia, and treatment of severe neurological disorders
08/2007-04/2008	speech and language therapist at the Aphasie Zentrum Josef Bergmann GmbH, Vechta-Langförden, with fields of expertise in the diagnostics and treatment of patients with aphasias, dysarthrophonias, dysphagias, neuropsychological and/or demential symptoms as well as patients with severe neurological impairments (in coma, waking coma and Locked-In Syndrome) in all stadia
05/2006-08/2007	lecturer for aphasiology, apraxiology, neurological disorders, language processing models, Dutch and ability trainings in aphasia diagnostics and Bobath transfer techniques; tutor for SLT essays and instructor and supervisor for students’ therapies with neurological patients at a private college for speech and language therapy
02/2004-01/2006	coordinator of the speech and language therapy department at Mulago Hospital and of the speech and language therapy course project at Makerere University in Kampala/Uganda; areas of work contained therapy, training, lecturing, financial and administrative management of the department and the course project, international networking, fundraising
11/1999-01/2004	speech and language therapist at the Aphasie Zentrum Josef Bergmann GmbH, Vechta-Langförden, with fields of expertise in the diagnostics and treatment of patients with aphasias, dysarthrophonias, dysphagias, neuropsychological and/or demential symptoms as well as patients with severe neurological impairments (in coma, waking coma and Locked-In Syndrome) in all stadia
1992-2002	freelancer for a market research institute (gfk-Gesellschaft für Konsumforschung), student assistant at an environmental institute (ttz-Umweltinstitut) in Bremerhaven, various jobs as waitress and assistant nurse
08/1990-03/1992	dispatcher at a taxi company (Taxi Lloyd) in Bremerhaven
10/1988-09/1989	volunteer at an institution for mentally handicapped people (Lebenshilfe) in Bremerhaven

School and University

03/1997-10/1997	research term and clinical training under the mentorship of Dr. Wolfram Ziegler of the EKN-Entwicklungsgruppe für klinische Neuropsychologie (Research Group for Clinical Neuropsychology) and Dr. Frank Glindemann of the KMB-Hospital of München-Bogenhausen in Munich
Master thesis:	„Assessment of speech perception and auditory language comprehension deficits in aphasia“
09/1995-02/1999	studies of General Linguistics, department of neurolinguistics with focal point on aphasiology at the Rijksuniversiteit Groningen/NL with the final mark “excellent”
04/1992-10/1999	M.A. studies of English, Psychology and Dutch with focal points on linguistics and cognitive sciences at the Carl-von-Ossietzky Universität Oldenburg
06/1988	A-levels at the Geschwister-Scholl Schule in Bremerhaven
1975-1988	primary and secondary school in Bremerhaven

Lecturing and teaching experience

02/2008-07/2015	lecturer for Dutch language at the Volkshochschulen (adult education programme) Oldenburg and Brake, in 2013 also at the University of Oldenburg (for employees)
02/2012-01/2013	lecturer for English language (absolute beginners) at the Volkshochschule (adult education programme) Hude
07/2010-08/2010	visiting lecturer for neuropsychology, neurolinguistics and cerebral palsy, and instructor and supervisor of students` therapies (both adult and children therapies) at UKM Kuala Lumpur
since 11/2008	lecturer and instructor of the workshop “management of dysphagia patients” for speech and language-, physio-and occupational therapists, other care professionals in hospitals, old-age homes and caring institutions
05/2008-09/2008	lecturer for linguistics, aphysiology, dysphagias and treatment of severe neurological patients
0.-22.4.2007	lecturer for the vocational training „Logogen, LeMo and NAT: introduction to the neurolinguistic aphasia therapy“
09/2006-08/2007	mentor for a class of speech and language therapy students
05/2006-08/2007	lecturer for the participatory teaching method and tutor for the Problem-Based-Learning method, and ability trainings, lecturer for Dutch (introduction and speech and language therapy related topics), instructor and supervisor for students’ therapies
10/2004-01/2006	lecturer at the Occupational Therapy School of the Paramedic Schools of Mulago Hospital for the modules „Bobath and F.O.T.T.™“ und „Basics of Human Neuropsychology“
06/2006-01/2006	lecturer and instructor at the Physiotherapy School at the Paramedic Schools of Mulago Hospital for the modules „Bobath and F.O.T.T.™“
05/2004-01/2006	lecturer and instructor for the workshop „Prevention of aspiration pneumonias“ for doctors, nurses and therapists of Mulago Hospital
03/2004-01/2006	lecturer at the medical faculty of Makerere University for the modules „Development of communication“, „Disorders of communication“ and „Management of tracheostomies“
03/2004-01/2006	lecturer and instructor for the workshops „Communication disorders and basic intervention“ and „Cerebral palsy: feeding disorders and intervention” for doctors, nurses, therapists, nursing students and teachers in hospitals, schools and special need institutions in Kampala and other parts of Uganda
03/2004-01/2006	instructor and supervisor for students of occupational-and physiotherapy as well as for international students visiting the speech and language therapy department at Mulago
08/2002-01/2004	lecturer and instructor for the workshops „Techniques for oral hygiene for neurological and geriatric patients“, and „Feeding techniques for neurological and geriatric patients“ for nurses and other care professionals in hospitals, old-age homes and caring institutions
01/2001-01/2004	lecturer and instructor for internal workshops for speech and language therapists of the Aphasie Zentrum Josef Bergmann
11/1999-01/2004	instructor and supervisor for students of speech and language therapy at the speech and language therapy department of the Aphasie Zentrum Josef Bergmann
08/2003-03/2007	lecturer and instructor for the workshops „techniques for oral hygiene for neurological and geriatric patients“ and „feeding techniques for neurological and geriatric patients“ for nurses and geriatric workers

