Observational Learning of a Baseball-Pitch:
The Effect of Different Model Demonstrations

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to my parents ...
“Be the change that you wish to see in the world.” | Mahatma Gandhi
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This work was created with the support of several people, and without their help completion of this amazing journey would certainly have been difficult.

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Abstract

Introduction: A main issue in observational motor learning is to identify the nature of information extracted by the observers from model demonstrations for later reproduction. Visual Perception Perspective (Scully & Newell, 1985) proposed that relative motion information is extracted and used for reproducing the modeled action. According to this perspective, a model demonstration such as point-light or stick-figure display, in which relative motion information is highlighted, is more effective than a model demonstration such as video display, in which relative motion information is not highlighted. This study was designed to investigate the proposition of Visual Perception Perspective by comparing the effects of observing video, stick-figure and point-light model demonstrations on performance and learning a Baseball-pitch. The present study is also aimed to examine the performances of the participants during the movement phases by analyzing the dependent variables at the level of overall movement and movement phases.

Methods: Forty one novice female and male adults have voluntarily participated in the study and were randomly allocated to video, stick-figure, point-light and no-demonstration control groups. Participants performed 5 familiarization trials, three blocks of 10 acquisition trials, and two retention tests of 5 trials in 10 minutes and one week after last acquisition block. Model demonstration groups observed respective model demonstrations three times before each acquisition block. Intra- and inter-limb coordination, movement form and absolute movement time differences were selected as dependent variables. Kinematic analysis and movement form are considered to be a determinant of learning the technique of the motor task and movement time is considered to be a determinant of motor control. The analysis was performed at the level of overall movement and movement phases.
**Results:** Results showed significant improvements from the pretest to the acquisition blocks for intra- and inter-limb coordination and movement form scores, however, regardless of model demonstration. Participants in all groups showed similar performances in two retention tests. Analysis of movement phases revealed a significant improvement in stride phase of the Baseball-pitch from pretest to acquisition blocks in all measured variables. In addition, participants in stick-figure group showed poor coordination performances than participants in other groups in later phases of the Baseball-pitch.

**Discussion:** The hypothesis of Visual Perception Perspective was not confirmed by the results, because the participants in point-light or stick-figure groups did not outperform the participants in classic video group. Moreover, lacking a superiority of model observation over no-observation might be due to insufficient amount of observational practice or instruction was given the participants before pretest. It has been suggested that the participants might have perceived the body/form information from the model and later used to reproduce the modeled action. Improvements in stride phase from pretest to acquisition blocks in all measured variables may indicate that stride phase is most practice-demanded phase of the pitch.

**Key words:** Observation, model demonstration, relative motion information, Baseball pitch
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1 Introduction

Learning new skills by observing others is an innate ability in humans. Over the years, the process of learning through observation is known as vicarious learning, social learning, imitation learning, modeling, observational learning, etc. (McCullagh & Weiss, 2001; McCullagh, Weiss, & Ross, 1989). In sports settings, the researchers have usually applied the term “observational learning” or “modeling” referring to the process of learning by observation. Maslovat, Hayes, Horn, and Hodges (2010) defined observational learning as “the process by which observers watch the behavior of a model and adapt their movement as a result, typically as assessed in a delayed retention test” (p. 315). The model demonstrations are extensively used by coaches, instructors, and physical educators as an instructional method in sport clubs or physical education classes where the students try to learn new motor (sport) skills. In fact, for many years the instructors and coaches thought that physical practice is the only way to acquire new motor skills, however, in recent years, it has been shown that model demonstrations alone or with physical practice can facilitate learning new motor skills (e.g., Wulf, Shea, & Lewthwaite, 2010).

Use of a model in the field of motor learning can benefit coaches and instructors to repeat the desired movement for several times while maintaining quality. In fact, it does not seem to be important whether the model is presented as a person, or whether it is displayed through the medium of video recording. When intentionally arranged, the model demonstration can be used for several objectives. For example, the model demonstration may be used to convey an action strategy to solve a specific motor task. As such, a basketball coach often demonstrates positions of the players in the field that guide basketball players to have a better team performance, or a gymnastics coach shows the routine of a floor routine in gymnastics. The model demonstration is also used to show the sequences of a particular movement technique (form) that must be integrated into the overall movement. Some examples include the technique of a basketball shot, tennis serve, soccer kicking, softball throw, and so on. In all cases, the skill acquisition process is facilitated and the learning goal can be achieved more quickly.
It has been suggested that the model demonstrations are more influential in the early stages of motor learning where the learners search for optimal solutions of how to execute the to-be-learned movement (Magill, & Schoenfelder-Zohdi, 1996). For example, for a beginner who learns a jump shot in Handball the main problem is how to temporally and spatially coordinate and control various limbs of his body in order to perform the skill correctly. In other situations, a child wants to know how a swimming skill looks before he attempts to perform it for the first time. In these situations, coaches or instructors require instruments in order to convey the relevant information of the to-be-learned movement to the learners. It has been shown that demonstrating a model that performs the skill as correctly as possible to the learners is effective on learning how to perform the skill (Ashford, Davids, & Bennett, 2006).

Besides the widespread use of model demonstrations in the motor learning domain, the mechanisms underlying observational learning are not completely understood. Over the years, several theories are formulated by various schools of thought to explain how observational learning occurs and what is learned. Of them, Social Cognitive Theory (Bandura, 1969, 1977, 1986) and Visual Perception Perspective (Scully & Newell, 1985) have received more attention in the research on observational learning of motor skills.

Bandura (1969, 1977, 1986) formulated a Social Cognitive Theory, which is theoretically based on information processing perspectives and addressed the question of how the observational learning process occurs. Scully and Newell (1985) formulated a Visual Perception Perspective which is theoretically based on theory of direct perception (Gibson, 1979). Visual Perception Perspective addressed the question of what information is picked-up from model demonstration for later reproduction. Scully and Newell (1985) proposed that while observing the model demonstration, the observers directly perceive relative motion information of the action, i.e., the movement of segments of body in relation to each other, and use this information for constraining the action coordination. The present study aims to investigate the hypothesis of Scully and Newell (1985) and should therefore add some scientific knowledge to the existing literature.
This work is divided into the theoretical part and the empirical part. In the theoretical part, a description of the different approaches on observational learning is provided (Chapter 2). In this chapter, a description of the theoretical basics of two approaches on observational learning including cognitive mediation and ecological approaches is presented. In addition to theoretical backgrounds, the research based on these theories has also been reviewed. In the next part of the theoretical background, the neurological mechanism underlying observational learning is considered. Following the theoretical basis of observational learning in Chapter 2, a statement of the problem for the current study is presented in Chapter 3 and also the formulation of the questions and general hypotheses. The empirical part of the study includes the description of the experimental method (Chapter 4) as well as the presentation of the results (Chapter 5). In Chapter 6 the results of the study are discussed and interpreted according to methodological and theoretical backgrounds. Finally, in Chapter 7, summary and conclusion of the study and ideas for further research are presented.
2 Theoretical Background

This chapter introduces the basic theories underlying observational learning. The first part describes social cognitive approach on observational learning which is theoretically based on information processing perspectives. In this part main focus is on Social Cognitive Theory (Bandura, 1969, 1977, 1986) as well as the empirical findings with regard to Banduras’ theory. Second part of this chapter describes an ecological alternative to social cognitive approach on observational learning which is theoretically based on direct perception theory (Gibson, 1979). In this part Visual Perception Perspective (Scully & Newell, 1985) as well as empirical findings related to this theory are described. Finally, third part reviews the neurophysiological mechanism underlying observational learning. In this part the discovery of mirror neuron system in monkey and following studies in humans are reviewed.

2.1 Social cognitive approach on observational learning

The earliest approaches on observational learning have been formulated by several schools of thought. Classical conditioning theories on imitation (e.g., Humphrey, 1921) believed that imitative behaviors are based on associative principles, so that temporal contiguity between to-be-imitated stimuli and imitator matching response was assumed to be sufficient for the occurrence of imitative behaviors (Bandura, 1969). Miller and Dollard (1941) provided theoretical explanations based on reinforcement principles, in which the attention was shifted from classical conditioning to reinforcement of imitative behaviors (i.e., stimulus-response reinforcement). According to reinforcement theories, the necessary conditions for observational learning include rewarding the person to match the correct responses of the modeled behaviors (Bandura, 1969).

Sheffield (1961) formulated theory of cognitive symbolic representation on observational learning to break from traditional classical conditioning and reinforce-
ment theories. Based on symbolic representation theory, when a person observes a modeled action, a sequence of perceptual and symbolic responses is held as a "symbolic/perceptual blueprint", which later is used to guide production of the modeled action. In Sheffield’s theory, the conception of perceptual blueprints refers to images of action sequences which are held in the memory. Sheffield (1961) claimed that during the process of observational learning, a perceptual blueprint must not only be learned and stored but must later be translated into overt performance.

Bandura (1969) advanced Sheffield’s theory and formulated Social Learning Theory, which later revised to Social Cognitive Theory (Bandura, 1986). Bandura designed originally his theory to account for acquisition of behaviors in social contexts, but it has received challenges in observational motor learning literature (Hodges, & Franks, 2004; Williams, Davids, & Williams, 1999). The central to Social Cognitive Theory is the conception of cognitive representation. Similar to Sheffield (1961), Bandura (1969, 1977, 1986) believed that the modeled actions are stored in forms of cognitive representations which later serve as a reference for overt performance. The Banduras’ theory is mainly based on information processing perspectives. According to Bandura, the phenomena of observational learning involves four interrelated sub-processes including attention, retention, motor reproduction and motivation. These sub-processes in observational learning and their internal/external attributes are illustrated in Figure 2.1 and are discussed below.

![Figure 2.1. The sub-processes of observational learning. Bandura (1986, p. 52).](image-url)
2.1.1 Sub-processes of observational learning

2.1.1.1 Attentional processes

Attentional processes take place in the beginning of the process of observational learning. Bandura (1969) believed that only repeated exposure to the modelled event (action) is not necessarily sufficient for the observers to attend carefully and select the most event relevant cues (information). For observational learning to occur, the observers must pay attention to the information related to the modelled action, and perceive accurately what they observed (Bandura, 1969, 1986). In fact, attentional processes decide on what the learners selectively attended and extracted from the modeled action (Bandura, 1977). In Bandura’s theory, attention is considered to be a selective mechanism and therefore selective attention is considered as an important sub-function in the observational learning process (Bandura, 1986).

Several factors internally and externally influence the process of selection and perception of information related to the modeled action (Bandura, 1969, 1977, 1986). These factors mostly relate to the properties of the modeled action, the model, stimulus input, and the observer. External variables are related to the characteristics of the modeled action, the model, and stimulus input. Characteristics of the modeled action relate to the complexity of the action such as number of parts and coordinative pattern of the action (Edwards, 2011). The model characteristics include age, model status, similarity, prevalence, etc. (McCullagh, 1986). Speed and number of model display and instruction given to the observers are considered as the characteristics of stimulus input (Horn & Williams, 2004; McCullagh, 1986). The characteristics of the observer include perceptual and cognitive abilities, level of emotional arousal, previous knowledge and experiences, observers’ awareness, etc. (Edwards, 2010; Horn & Williams, 2004; McCullagh, 1986).

Bandura stated that the process of attention can be improved by highlighting the most crucial cues of the to-be-learnt-action. A large number of studies arose to
examine the influence of above mentioned factors on observational learning. I will provide a review of these research later in this chapter.

2.1.1.2 Retention processes

The second component of observational learning involves retention of observed cues. Bandura (1969, 1977, 1986) believed that if the observers do not retain the modeled action, it cannot be presumed that they are affected by observation of modeled action. Thus, the second sub-function in the process of observational learning is related to retention of observed action. According to Bandura (1969), for later reproduction of modeled action, which is no longer present, the observer must memorize the relevant features of the observed action in the form of a cognitive (symbolic) representation. Only due to a large memory capacity humans are able to learn many kinds of behaviors through observation.

Bandura (1977, 1986) held that retention processes involve two representational systems called imaginal and verbal systems. Information relevant to some features of action is mainly represented in imaginal codes. Imaginal representations, as reported by Bandura (1986), contain spatial characteristics which are identical to the spatial properties of observed actions. They are internal abstracts of actions and become stable in memory with repeated exposure to the modeled action. Bandura (1986) stated that two repetitions of an action are seldom identical. The observers have to form a general image that contain crucial aspects of a to-be-learnt action. As such, visual memory plays an important role in observational learning (Bandura, 1986). Moreover, in the early developmental stages, when there is a lack of prerequisite verbal abilities, visual imaginations play a crucial role in observational learning (Bandura, 1977).

The modeled events (actions) can also be coded in the form of verbal-perceptual representations, which is considered as second representational system (Bandura, 1977, 1986). Bandura believed that most of the cognitive processes that control human behaviors are primarily conceptual/verbal rather than imagery/vis-
ual (Bandura, 1977, 1986). Bandura (1986) pointed out that verbal symbols possess unique flexibility, such that complex behaviors could be acquired easily by verbal symbols. For example, a person can acquire, retain, and reproduce a series of right and left turns (e.g., RLRRL) readily by transforming the visual cues into verbal codes (Bandura, 1977, 1986).

Bandura (1986) argued that these two representational systems are very closely interrelated and hence it is difficult to separate them. Cognitive representations of modeled behaviors usually contain both representational systems in some degrees. Verbal representations often re-call visual representations and vice versa. Bandura believed that when these two representational systems share the same meaning, then learners combine the information into a common cognitive representation (Bandura, 1986).

According to Bandura (1986), the retention process can be improved by physical and cognitive rehearsal. Rehearsal is considered as an important memory aid, in which the observed actions that are exposed with physical or cognitive (mental) practices are assumed to be less likely forgotten. Moreover, physical or cognitive rehearsal can strengthen observed pattern in memory. Bandura (1986) believed that there is more than one mechanism that explains the influence of physical or cognitive rehearsal on learning and retention. This mechanisms involve semantical elaboration, transformation, and reorganization of cognitively retained behaviors into meaningful memory codes that aid recall (Bandura, 1986).

It is important to note that Bandura (1986) believed that symbolic transformation of retained behaviors includes a constructive process rather than a template-matching process. Template-matching perspective claims that observed events are stored in form of a cognitive template for action (Bandura, 1986). Bandura (1986) stated that the symbolic codes must retain the relevant cues and also include the operations for translating symbolic representations into actions.

Once the modeled behaviors are transferred in form of visual or verbal representations, learners can use these memory codes as an internal model to control and
perform the modeled behavior (Bandura, 1977). Moreover, cognitive representations serve as a standard of reference for detection and correction of erroneous performances (Blandin & Porteau, 2000).

2.1.1.3 Reproduction processes

The third component in process of observational learning is reproduction. Reproduction processes refer to translation and conversion of symbolic representations of modeled behaviors into approximate overt actions (Bandura, 1969, 1977, 1986). According to Bandura (1986), actions are reproduced by spatiotemporal organization of responses on the basis of a conception-matching mechanism. Bandura believed that action observation leads to formation of a conception of how to do. The conception involves how to combine and sequence the components of the observed action. Bandura pointed out that the observers learn the modeled action as a whole in the form of conceptual representations before they perform it (Bandura, 1986).

The process of behavior production can be divided into several distinct processes including cognitively spatiotemporal organization of behavior patterns, centrally guided initiation, monitoring of behavior production, matching behavior to conception (Bandura, 1986). Behavior is formed by combining the components of the observed action into new patterns. In the primary stage of behavior reproduction, responses are selected and organized cognitively. A driven conception of the behavior then enables the observer to perform an approximation of the modeled action (Bandura, 1986).

The conceptual representations can be utilized not only for action production, but also it serves as an internal model for correcting the later actions. In this case, incoming sensory feedback is compared with conception within the conception-matching process. If the performed action is not the same as that observed, conceptual representation will be changed until it becomes like the observed action (Bandura, 1977, 1986). Sensory feedbacks that the learners receive can be driven from internal resources such as visual, auditory, or kinesthetic information.
following the action performance or from external resources such as those pro-
vided by a coach including knowledge of performance or knowledge or results.
With increased practice, behaviors become well organized, so that they do not
need any conscious monitoring and are performed quickly and accurately (Ban-
dura, 1986). I will return to this topic in the next section where I will review the
research on observational learning influenced by Social Cognitive Theory.

2.1.1.4 Motivational processes

Bandura (1986) claimed that acquisition and execution of observed actions are
two different processes. As people retain and acquire the requirements for pro-
ducing the observed actions, but they do not perform everything that is acquired.
This is the case when retained and acquired behaviors are functionally less val-
uable or performing them is too risky. Hence, Social Cognitive Theory claimed
that individuals perform the observed actions only if they are motivated to do so

In Social Cognitive Theory, rewarding or punishing are considered as key moti-
vational factors. These factors could be driven from three sources of incentives
including direct, vicarious, and self-produced. As such, the individual is assumed
to exhibit the observed actions more likely if it is rewarded positively rather than
if it results in punishment (Bandura, 1986). Bandura believed that not only the
rewarding or punishment in regards to performance outcome affects production
of modeled behavior, but also the model itself plays an important role. In this
case, models exhibit the to-be-learnt behavior while simultaneously rewarding
observers (Bandura, 1977, 1986).

Thus far, it is discussed that motivational variables affect observational learning
by regulating overt performances of retained actions. However, Bandura believed
that motivational processes also influence the level of attention and retention dur-
ing the early sub-processes of observational learning. Motivation exerts selective
control over the cues within a modeled behavior to which the learners attend.
Moreover, motivational variables affect selective retention by activating the deliber-erate coding and rehearsal of modeled responses (Bandura, 1969). Bandura pro-
posed that the conception of self-efficacy can have a predictive impact on moti-
vational processes of observational learning. Self-efficacy is defined as one’s confidence concerning his ability to perform an observed action (see Bandura, 1997, for more information about self-efficacy).

In Banduras’ Social Cognitive Theory, the sub-processes of attention and retention are considered to represent acquisition and learning of observed actions, and sub-processes of reproduction and motivation are considered to represent performance and control of observed actions (Horn & Williams, 2004).

The four sub-processes of observational learning have been received huge at-
tention in observational motor learning domain. Many motor learning scientist have attempted to find out the factors that influence positively these four sub-
processes to optimize the process of observational motor learnings. In below, a review of the research conducted to examine the role of various factors on observ-
ational motor learning on the basis of Banduras´ theory is presented.