Continuing education

2012-2015	several workshops for statistical methods (e.g., mixed effects analysis) and programs (SPSS, R)
07. – 08.05.2010	“Differential diagnostics, therapy and parental counselling for multilingual children”
13.06. -15.06.2008	„Managing teams“
29.05.2008	„Quality management systems“
29.02. 2008	„Workshop Dysphonias“
24. -25.11.2007	„Management of dysphagia patients with tracheo-s-tomies“
07.11.2007	„PC-supported communication“
11.10.2007	„Symposium Waking coma“
04-05.08.2006	„Problem-Based Learning with students' groups“
01.-04.11. 2005	„Assessment methods for the Problem-Based Learning approach“
15.09., 17.09. and 30.09.2005	Training for selecting and recruiting local volunteers for VSO (Voluntary Service Overseas) Uganda
27.01. 2005	„Laryngectomy and voice compensation in East Africa“
26.01. 2005	”Aural rehabilitation in East Africa”
13.-14.01. 2005	“Finances for non-finances managers”
19.-22.01. 2004	“Teaching skills-an introduction”
16.-19.01. 2004	“Organisational development”
21.-22.08. 2003, 20.-21.11. 2003	“Basal Stimulation” (introduction course)
23.-24.11. 2002	“PNF-techniques for orofacial disorders 2”
06.-07.09. 2002	„TAKTKIN-an approach for the treatment of speech-planning disorders” (second course)
05.-09.08. 2002	„The Bobath-approach for speech and language therapists: Management of patients with acquired brain lesions“
18.-22.03. 2002	guest therapist at the speech and language therapy department of the Therapie Zentrum Burgau (an institution for the treatment of patients with severe neurological disorders)
02.-03.02. 2002	„PNF-techniques for orofacial disorders 1“
22.-26.10. 2001	„G/F.O.T.T.™: introductory course of the approach of Kay Coombs for the rehabilitation of the face and the oral tract of patients with central lesions “
03.-04.09. 2001	„Composure wins-techniques for staying composed in job and everyday activities“
23.-25.03. 2001	„TAKTKIN-an approach for the treatment of speech-planning disorders“ (introduction course)
16.-17.03. 2001	„The Schluckschlus: a therapy approach for myofunctional disorders at pre-school age“
18.-19.08. 2000	„Therapy approaches for disorders of swallowing and eating“
28.-29.04. 2000	„AAT, ANELT, LeMo, BMTDA und CO KG-comparing aphasia diagnostics“
31.03.-01.04. 1999	„Diagnostics und therapy of dysphasias in neurology, geriatry and clinical settings“
03.-14.05. 1999	guest speech and language therapist at the SSH-Frührehabilitation für Schwerst-Schädel-Hirnverletzte (ward for patients with severe neurological disorders) under the supervision of Prof. Dr. Andreas Zieger at the Evangelische Krankenhaus Oldenburg

Publications

02/2016	“The Effect of Slowed Speech on Comprehension of German Non-Canonical Sentences in Aphasia with and without Hearing Impairment” (in progress)
10/2016	“Effects of time-compressed speech on the processing of sentences with differing syntactic complexity” (subm)
12/2006	„Speech and language disorders in East Africa: causes and consequences“ (*Health Studies Africa*)
02/2006	“Let's talk: the first East African speech therapy conference” (*The ASHA Leader*/USA)
09/2005	“Let's talk: the first East African speech therapy conference” (*Puheterapeutti*/ Finland; Link on the homepage of the CPLOL) „Let's talk: Die erste ostafrikanische Sprachtherapeutenkonferenz“(SAL-Bulletin/Switzerland; ZBL-Journal/Switzerland; BDLÖ-Journal/Austria)
07/2005	„Let's talk: Die erste ostafrikanische Sprachtherapeutenkonferenz“ (*Forum Logopädie*/Germany, Homepage of the BKL/Germany)

1998	„Assessment of speech perception and auditory language comprehension deficits in aphasia" (ICPLA Manual)

Talks and posters

09/2014	"Effekte langsamerer Sprechraten auf das Verständnis von gesprochenen Sätzen bei Aphasie mit und ohne Schwerhörigkeit". Talk held at „29th annual meeting Gesellschaft für Neuropsychologie (GNP)", Oldenburg, 18.-20-09.2014
09/2014	"The effect of slowed speech on comprehension of German non-canonical sentences in aphasics with and without hearing impairment". Talk held at "Sciences of Aphasia (SOA)", Venice, 19.-24.05.2014
12/2013	„The effects of fast speech on comprehension of German verb second and relative clauses". Poster presentation at Nordwestdeutsches Linguistisches Kolloquium (NWLK), Bremen, 12.-13.12.2014
09/2013	„The effects of fast speech on comprehension of German verb second and relative clauses". Poster presentation at "Architectures and Mechanism in Language Processing (AMLaP)", Marseille, 02.-04.09.2013
05/2013	„The effects of fast speech on comprehension of German verb second and relative clauses". Talk held at "Psycholinguistics in Flanders (PLiF)", Leuven, 29.-31.05.2013.

Summary

Almost all persons with aphasia (PWA) demonstrate difficulties comprehending non-canonical structures, such as object-first sentences, in terms of longer response times and/or lower accuracy. This so called *canonicity effect* also occurs in hearing-impaired non-aphasic listeners. Hearing-impaired PWA may therefore face a higher degree of the canonicity effect than normal-hearing PWA. This potential relationship between hearing loss and aphasia and their impact on auditory non-canonical sentences has not been investigated so far.

Slower speech was seen not only to facilitate comprehension for some PWA, but also intelligibility and comprehension for hearing-impaired non-brain-damaged listener, but up to now, a systematic investigation of the effect of slower speech on non-canonical sentence comprehension for both aphasic and hearing-impaired non-aphasic persons has not been executed. The present study examines potential effects of slower speech on comprehension of active transitive canonical and non-canonical verb-second- and centre-embedded relative clauses for aphasic and non-brain-damaged hearing-impaired and normal hearing German speakers.

Compared to English, German has a richer overt morphosyntactic system for case and agreement markers, which allows not only the construction of object relative clauses (OR), but also of object-first verb second or main clauses (OVS). The first chapter describes these sentences by a Generative Grammar account, which assumes that object-first structures are generated through a movement of the object to a sentence-initial position, leaving a trace at the original position. Also, German case-and agreement markers are introduced. The second chapter presents studies of auditory non-canonical sentence processing by normal-hearing non-aphasic German speakers, introduced as a process demanding an exact *timing* between linguistic parsing operations and the duration of the acoustic sentence presentation. While transitive subject-first sentences can be processed incrementally in a „who did to whom“-manner, non-canonical sentences are considered to demand object integration at the precise point when the trace occurs in order assign the thematic role. Chapter 4 describes non-canonical sentence processing in aphasia. While canonical sentences can be interpreted using an agent-first strategy, interpretation of object-first sentences is often erroneous. Cross-linguistic research suggests that this canonicity effect is caused by insufficient processing of morphosyntactic markers. For agrammatic aphasia, the *Slowed Processing Hypothesis* proposes that these effects result from slower-than normal processing. Online observations

imply that agrammatic PWA need more time to construct a syntactic representation, which can affect in particular moved object integration. Recent German studies demonstrated that integration of morphosyntactic features for case and agreement were often delayed in agrammatic PWA, jeopardizing thematic role assignment in non-canonical sentences. Slower speech may partially compensate for this processing delay, as two English studies found.