2.1.2 Research on observational learning influenced by Social Cognitive Theory

During the last decades many researchers have focused on the efficiency of ob-
servation on learning new motor skills, especially in sport settings, on the basis of Social Cognitive Theory (Bandura, 1969, 1977, 1986). The research attempted to manipulate the characteristics of the model to find out the most efficient fea-
tures of the model for skill acquisition. In addition, some of the research has fo-
cused on the observer characteristics, whilst others examined other features of Social Cognitive Theory such as factors that influence cognitive representations. A body of research also has investigated the influential factors in regards to the demonstration itself. Here I shall provide a review of literature of observational learning with focusing on the mentioned factors.
2.1.2.1 The model

The characteristics of the model that show the to-be-learnt motor skill to the learners have been extensively investigated. It is therefore not surprising that the most influential model characteristics on observational learning are well known (Weiss & McCullagh, 2001). The majority of the research conducted to investigate the role of the model on observational learning has focused on the features such as skill level, status, gender, etc. According to Bandura (1977), the models who are highly skilled with high social status and of the same gender are presumed to be more effective on observational learning. Bandura (1969) pointed out that the characteristics of the model could affect the primary sub-process of observational learning, i.e., attention.

2.1.2.1.1 Skilled vs. unskilled models

If the observation of modeled action should result in formation of a cognitive representation which will be used later for producing and correcting the action, it then seems logical that one uses a skilled model to show the learners the technique of the to-be-learnt action, because he performs the action perfectly. Therefore, most of the research on observational learning used a skilled model. Some research attempted however to uncover the effects of observing an unskilled model on observational learning.

Landers and Landers (1973) asked participants to learn a motor task involving climbing a special ladder called Bachman ladder. This motor task was later used in several research on observational learning. The motor task was shown by skilled and unskilled teacher and peer models. The results showed that both demonstration groups performed significantly better than control group, particularly in early blocks of the acquisition phase. However, the participants who observed the unskilled peer model exhibited the same performance as those who observed the skilled peer model. This was however not the case for teacher models. In this case, the observers of the skilled teacher model showed a significantly better performance than those who observed the unskilled teacher model.
Adams (1986) applied a particular paradigm to involve the unskilled (learning) model into research on observational learning. The paradigm included two groups of novice learners who were asked to learn a timing task. One group was asked to perform the task physically while other group was asked to observe the first group while they performed the motor task. As such, there was a physical practice group who served as learning (unskilled) models. In addition, the observers were further divided into two groups of receiving the knowledge of results (KR) of the observed action or without KR. The results revealed that the participants who observed the learning model with access to KR performed the motor task significantly better than the participants in demonstration group without KR and no-demonstration control group. Adams (1986) suggested that observing a learning (unskilled) model with KR can result in formation of a cognitive representation of modeled action and can help the observers become engaged in a “problem-solving process” that aids them to learn the observed action.

In two studies, Lee and colleagues (Lee & White, 1990; Pollock & Lee, 1992) replicated the results of Adams (1986) by using two different computer games as the learning task. Pollock and Lee (1992) added a skilled model to the method used by Adam (1986) and found that both demonstration groups performed better than the no-demonstration group (the participants who acted as the learning model). However, no significant difference was observed between skilled and learning models groups. Those results suggest that for learning motor skills by observation skilled and unskilled models are equally effective.

Moreover, some research provided evidence in favor of unskilled model over skilled model in learning new motor tasks (McCullagh & Caird, 1990; Meany, Grif- fin, & Hart, 2005). McCullagh and Caird (1990) investigated effects of skilled and unskilled models on learning a timing task. A retention test was also utilized to assess the effect of observation on learning as well as performance. The results showed that the participants who observed the learning model performed better than those who observed the skilled model.
However, those results were not replicated by a subsequent experiment by using a sport skill involving a free-weight squat lift. McCullagh and Meyer (1997) criticized that previous studies only measured outcome scores when examining the effects of model demonstration. They pointed out that assessing the movement form is also necessary in order to provide an accurate estimation of the observational learning process. No significant differences were observed between observation of skilled and unskilled models in acquisition phase and retention test in terms of both outcome and form scores. However, the observation with feedback had resulted in better form scores in the retention test than observation without feedback, which indicates the importance of availability of feedback in the process of learning motor skills by observation as well as observational learning has a greater influence on movement form than movement outcome (McCullagh & Meyer, 1997).

It seems that availability of KR during watching skilled and unskilled models is a crucial factor on effectiveness of the model. Weir and Leavitt (1990) examined the role of observing skilled and unskilled models under circumstances of access to KR and without KR on learning a dart throwing task. Motor learning here was measured by accuracy of throwing the dart onto a dart board. The results showed that in the presence of KR both skilled and unskilled model had the same effects on observational learning. However, in the absence of KR the unskilled model resulted in a better performance than the skilled model. Those findings indicate that the observers of the skilled model needed KR to perform as same as the observers of the unskilled model, who in contrast obtained the same results regardless whether the KR was present or not.

In summary, although skilled models are extensively used in the research on observational learning, some evidence showed that unskilled models are also effective as skilled models in the process of learning new motor skills by observation. Adams (1986) suggested that observing an unskilled model engages the observer in a problem-solving process that subsequently helps them to learn the observed action. Moreover, it seems that the impact of skilled and unskilled models depend on the nature of to-be-learnt motor task and availability of KR (see
2.1.2.1.2 Model status

The impact of social status of the model on observational learning has been investigated in some reports. Those research compared the role of high and low social status of the model on observational learning. Landers and Landers (1973), as noted earlier, asked young female pupils to observe either a skilled or unskilled teacher (high status) or a peer (low status) model and perform a Bachman ladder motor task. The results indicated that the group of children who observed a high status model demonstrated skillfully the motor task performed significantly better than other groups. McCullagh (1986) further examined this issue and replicated the results of Lander and Landers (1973). McCullagh also added a retention test to the experiment in order to assess the lasting effect of model observation. The results showed a superiority of observing a high status model over low status model on executing a Bachman ladder during the acquisition phase and not the retention test.

2.1.2.1.3 Coping vs. mastery models

Coping and mastery models are also used to demonstrate the to-be-learnt activity in some research on observational learning. Those seem basically similar to skilled and unskilled modes because a coping model is a model which demonstrates the action during learning (unskilled/learning model) and a mastery model can be considered as a skilled model. However, the coping model was used in a situation in which the to-be-learnt motor task was a very fearful and dangerous activity such as swimming or diving (see McCullagh & Weiss, 2001; Ste-Marie et al. 2012). Weiss, McCullagh, Smith, and Berlant (1998) examined the effects of observing coping and mastery models on learning swimming skills of fearful chil-
Children. Fear and self-efficacy were measured as psychological variables. The variables were assessed in pre, post, and follow-up tests. The results showed that the children who observed either a coping or mastery model performed the motor task in post and follow-up tests significantly better than children in the control group. In addition, observing the coping model affected self-efficacy more than observing the mastery model.

Clark and Ste-Marie (2002) extended the study of Weiss et al. (1998) by investigating the effects of observing coping and mastery models on learning a diving task. The results of this study revealed that observing the mastery model influenced the motor learning better than the coping model, but perceived task difficulty and self-efficacy have been affected by coping model better than mastery model. Ramsey, Cumming, Mathews, Binstock, and Robson (2007) used a balance task as a learning task and found no difference between coping and mastery models in motor learning, perceived task difficulty, and self-efficacy expectations. Altogether, the research mentioned here indicate that coping and mastery models affect the motor learning and psychological variables differentially (see also McCullagh & Weiss, 2001; Ste-Marie et al. 2012).

2.1.2.1.4 Gender

Some research has examined whether gender of the model play a role in the process of observational learning. Gould and Weiss (1981) divided the female participants into two modeling groups including observation of a nonathletic female and observation of an athletic male. The learning task was a muscular endurance task. The results revealed that the girls who observed a female model performed better than those who observed a male model. George, Feltz, and Chase (1992) added an athletic female model and a non-athletic male model to the earlier study in an attempt to separate the effects of gender and skill level of the model. The results indicated that the observers of a non-athletic model, regardless of gender of the model, performed better than those who observed an athletic model. The authors concluded that skill level of the model plays a role in
observational learning not the gender of the model. However, Meany, Griffin, and Hart (2005) used a similar paradigm to George et al. (1992) and found that the girls who observed an unskilled female model performing a juggling motor task demonstrated superior performance and more learning strategies. The mentioned studies revealed contradictory results, but it seems that the observers benefit more from observing a model with same gender (see also Horn & Williams, 2004).

2.1.2.1.5 Model similarity

The degree to which the observer perceives similarity between themselves and the model has been tested in some studies on observational learning (Gould & Weiss, 1981; McCullagh, 1987; Meany et al. 2005). Gould and Weiss (1981) investigated the effects of observing similar (nonathletic) and dissimilar (athletic) models on performing a muscular endurance task and self-efficacy. The results showed that the participants who observed a similar model performed the motor task significantly better than those who observed a dissimilar model. Moreover, a similar model led to higher self-efficacy than observing a dissimilar model. These results were replicated by McCullagh (1987) and Meany et al. (2005) by using a motor task involving Bachman ladder and juggling, respectively.

The effects of the above-mentioned characteristics of the model on observational learning could in fact be explained through the mechanism of model-observer similarity. For example, observing an unskilled or a coping model leads to learning a new motor skill because the observers perceive a copy/unskilled model similar to themselves (see also McCullagh & Weiss, 2001).

2.1.2.1.6 Self-as-a-model

The self-as-a-model is a modeling technique during which the performer views a video replay of his or her performance. As mentioned in the previous section,
individuals perform better when they observe a similar model. Thus, one can expect that people perform better when they view their performances, because nobody is similar to me more than myself. The technique of self-as-a-model is extensively used in research on observational learning (Dowrick, 1999; McCullagh & Weiss, 2001; Ste-Marie et al. 2012). There exists two types of self-as-a-model including self-observation and self-modeling (Martini, Rymal, & Ste-Marie, 2011). Self-observation shows the observer a video of his or her current performance. Self-modeling involves an edited videotape of the observers’ performances (Martini et al. 2011). Self-modeling is further divided into two types: positive self-review (PSR) and feed-forward (FF) (Dowrick, 1999; see also Law & Ste-Marie, 2005). PSR self-modeling is a procedure in which an edited videotape of best performance of the learner at the time is presented to him. On the other hand, FF self-modeling involves editing the videotape to create a presentation that shows the learner performing a skill at a higher level than his or her actual capability (Dowrick, 1999; Law & Ste-Marie, 2005). Some research in observational learning of motor skills have examined the effectiveness of these types of self-as-a-model on learning new motor skills.

The role of self-observation on observational learning has been examined by several researchers (Barzouka, Bergeles, & Hatziharistos, 2007; Starek & McCullagh, 1999; Winfrey & Weeks, 1993; Zetou, Fragouli, & Tzetis, 1999; Zetou, Kourtesis, Getsiou, Michalopoulou, & Kioumourtzoglou, 2008; Zetou, Tzetzis, Vernadakis, & Kioumourtzoglou, 2002). Winfrey and Weeks (1993) compared the effects of self-observation with no-observation on learning a balance beam routine and self-efficacy. They found no difference between groups in performance scores or self-efficacy. However, the correlation between actual performance scores and self-rated scores was only significant for the self-observation group. Similarly, Zetou et al. (2008) investigated whether self-observation enhances skill acquisition in volleyball. The results revealed that the participants in self-observation groups improved their performance much more than those in the control group who only received verbal instructions.
In an attempt to compare the effects of self-observation and observation of a learning model on learning a crawl skill in swimming, Starek and McCullagh (1999) found that self-observation led to better motor performance, but no difference was observed between groups in terms of self-efficacy scores. The effectiveness of self-observation on observational learning was compared with observing an expert model in volleyball (Barzouka et al. 2007). They found that both modeling groups improved their performance outcome and from scores from pre-test to retention test, but no significant difference was observed between the modeling groups and the control group who only received verbal instructions. However, Zetou et al. (2002) found some advantages for observing an expert model in comparison to self-observation in volleyball. In this study, the observers of an expert model performed in the retention test significantly better than those in the self-observation group in terms of performance outcome and form scores.

The effects of both types of self-modeling have been examined by Ste-Marie and colleagues (Clark & Ste-Marie, 2007; Law & Ste-Marie, 2005; Ste-Marie et al. 2011). Law and Ste-Marie examined the influence of a PSR self-modeling on learning skate jump performance, self-efficacy, motivation, and state anxiety. The results indicated that the observation of a PSR self-modeling was not superior to control condition with no observation. In a subsequent study, Clark and Ste-Marie (2007) compared the effects of observing a PSR self-modeling and self-observation on learning swimming skills. The results of this study showed that the participants of the PSR self-modeling group performed significantly better than the participants in self-observation and control groups in performance and psychological variables. Two groups later demonstrated similar performances. Ste-Marie et al. (2011) examined the role of FF self-modeling on learning trampoline skills. A group of children practiced two trampoline routines. They received a FF self-modeling for one routine, while they practiced the other routine without any modeling. The results revealed that the children showed superior motor performance in the routine with FF self-modeling over the other routine. However, self-regulatory variables were similar during the both routines.
Altogether, some studies have examined the effects of different types of self-as-a-model such as self-observation, PSR, FF self-modeling on observational learning. The findings of these research are very contradictory. In general, the research provided evidence in favor of using self-as-a-model in the process of observational learning, but drawing any firm conclusion from these few research is difficult (see also McCullagh & Weiss, 2001; Ste-Marie et al. 2012).

2.1.2.1.7 Auditory model

Visual demonstration is the traditional form of presenting new skills to the learners. However, are visual demonstrations still effective if the to-be-learnt task focuses on temporal components more than spatial components? Some research has suggested that an auditory model may be more effective in learning such skills than a visual model (Doody, Bird, & Ross, 1985; Han & Shea, 2008; Shea, Wulf, Park, & Gaunt, 2001).

The effects of an auditory model was compared with a visual model on learning a timing task (Doody et al. 1985). The timing task involved seven barriers and the participant had to displace them in a predetermined timing order. The results showed that the auditory model and audiovisual model groups performed better than the visual model and the no-model group in the acquisition phase. The effects had reached a significant level on the transfer test. The authors suggested that in motor tasks involving relative timing components an auditory model may develop a cognitive representation of movement timing. Shea et al. (2001) replicated the results of Doody et al. (1985) and found that an auditory model is better than no model in acquiring the relative timing (Experiment 1), but for enhancing absolute timing physical practice was needed.
2.1.2.1.8 Summary of the research on model

Bandura (1969, 1977) stated that the model characteristics have an influence on the process of selecting the required information for building a cognitive representation. Furthermore, he suggested that the skilled models with high social status and more similar appearance to the observers are presumed to be more effective on formation of cognitive representations. In the previous section, I have reviewed the research conducted to examine various features of the model in the process of observational learning.

Skilled and unskilled models have been compared in some research. Some evidence shows that unskilled models are just effective as skilled, however it depends heavily on availability of KR. Adams (1986) suggested that observing an unskilled model engages the observers in a problem-solving process that subsequently leads to forming cognitive representations. Moreover, comparison of high and low social status of the model revealed superiority of observing a high status model over low status model in observational learning. In addition, using coping and mastery models show contradictory results in regards to motor learning and psychological variables. While mastery models led to a better motor learning, coping models improved psychological factors. The observers benefit more from the models who they perceive similar to themselves. It has also been showed that self-as-a-model is an effective method for enhancing skill acquisition. The reviewed studies indicate that unskilled models and self-as-a-model method can also be used in addition to skilled models for conveying information of the to-be-learned motor skill. Similarity to the observer and high status are influential factors that should be taken into account.

2.1.2.2 The observer

In addition to the features of the model that affect the learning process of observation, the observer characteristics are also an important factor in this process. Although a large number of research have examined the influence of various fea-
tures of the model on observational learning, to date very few studies have directly examined the role of the observer characteristics on observational learning. In this context, most of the research have based theoretically on two-factor theory of imitation proposed by Yando, Seitz, and Zigler (1978). Two-factor theory of imitation originates largely from the Bandura’s Social Learning Theory. However, Yando et al. (1978) emphasized primarily on the developmental factors in the process of observational learning. According to two-factor theory of imitation, cognitive-developmental level (e.g. the observer’s attention span, memory capacity, coding capabilities, and physical capabilities) and motivational orientation (intrinsic or extrinsic) are two factors which influence the observational learning process. In relation to Social Learning (Cognitive) Theory the cognitive-developmental level of the observer could affect attentional, representational, and reproduction processes and, of course, motivational orientation factor could influence the motivational process. Here I will provide a review of the research conducted to examine the effects of these two factors on observational learning.

2.1.2.2.1 Cognitive-developmental level

The first factor of two-factor theory of imitation has been investigated by comparing various age groups. One of the earliest studies was conducted by Thomas, Pierce, and Ridsdale (1977). They asked seven- and nine-year-old children to learn a stabilometer balance task. The children within each age group were subsequently divided into three groups according to whether a model was presented in the beginning or middle of the acquisition phase, or the no-model demonstration. The results showed that the children of both age groups in the no-demonstration condition performed similarly. Moreover, observation of a model in the beginning of the acquisition phase was found to facilitate performance. In addition, observing the model in the middle of the acquisition phase had detrimental effects on the performance of seven-year-old children and beneficial effects on the performance of nine-year-old children. Thomas et al. (1977) interpreted these findings in terms of larger information processing capabilities for nine-year-old
children and their larger motor repertoire in comparison to seven-year-old children.

Feltz (1982) compared the ability of children and adults to model a Bachman ladder-balance task. Both movement form and outcomes were measured. Results revealed that adults had higher form and outcome scores than children. Furthermore, most of the children had correctly described only one component of the movement form, in comparison to three correct components for adults. Feltz concluded that the lower scores of children in comparison to adults may be because of their lower attentional and/or retentional capabilities. Weiss (1983) has subsequently examined the correlation according to the age of the observers (4-5 vs. 7-8 years old) and the instruction (verbal model, silent model, no model) in modeling a sequential motor task. Weiss found that older children showed better performance than younger children in all measured variables including motor performance, verbal-cognitive, and attentional measures. The correlation between age and instruction showed that younger children performed better under the condition of verbal model, while older children performed equally under both verbal and silent models. Weiss interpreted these findings in terms of lower cognitive capabilities of younger children.

Meany (1994) compared the ability of children (9-10 years old) and adults (18-45 years old) to model a juggling task. The participants of each age group were assigned to four demonstration groups including visual model, visual model plus cues, visual model plus verbal rehearsal, and visual model, verbal rehearsal plus cues. The participants’ performances were measured during acquisition, retention and transfer. The results indicated that the children who observed visual model plus verbal rehearsal and visual model, verbal rehearsal plus cues performed significantly better than those who observed only visual model or visual model plus cues. The adults in all groups performed equally well during the acquisition phase. Performances of the children in the retention test were the same for all groups, while the adults in visual model plus cues showed superiority over all other model groups. In the transfer test, adults performed better than children.
These results provide support for the theory of Yaldo et al. (1978) that cognitive-developmental factors affect observational learning.

The superiority of adults over children in modeling new motor skills has been subsequently shown by other studies. For example, Hayes, Hodges, Scott, Horn, and Williams (2007) investigated the effect of observing video and point-light demonstrations on learning a bowling action in two age groups of adults and children. The results of this study showed that adults were more accurate than children (Experiment 1). Moreover, adults showed a similar performance in both video and point-light condition, while children were poorer when observing point-light demonstration in comparison to video demonstration (Experiment 2). The children in the point-light group reached the level of those in the video group after a perceptual-cognitive training with various kinds of movements in the form of point-light presentations (Experiment 3). This study will be described in detail in a future chapter where a comparison between the role of observing video and point-light demonstrations is presented.

Finally, Ashford, Davids, and Bennett (2006, 2007) conducted two meta-analysis on the literature of observational learning. In the first study, they focused on the effects of model observation on movement outcome and dynamics (form) across different task constraints. In the second study, developmental effects influencing observational learning were considered. The results of these two meta-analysis are summarized in Figure 2. The results revealed that overall effect size obtained from movement dynamics data was larger for adults (0.8) in comparison to children (0.24), whereas overall effect size obtained from movement outcome data was larger for children (0.48) than for adults (0.02).

The finding that children achieved movement outcome goals higher than movement dynamics (form) is in line with the theory of goal-directed imitation proposed by Wohlschläger, Gattis, and Bekkering (2003). According to this theory, the observed actions are not imitated as a whole, but rather the observers cognitively decompose the observed task into a hierarchy of aspects (goals), select the most important aspects, and finally order hierarchically the selected aspects with a major focus on the most important one. In other words, the observers imitate the
end-goal of the observed action instead of imitating the means to achieve that goal (Wohlschlänger et al. 2003; see also Hayes, Ashford, & Bennett, 2008). Wohlschläger et al. (2003) discussed that although goal-directed imitation should be valid for all individuals regardless of age difference, but children, probably because of smaller working memory capacity than adults, tend to focus on imitating the goal of the modeled movement than movement dynamics (form). This assumption is, in fact, in accordance with the findings of Ashford et al. (2006, 2007).

Altogether, the results of research conducted to compare the ability of children and adults in learning new motor skills by observation indicate that adults perform better than children. It might be because of the lower attentional and retentional capabilities of children. These results are consistent with the two-factor theory of imitation which primarily focused on performance differences between children and adults in observational learning (Yando et al. 1978). Moreover, Ashford et al. (2007) showed that children tend to imitate movement goal rather than movement form which is in line with the theory of goal-direction imitation (Wohlschlänger et al. 2003).
Figure 2.2. Summary of the results of two meta-analysis of the research on observational learning conducted by Ashford et al. (2006, 2007) for motor task and age with regards to movement dynamics (top) and movement outcome (bottom).

2.1.2.2.2 Motivational orientation

The second factor in two-factor theory of imitation is related to motivational components influencing observational learning. Motivational processes in social learning (cognitive) theory held that the observers should be motivated to reproduce the modeled action. Yando et al. (1978) suggested that both intrinsic and extrinsic motivations may guide observational learning. In this context, extrinsic
motivations refer to the motivation that comes as a result of performing the observed action. On the other hand, intrinsic motivations refer to the motivation that comes from the observer. The focus in two-factor theory is on intrinsic motivations. In observational learning literature very few empirical studies have examined the effects of motivational components on observational learning. Feltz and Landers (1977) asked male and female children to imitate a Bachman ladder balance task. The participants were assigned into four experimental groups including observation of a model (informational cues) plus verbal knowledge of results (motivational cues), only observation of model (informational cues), only knowledge of results (motivational cues), and no-cue. Knowledge of result was applied, in this study, to encourage intrinsic motivation of the learners. The results showed that motivational cues provided by knowledge of performance did not influence motor performance. However, the observers benefited from informational cues (model observation).

Manipulating the model similarity was also used as a method for motivating the learners. A review of the effects of model similarity was presented in previous sections. However, it must be noted that similar model has a beneficial effect on observational learning (see the section related to model characteristics).

To summarize, characteristics of the observer such as cognitive-developmental level and motivational orientation can affect observational learning. Results from the research on age-related differences showed that adults are better than children in modeling new motor tasks. This is in accordance with the two-factor theory of imitation proposed by Yando et al. (1978). The main difference between adults and children is that adults focus more on learning movement dynamics (form) and children focus more on movement outcome (goal) (Ashford et al. 2006, 2007).
2.1.2.3 The demonstration

Over the past few decades many studies have attempted to determine the optimal condition for demonstrating the to-be-learnt movement to the learners. These factors can be mainly divided into two main categories including a) How to demonstrate and b) Availability of augmented information. Below I have provided a review of research which have examined the mentioned factors in the process of observational learning.

2.1.2.3.1 Spacing and timing of demonstration

When is the best time to present the learners a demonstration? Is it necessary to show them the modeled action at the beginning of the acquisition phase, or should it be presented after a period of physical practice? These questions were addressed in some studies (Anderson, Gebhart, & Pease, & Ludwig, 1982; Anderson, Gebhart, Pease, & Rupnow, 1983; Carroll & Bandura, 1985; Landers, 1975; Weeks, & Anderson, 2000).

Landers (1975) asked children to learn a Bachmann ladder balance task. Children had observed a model demonstration a) before practice, b) before and middle of practice, and c) only middle of practice. The results indicated that both groups of children who observed the model before practice performed better than those who did not observe a model. Moreover, observing the model in the middle of practice had contradictory effects. For children who observed the model before practice, viewing a model in the middle of practice enhanced motor performance, while no enhancements were observed for only middle group. Landers (1975) concluded that observing the model before practice led to forming a mental picture or cognitive representation of the to-be-performed action. In addition, viewing the model for the children who observed the model before practice, resulted in strengthening and stabilizing the previously acquired cognitive representation. However, presenting the model for children who never observed the model led to an interference with performance and children may had disregarded the model. Carroll and Bandura (1985) observed similar findings with Landers (1975). They
used a complex action including nine components and presented the action to the participants either concurrently, with delay, or no-model. The results showed that observing the modeled action concurrently facilitated motor performance in the acquisition phase and the retention test, while delayed observation did not influence acquisition or retention.

However, the findings of Carroll and Bandura (1985) and Landers (1975) were not replicated by Anderson et al. (1982, 1983) by using a stabilometer balance task and ball-striking task respectively. In these two studies, the children who observed no model at the beginning of the acquisition phase did not actually perform better than those who observed no model. Furthermore, introducing the model in the middle of practice did not result in any improvement in motor performance. Anderson et al. (1983) discussed that the features of the motor task used in these studies may have been the reason why no improvements were observed in the acquisition phase.

Weeks and Anderson (2000) examined the effects of timing of model demonstration on learning an overhand volleyball serve. The participants in this study were assigned into three groups including a) all-pre-practice demonstration group observed 10 pre-practice demonstrations and then engaged in practice, b) an interspersed demonstration group observed one pre-practice demonstration and one demonstration in every three trials during acquisition phase, and c) a combination demonstration group observed five demonstrations before practice and one demonstration in every three trials until the middle of the acquisition phase. Form and outcome scores were measured as dependent variables. Two retention tests were added to this study for assessing learning effects. The results revealed that the combination group performed better than other groups in the acquisition phase and the retention tests in terms of movement form scores followed by all-pre-practice demonstration group. However, movement outcome scores revealed no significant differences between groups in either acquisition phase or retention tests. Overall, it seems that early provision of demonstrations would be more effective than later provision, it however relies mainly on the features of the task.
2.1.2.3.2 Frequency of demonstration

The main question in this section is how many times a model should be demonstrated to facilitate motor learning. Feltz (1982) investigated this issue by using a Bachman ladder balance task. The participants observed either 12, 8, 4, or no model demonstrations. The findings indicated that the participants in all four groups performed similar in terms of outcome scores, but the participants who observed a model twelve times performed better than the no-demonstration control group. Sidaway and Hand (1993) presented to four groups of participants 100%, 20%, 10%, and no demonstration of a model hitting a golf ball. In this study, the participants who observed a model with more frequency performed better than other groups in the retention test. The authors concluded that frequent demonstration of a model can be a powerful way to enhance motor skill acquisition.

2.1.2.3.3 Speed of demonstration

Do real-time demonstrations affect observational learning better than slow-motion demonstrations? Al-Abood, Davids, Bennett, Ashford, and Marin (2001) examined this issue by using a dart-throwing motor task. The participants observed either a real-time demonstration or a slow-motion demonstration before practice and then again every 10 trials in the acquisition phase which totaled 100 trials. A retention test of 20 trials was employed in one day after the acquisition phase. Movement coordination, control and outcomes were measured as dependent variables. The results showed that the observers of the real-time demonstration performed significantly better than those in the slow-motion group in terms of movement outcomes and coordination during both the acquisition phase and the retention test. However, analysis of movement control variables including elbow release angle, elbow release velocity and movement time revealed no significant differences between groups. The authors suggested that the real-time demonstrations are more effective than slow-motion demonstrations in early stage of motor learning. However, in later stages of motor learning, when the desired
movement coordination is already established, slow-motion demonstration may be more effective than real-time demonstrations.

2.1.2.3.4 Schedule of model observation

Some research have attempted to identify optimal practice schedule in the process of observational learning. Variables related to practice scheduling such variable vs. constant, self-control, and blocked vs. random have been investigated. Bird and Rikli (1983) compared the effects of observing a variable schedule of model observation with a constant schedule. The learning task was an angular positioning motor task. The participants performed 60 trials for the acquisition phase and 20 trials for the retention test. During the acquisition phase, the participants in constant condition observed the model for 15 trials at each of the four locations, 40°, 50°, 70°, and 80°. The variable group observed an equal number of model demonstrations, but randomly. The results indicated that the participants in the constant group showed lower trial-to-trial error than those in the variable group during the acquisition phase. In the retention test however, the variable group performed significantly better than the constant group.

Han and Shea (2008) examined the effects of observing an auditory model with blocked, random, and mixed practice schedules on learning three five-segment timing tasks. The participants practiced the motor tasks in two sessions (acquisition phase) and a retention session. Each session in the acquisition phase consisted of six acquisition blocks of nine trials. The retention session consisted of two blocks of nine trials. The participants were divided into eight groups defined by practice schedule (block-block, block-random, random-random, random-block) and availability of auditory model (with model, no model). The participants in demonstration groups were differentiated with respect to type of practice schedule in first and second session. For example, block-block group indicated that the participants observed the model in both the first and second session in a block practice schedule, and so on. Block practice schedule consisted of practic-
ing one of three timing tasks for two consecutive acquisition blocks before switching to the second timing task. Random practice schedule consisted of a random distribution of timing tasks during acquisition blocks. Relative and absolute timing were measured as dependent variables. The results of this experiment revealed that the participants in blocked-blocked and blocked-random demonstration groups showed better relative timing performances in comparison to random-blocked and random-random demonstration groups. In the acquisition phase, random-random and blocked-random practice schedules led to better absolute timing performances relative to blocked-blocked and random-blocked practice schedules. Han and Shea (2008) concluded that the blocked-random practice schedule leads to better motor learning than other practice scheduling.

Wulf, Raupach, and Pfeiffer (2005) examined the role of a self-controlled practice schedule on observational learning of jump shot in Basketball. The participants were assigned into two groups consisting of a self-control group and a yoked group. The participants in self-control group were informed that they were allowed to observe the model demonstration whenever they wanted during the acquisition phase. The participants in the yoked group were told that the model demonstration would be presented from time to time during acquisition phase to enable them to watch the technique of the movement. Movement form and outcome were measured as dependent variables. The results of this study showed that the participants in the self-control group asked for more model demonstration relatively early in the acquisition phase. In the acquisition phase, both groups showed relatively similar movement form and outcome performances. In retention test however, the participants in the self-control group outperformed those in the yoked group in terms of movement form scores. The authors discussed that the observers of the self-controlled group might have picked-up more relevant information from the model than the yoked group.

Altogether, practice schedule may play an important role in the process of observational learning. According to the mentioned results, variable, self-controlled, and blocked-random practice scheduling could be effective practice programs in learning motor skills through observation.
2.1.2.3.5 Viewing angle of demonstration

Ishikura and Inomata (1995) addressed the question whether viewing angle of model demonstration affects learning new motor skills. The participants were divided into three demonstration groups including a) Objective: Skill was demonstrated from the front angle of the model, b) Looking-glass: Skill was demonstrated as an image in the mirror, and c) Subjective: Skill was demonstrated from the rear angle of the model. The learning task was a sequential gross-movement pattern. Under this condition, the participants who observed subjective model demonstration performed significantly better than the other two groups in the acquisition phase. Moreover, the looking-glass demonstration group outperformed the objective demonstration group in the acquisition phase. In retention tests however, all three groups showed similar performances. Ishikura and Inomata (1995) suggested that the lower amount of cognitive processing in the subjective demonstration group led to greater performance, because the observers did not need to reverse information presented in demonstration, whilst the observers in the looking-glass demonstration group had to reverse the information one time, and those in the objective demonstration groups had to reverse the information two times (front-rear/left-right).

2.1.2.3.6 Availability of augmented information

Augmented information refers to the information that is externally provided to learners following execution of the movement. In the research on observational learning, augmented information is often used in various forms like knowledge of results (KR), knowledge of performance (KP), and verbal instruction. The central question was whether availability of augmented information in any form would be beneficial for acquisition of new motor skills through observational learning. In fact, the mentioned forms of augmented information are extensively used as an individual method for enhancing motor learning (see Wulf, Shea & Lewthwaite, 2010 for more details), but the purpose here is to explore the role of applying
these information along with model demonstration in the process of observational learning.

**Knowledge of results**

McCullagh and Little (1990) compared the effects of modeling plus KR with KR only condition on learning a barrier task, in which the participants had to displace seven barriers with their right hand in 2,100 ms. KR only participants were further divided into two groups of KR-100% and KR-33%. All participants completed 60 trials during the acquisition phase, but varied in amount of KR or availability of demonstration. The participants in demonstration plus KR received two correct model demonstrations followed by one physical practice with KR and that was repeated throughout the acquisition phase. KR-100% group received 60 physical practice with KR and KR-33% group received 20 physical practice with KR and 40 physical practice without KR. In the latter group, KR was presented randomly during the acquisition phase. Immediate transfer (following two minutes rest) and retention (24-hours later) tests were performed containing 20 no-KR no-demonstration trials. The results of this study showed that during the acquisition phase all groups decreased their errors, but no significant differences were observed between groups. However, during the immediate transfer test, the participants in model demonstration plus KR group increased their errors. There was no significant difference between groups in the retention test. Weir and Leavitt (1990) extended these results by comparing the effects of skilled and unskilled models with or without KR on learning a dart throwing task. The results showed that availability of KR was redundant for the observers of the skilled model not for those who observed the unskilled model. That was possibly because the observers had difficulty in detecting errors from the skilled model which would have demonstrated no errors.

Some research have investigated the effects of manipulating the frequency of KR in the observational learning process. Badets and Blandin (2004) found some beneficial effects of KR-33% in comparison to KR-100% during observational

Above-mentioned studies indicate that KR is an important factor in observational learning. However, these studies only measured the movement outcome and not movement form. As mentioned earlier, Ashford et al. (2006) showed that model observation would have greater effects on movement form and lower effects on movement outcomes. Therefore, the effects of availability of KR during model demonstration has to be assessed by both movement form and outcome, in order to obtain an accurate estimation of its efficacy. This issue has been examined by Horn, Williams, and Scott (2002) and Horn, Williams, Scott, and Hodges (2005).

In the first study, Horn, Scott, and Williams (2002) asked participants to learn kicking a ball onto a target by observing video and point-light demonstrations. In this experiment, KR was as an intrinsic task-related information not an augmented information provided from an external resource. However, this study and the following study shed light on the role of the combination of KR and modeling on learning movement form and outcome. Horn et al. (2002) found no significant differences between the demonstration groups and the no-demonstration control group in terms of movement coordination or outcome. In the subsequent study, Horn et al. (2005) removed intrinsic KR and found that model observation led to better movement coordination than no-observation. However, no significant differences were observed between groups in terms of movement outcome. These two studies indicate that when KR is available, the participants use it as a primary source of information for later reproduction of the observed action and that KR may prevent the role of model observation.
Overall, availability of KR along with model demonstration could result in learning movement outcomes (Badets & Blandin, 2004, 2005, 2010; Horn et al. 2002), but in order to learn movement form, one needs to remove KR to make the model a primary source of information (Horn et al. 2005).

**Knowledge of performance**

Another form of augmented information that can be provided for the individuals is knowledge of performance (KP). KP refers to information provided by an external resource about the various components of the movement being practiced. Magill and Schoenfelder-Zohdi (1996) examined the effects of modeling and KP on learning a rhythmic Gymnastics skill. Four groups of participants were presented with model demonstration plus KP, only model demonstration, only KP, or no-model no-KP. KP here was provided by an experimenter as one statement that reflected the most important error to be corrected in the next trial. The participants performed 54 acquisition trials and 20 retention trials the next day. The results showed that the no-model no-KP group performed significantly worse than all other groups in terms of movement form scores during the acquisition phase and the retention test. Moreover, observing the model plus KP did not provide any advantages over only modeling or only KP in both the acquisition phase or the retention test. The authors concluded that modeling can facilitate acquisition of required coordination pattern for reproducing the motor skill.

**Verbal instruction**

The effects of providing verbal instruction along with model demonstration has been investigated in several studies Buchanan & Dean, 2010; Haguenuer, Fargier, Legreneur, Dufour, Cogerino, Begon, & Monteil, 2005; Janelle, Champenoy, Coombes, & Mousseau, 2003). There are similarities and differences between verbal instruction and KP in research on observational learning. Although both verbal instruction and KP, as used by Magill and Schoenfelder-Zohdi (1996), are
verbal statements, KP refers to the information related to the movement errors, while verbal instruction refers to the information of what has to be learned.