In chapter 5, canonicity effects due to hearing loss are described as a timing deficit considered to result from a higher perceptual processing load through the degraded acoustic signal. Hearing loss might in particular affect perception and intelligibility of normally non-accentuated and therefore with lesser volume articulated case and agreement markers. Similar to aphasia, a slower speech rate may improve comprehension for hearing-impaired persons.

The combination of hearing impairment and aphasia may aggravate the canonicity effects, assumed in chapter 6. Studies noted that a high number of PWA present with a hearing impairment, and for many, the hearing loss may go undetected. The current study seeks more insight into following questions:

3 Are PWA, and in particular agrammatic PWA, with a hearing impairment more affected in general auditory sentence comprehension, and especially in non-canonical sentence comprehension, than their normal-hearing counterparts?

4 Can slower speech facilitate general and non-canonical sentence comprehension for agrammatic and other PWA, and is this hypothesized positive effect of slower speech higher for hearing-impaired PWA compared to normal-hearing PWA?

5 Is non-canonical sentence comprehension affected in hearing-impaired non-brain-damaged adults (NBD), and can slower speech facilitate in particular the comprehension of non-canonical sentences for hearing-impaired NBD?

Accuracy rates from a sentence-picture matching task of a group of 37 normal-hearing or hearing-impaired PWA, a subgroup of 15 agrammatic PWA, and of 50 normal-hearing or hearing-impaired NBD were analysed in chapters 9 and 10. While hearing-impaired PWA demonstrated a lower accuracy on general comprehension than the normal-hearing PWA, hearing loss had a reverse effect on non-canonical comprehension performance in as such that hearing-impaired PWA demonstrated better comprehension for OVS and OR than the normal-hearing group. Slower speech did not facilitate aphasic and agrammatic comprehension of verb-second sentences, but comprehension of both centre-embedded subject- and object relative clause sentences improved for agrammatic PWA at the very slow speech rate.

Hearing-impaired NBD demonstrated a marginal canonicity effect for OR Slower speech on the other hand appeared to facilitate comprehension only for the normal-hearing NBD. But effects were only marginal, and comprehension of both sub groups were close to ceiling for all items.

These findings, discussed in chapters 9, 10 and 11, tentatively suggest that the syntactic processing deficit in agrammatic aphasia may be partly caused by slowed-down processing of morphosyntactic features. Improved comprehension of the centre-embedded relative clauses through slower speech gives cautious evidence in favour of the Slowed Processing Hypothesis. The absent effect of hearing impairment in the whole group of PWA might be due to fact that the groups were not comparable in terms of main aphasic symptoms, age and other factors. The marginal canonicity effect found for the hearing-impaired NBD might have been caused by a perceptual deficit of identification and/or discrimination of non-accentuated morphosyntactic agreement features.

Although the effect of hearing loss on non-canonical sentence comprehension in aphasia could not be established in this study, the potential negative impact of hearing impairment on sentence comprehension should not be neglected. A hearing screening for aphasic and non-aphasic persons should include assessment of higher frequencies in order to give a more comprehensive insight on intelligibility abilities.

Zusammenfassung (German Summary)

Auswirkungen von langsamerer Sprechrate auf das Verständnis nicht-kanonischer Sätzen bei normalhörenden und schwerhörigen Personen mit Aphasie