Janelle et al. (2003) asked 60 males and females to learn a soccer accuracy pass. Participants were assigned to six groups involving verbal instruction, video model, video model plus visual cues, video model plus verbal cues, video model plus visual and verbal cues, and control groups. All participants completed 20 pretest trials (without manipulation), 40 acquisition trials (with manipulation), and 20 retention trials (without manipulation). Movement form and outcomes were measured as dependent variables. The results of this study showed that the participants who observed the video model with visual and verbal cues performed better than other groups during the acquisition phase and the retention test. Janelle et al. (2003) suggested that adding verbal information to visual cues enhances cognitive representation and retention of modeled actions and, hence, improves reproduction of motor skills. Haguenauer et al. (2005), however, did not replicate the results of Janelle et al. (2003) by using a figure skating as a learning task. Three groups of participants observed the video model before practice. Once practice started, two groups of participants were instructed verbally, while other group were not instructed (control group). They found no superiority for the learners who received verbal instruction during the acquisition phase in comparison to those who did not receive verbal instruction.

Altogether, contradictory results emerged from the research on the role of verbal instruction on observational learning and further research is required.

2.1.2.4 Cognitive representation

Bandura (1969, 1979, 1986) stated that the observers must memorize the relevant features of the observed action in the form of cognitive representations which will be later used for reproduction of the modeled action and also detection and correction of errors arising from action performance. Some studies have examined the hypothesis of Bandura that action observation results in formation of cognitive representations. Carroll and Bandura (1990) investigated the effects of
the number of model demonstrations and verbal coding on movement outcome and cognitive representations. The learning task was a complex action including nine components. The participants observed the motor task either two or eight times with or without verbal coding. Then, they were asked to perform the observed action in the correct pattern. Cognitive representation was assessed by using recognition and pictorial-arrangement test. In the recognition test, the participants had to recognize the correct component of the action from three highly similar distractors. In the pictorial-arrangement test, the participants were asked to arrange the images of nine components of the action which were reordered randomly. The results showed that the participants who observed the model demonstration eight times performed better than the other group in terms of movement outcomes. The results of cognitive representation tests revealed that the participants who were presented with the model demonstration eight times achieved better scores in both recognition and pictorial-arrangement tests. In addition, by using a causal analysis, Carroll and Bandura (1990) provided evidence for the mediating role of development of a cognitive representation for reproduction of the action. These findings were also replicated by Wiese-Bjornstal and Weiss (1992) by using an underarm modified softball pitch as a learning task.

Additionally, there are some evidence in favor of facilitating role of action observation on error detection and correction mechanisms. Blandin and Proteau (2000) found that the observers were able to detect and correct their errors in a timing motor skill similar to the individuals who practiced the motor task physically. These findings were replicated by several research (Badets, Blandin, Wright, & Shea, 2006; Black & Wright, 2000; Black, Wright, Magnuson, & Brueckner, 2005). These results brought the authors to the conclusion that observational and physical practices engage a learner in similar cognitive processes.
2.1.2.5 The task

In the previous sections, it was discussed that the characteristics of the model, the demonstration, and the observer can influence the observational learning process. Here, the characteristics of the to-be-learned task itself will be considered as an important factor in the observational learning process. Very little research has attempted to investigate the characteristics of the task individually. Laguna (2008) had participants learn a simple version and a complex version of a barrier motor task used earlier by Carroll and Bandura (1990). The participants were assigned into six groups including 1) model observation throughout the acquisition phase, 2) model observation plus physical practice with knowledge of performance, 3) model observation plus physical practice without knowledge of performance, 4) physical practice without knowledge of performance, 5) physical practice with knowledge of performance, and 6) only verbal instruction. Cognitive representation and spatial and temporal aspects of motor performances were assessed as dependent variables. The simplicity/complexity of the task was manipulated by the number of task components, so that the simple task involved fewer task components than the complex task. The participants completed 18 acquisition trials, 20 immediate retention trials, and 20 delayed retention trials. During 18 acquisition trials, the participants of different groups were exposed to various interventions. The results of this study revealed that task type does influence the practice interventions during skill acquisition. Model demonstration plus physical practice with knowledge of performance outperformed other practice interventions, however, the simple task benefited from model demonstration, physical practice with or without knowledge of performance too, whilst the complex task benefited more from model demonstration plus physical practice with knowledge of performance. This study clearly shows the influence of task complexity on the observational learning process.

As mentioned earlier, Ashford et al. (2006) conducted a meta-analysis of the research on observational learning with emphasize on movement dynamics and outcomes across different types of motor tasks. The results of the meta-analysis indicated that overall effect size obtained from movement dynamics data was
larger for continuous motor tasks (1.62) in comparison to serial (1.01) and discrete (0.56) motor tasks. Moreover, the overall effect size for movement outcomes were 0.61, 0.51, and 0.10 for continuous, serial, and discrete motor tasks, respectively. It is clear from the results of Laguna (2008) and Ashford et al. (2006) that the influence of model demonstrations on skill acquisition is increased with increasing the complexity of the to-be-learnt motor task.

2.1.3 A summary of social cognitive approach

In this section, a review of cognitive theories on observational learning proposed by Sheffield (1961) and later Bandura (1969, 1977, 1986) was provided. Cognitive theories claimed that when a person observes a modeled action, relevant information are rehearsed mentally in form of a cognitive representation, which is stored in the memory and acts later as a reference for reproduction of the modeled action (Bandura, 1969, 1977, 1986; Sheffield, 1961). Bandura (1969, 1977, 1986) formulated four interrelated sub-processes for the observation learning process including attention, retention, motor reproduction, and motivation. The research influenced by Social Cognitive Theory (Bandura, 1986) manipulated many aspects of the model, the demonstration, the observer, and the task to examine observational learning in the motor learning domain (see Figure 2.3. for a schematic view of the influential factors on observational motor learning. Two meta-analysis of Ashford et al. (2006, 2007) revealed that action observation has a greater effect on acquisition of movement form than on movement outcomes. These effects are greater for adults than children and for continuous motor tasks than serial and discrete motor tasks (see Figure 2.2).

Although Social Cognitive Theory has been well investigated in the motor learning domain and provided great insights into observational motor learning, some authors have criticized that Social Cognitive Theory was originally formulated for social learning rather than motor learning (Horn & Williams, 2004; McCullagh et al. 1989). In addition, Scully and Newell (1985) pointed out that Social Cognitive Theory has emphasized on how the process of observational learning occurs,
e.g. attention, retention, motor reproduction, motivation, and argued that a theory of observation learning has to focus on what information has to be extracted and perceived from model demonstrations and later used to produce the modeled action. Scully and Newell (1985) formulated Visual Perception Perspective with emphasizing on the nature of the picked-up information from model demonstration. Visual Perception Perspective is mainly based on the theory of direct perception (Gibson, 1950, 1966, 1979) and the research on biological motion perception (Cutting & Proffitt, 1982; Johansson, 1973, 1975). Scully and Newell (1985) proposed that during the observational learning process, the visual system of the observers is able to directly perceive and minimize relative motion information of the movement, i.e., spatiotemporal changes of body joints or extremities in relation to each other, from a model demonstration. In subsequent attempts, this information is utilized to constrain the emergence of a coordination pattern. In the following section, a review of Visual Perception Perspective will be presented.

Figure 2.3. A summary of the influential factors on observational motor learning.
2.2 Ecological approach on observational learning

Ecological approach in psychology is considered as an alternative to information processing approach in psychology. Generally, ecological approach rejects the assumption of processing the information by the perceivers that rely on mental representations (see Gibson, 1950, 1966, 1979 for more information about ecological approach). Accordingly, Scully and Newell (1985) proposed Visual Perception Perspective as an ecological alternative to Social Cognitive Theory of observational learning. They criticized Bandura´s theory (Bandura, 1977, 1986) and stated that a theory of observational learning should focus on the nature of the picked-up cues by the observer from a model demonstration rather concentrating on the cognitive processing of the movement cues. This argument is highlighted in observational motor learning literature as what, i.e., what information is picked-up and used for later movement reproduction, versus how, i.e., how the picked-up information is later used for action reproduction (Scully & Newell, 1985; see also Hodges, Hayes, Breslin, & Williams, 2005).


2.2.1 Gibson´s theory of direct perception

According to the theory of direct perception (Gibson, 1950, 1966, 1979), individuals directly perceive the external environment through retina stimulation. Gibson objected the traditional theories of information processing in perception (see Banks & Krajicek, 1991, for more information about information processing theory of perception), which claimed that perception is mediated by cognitive processes of extracted information, and suggested that visual perception is exploration and detection of stimulus-information by the visual system.
The central concepts of Gibson´s theory included optic array information, invariant features and affordances. According to Gibson, optic array information is information in light, outside and available to the observer, and contains the important information about the type of movement which is currently taking place in the environment. Invariant features involve objective information that are non-changeable and remain constant during change of the environment. Gibson suggested that invariant information is what is perceived by the observer and the process of perception of invariants occurs directly without any manipulation or mental/cognitive processing. Affordances are described as action possibilities. In other words, objects and environment involve properties that let individuals execute an action. Different objects within a given environment may afford different actions. For example, water may afford drinking and a ball may afford kicking (see Fajen, Riley, & Turvey, 2008, for more information about affordances especially in sport).

Gibson believed that the visual system is able to directly pick up invariant features in the environment, which is transmitted to the observer’s retina (perceiver) through optic flow. Picked-up information is perceived directly and without any subsequent information processing. According to Gibson, there is a mutual relationship between the environment and the observer, so that perceived information is functionally related to the observer’s potential ability for performing an action. Affordances play a central role in this process. In addition, the idea of perception-action coupling came from Gibson’s notion of direct perception and affordances. Perception and action coupling asserts that perception and action processes are functionally linked to one another, such that perceiving the environment guides action, and, on the other hand, action is a means to collect information for perception. In this respect, perception and action seem to occur simultaneously (see Kugler & Turvey, 1987, for more information about the concept of perception-action coupling).

On the basis of Gibson’s direct perception theory, Scully and Newell (1985) argued that motion is an integral part of perception. They criticized traditional views of the research in perceptual psychology that concentrated on the perception of
static images and stated that motion perception must focus on a dynamic view rather static.

According to perceptual psychologists, there are three components of motion including absolute, common and relative motion. Absolute motion is described as the motion of each single element in a display relative to the observer (e.g., a motion of elbow in a human body). Common motion is the motion common to all elements in a display relative to the observer (e.g. the motion of a human body to the left or right in a display). Relative motion refers to the spatiotemporal changes of body joints or extremities in relation to each other (e.g., the shoulder motion relative to that of the elbow) (Breslin, Hodges, & Williams, 2009; Cutting & Proffitt, 1982; Horn & Williams, 2004; Scully & Newell, 1985). Visual Perception Perspective applied the results obtained by the research in visual perception of biological motion to propose which component of motion (absolute, common, or relative) is extracted by the observer from a model display and used for subsequent reproduction of the observed action.

2.2.2 Visual perception of biological motion

Biological motion is a term used by Johansson (1973) to differentiate human motion patterns from patterns of mechanical motions, i.e., the motion of rigid objects. Johansson used the point-light technique to study the visual perception of biological motions. Point-light technique first used by Marey (1895/1972) who was interested in studying and understanding human movements (see Blake & Shiffrar, 2007, for more information). A point-light technique is a procedure in which a human body is displayed by only light dots placed on the main joints of the body in a darkened background (Figure 2.4). Using this procedure, structural information such as shape, color, and so on could be removed from the display.
In classic works on visual perception of biological motion, Johansson (1973, 1976) generated a point-light display by placing light dots on major joints and head of a human actor and filmed his walking/running movements while he dressed entirely in the dark. The generated display represented only light points moving against a darkened background. The subjects in Johansson’s work were shown by point-light displays of activities like walking, running, etc. and were asked to report verbally what they perceived. Johansson found that humans need exposure time shorter than 200 ms and less than 10 light points to recognize the activities in form of a point-light display. Johansson also found that a static image of a point-light display did not result in perception of a human activity and the subjects were able to immediately perceive the observed activity when the point-light display started to move. These results brought Johansson to the conclusion that the motion signals over time, which conveyed in a moving point-light display and detected quickly by visual system, were sufficient to perceive and recognize biological motion. The mechanism of biological motion perception is often called as form-from-motion perception (see Lappe, 2012, for more information).

Stimulated by the work of Johansson, Cutting and his colleagues (Cutting & Kozlowski, 1977; Cutting, 1978; Kozlowski & Cutting, 1978) studied visual perception of biological motions in various conditions. They found that humans not only can recognize the observed actions in a point-light display, but they are able to
perceive the gender or identity (friend) of the person acting in a point-light display. Troje and colleagues replicated those findings in regards to gender recognition (Troje, 2002) and identity recognition (Troje, Westhoff, & Lavrov, 2005). Other research showed that emotion (Atkinson, Dittrich, Gemmell, & Young, 2004, Clark, Bradshaw, Field, Hampson, & Rose, 2005), animal locomotion (Mather & West, 1993), affect (Pollik, Paterson, Bruderlin, & Sanford, 2001a), tennis serve (Pollik, Fidopiastis, & Braden, 2001b) and technical execution and aesthetic quality of gymnastic movements (Scully, 1986) are also recognized by observing a point-light display (see Blake & Shiffrar, 2007, for a review of the literature of biological motion perception). Fox and Mc Daniel (1982) also demonstrated that human infants, similarly to adults, are also able to recognize biological motion presented in the form of a point-light display.

The research on perception of biological motion has also used other techniques than point-light display for investigating the perception of biological motions. One technique often used by researchers is the stick-figure technique/animation (Hodgins, O’Brien, & Tumblin, 1998). A stick-figure display is a procedure which, similar to point-light display, removes structural information, but unlike to point-light display, connects the light points with visible lines (Figure 2.5).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure25.png}
\caption{A schematic view of a stick-figure display representing a human actor during rightward walking activity. Lange, Geroge, and Lappe (2006, p. 839).}
\end{figure}

It is noteworthy here to say that the research interested in finding the neural mechanism of perception of biological motions found a region in human brain, superior temporal sulcus (STS) in the temporal lobe, which is mostly activated during watching biological motions presented in a point-light display (Grezes, Fonlupt, Bertenthal, Delon-Martin, Segebarth, Decety, 2001; Grossman & Blake
2002; Grossman, Price, Pickens, Morgan, Neighbor, & Blake, 2000; see also Giese & Poggio, 2003, for a review of the literature on neural mechanism of biological motion perception). Here, I only mention that STS is a part of the human mirror neuron system, but with only visual properties and no motor properties. Mirror neuron system is within the core of neural substrates underlying observational learning (see the section of mirror neuron system in the following pages).

Generally, the research on perception of biological motions revealed that humans are able to perceive and recognize human motions from point-light or stick-figure kinematic displays. However, a question remained unclear: Which kind of motion information, absolute, common, or relative, is extracted by the observers from a point-light display for perception of biological motions? Cutting and Proffitt (1982) considered this question and proposed that humans minimize relative motion information in perception of human motions. Scully and Newell (1985) combined the results of research on biological motion perception with theory of direct perception (Gibson, 1950, 1979) and postulated an integrated theory for observational learning. They proposed Visual Perception Perspective as an alternative approach to cognitive theories of observational learning (Bandura, 1977, 1986; Sheffield, 1961) and emphasized what information is picked-up by observers from a model demonstration and later used to reproduce the observed action.

### 2.2.3 Visual Perception Perspective

Scully and Newel (1985) linked perception and reproduction of movement in observational learning by advocating Visual Perception Perspective. In contrast to cognitive approaches in observational learning (Bandura, 1977, 1986), Scully and Newell (1985) prompted the question of what is the nature of the information perceived by the observer from a demonstration and postulated how the perceived information might be used for later reproduction. Based on the results of the research on biological motion perception (Johansson´s and Cutting´s works) and the role of the visual system in direct perception theory (Gibson, 1950, 1979), Scully and Newell (1985) suggested that during the process of observational learning, the observer’s visual system is able to directly perceive and minimize
relative motion information of the movement from a model demonstration. The primary problem for the observers is to coordinate many parts of the body to reproduce the observed action. Visual Perception Perspective assumes that once relative motion information is perceived, this information is utilized to constrain the emergence of a coordination pattern.

Scully and Newell (1985) linked the concept of relative motion with embedded hierarchy of coordination, control and skill (Kugler, Kelso, & Turvey, 1980, 1982; Newell, 1985). These terms are also considered as stages of motor learning (Newell, 1985). Coordination refers to the relationship between movements of body segments (i.e., degrees of freedom, Bernstein, 1967). Coordination can be considered as intra-limb coordination (i.e., relationship between movements of segments of a single limb, for example, right shoulder related to right elbow) or inter-limb coordination (the relationship between movements of two limbs, for example the right elbow related to the left elbow). Control is scaling and parameterization of the coordinated pattern. Finally, skill describes optimal scaling and parameterization of coordinated pattern (Horn & Williams, 2004; Scully & Newell, 1985). Here it is important to note that these stages occur synergistically and not serially during the motor skill learning process (Horn & Williams, 2004).

Scully and Newell (1985) predicted that skill demonstration would be more effective in the early stage of learning a new motor skill, i.e., coordination, where the observers attempt to pick up important information regards to topological characteristics of the movement, namely relative motion. They suggested that if the observers approximate the relative motion information within “certain bandwidths”, then the observed action is considered to have been reproduced. It is also suggested that in later stages of motor learning, i.e., control and skill, where the learners attempt to scale and parameterize acquired coordinated pattern, skill demonstration may be less effective (Horn & Williams, 2004; Scully & Newell, 1985). Scaling and parameterization is in general influenced by individual differences. An optimal parameterization of coordinated pattern would be acquired only via physical practice (Scully & Newell, 1985).
Based on Visual Perception Perspective, if relative motion information is minimized by observers for later reproduction, then a model demonstration would be particularly more effective when relative motion information of the movement is highlighted. This can be achieved by removing the non-essential structural information such as body shape, color and so on from a demonstration through representing the human body in form of a point-light or stick-figure display, as used by researchers of biological motion perception, rather than showing the observers a classic video containing structural information. In other words, observing a point-light display, in which relative motion is made salient, would be superior to watching a classic video display in observational motor learning in early stages of motor learning (e.g., Horn et al. 2002).

This assumption has been studied within recent years (Al-Abood et al. 2001; Breslin et al. 2005, 2006, 2009; Hayes et al. 2007; Horn et al. 2002, 2005, Rodrigues, Ferracioli, and Denardi, 2010, Romack, 1995; Scully & Carnegie, 1998; Williams, 1989). In the next section, I will provide a review on research conducted to investigate the effects of highlighting relative motion information within a display on learning the coordinative pattern of the observed movement.

2.2.3.1 Point-light vs. video displays

Research that compared the influence of point-light and video displays on observational learning have often applied a special design. The design was included a quantitative comparison of coordination pattern of the participants with that of the model by assessing movement kinematics. The rational reason for this kind of analysis was that kinematic data may identify spatiotemporal changes of to-be-acquired motor skill better than traditional qualitative analysis of movement form (Horn & Williams, 2004). Of course, developing the technology in recent years is resulted in producing advanced motion analysis systems that allowed researchers to perform such kinematic analysis.

Williams (1989) examined whether observing video, point-light, and segment-light (stick-figure) model demonstrations facilitate performing an arm movement
sequence/dart style throwing action. Model demonstrations were designed to present the observer with only the movements of arm and other parts of the body were not on the focus of camera lens. Order of correct movement sequence, elbow displacement, and limb timing were measured in that experiment as dependent measures. The results showed that the participants of all experimental groups were able to perform the order of correct sequence of movement (inclusive eight sub-movements) only after four practice trials. The results also revealed no significant difference between three experimental groups in the production of angular displacement at the elbow joint. The results of limb timing showed no significant difference between video and point-light groups, but the observers of video group performed significantly better than segment-light group in movement timing. Moreover, movement timing remained relatively unchanged during the practical trials. The author concluded that making salience (relative) motion in the form of a point-light or segment-light (stick-figure) displays do not seriously impair later production of observed action. However, acquiring timing variables may require a combination of form and motion in a form of normal video display (Williams, 1999).

Romack (1995) used a basketball dribbling as criterion task and found that observing a video model demonstration led to better learning effects among children than observing a point-light display. In this experiment, the participants in point-light group performed fewer consecutive bounces of the ball per trials than the participants in video or control groups. Kinematic analysis revealed a superiority of observing video model than point-light model, such that the observers of video model showed less disparity than those of point-light model (see Horn, Williams, & Scott, 2002).

Contrary to the findings of Romack (1995), Scully and Carnegie (1998) found that the participants who observed a point-light model demonstration showed a better reproduction of observed action than those who observed a video display. The motor task in that experiment was a ballet sequence and dependent measures were included landing accuracy, angular displacement and relative timing. The results showed that the observers of a point-light display performed a better landing accuracy, produced a closer approximation of modeled action, and replicated
the motor task with a better relative timing than the observers of a video model. The point-light groups showed these superiorities while the points of hip, knee, ankle, and toe were removed from the point-light display (see Hodges, Williams, Hayes, & Breslin, 2007; Horn et al. 2002).

No further research have subsequently replicated the findings of Scully and Carnegie (1998) in favor of superiority of point-light display over video display in observational learning of a new motor skill (see Hodges et al. 2007). Al-Abood, Davids, Bennett, Ashford, and Marin (2001) compared the effects of observing point-light and video displays on learning an underarm dart throwing action (experiment 1). The results showed that the participants in both demonstration groups improved their scores of movement outcomes, i.e., accuracy of throwing the dart towards a target located on the floor 3 m away, from first acquisition block to second block of retention test. No significant differences were observed between point-light and video groups in movement outcomes. The results of analysis of movement coordination, including angular velocities and displacements of throwing arm, revealed no significant difference between point-light and video groups and also no significant improvement in acquisition blocks. The analysis of movement control variables such as elbow release angle, elbow release velocity and movement time showed, similar to movement coordination, no significant difference between point-light and video groups and also no significant improvement in acquisition blocks.

Another experiment of this research group involved a no-demonstration control group to the experiment using the same motor task (Al-Abood, Davids, and Bennett, 2001). They found that the participants in demonstration groups improved significantly in approximation of models’ coordination pattern in comparison to the participants in control group who adopted different forms of overarm throwing actions than the model. Despite performing different forms of throwing actions, the participants in control group showed a same level of outcome accuracy in comparison to the modeling group. These findings along with the findings of other experiment (Al-Abood et al. 2001b) suggested that movement form is facilitated by skill demonstrations in either form of point-light or video presentations,
whereas acquiring a movement goal involving throwing the dart towards a goal is facilitated by physical practice without any model demonstrations.

Horn et al. (2002) compared the effects of observing point-light and video demonstrations on learning a motor task involving chipping a soccer ball into a target (this task was later used by other researchers, e.g., Horn et al. 2005; Hodges et al. 2005; see also Figure 2.6). The results of this experiment showed that the participants in demonstration groups did not learn to become more like the model in terms of kinematic assessments in comparison to the participants who never watched a model demonstration and practiced only physically. In addition, analysis of outcome scores revealed that the participants in all groups learned to achieve better movement outcomes from pretest to post test. The only difference between demonstration groups and no-demonstration control group was that in retention test the point-light and video groups become more like the model in terms of the number of steps in the approach to the ball in comparison to control group. In this experiment, researchers also used a technique called “Visual Search” to determine the information is attended to during observing a demonstration. Visual search is a technique used in attention research in sport and is considered to be a method for examining selective attention (see Williams, Davids, & Williams, 1999 for more details in visual search). Using this technique, Horn et al. (2002) showed that the participants in point-light group were more selective in visual search in terms of fixation time per location compared with video group. The authors discussed that in this experiment model demonstration was not the primary source to convey information regards to movement, as the observers were able to see the results of their performances (knowledge of results). In a subsequent experiment, Horn et al. (2005) attempted to remove knowledge of results from the experiment in order to make model demonstration as the only source of relative motion information of movement for the observers.
As such, Horn, Williams et al. (2005) found that the participants in video and point-light groups, particularly video group, showed a closer approximation of lower body intra-limb coordination to that of the model. In addition, the participants in control group did not change to become more like the model in terms of intra-limb coordination. Moreover, the results of outcome scores showed that the participants in all groups did not learn to improve outcome scores in the absence of intrinsic knowledge of result. The findings of number of steps used to approach the ball and visual search strategy were same as for previous experiment (Horn et al. 2002). The results of two experiments of Horn and coworkers indicate that the point-light and video displays convey the relevant information of movement coordination when action reproduction is the only goal (see also Hodges et al. 2007). Here, it is noteworthy to note that Horn, Williams, Scott, and Hodges (2005) developed a method to quantify variability of intra-limb coordination. This method is a combination of normalized root mean square error (NoRMS) proposed by Sidaway, Heise, and Schoenfelder-Zhodi (1995) with the interpretation of excursion presented by Mallineaux, Bartlett, and Bennett (2001). Horn et al.
(2005) termed the resulting measure *normalized root mean square difference* (*NoRM-D*). The measure was used later in some studies (e.g. Breslin et al, 2005, 2006, 2009; Rodrigues, Ferracioli, & Denardi, 2010) as well as in the present study.

In one study, children were added to the experiment as well as adults (Hayes et al. 2007b). The motor task was a whole-body bowling action, in which the participants had to throw the ball into a target (goal). In Experiment 1 of this study, task constraints were manipulated by asking the participants to reproduce the motor task with or without the requirement to throw the ball into the goal. The reason for this manipulation was the previous results which showed that individuals are able to achieve a specific movement goal/outcome without producing the accurate action (Horn et al. 2002), at least for the motor tasks, in which the goal of the movement is not directly associated with a specific movement form (see Maslovat et al. 2010 for more detail). Hayes et al. (2007b) predicted that the participants acquire better movement form scores in condition without bowling the ball. The results showed that both adults and children obtained higher movement form scores, which were assessed qualitatively in this study, in condition without throwing the ball into the target in comparison to the condition with bowling the ball. These results indicate that requiring to achieve an outcome would negatively affect the accuracy of reproducing movement form. Moreover, the adults replicated movement form more accurate than the children.

In Experiment 2, Hayes et al. (2007b) compared the effects of point-light and video displays on learning the bowling action. Results showed no significant difference between point-light and video displays for adults, but children in point-light group performed significantly poorer at replicating the movement form than video group. In Experiment 3, a group of children were provided with perceptual-cognitive training of various kinds of movements in form of a point-light presentation prior to observing a point-light display of bowling action. Results revealed that the children who received perceptual-cognitive training achieved significantly better movement form scores than the children who observed point-light display without previous training, although no significant difference was observed between training group and video group.
Rodrigues et al. (2010) compared the effects of observing video and point-light model demonstrations on learning a pirouette action in classical ballet dance. In this experiment, movement form was measured qualitatively and quantitatively. Quantitative data revealed no significant difference between two groups, but qualitative analysis, which was performed by three expert ballet dancers, showed that the observers of video display performed the motor task significantly better than the observers of point-light display. Moreover, the participants of both groups did learn to perform temporal variables of the pirouette action more accurately during the acquisition phase. No control groups was involved in this experiment.

Altogether, the findings of previous research which attempted to compare effects of observing point-light display vs. video display failed to yield any superiority for point-light display over normal video display (an exception is the study of Scully and Carnegie, 1998). Those results indicate that although a point-light demonstration would result in improvement in coordination pattern of movement (Al-Abood et al. 2001a; Al-Abood et al. 2001b; Horn et al. 2005), but its effects on observational learning is not superior to normal video demonstration (Al-Abood et al. 2001b; Horn et al. 2002, 2005; Rodrigues et al. 2010), which is in contrary with the assumption of Visual Perception Perspective. In fact, some evidence indicate that a point-light display has even detrimental effects on observational learning in comparison to video display (e.g. Romack, 1995; Hayes et al. 2007).

Other important findings from this body of research was that observational learning is affected by task constraints (Al-Abood et al. 2001a; Hayes et al. 2007b; Horn et al. 2002, 2005). The findings of these studies indicate that if there is a requirement to achieve a movement outcome, intrinsic knowledge of results would be the primary source of information for the observers (Horn et al. 2002, 2005), as well, if one remove goal achievement from a motor task, the observed model is used as primary source for conveying relevant information (Hayes et al. 2007b).

According to the findings of mentioned studies, several authors concluded that relative motion information available in point-light display is picked-up and used for reproducing the observed action (Al-Abood et al. 2001a; Al-Abood et al.
2001b; Horn et al. 2005). However, some researchers discussed that only making salience the relative motion information within a demonstration is not enough to conclude whether it is relative motion information extracted by the observers without any direct manipulation of relative motion information within a point-light display (Breslin et al. 2006, 2006, 2009; Hodges, Hayes, Breslin, & Williams, 2005; Hayes et al. 2007b; see also Hodges et al. 2007 for a review).

2.2.3.2 Manipulation of intra- and inter-limb relative motion information

The research conducted to examine the possible role of manipulated relative motion information on observational learning often applied a special paradigm, in which a group of participants who observe a full-body pint-light display is compared with the groups who observe only relative information of one single limb (intra-limb coordination), two limbs (inter-limb coordination), or no relative motion. Using a soccer kicking action (Figure 3), Hodges, Hayes, Breslin, & Williams (2005) examined effects of manipulating the relative motion information on observational learning. Three groups of participants observed various edited demonstrations of a point-light display including LEG (corresponding to the knee, ankle, and toe), FOOT (corresponding to the ankle and toe), and TOE (corresponding to only the toe). The results of this experiment showed no significant difference between demonstration groups in imitating the knee-ankle intra-limb coordination (Phase 1, in which the observers performed the modelled action without kicking the ball into the target). Following the presenting the observers with a full-body point-light display there was no significant improvements across the three groups, but the observers of TOE group showed some improvements after presentation of full-body point-light display (Phase 2). In Phase 3, the observers received a task constraint, in which they were asked to kick the ball into a target. Following the presentation of task constraints, there as an overall improvement for groups, but the observers of TOE group performed more like the model than FOOT and LEG groups, who did not differ significantly from each other. The results of hip-knee intra-limb coordination showed that TOE group approximated the model more closely than FOOT and LEG groups in Phase 1. This
significant difference remained between TOE group and other two groups after presenting the observers with a full-body point-light display (Phase 2) and introduction of task constraints (Phase 3). These results show that the observation of absolute motion information (only toe) leads to a more accurate approximation of the modeled action in comparison to the observation of relative motion information (ankle-toe, or knee-ankle-toe). Moreover, end-point information of main effector (toe) is sufficient to imitate the observed action (Hodges et al. 2005). No normal video demonstration or control groups were involved in this study.

The relative motion information was also manipulated in various ways by Breslin and colleagues (Breslin et al. 2005, 2006, and 2009). Breslin et al. (2005) compared the effects of observing three types of model demonstrations with a control group on learning a cricket bowling. Model demonstrations were included normal video, full-body point-light, and wrist only (no relative motion) displays. The results of elbow-wrist intra-limb coordination of bowling arm (right hand) showed that demonstration groups performed more like the model than control group. Moreover, video and full body point-light groups did not differ from each other in terms of intra-limb coordination pattern of bowling arm (as showed by previous research, Al-Abood et al. 2001; Horn et al. 2005; Rodrigues et al. 2010), but both showed a closer approximation to the model than the wrist group. For outcome scores, there was no significant difference between four groups. Demonstration groups did not differ significantly from each other in terms of accuracy in movement time, but all of them were significantly more accurate than control group. Interestingly, the results of this study revealed that the participants in demonstration groups did not significantly differ from control group in terms of imitating intra-limb coordination of non-bowling arm (left hand), given the fact that the observers of video and full-body point-light displays were presented with this information. Those results brought the authors to the conclusion that observational learning is facilitated by the presence of relative motion information in form of point-light and video displays, and the observers prioritize the relative motion information of main effector (in this case, bowling arm), even if the other relative motion information such as non-bowling arm was presented within display (Breslin et al. 2005).
In subsequent study and by using similar motor task, Breslin et al. (2006) changed the presence of relative motion information within a point-light display and created four groups including a FULL-BODY, INTRA-LIMB (motions of bowling arm), INTER-LIMB (motions of right and left wrists), and NO-relative motion (only motions of right wrist). No video or control group was involved in this experiment. Intra-limb coordination of bowling and non-bowling arm and inter-limb coordination of right and left wrists were measured as kinematic data. The results revealed that FULL-BODY and INTRA-LIMB groups did not differ in approximation of modeled action in acquisition phase or retention test in terms of intra-limb coordination of bowling arm. INTRA-LIMB group performed significantly more accurately then NO-relative motion group. In addition, relative motion groups replicated the modeled action more accurately than NO-relative motion group. Similar to previous findings (Breslin et al. 2005), all groups did not differ significantly in acquisition or retention tests in terms of intra-limb coordination of non-bowling arm or inter-limb coordination of right and left wrists.

The results of Breslin et al. (2005, 2006) indicate that, in contrary to the findings of Hodges et al. (2005), only observing the end-point of an action (only wrist) is not necessarily sufficient to bring about a coordination profile similar to the model. However, because there was no significant difference between INTRA-LIMB and INTER-LIMB groups in the experiment of Breslin et al. (2006), making any conclusion about the importance of presenting the observers with intra-limb coordination for accurate reproduction is impossible.

Breslin et al. (2009) repeated the earlier experiment of Breslin et al. (2006) with two main changes. First, they replaced NO-relative motion group with a no-demonstration control group. Moreover, the participants were presented with a full-body point-light display following first retention test and were asked to perform second acquisition phase and retention test. The results of intra-limb coordination of bowling arm showed that FULL-BODY group was more accurate than other groups. However, no significant difference was observed between FULL-BODY and INTRA-LIMB groups. In addition, INTRA-LIMB group was significantly better than INTER-LIMB group in imitating the bowling arm. Providing the observers with extra full-body point-light display did not result in any improvements.
results of imitating the intra-limb coordination of non-bowling arm and inter-limb
coordination of right and left wrists were as the same of previous study (Breslin
et al. 2006). A measurement of visual search strategy was also applied to this
experiment. The results showed that the main location that the participants fo-
cused during practice was on the bowling arm of the model, indicating the im-
portance of end-effector information during observational learning (Breslin et al.
2009).

Hayes, Hodges, Huys, and Williams (2007) manipulated the relative motion infor-
mation along with task constraints. The participants were divided into two groups
of model demonstrations including a FULL-BODY point-light display and an END-POINT
point-light display containing right wrist, right toe, and left toe. These two
groups were further subdivided to two groups, such that a group perform the mo-
tor task with BALL and other group performed that with NO-BALL. The motor task
was a crown-green bowling action. Intra-limb coordination of right shoulder-elbow
(bowling arm) and right hip-knee were measured and compared with that of the
model. The results showed no significant difference between four groups in shoul-
der-elbow coordination in acquisition phase or retention test. Moreover, in early
acquisition phase the observers of FULL-BODY group showed a closer approxi-
mation of hip-knee coordination in comparison to END-POINT group. The authors
concluded that replication of models’ coordination pattern (shoulder-elbow or hip-
knee) is not necessarily a production of picking-up and using relative motion in-
formation from demonstration (Hayes et al. 2007a).

Taken together, the above findings suggest that observing the main effector of
the action (e.g. toe in kicking action or throwing arm in bowling action) results in
a relatively accurate reproduction of observed action (Breslin et al. 2006, 2009;
Hodges et al. 2005). However, some evidence indicate that presenting the ob-
servers with the distal information of a whole-body task (e.g. right wrist, right and
left toes, Hayes et al. 2007a) leads to an approximation of modeled action similar
to a full-body demonstration. Hodges et al. (2007) provided a review of studies
conducted to examine the extraction of relative motion information from a demon-
stration and proposed that observers adopt a “local processing strategy”, in which
the information of end-effector is prioritized and used for action reproduction.
Breslin et al. (2009) suggested that for producing an accurate coordination profile of other aspects of movement form (for example, non-bowling arm or the form of lower body in bowling action), physical practice may be more effective than model demonstrations.

Although these studies showed the importance of end-effector information as the primary source of information for action replication, it remained unclear whether relative motion information within a demonstration, especially in end-effector information, is picked-up and used. Some researchers discussed that it is relative motion information that is extracted and used for replication of modeled action (Breslin et al. 2005), but some evidence show that relative motion information is not the primary source of information for later reproduction (Hayes et al. 2007a; Hodges et al. 2005).