Fast alle Personen mit Aphasie (PMA) weisen Probleme beim Verständnis nicht-kanonischer Sätze, wie z. B. Objekterstsätze, auf. Dieser *Kanonizitätseffekt*, wenn auch nicht in demselben Ausmaß, tritt auch bei schwerhörigen nicht-aphasischen Personen auf. Schwerhörige PMA könnten deshalb zu einem höheren Grad beim Verständnis von Objekterststrukturen beeinträchtigt sein als normalhörende PMA. Diese potentielle Verbindung zwischen Schwerhörigkeit und Aphasie sowie deren gegenseitiger Einfluss auf das Verständnis gesprochener nicht-kanonischer Strukturen wurde bis jetzt nicht untersucht. Weiterhin bekannt ist der fazilitierende Effekt einer verlangsamten Sprechgeschwindigkeit auf Verständlichkeit und Verständnis von sprachlichen Elementen und gesprochenen Sätzen bei sowohl aphasischen als auch schwerhörigen Erwachsenen, allerdings ist bisher keine systematische Erforschung dieses Einflusses auf das Verständnis von nicht-kanonischen Sätzen bei diesen beiden Gruppen erfolgt. Die vorliegende Studie befasst sich mit der Untersuchung von der Auswirkung einer langsameren Sprechrate auf das Verständnis von aktiven transitiven (mit einer Argumentstruktur von Subjekt und direktem Objekt) Subjekterst- und Objekterstsätzen einer Verbzweitsatz- und einer eingebetteten Relativsatzstruktur bei normalhörenden und schwerhörigen aphasischen sowie nicht-aphasischen deutschen Muttersprachlern.

Aufgrund seines relativ reichen morphosyntaktischen Systems für Kasus und Verbkongruenz, verglichen mit dem des Englischen, gibt es im Deutschen nicht nur aktive transitive Objektrelativsatzstrukturen, sondern auch Objektverbzweitsätze, welche im ersten Kapitel kurz vorgestellt werden. Innerhalb der Generative Grammatik wird vermutet, dass diese Strukturen durch eine Transformation des Objektes von einer hinteren Position zu einer satz-initialen Position generiert werden. Eine Beschreibung von overten Kasusmarkierungen für Subjekt und direktes Objekt sowie von Kongruenzmerkmale des Verbes vervollständigen das Kapitel. Danach erfolgt eine Darstellung von Studien zur Verarbeitung nicht-kanonischer Sätze von nicht schwerhörigen und nicht aphasischen deutschen Muttersprachlern, die als Prozess beschrieben wird, der ein exaktes *Timing* zwischen auditiver Präsentation und

linguistischer Verarbeitungsprozessen benötigt. Während kanonische Strukturen inkrementell verarbeitet werden können, wird angenommen, dass die Interpretation von Objekterstsätzen eine zeitlich genau abgestimmte Integration des Objektes an der Originalposition erfordert. Es wird angenommen, dass diese nicht-lokale Integration die Verarbeitungslast erhöht, welches sich u. a. in längeren Verarbeitungszeiten und sogar in Fehlinterpretationen zeigt.

Kapitel 4 befasst sich mit den Schwierigkeiten, die PMA bei der Verarbeitung und dem Verständnis nicht-kanonischer Sätze zeigen. Während kanonische Strukturen durch nicht-syntaktische, *heuristische,* Strategien verarbeitet werden können, weist die Interpretation von nicht-kanonischen Sätzen häufig Fehler auf. Inter-linguistische Studien belegen, dass diese teilweise durch unzureichende morphosyntaktische Verarbeitung verursacht wird. Die *Slowed Processing Hypothesis* nimmt an, dass Kanonizitätseffekte bei insbesondere agrammatischer Aphasie durch eine verlangsamte Verarbeitung entstehen. Beobachtungen aus Onlinestudien implizieren, dass PMA mehr Zeit bei spezifischen oder allgemeinen linguistischen Prozessen benötigen als nicht-aphasische Personen, was beim Aufbau einer syntaktischen Repräsentation von nicht-kanonischer Strukturen insbesondere die Objektintegration beeinträchtigen kann. Bei neueren deutschen Studien wurde deutlich, dass die Integration von overten morphosyntaktischen Kasus- und Kongruenzmarkierungen bei PMA oft verzögert ablief, welches die thematische Rollenzuweisung erschwerte. Verlangsamte Sprechgeschwindigkeit kann dieses verzögerte Verarbeiten teilweise kompensieren, wie einige Studien herausfanden. Ein Timingdefizit wird auch bei schwerhörigen Normalsprechern angenommen, und Kapitel 5 zeigt auf, dass auch Schwerhörigkeit zu Kanonizitätseffekten führen kann. Im Gegensatz zu Aphasie wird bei Schwerhörigkeit der Grund für die Verzögerung in der verlängerten perzeptuellen Verarbeitungszeit des akustisch degradierten Sprachsignals vermutet, welche gerade bei nicht-kanonischen Sätzen zu Problemen bei der Objektintegration führen kann. Weiterhin kann ein beeinträchtigtes Hörvermögen zu vermehrten Problemen bei der Wahrnehmung von normalerweise nicht akzentuierten und damit leiseren morphosyntaktischen Markierungen führen. Ähnlich wie bei Aphasie kann eine verlangsamte Sprechrate das Satzverständnis bei schwerhörigen Menschen verbessern, welches eine zumindest eine partielle Kompensation des Timingdefizit durch eine Verlängerung der Darbietung impliziert. Die Kombination von Schwerhörigkeit und Aphasie kann deshalb das Verständnis von Objekterststrukturen zu einem höheren Grad erschweren, wie in Kapitel 6 angenommen wird. Studien belegen, dass eine große Anzahl von PMA unter

Hörverlust leidet, und dass bei vielen die Schwerhörigkeit nicht diagnostiziert ist. In der vorliegenden Studie wurde folgenden Annahmen nachgegangen:

1.) Sind schwerhörige PMA stärker beeinträchtigt im allgemeinen Verständnis als normalhörende PMA, und im Besonderen im Verständnis für nicht-kanonische Sätze?

2.) Kann eine langsamere Sprechrate das Verständnis im Allgemeinen und im Besonderen für nicht-kanonische Sätze generell bei Aphasie, und im Besonderen bei agrammatischen PMA verbessern? Hat eine langsamere Sprechrate einen höheren Effekt auf das Verständnis von nicht-kanonischen Sätzen bei schwerhörigen im Vergleich zu normalhörenden PMA?

3.) Weisen schwerhörige nicht-aphasische Sprecher im Vergleich zu normalhörenden Sprechern einen Kanonizitätseffekt beim Verständnis auf? Kann eine langsamere Sprechrate das Verständnis von im Besonderen nicht-kanonischen Sätzen bei schwerhörigen Normalpersonen verbessern?

Zur Beantwortung dieser Hypothesen wurde die Korrektheitsrate von einer Gesamtgruppe von normal-hörenden und schwerhörigen 37 PMA, von einer Gruppe von 15 agrammatischen PMA, und von 50 normal-hörenden und schwerhörigen nicht-aphasischen Personen mit einem Satz-Bild Zuordnungstest gemessen und die Ergebnisse analysiert. Die Resultate zeigen, dass entgegen der Annahme die getesteten schwerhörigen PMA ein besseres Satzverständnis für Objektverbzweitsätze und eingebettete Objektrelativsätze als normal-hörende PMA. Eine verlangsamte Darbietung erhöhte sowohl bei der Gruppe der agrammatischen PMA als auch bei normal-hörenden nicht-aphasischen Teilnehmern das Verständnis von Relativsätzen, während schwerhörige PMA keinen signifikanten Nutzen aus der Verlangsamung zogen konnten. Die verbesserte Performanz bei den agrammatischen PMA deutet darauf hin, dass eine Verlängerung der Präsentationsdauer die Verarbeitung von Kasus und/oder Kongruenzmerkmalen das Verständnis begünstigt haben könnte. Die Ergebnisse, wenn auch nicht immer konform mit den Hypothesen, implizieren, dass insbesondere bei agrammatischer Aphasie die Satzverarbeitung verlangsamt zu sein scheint, was eher zu den Annahmen der Slowed Processing Hypothesis passt.

Hörverlust von hohen Frequenzen schien tendentiell das Verständnis von Objektrelativsätzen von nicht-aphasischen Personen zu beeinträchtigen, was möglicherweise durch eine reduzierte Wahrnehmung von Kongruenzmerkmalen und/oder Kasusmarkierungen des Relativpronomens verursacht wurde.

Obwohl Schwerhörigkeit bei Aphasie in dieser Studie keinen negativen Einfluss zeigte, sollte der potentielle negative Effekt von Hörverlust auf das Sprachverständnis immer bei Diagnostik, Therapie und wissenschaftlichen Untersuchungen von Aphasien berücksichtigt werden. Weiterhin zeigen die Ergebnisse, dass Hörverlust von hohen Frequenzen Auswirkungen auf das Sprachverständnis haben kann. Aus diesem Grund sollte die Hörschwelle von hohen Frequenzen bei einer Erhebung der Hörfähigkeit einbezogen werden.