2.2.4 A summary of ecological approach

In this section, I reviewed an ecological approach on observational learning proposed by Scully and Newell (1985). Visual Perception Perspective (Scully and Newell, 1985) criticized the mediation of cognitive processes in observational learning (Bandura, 1977, 1986) and pointed out that a theory of observational learning should focus on what is the nature of information extracted by the observers for subsequent reproduction. Mainly influenced by the theory of direct perception (Gibson, 1950, 1979) and the studies of Johansson and Cutting on biological motion perception (Cutting, 1978, Cutting & Proffitt, 1982; Kozlowski & Cutting, 1977; Johansson, 1973, 1975, 1976), Scully and Newell (1985) suggested that during the process of observational learning, visual system of the observers is able to directly perceive and minimize relative motion information of the movement from a model demonstration. Based on Visual Perception Perspective, highlighting the relative motion information within a display, e.g. point-light or stick-figure displays, would be particularly more effective than a classic video display in observational learning. Research examined this assumption showed controversy results. Some evidence show that observing point-light display is superior to video display (Scully & Carnegie, 1998) and some evidence
indicate that a video display is superior to point-light display (Hayes et al. 2007; Romack, 1995). There is also evidence show the importance of task constraints such as availability of knowledge of results (Horn et al. 2002, 2005) or movement goal (Hayes et al. 2007b) in process of observational learning.

Some authors stated that it is relative motion within a point-light display that is extracted and used for action reproduction (Al-Abood et al. 2001a; Horn et al. 2005). Others discussed that it is not possible to conclude that relative motion information is picked-up from a point-light display without manipulation of intra-limb and inter-limb relative motion information within a point-light display (Breslin et al. 2005, 2006, 2009; Hayes et al. 2007a; Hodges et al. 2005). Overall, these studies showed that end-effector information is primary source of information and is prioritized for reproduction of observed action (Breslin et al. 2006, 2009; Hodges et al. 2005). However, the nature of extracted information, especially in end-effector, is still unclear. Although there is evidence in favor of extraction of relative motion information (Al-Abood et al. 2001b; Breslin et al. 2005; Horn et al. 2005), some evidence show that relative motion information is not what is extracted (Hayes et al. 2007a; Hodges et al. 2005). Altogether, further research seems necessary to identify the nature of information picked-up from a demonstration for later reproduction of observed action.
2.3 Neurophysiological approach on observational learning

In last two parts of this chapter, a review of social and ecological approaches on observational learning was presented. Social Cognitive Theory and Visual Perception Perspective have basically considered observational learning as a behavioral point of view. In this part of the present chapter neurophysiological basis of observational learning is reviewed. Although the present work has not investigated the neurophysiological responses to observational learning, reviewing the neurophysiological mechanism underlying observational learning seems important for theoretical backgrounds. This part contains a review of mirror neurons, i.e., neurons which seem to be responsible for learning through observation, from its discovery in monkey to its role in humans.

About two decades ago, a group of neurophysiologists at the University of Parma in Italy, discovered almost accidentally a group of neurons in area F5 of premotor cortex of macaque monkeys which discharge during both execution and observation of a goal-directed action (Di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992). Since the discovery of these neurons, which later called “Mirror Neurons” (Gallese, Fadiga, Fogassi, & Rizzolatti, 1996), many researchers in various scientific disciplines made a great effort to understand the possible roles of mirror neurons in monkey and also humans. Findings of a large body of research revealed that mirror neurons play an important role in the recognition of action, understanding the intention of action, sympathy, development of language and also imitation learning (for review see Rizzolatti & Craighero, 2004; Rizzolatti, 2005). Here I will provide a review of the literature of MN from the early discovery in macaque monkey to later studies in humans and also to present an overview of its role on many aspects of primates and humans with an emphasize of its possible role in learning new motor skills in humans.

2.3.1 Mirror neurons in macaque monkey

The mirror neurons were first discovered in monkey. In the early of nineteen’s researchers in laboratory of physiology at University of Parma investigated the
responses of neurons in areas F5 in premotor cortex of macaque monkey to performing goal-directed actions such as grasping by using a single cell recording technique. It is noteworthy to say that the neurons in area F5 have been found to have motor properties (Rizzolatti, Fogassi, & Gallese, 2001). It means that these neurons discharge when the monkey performs a goal-directed action such as grasping, holding and so on. While researchers had connected an electrode to a single neuron in this area, they observed that this single neuron fires when the monkey observes the experimenter performs the same action, i.e., grasping the food (Di Pellegrino et al. 1992). This neuron was also fired when the monkey itself picked up the food from the table (Figure 2.7). Di Pellegrino et al. (1992) reported that almost a large number of neurons in area F5 in macaque monkey have such complex visual properties. This finding showed for the first time that visual and motor systems of primates are strongly correlated to each other when they perform an action.

![Figure 2.7. The experimental condition of discovery of mirror neurons. Mirror neurons are discharge both when a monkey observes an experimenter grasping food (A), and when he is taking a piece of food (B). Di Pellegrino et al. (1992, p. 178).](image)

After this discovery, many researchers have followed this study by investigating the properties of mirror neurons in monkey through single cell recording technique and later in humans by using brain imaging techniques. Gallese et al. (1996) investigated a large number of neurons in area F5 of macaque monkey and replicated the findings of Di Pellegrino et al. (1992). They reported that the mirror neurons were not fired only by observing the food or the experimenter;
rather they need an interaction between the experimenter and the intention of the experimenter, in this case grasping the food from the table, to become discharged. The authors suggested that mirror neurons play an important role in matching the executed and observed action and they discussed that by this matching system mirror neurons are possibly able to recognize the actions performed by others. Later studies revealed that mirror neurons do not take place only in area F5, but there is a mirror neuron system (MNS) which is activated when the monkey observes an action performed by another individual. It has been shown that in addition to mirror neurons in area F5, mirror neuron system in macaque monkey includes the neurons in area 7b or PF in parietal lobe and also neurons in superior temporal sulcus (STS) in temporal lobe (Rizzolatti & Craighero, 2004). The neurons in area STS have been reported to have no motor properties, rather they fire when biological motions like walking, movement of the head and so on are observed (Rizzolatti, Fogassi, & Gallese, 2001). The neurons in area 7b or PF contains both visual and motor properties. PF neurons have connections with both areas STS and F5. An illustration of the mirror neuron system in macaque monkey is provided in Figure 2.8.

In addition to respond to the visually observed goal-directed action performed by hand, the mirror neurons in area F5 of macaque monkey have been shown to contain the mirror properties which respond to the movements of mouth (Ferrari, Gallese, Rizzolatti, & Fogassi, 2003). These authors found two kinds of responses of mirror neurons in area F5 to the mouth actions: ingestive and communicative responses. Ingestive mirror neurons were discharged when the monkey both executes and observes the mouth action related to ingestive behavior such as grasping the food with the mouth, sucking or breaking the food. On the other hand, communicative mirror neurons fire when the monkey both performs and watches the mouth movements related to communicative mouth gestures such as lip smacking (Ferrari et al. 2003).
Rizzolatti et al. (2001) discussed on the basis of “direct-matching hypothesis” (see also Iacoboni, Woods, Brass, Bekkering, Mazziotta, & Rizzolatti, 1999) that mirror neuron system in monkey plays a role in the process of action understanding. According to this hypothesis, monkey recognizes and understands an action because the visual representation of the viewed action is paired with its internal motor representation. In other word, when monkey observes the action of grasping the food from the table performed by another person, the same motor representation that is responsible for performing the action of grasping in motor area of monkeys’ brain is activated (Rizzolatti et al. 2001).

The following research using brain imaging techniques in humans, which I will explain in next section, also applied direct-matching hypothesis as a central mechanism in human imitation and imitation learning, i.e., the act of copying the action executed by others (Iacoboni et al. 1999).
2.3.2 Mirror neuron system in humans

Following the discovery of mirror neurons in monkey, a large body of works has been done to find the neurons in human brain contained the similar mirror properties with monkey. Because of the limitations in applying the single cell recording technique in humans, there is a lack of direct evidences for the presence of a mirror neuron system in humans (Rizzolatti & Craighero, 2004). However, there are many indirect evidences provided from neurophysiological and brain imaging studies which prove a human mirror system exists in humans, too. In this section I will consider these evidences in two different parts including evidence from neurophysiological studies and evidence from brain imaging studies. Then, I will discuss the possible roles of mirror neuron system in humans with an emphasis on its role in learning from observation.

2.3.2.1 Evidence from neurophysiological studies

One of the first studies done to examine the existence of a mirror system in humans was conducted by Fadiga, Fogassi, Pavesi, and Rizzolatti, (1995). They applied a non-invasive technique called transcranial magnetic stimulation (TMS) and recorded the activity in hand muscle while normal human subjects were placed in various experimental conditions. It is noteworthy to say that TMS is a technique that stimulates electrically the neurons in human brain. Using this technique, one is able to record the muscle activity, called motor evoked potentials (MEPs), when TMS is applied to the motor cortex (Rizzolatti et al. 2004). Fadiga et al. (1995) asked human healthy subjects to 1) observe an experimenter performing a hand-grasping, 2) observe an experimenter doing meaningless arm movement in air, or 3) observe 3-D object. They recorded the MEPs from hand and arm muscles during all conditions. The results of their experiment revealed a significant increase of MEPs during both conditions in which the subjects observed meaningful and meaningless arm movements, but not in control condition with only observation of the object. They reported that the pattern of muscle activity during the observation of arm movements was a replication of the pattern of
muscle activity during the performance of the same action by subjects. The authors interpreted these findings as the existence of an observation-execution matching system in humans that contains very similar characteristics with that of the monkeys (Fadiga et al. 1995).

In a following study Cochin, Barthelemy, Lejeune, Roux, and Martineau, (1999) used an electroencephalography (EEG) technique to measure the cortical activity of normal young adults in three conditions including execution of finger movements, observation of same movement done by another individual, and resting. EEG is a non-invasive technique, in which the cortical activity during human movements is measured by reduction of an electrical wave so-called mu rhythm (see Ward, 2010 for more detail). Using this technique, Cochin et al. (1999) demonstrated that same cortical areas including posterior frontal cortex, posterior temporal cortex, and centroparietal cortex are activated during both execution and observation conditions in comparison to resting condition. The authors discussed that these findings provide evidence for existence of a human mirror neuron system as similar as in the monkeys.

Additional support for this claim is provided by the research conducted by Hari, Forss, Avikainen, Kirveskari, Salenius, and Rizzolatti, (1998). In this experiment, healthy humans were asked to manipulate a small object with right hand, watch another person who perform the same task, or observe stationary or moving objects (control condition). The experimenter recorded neuromagnetic oscillatory activity of the precentral cortex during the experimental conditions. The results of the experiment showed that the activity of precentral motor cortex during the action observation was as similar to action execution, but with a weaker intensity. The control condition, in which the subjects only observed objects, did not show the same pattern of activity. Hari et al. (1995) concluded that both observation and execution of an action activate the motor cortex of humans and proposed that motor cortex of humans involves mirror properties.

Taken together, the neurophysiological evidences confirm that a mirror neuron system exists in humans as in the monkeys. However, those studies did not show the localization of human mirror system inside the brain, e.g., which region of the
brain is activated while humans observe or perform an action. This issue has been concerned by brain imaging studies. I will consider these studies in next section.

2.3.2.2 Evidence from brain imaging studies

Following the discovery of mirror neurons in the monkey and along with electrophysiological studies there was a large research effort to find out the regions of the brain which contain mirror properties. In one of the first research done to investigate this topic, Rizzolatti, Fadiga, Matelli, Bettinardi, Paulesu, Perani, and Fazio, (1996) asked normal human subjects to grasp an object, observe the experimenter grasping the object, or observe only the object. They measured brain activity during experimental conditions by using a positron emission tomography (PET) technique. PET is a non-invasive technique used often to monitor cerebral activity by measuring regional cerebral blood flow in the brain (see Ward, 2010 for more detail). Rizzolatti and his colleagues found two regions in brain including inferior temporal sulcus and left inferior frontal gyrus which were activated during observation of grasping.

In other PET study, Grezes, Costes, Decety, (1998) measured the brain activity during observation of meaningful and meaningless hand actions. The normal human subjects were also instructed to either observe the hand actions in order to recognize or observer the hand actions in order to imitation. Therefore, brain activity was recorded in four experimental conditions including meaningful-recognition, meaningless-recognition, meaningful-imitation, and meaningless-imitation. The results of the experiment showed that perception of meaningful and meaningless hand actions involve some similarities and some differences. Both actions share cortical areas including occipito-temporal junction and superior occipital gyrus in both hemispheres, and middle temporal gyrus, the inferior parietal lobe, and the precentral gyrus in left hemisphere. However, perception of meaningful hand action specified the inferior frontal gyrus (called also Broca’s area, and was also an activated area in the study of Rizzolatti et al. 1996b) and the fusiform gyrus, while observation of meaningless action led to activation of dorsal pathway
bilaterally and the right cerebellum. Observation in order to later imitation led to almost same cortical activation involved in the right cerebellum and bilaterally in the dorsal pathway reaching the premotor cortex. Additionally, observation of meaningful actions for imitation resulted in activation in the supplementary motor area (SMA) and in the orbitofrontal cortex bilaterally. The SMA is considered to underlie the preparation and planning for action (see Decety & Grezes, 1999). This study shows the engagement of motor areas in observation of meaningful hand actions, and the impact of subject’s strategy on cortical activation.

Iacoboni et al. (1999) replicated partly the mentioned findings by using a functional magnetic resonance imaging (fMRI) technique. fMRI is a non-invasive brain imaging procedure similar to PET, which measure brain activity through a Blood-Oxygen-Level dependent (BOLD) contrast. The authors measured brain activity while the normal human subjects observed a simple finger movement or they imitated the observed movement. In this experiment, two regions of the brain including left inferior frontal cortex (Broca’s area) and the right superior parietal lobule were activated during both observation of action and imitation of action. Based on the direct-matching hypothesis, Iacoboni et al. (1999) proposed that a matching system does exist between observed actions and executed actions.

Other studies also provided evidence in favor of existence of a mirror neuron system and its localization in humans (Buccino, Binkofski, Fink, Fadiga, Fogassi, Gallese, Seitz, Zilles, Rizzolatti, & Freund, 2001; Koski, Iacoboni, Dubeau, Woods, Mazziotta, 2003). Rizzolatti and Craighero (2004) reviewed the literature of mirror neuron system in humans and proposed two regions in human brain as the core of human mirror neuron system, which contain action observation-execution matching properties. The first region is located in the rostral part of the inferior parietal lobule (IPL) and the other region is located in premotor cortex including lower part of the precentral gyrus and the posterior part of the inferior frontal gyrus (IFG). A schematic view of the anatomy of human mirror neuron system is illustrated in Figure 2.9.

In the next section I will review the possible role of mirror neuron system in monkey and humans and additionally I will present a comparison between the properties of mirror neuron system in monkey and humans.
Figure 2.9. An illustration of human mirror neuron system. MNS: mirror neuron system; PMC: premotor cortex; IFG: inferior frontal gyrus; IPL: inferior parietal lobule; STS: superior temporal sulcus. Iacoboni and Dapretto (2006, p. 943).

### 2.3.3 The functional roles of mirror neuron system

In the early years following the discovery of mirror neurons in the monkey, researchers postulated two possible roles for mirror neuron system. Rizzolatti et al. (1996a) proposed that mirror neurons represent internally the observed actions in the brain and postulated that mirror neurons play a possible role in understanding of motor events. The authors stated that the term “action understanding” in this case implies the ability of a person in recognizing the actions performed by another individual and distinguishing the different actions from each other (Rizzolatti et al. 1996a).

It is important to say that the nature of action understanding in the monkey and humans is a little different. Umitla, Kohler, Gallese, Fogassi, Fadiga, Keysers,
and Rizzolatti (2001) found that the neurons in area F5 of the macaque monkey are activated in both conditions in which the monkey sees the whole grasping action and also when the monkey observes the grasping action in absence of final part, i.e., the part of grasping was hidden from the video-clip. Those results show that the monkey understands the goal of the action instead of the way to reach into the goal. In this case, the monkey knew that the goal of the hand movement is to grasp the food. Therefore, the mirror neurons in the area F5, which are activated during the grasping action by the monkey, are also discharged when the monkey had seen only the hand movement without a final grasping. The mirror neuron system in humans is also triggered in response to goal-directed actions, but human mirror neurons contain the properties that mirror neurons in the monkey do not possess. Rizzolatti and Craighero (2004) reviewed the literature of mirror neuron system in humans and monkey and stated that two characteristics differentiate mirror neuron system in humans from that of the monkey. First, human mirror neuron system is activated during the observation of both goal-directed and not goal-directed (intransitive) actions, whereas the monkey’s mirror neurons response only to goal-directed actions. Second, the activity of human mirror neuron system is also related to temporal coding of observed actions indicating the response of human mirror neurons to the form of the movement. The superiority of mirror neurons in humans over the monkey may be linked to the ability of humans to imitate the actions (Rizzolatti & Craighero, 2004). Action understanding role of mirror neurons has, however, got some critics later (see Hickok, 2009; Hickok & Hauser, 2010).

Other possible role for mirror neuron system is imitation of the observed actions. Experimental evidence revealed that humans share cortical mechanism during observation of an action and imitation of the observed action. Iacoboni et al. (1999), as described earlier, showed that left inferior frontal cortex (Broca’s area) and the right superior parietal lobule are involved in an imitation mechanism. It is noteworthy, here, to say that Broca’s area is known to contain the properties for speech recognition. Rizzolatti and Arbib (1998) proposed that the properties of mirror neurons in Broca’s area including recognition of hand and gesture move-
ments might suggest a possible evolutionary link between development of language in humans and recognition of gesture movements (see Corballis, 2010; Hickok, 2010; Rizzolatti et al. 1996a).

The importance of Broca’s area in the process of imitation of goal-directed actions has been shown by several studies (See Rizzolatti & Craighero, 2004). Moreover, Iacoboni, Koski, Brass, Bekkering, Woods, Dubau, Mazziotta, and Rizzolatti (2001) showed that a sector of superior temporal sulcus (STS) is activated while the normal human subjects observed or executed hand movements. Mirror neurons in STS are visual neurons (see Rizzolatti et al. 2001) which are activated during only action observation. Iacoboni et al. (2001) stated that the activity of STS during execution of finger movement might be because of the activation of neurons in frontal and parietal regions during action execution which are connected to STS.

An interesting issue on the role of mirror neurons in imitation is the question of what is its function in imitating a movement that is not present in the motor repertoire of the observer. In other word, how can an individual produce (imitate) a new motor task through observation of the task performed by another person. Buccino et al. (2004) addressed this issue by conducting an interesting experiment. The motor task in this experiment was a guitar chord played by a professional guitarist. The subjects were normal human adults with no experience on playing guitar. Experimental conditions were included a) observation of guitar chord, then performing the guitar chord b) observation of guitar chord, then performing a non-related hand action c) observation of guitar neck, then observation of guitar chord d) observation of the guitar neck, then playing a free guitar chord (Figure 2.10). An event-related fMRI was used to scan the cortical activity during four experimental conditions.

The results showed that observation of guitar chords with aim to imitation shares a cortical network with observation with aim to imitate a non-related action or observation with no imitation. The strength of activation during observation with later imitation was, however, much stronger than during two other observation conditions. The activated areas were located in the inferior parietal lobule and two foci in premotor cortex (PM) including ventral part of the precentral gyrus plus
the pars opercularis of inferior frontal gyrus (mirror neuron circuit). The results of pause event in observation-imitation condition, which was aimed to unveil the cortical activation during the formation of a new motor pattern, showed that same cortical network as action observation became active. There was, however, some differences including activations involved in the middle frontal gyrus (Broadmann’s area 46), dorsal premotor cortex, superior parietal lobule, and rostral mesial areas.

Buccino et al. (2004) concluded that neural basis underlying the imitation of a novel motor task relies on mirror neuron system. They stated that during imitating a novel motor task, the visual representations of elementary motor acts of the observed action activate the corresponding motor representations through the mirror neurons system. Then, the represented individual motor acts are selected and recombined into a new motor pattern through the involvement of areas 46, which was found to be activated during motor preparation (pause event). The importance of mirror neuron system in early stages of imitation (observation) learning has been later replicated by other researchers (Vogt, Buccino, Wohlschlager, Canessa, Shah, Zilles, Eickhoff, Freund, Rizzolatti, & Fink, 2007).

Figure 2.10. An illustration of the experimental design used by Buccino et al. (2004). Buccino et al. (2004, p. 324).
Buccino et al. (2004) showed the importance of mirror neurons system in learning a new motor task by imitation (observation). However, it remains unclear whether mirror neurons system is activated also during action observation of already acquired motor skills. In other word, is the mirror’s mechanism of individuals with expertise in different kind of motor skills different from each other or different from non-expert (novice) individuals? This issue was considered by some researchers (Calvo-Merino, Glaser, Grèzes, Passingham, & Haggard, 2005; Calvo-Merino, Grèzes, Glaser, Passingham, & Haggard, 2006).

Calvo-Merino et al. (2005) investigated this topic by using a fMRI technique. The participants in this study were the experts in classical ballet, experts in capoeira and control subjects with no experience in dance (inexperts). The brain activity of the subject was recorded while they observed videos of ballet or capoeira actions. Differences in brain activity between experts itself and experts with no-experts during watching different kind of actions were assumed to be an effect of expertise. The results showed stronger brain activity in mirror neurons areas including premotor and parietal cortices and STS during observing the motor action that was related to the motor repertoire of the subjects in comparison to observing the non-acquired motor action. In other word, the experts in ballet dance showed stronger brain activity during observing the ballet actions and the experts in capoeira when watching capoeira actions. Moreover, the subject with no experience in any kind of observed actions showed no such differences. These results confirm the link between observed actions and its specific motor representations. The strong activation of mirror neurons during watching the learned motor skills show the importance of mirror neurons in transforming the visual inputs to specific motor representations (Calvo-Merino et al. 2005).

In the following experiment, Calvo-Merino et al. (2006) investigated whether the response of mirror neurons to observing the learned actions existed in motor repertoire of the experts depends on the visual familiarity of the observer or motor familiarity. They asked female and male dancers to observe some moves of ballet dance. The selected ballet actions were those that perform only by one gender during dancing, but normally male and female dancers practice together and of course both genders visually expose to non-performed ballet actions. The results
showed that the activation of premotor, parietal, and cerebellar regions were greater when the subjects observed a movement that they had performed than when they viewed a movement that they had not performed. This study showed that action can be understood not only visually, but also motorically (Calvo-Merino et al. 2006).

The mentioned studies strongly show the role of mirror neuron system in learning new motor skills through observation. These results also confirm the involvement of mirror neuron system in observation of the acquired actions.

In addition to action understanding and imitation (observation) learning, other researchers have proposed some other roles for mirror neurons system such as empathy (see Iacoboni, 2009), but because my focus in this section was on its role in observational learning, I do not discuss further about mirror neurons and empathy.

2.3.4 A summary of neurophysiological approach

In this section, I focused on mirror neurons system as the center of neural mechanism underlying observational learning. In the beginning, a brief history of discovery of mirror neurons in macaque monkey is presented. Then, I discussed the existence of a same mirror system in humans by reviewing the neurophysiological and brain imaging evidences. The possible roles of mirror neurons system are discussed. The evidence showed that mirror neurons could be involved in action understanding in terms of both goal of the movement or the form of the movement. The most important role of mirror neurons in humans which is related to my project is its role in observational (imitation) learning. I have considered some studies related to observational learning which showed that mirror neurons are in the core of the process of learning a new motor skill through observation. Other evidence also shows the involvement of mirror neurons in observation of the learned actions (expertise effects).
2.4 A summary of theoretical background

The present chapter reviewed the theoretical background on observational learning. In first part, a review of Social Cognitive Theory (Bandura, 1969, 1977, 1986) has been presented, which is theoretically based on information processing perspective. Bandura (1969, 1977, 1986) formulated four sub-processes for the observation learning process including attention, retention, motor reproduction, and motivation. Many studies influenced by Social Cognitive Theory manipulated many aspects of the model, the demonstration, the observer, and the task to examine observational learning in the motor learning domain (see Figure 2.3). Two meta-analysis of Ashford et al. (2006, 2007) revealed that action observation has a greater effect on acquisition of movement form than on movement outcomes. These effects are greater for adults than children and for continuous motor tasks than serial and discrete motor tasks (see Figure 2.2).

In second part Visual Perception Perspective (Scully & Newell, 1985) has been reviewed, which is theoretically based on direct perception theory (Gibson, 1979). According to Scully and Newell (1985), the observers directly perceive and minimize relative motion information of the movement from a model demonstration and use later to constrain the emergence of a coordination pattern. Based on Visual Perception Perspective, highlighting the relative motion information within a display, e.g. point-light or stick-figure displays, would be particularly more effective than a classic video display in observational learning. Some evidence show that observing point-light display is superior to video display (Scully & Carnegie, 1998) and some evidence indicate that a video display is superior to point-light display (Hayes et al. 2007; Romack, 1995). Some authors discussed that it is not possible to conclude that relative motion information is picked-up from a point-light display without manipulation of intra-limb and inter-limb relative motion information within a point-light display (Breslin et al. 2005, 2006, 2009; Hayes et al. 2007a; Hodges et al. 2005). Overall, these studies showed that end-effector information is primary source of information and is prioritized for reproduction of observed action (Breslin et al. 2006, 2009; Hodges et al. 2005). However, the nature of extracted information, especially in end-effector, is still unclear.
In third part, mirror neurons system has been reviewed which seems to be the center of neural mechanism underlying observational learning. In this part, a brief history of discovery of mirror neurons in macaque monkey as well as existence of a same mirror system in humans is presented. The possible roles of mirror neurons system are discussed. The evidence showed that mirror neurons could be involved in action understanding and observational (imitation) learning.
3 Statement of the problem and research hypotheses

In this chapter, the main research questions of the present work and appropriate research hypotheses are formulated on the basis of theoretical explanations described in previous sections.

Bandura (1986) proposed “Social Cognitive Theory” with emphasize on the cognitive processes underlying observational learning and stated that viewing a model leads to the development of a “cognitive representation”, such that the picked-up information from the model are rehearsed mentally by the observer and retained in form of a symbolic representation which mediates perception and action. Scully and Newell (1985) criticized the mediating role of cognitive representation in perception-action cycle and proposed a “Visual Perception Perspective” as an ecological alternative to the Social Cognitive Theory. Scully and Newell suggested that while observing a demonstration, relative motion information of the action, i.e., the spatiotemporal changes of body joints or extremities in relation to each other, is directly picked up and perceived by the visual system and later used to imitate the action of the model. According to the "Visual Perception Perspective ", a demonstration would be particularly more effective when relative motion information of the movement is highlighted by removing the structural information such as shape, color and so on from a demonstration through generating point-light or stick-figure display than classical video demonstration. This hypothesis raises the question:

*Does observing point-light or stick-figure model demonstrations lead to better motor performance and learning than observing classical video model demonstrations?*
The question has been addressed by some research. However, experimental research, which has been reviewed in previous sections, has generally not confirmed this hypothesis. For example, Horn et al. (2002) found no significant difference between video and point-light demonstration groups for neither outcome accuracy nor intra-limb coordination pattern. There was also no significant difference between demonstration groups and no-demonstration control group in any of measured variables. Horn et al. (2005) found video and point-light model demonstration improved motor performance and learning. However, no difference was observed between video and point-light groups. Moreover, Breslin et al. (2005) found that the subjects who observed either video or point-light demonstration performed intra-limb coordination of the bowling arm significantly better than no-demonstration control group. Observation of the model led also to a close approximation of the movement time in comparison to control group. There was no significant difference between groups in terms of outcome scores or imitation of non-bowling arm. Generally, the aforementioned studies do not confirm the assumption of “Visual Perception Perspective”, that relative motion information is extracted by the observer for later motor production. The primary aim of this study, therefore, is to extend the literature and to examine the Scully and Newell’s (1985) hypothesis by using a novel, highly complex and multi-limb sport skill involving a Baseball pitch. In addition to video and point-light model demonstrations, a stick-figure model demonstration is also added to the experiment. The aim of adding a stick-figure model demonstration to the experiment was to explore its effects on the observational motor learning of new motor skills. According to the “Visual Perception Perspective”, it was hypothesized that:

H1 Model demonstrations, in which relative motion information is highlighted, lead to a better motor performance and learning in comparison to classic video model demonstrations.
Following statistical hypotheses were driven from H 1.

H 1.1 Participants in point-light group perform significantly better than participants in video group in acquisition phase in terms of all dependent variables (intra- and inter-limb coordination, movement form, and movement time).

H 1.2 Participants in point-light group perform significantly better than participants in video group in early retention test in terms of all dependent variables (intra- and inter-limb coordination, movement form, and movement time).

H 1.3 Participants in point-light group perform significantly better than participants in video group in late retention test in terms of all dependent variables (intra- and inter-limb coordination, movement form, and movement time).

H 1.4 Participants in stick-figure group perform significantly better than participants in video group in acquisition phase in terms of all dependent variables (intra- and inter-limb coordination, movement form, and movement time).

H 1.5 Participants in stick-figure group perform significantly better than participants in video group in early retention test in terms of all dependent variables (intra- and inter-limb coordination, movement form, and movement time).

H 1.6 Participants in stick-figure group perform significantly better than participants in video group in late retention test in terms of all dependent variables (intra- and inter-limb coordination, movement form, and movement time).
In order to determine whether improved motor performance in the acquisition phase or retention tests is derived from model observation, a no-demonstration control group is added to the experiment. In fact, the purpose of adding a no-demonstration control group in the research on observational learning is basically to demonstrate the effects of model observation, regardless of the type of model, on motor performance and learning. The research showed that observing a model demonstration would increase motor performance and learning in comparison to no observing (see Ashford et al. 2006; Wolf et al. 2010 for a review). Therefore, the secondary objective of the present study is to investigate the effectiveness of model observation on motor performance and learning by comparing model observation groups with no-observation control group. As such, it was also hypothesized that:

H 2  Model demonstration groups perform better than no-demonstration control group in acquisition phase and retention tests in all dependent variables.

Following statistical hypotheses were driven from H 2.

H 2.1  Participants in model demonstration groups perform significantly better than participants in control group in acquisition phase in terms of all dependent variables (intra- and inter-limb coordination, movement form, and movement time).

H 2.2  Participants in model demonstration groups perform significantly better than participants in control group in early retention test in terms of all dependent variables (intra- and inter-limb coordination, movement form, and movement time).

H 2.3  Participants in model demonstration groups perform significantly better than participants in control group in late retention test in terms of all dependent variables (intra- and inter-limb coordination, movement form, and movement time).
It is here important to note that the above-mentioned hypotheses will be tested according to the overall movement scores. In the present study, dependent variables (see Chapter 4) were analyzed at the level of overall movement as well as movement phases. The previous studies (Horn et al. 2002, 2005; Hayes et al, 2007 a, b) have analyzed dependent variables only at the level of overall movement. In the present study, we also aimed to consider the analysis of dependent variables at the level of movement phases in an attempt to explore the performance of the participants in each single phase of the motor task.
4 Methods

The present study was designed to investigate the role of observing video, stick-figure, and point-light demonstrations on motor performance and learning of a complex sport skill. This chapter explains the procedure used to perform the experiment and address the issues related to participants, model and videos, procedure, dependent variables, and statistical analysis.

4.1 Participants

A total of forty one young adults (Mean age = 24.2, SD = 3.3, range 21-40 years), 21 females and 20 males, participated voluntarily and free of charge in the study. Number of males and females was equal in all groups, five females and five males, with exception of video group consisted of six females and five males. Assessed by a self-report questionnaire (Appendix 2), all participants were right-side dominant and were novices with no previous experiences in Baseball.

4.2 Experimental groups

The participants were randomly assigned to four experimental groups on the basis of type of the model demonstration, in which an expert model performed the learning task. The four experimental groups were as the following:

- Video: The participants in this group watched a normal and not-edited video demonstration
- Point-Light: The participants in this group watched an edited video demonstration, in which the action of the model was displayed by only light points of the body joint of the expert.
• Stick-Figure: In the video for the participants of this groups the light point were connected to each other with lines, so that the expert was displayed like a stick-figure.
• Control: The participants in this group watched no video demonstration and acted as a control group.

4.3 Motor task

In this study, the motor task was a very complex and dynamic throwing action, Baseball pitch. Baseball pitch involves high coordinative demands. In particular, the pitch demands both the coordination of individual extremities such as throwing arm (intra-limb coordination) as well as multiple and simultaneously moving extremities such as throwing arm and striding leg (inter-limb coordination). In Baseball pitch, the quality of intra- and inter-limb coordination could be used to assess the progress in the process of motor learning. Moreover, Baseball pitch is extensively used in the Anglo-American research on biomechanical analysis of sport skills and is reported to have a clear phase structure. For example, Dillman, Fleisig, and Andrews (1993) divided the pitch into six phases including wind-up, stride, arm cocking, arm acceleration, arm deceleration, and follow-through (Figure 4.1). From the initial position, the pitcher elevates the left knee (phase 1: wind-up), and the body is rotated into the throwing direction, left leg falls down, and two arms separate from each other (phase 2: stride). Then, throwing arm is initiated a forward movement (phase 3: arm cocking), and is increasingly accelerated (phase 4: arm acceleration). Finally the movement is slowed down (phase 5: arm deceleration), and the right arm finishes its movement in a position outside of the stride leg (phase 6: follow-through). The clear phase structure of pitch makes it possible to perform a differentiated analysis of the movement coordination at the level of both overall movement and individual movement phases.
4.4 Model and stimulus preparation

A right-handed male pitcher (age = 32 years) with eight years of experience in second league in northern Germany acted as the model. A total of 14 retro-reflective markers were attached to right and left side of the model’s relevant body joints including shoulder (acromion process), elbow (lateral epicondyle), wrist (ulnar styloid), hip (greater trochanter), knee (lateral condyle of the femur), ankle (lateral malleolus), and toe (distal head of the fifth metatarsal) joints.

Four digital, synchronized, high frequency (120 Hertz) cameras filmed spatio-temporal positions of markers during model’s performances. The model performed three times the Baseball pitch and all three were recorded. The best pitch in the opinion of the model was selected for model demonstration and further edition. Thereafter, Simi Motion software 5.0™ (SIMI Reality Motion Systems GmbH, Germany) was applied to generate stick-figure and point-light demonstrations. A normal video demonstration was produced by a digital video camera. Video, stick-figure, and point-light demonstrations were edited so that they involved identical start and end points and lasted exactly four seconds. Figure 4.2 shows static images of specific model demonstrations.
Figure 4.2. Static images of various model demonstrations. a) Normal video, b) Point-light, c) Stick-figure.

4.5 Apparatuses and software

1. Simi Motion

A Simi Motion system (SIMI Reality Motion Systems GmbH, Germany) was used in the present study in order to collecting and analysing the data. Simi Motion is one of the many motion capture and 2D/3D motion analysis systems in the world. Simi Motion system is consisted of several hardwares and a software. Hardwares are included four digital cameras (Figure 4.3), a calibration system (Figure 4.4), and reflective markers (Figure 4.5). Digital cameras were used to capture high quality video recordings with 120 frames per second. The Simi Motion software 5.0™ was used to capture, process, edit, and analyze the collected data (Figure 4.6). The software captures the movements through tracking the reflective markers placed on joint centers of individuals. The software is also able to process the captured movements for calculating velocity, acceleration, joint angles and so on. Finally, the software would able one to export the calculated data to other programms for further analysis and calcualtion.
Figure 4.3. One of four digital cameras with stand (a) and without stand (b).

Figure 4.4. The calibration system.
Figure 4.5. The reflective marker.

Figure 4.6. Simi Motion 5th Software.
2. Video camera

A normal video camera (HC-V500M) was used to generate normal video model demonstration.

3. Ball

A standard baseball was used in the experiment.

4. Laptop for demonstrating the models to the participants

For demonstrating the model display to the participants a Sony Laptop 17” was used.

4.6 Experimental setting

The present experiment was performed in a laboratory room at the University of Oldenburg. Figure 4.7 represents the experimental setting from different angles. A marked area of 1.1 x 2.1 meter was designed in the center of the laboratory room where the participants stood and threw the baseball. The marked area was also included the calibration area, in which the cameras were able to recognize the movement of the markers. The four digital cameras were placed in the corners of the experimental room so that the performances of the participants were filmed from any possible angle. Position of the cameras was 5 to 10 meter far from the marked area. Laptop was placed on a table in 3 meter far from the participants. Simi Motion computer was placed behind the participant so that he/she had no possibility to watch his/her performance during recording.
4.7 Procedure

The participants were tested individually in two days in the Sports Science laboratory at University of Oldenburg. In first day and after the participant entered to the laboratory, he/she was given general information about the aim of the study and experimental procedure (Appendix 1). Then, the participant completed a questionnaire designed specifically to assess items such as age, gender, side-dominant and previous experiences in Baseball (Appendix 2). If there was a participant here with previous experience, he/she was excluded from the study. Because of the low spreading of the baseball sport in Germany that was the case in only two subjects.

Retro-reflective markers were attached to the major joint centers of the upper and lower body limbs of the participant which corresponding to the same positions on the model. The position of markers on the participant are presented in Figure 4.8. It is important to note that the marker on the center of the forehead was not placed on the body of the participants, because that was not necessary for later analysis. Finally, participants were given instruction of the motor task for a right-handed
pitcher presented via a paper sheet (Appendix 3) and they were requested to read the instruction carefully.

The instruction consisted of a series of images of pitch phases, as represented in Figure 4.1, as well as additional notes, in which the main features of six phases of pitch were briefly described. Participants were instructed that the only aim is to perform the technique of the throwing action as correct as possible, not attaining a specific outcome or throwing the ball very fast. As here mentioned, movement outcome (goal) was removed from the motor task. The reason was that the previous studies showed that movement outcomes could be achieved by using different motor solutions and it is not necessary that the individuals imitate the correct movement form to achieve movement goal (see Hayes et al. 2007 for more detail). In addition, the meta-analysis of Ashford, Davids, and Bennett (2006) revealed that observing the model demonstration has strong effect size on movement dynamics (form) and small effect size on movement outcome. Therefore, the movement goal was removed from the motor task in an attempt to assess the role of model observation on only movement form. To ensure that all participants begin the experiment with the same information, the experimenter did not answer the participants’ questions of about the Baseball pitch in principle.
To familiarize with experimental room, task, and markers, participants, then, received two practical trials. Following the five trials in pretest the participants completed three blocks of 10 trials in acquisition phase. Before each acquisition block, the participants in demonstration groups observed three times respective model demonstrations on a 17.3 inch laptop. They were instructed that the observed action was a perfect pitch and they should only attempt to copy the modeled action as accurate as possible. The participants in no-demonstration control group followed the same protocol but watched no model demonstration. No additional information such as knowledge of performance was provided during the experiment. The intervals between the acquisition blocks were same for all experimental groups and set in two minutes. Early and late retention tests with 5 trials were performed with no model observation ten minutes and one week after the last acquisition block. A schematic illustration of experimental procedure is presented in Figure 4.9. The time required for the participants was about one hour on the first day about 30 minutes on the second day. After the experiment the participants were thanked for their participation in the study.

![Experimental Procedure Diagram](image)

Figure 4.9. An illustration of experimental procedure used in the present study.
4.8 Variables

4.8.1 Independent variable

The independent variable of the study was observing the video, point-light and stick-figure model demonstrations. Dependent variables from before and after model observation were compared. Repeated measure of time including pretest, acquisition blocks, and early and late retention tests was also used as independent variable in statistical point of view.

4.8.2 Dependent variables

The dependent variables of the study have been considered for evaluating the learning progress of the participants relating to performing the Baseball-pitch during the experiment. Two variables of interest were related to the appropriate technique and temporal features of the Baseball-pitch. Technique (form) of the motor task has been shown to be a stronger determinant of the observational learning effect (see Ashford et al. 2006, 2007). Technique of the pitch was evaluated by comparing intra- and inter-limb coordination profile of the participants with that of the model as well as by an movement form evaluation of the video recordings of the throws of the participants in the pretest, the acquisition blocks and the two retention tests. Temporal characteristics of the pitch were evaluated by absolute difference between the times took the participant to execute the movement and that of the model. Movement time is considered to be a measure of motor control (Breslin et al. 2005). All analyses were performed at the level of the overall movement, as well as at the level of the above mentioned six phases of the Baseball-pitch. As mentioned in previous chapter, the aim of considering the analysis of movement phases was to explore the performance of the participants in various movement phases.
4.8.2.1 Kinematic analysis

The term "intra-limb coordination" means the coordination of an individual limb in the context of the overall movement, e.g. the arm. In Baseball-pitch, of course, the throwing arm is one of interest. Another interesting intra-limb coordination could be that of the left leg (for right-handed), which is used for striding. Thus, in this study, intra-limb coordination of throwing arm and striding leg are of interest. The operationalization of the intra-limb coordination took place via the kinematic analysis of the angles of each two extremities. These were the shoulder and elbow angles (intra-limb coordination of the throwing arm) and the knee and ankle angles (intra-limb coordination of striding leg). In both cases, the relative kinematics of the pairs of angles was considered, i.e. their spatiotemporal changes of each angle relative to other in course of the movement. The operational views of the both intra-limb coordination are presented in Figures 4.10 and 4.11.

Figure 4.10. Operational view of shoulder-elbow intra-limb coordination. a) Shoulder angle, b) elbow angle, c) Relative changes of shoulder and elbow angles: shoulder-elbow intra-limb coordination.
In contrast, the inter-limb coordination describes the coordination of two or more extremities (limbs). Since in the Baseball-pitch both upper and lower body must be coordinately moved, we chose, here, the coordination between elbow angle of the throwing arm and the knee angle of the striding leg. Here, the analysis was again the relative spatiotemporal change of these two angles and, thus, the relative motions of the respective body segments (Figure 4.12).
The deviation of the intra-and inter-limb coordination of a participant from the intra-and inter-limb coordination of the model was determined using the normalized root mean squared difference (NoRM-D) proposed by Horn et al. (2005). The NoRM-D quantified for a defined number of video frames the difference between the participant and the model regarding the position of a pair of angles in space (e.g. shoulder and elbow angles in intra-limb coordination of the throwing arm). The comparison is made for each video frame, so that each frame produces a data point. The smaller the NoRM-D is, the smaller the deviation of the intra- or inter-limb coordination of the participant from the coordination pattern of the model and as the greater the learning progress of the participant. A detailed description of NoRM-D calculation can be found in Mullineaux, Bartlett and Bennett (2001). An illustration of the NoRM-D score is schematically shown in Figure 4.13 which demonstrates the difference between the participant and the model in terms of shoulder-elbow intra-limb coordination.

Normalized Root Mean Square-Difference
[NoRM-D]

Figure 4.13. A schematic view of NoRM-D.
To calculate the NoRM-D, it is required to standardize the video recordings of all participants and the model into same number of video frames. This was initially not the case, since the rate and time of throwing movements performed by the participants were, of course, intra-and inter-individually different. Therefore, in order to match the range of motion of the participants and the model, a linear interpolation was used to standardize the start and end points of the throwing movements of the model and participants. For this purpose, the data was first smoothed with a recursive 4th order low pass Butterworth filter using a cut-off frequency of 7 Hz. Then, the normalization function available in the Simi Motion 5.0™ software was applied to normalize the number of frames (and therefore the data points) for the individual movement phases. The distribution of the frames and data points on each phase of the Baseball pitch was based on the time it took the model to perform respective movement phase (phase duration). Information of the normalization data are shown in Table 4.1.
Table 4.1. Start and end points of the six phases of movement and the consequent data points and phase durations (pictures adopted from Rojas et al. 2009, p. 560)

<table>
<thead>
<tr>
<th>Phase</th>
<th>Start- and end-point</th>
<th>Phase duration</th>
<th>Data points</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Wind-up</td>
<td>Start point: Left foot elevated from ground&lt;br&gt;End point: Left knee at the highest point</td>
<td>1.072</td>
<td>100</td>
</tr>
<tr>
<td>2 Stride</td>
<td>Start point: Left knee at the highest point&lt;br&gt;End point: Striding finished, throwing arm back</td>
<td>0.958</td>
<td>90</td>
</tr>
<tr>
<td>3 Arm cocking</td>
<td>Start point: Striding finished, throwing arm back&lt;br&gt;End point: right arm was cocked</td>
<td>0.168</td>
<td>15</td>
</tr>
<tr>
<td>4 Arm acceleration</td>
<td>Start point: right arm cocked&lt;br&gt;End point: ball released</td>
<td>0.093</td>
<td>10</td>
</tr>
<tr>
<td>5 Arm deceleration</td>
<td>Start point: ball released&lt;br&gt;End point: velocity of the right arm decreased</td>
<td>0.075</td>
<td>10</td>
</tr>
<tr>
<td>6 Follow-through</td>
<td>Start point: velocity of the right arm decreased&lt;br&gt;End point: right arm decelerated fully</td>
<td>0.236</td>
<td>25</td>
</tr>
<tr>
<td>Overall movement</td>
<td>Start point: Left foot elevated from ground&lt;br&gt;End point: right arm decelerated fully</td>
<td>2.602</td>
<td>250</td>
</tr>
</tbody>
</table>

Due to the large amount of kinematic data, the coordination profile of each participant was compared with the model on a selection of trials. All trials on the pretest and retention tests and first 3 trials of each acquisition block were selected for later analysis. Thus, a total of 24 trials including 5 pretest, 3 x 3 acquisition blocks, and 2 x 5 retention tests were analyzed for all subjects and compared to the model to yield NoRM-D scores. It is important to note that NoRM-D score was separately calculated for overall movement and each individual phase of Baseball-pitch.
4.8.2.2 Movement form

Form of pitch was evaluated by two male, high-class and experienced baseball coaches (32 years) for an available fee. To do this, an evaluation form especially for this purpose was developed in collaboration with the two raters (Appendix 4). The evaluation form was consisted of seven items including one item for every phase and one item as an overall evaluation. At each item, two to four movement criteria were formulated on a four-point scale from 0 (not performed) to 3 (completely performed). For example, a criterion for the phase of the wind-up was "body laterally to throwing direction", and a criterion for the phase of arm acceleration was "throwing arm is accelerated rapidly in throwing direction and is stretched". Two criteria that refer to the overall evaluation were "movement is totally balanced" and "movement is totally fluent". The evaluation form contains a total of 21 items, so that the evaluation of a pitch trial varies between 0 to 63 points.

Following the preparation of evaluation form and in order to providing the raters an experimental training, they watched some video recordings of the participants independently and in a random order over two extending days and rated them based on evaluation form. Similar to kinematic analysis, a selection of trials for were selected for later analysis. For each participant, a total of 24 trials were chosen including all trials on the pretest and retention tests and first 3 trials of each acquisition block. Videos were saved as AVI files onto two USB sticks and could be taken by the raters to home with after two training days. On each stick, thus, were 984 files (24 trials x 41 participants). The files were stored in random order and only labeled with a code number, so that the raters were blind to which experimental group the respective participant had belonged to as well as the experimental phase (pretest, acquisition phase or retention test). This code number had to be registered by the raters on each evaluation form so that later it could be made an allocation to the experimental group and phase.
4.8.2.3 Movement time

Absolute movement time difference, i.e., absolute difference between the times took the participant to execute the movement and that of the model, was measured in each individual phase of the criterion task. Similar to kinematic data, the data of movement time was measured across 24 trials. Absolute time difference of total movement was measured by adding the absolute time differences of all phases together. Movement time is considered to be a measure of motor control (Breslin et al. 2005). Lower difference score would represent greater similarity with the model and negative scores would indicate faster performance of the participant than the model.

4.9 Statistical analysis

The performance of the participants in the pretest (baseline-check) were analyzed by one-way analysis of variance (ANOVA). NoRM-D scores, movement form scores, and absolute movement time difference scores were entered into all statistical analyses as dependent variables. Post hoc comparisons were made using the Schefé test. The performance development in the acquisition phase was analyzed by 4 (experimental groups) x 3 (acquisition blocks) ANOVAs with repeated measures on the last factor. Greenhouse-Geisser-corrected F value was used in the case of violation of Sphericity assumption. In an additional 4 (experimental groups) x 4 (pretest, acquisition blocks) ANOVA the pretest was also included in the repeated measures analysis. The analysis of performance of the participants in early and late retention tests was performed by a one-way ANOVA. Normal distribution for the scores of two raters was measured by the Kolmogorov-Smirnov test. The correlations between and two raters were measured by Pearson Test and intra-class correlation coefficient. Significance level was set at $p < .05$ for all analysis. Partial eta squared was computed for all ANOVAs as a measurement of effect size and is reported for significant effects.
5 Results

This chapter provides a comprehensive overview of the results of the study. The results are presented by each dependent variable separately. The results for kinematic variables are included angle-angle plots and statistical analysis. The results for movement form and movement time variables are presented only with statistical analysis. The results are presented under the following titles: (1) kinematic analysis including shoulder-elbow intra-limb coordination, knee-ankle intra-limb coordination and elbow-knee inter-limb coordination, (2) movement form and (3) movement time. The critical consideration is whether changes are temporally related to the introduction of model demonstrations. The results of overall movement and individual movement phases are presented separately. The data are described and illustrated with suitable graphics and tables across pretest, acquisition phase, and retention tests.

5.1 Kinematic analysis

Kinematic analysis is included shoulder-elbow intra-limb coordination, knee-ankle intra-limb coordination, and elbow-knee inter-limb coordination.

5.1.1 Shoulder-elbow intra-limb coordination

The descriptive data of the shoulder-elbow intra-limb coordination for overall movement and movement phases are presented in Table 5.1.
Table 5.1. Mean and standard deviation of NoRM-D scores of shoulder-elbow intra-limb coordination for overall movement and movement phases

<table>
<thead>
<tr>
<th>Phase</th>
<th>Group</th>
<th>Pretest</th>
<th>Block 1</th>
<th>Block 2</th>
<th>Block 3</th>
<th>Early Ret</th>
<th>Late Ret</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall movement</td>
<td>VI</td>
<td>35.26 (11.23)</td>
<td>35.90 (10.97)</td>
<td>35.29 (10.34)</td>
<td>35.38 (10.19)</td>
<td>34.31 (09.64)</td>
<td>36.55 (10.23)</td>
</tr>
<tr>
<td></td>
<td>SF</td>
<td>45.00 (07.69)</td>
<td>39.45 (07.93)</td>
<td>37.13 (08.73)</td>
<td>38.22 (06.29)</td>
<td>38.29 (06.25)</td>
<td>37.43 (08.07)</td>
</tr>
<tr>
<td></td>
<td>PL</td>
<td>38.89 (08.27)</td>
<td>37.91 (08.41)</td>
<td>35.02 (08.46)</td>
<td>34.71 (09.46)</td>
<td>32.68 (06.99)</td>
<td>33.62 (07.58)</td>
</tr>
<tr>
<td></td>
<td>CO</td>
<td>35.22 (12.19)</td>
<td>34.45 (08.12)</td>
<td>35.26 (08.16)</td>
<td>34.07 (07.74)</td>
<td>34.59 (07.34)</td>
<td>34.30 (05.36)</td>
</tr>
<tr>
<td>Wind-up</td>
<td>VI</td>
<td>30.53 (15.33)</td>
<td>33.31 (17.01)</td>
<td>34.06 (15.47)</td>
<td>33.70 (16.94)</td>
<td>31.50 (14.33)</td>
<td>37.20 (15.89)</td>
</tr>
<tr>
<td></td>
<td>SF</td>
<td>32.38 (12.36)</td>
<td>25.49 (03.91)</td>
<td>22.85 (05.47)</td>
<td>24.24 (02.59)</td>
<td>28.02 (07.25)</td>
<td>26.89 (07.27)</td>
</tr>
<tr>
<td></td>
<td>PL</td>
<td>28.72 (10.50)</td>
<td>29.47 (12.37)</td>
<td>26.36 (15.19)</td>
<td>25.89 (17.10)</td>
<td>23.13 (12.87)</td>
<td>30.30 (13.70)</td>
</tr>
<tr>
<td></td>
<td>CO</td>
<td>29.23 (19.53)</td>
<td>30.05 (14.43)</td>
<td>28.94 (11.31)</td>
<td>30.20 (16.06)</td>
<td>29.28 (13.30)</td>
<td>28.99 (13.18)</td>
</tr>
<tr>
<td>Stride</td>
<td>VI</td>
<td>42.38 (17.36)</td>
<td>40.22 (17.28)</td>
<td>39.26 (15.55)</td>
<td>40.17 (14.77)</td>
<td>38.74 (16.94)</td>
<td>38.98 (17.17)</td>
</tr>
<tr>
<td></td>
<td>SF</td>
<td>60.73 (13.34)</td>
<td>52.51 (14.84)</td>
<td>49.13 (17.23)</td>
<td>50.61 (12.24)</td>
<td>47.36 (15.16)</td>
<td>45.57 (14.98)</td>
</tr>
<tr>
<td></td>
<td>PL</td>
<td>50.79 (13.97)</td>
<td>48.60 (13.09)</td>
<td>44.06 (12.32)</td>
<td>43.65 (11.47)</td>
<td>40.93 (10.16)</td>
<td>39.69 (07.05)</td>
</tr>
<tr>
<td></td>
<td>CO</td>
<td>43.83 (13.15)</td>
<td>41.07 (10.18)</td>
<td>44.09 (12.76)</td>
<td>39.55 (10.21)</td>
<td>41.61 (12.00)</td>
<td>41.51 (09.92)</td>
</tr>
<tr>
<td>Arm cocking</td>
<td>VI</td>
<td>27.91 (08.75)</td>
<td>30.24 (10.02)</td>
<td>27.48 (09.68)</td>
<td>27.95 (08.73)</td>
<td>30.13 (10.35)</td>
<td>26.40 (10.09)</td>
</tr>
<tr>
<td></td>
<td>SF</td>
<td>24.06 (12.32)</td>
<td>27.42 (11.45)</td>
<td>26.60 (13.82)</td>
<td>25.83 (12.95)</td>
<td>27.25 (14.56)</td>
<td>31.86 (19.18)</td>
</tr>
<tr>
<td></td>
<td>PL</td>
<td>25.59 (08.74)</td>
<td>25.43 (09.41)</td>
<td>23.94 (09.41)</td>
<td>23.44 (08.44)</td>
<td>22.40 (09.25)</td>
<td>21.56 (06.39)</td>
</tr>
<tr>
<td></td>
<td>CO</td>
<td>26.90 (12.33)</td>
<td>26.44 (09.64)</td>
<td>28.27 (14.03)</td>
<td>27.85 (12.02)</td>
<td>27.27 (11.94)</td>
<td>25.11 (07.10)</td>
</tr>
<tr>
<td>Arm acceleration</td>
<td>VI</td>
<td>23.01 (10.84)</td>
<td>24.55 (11.75)</td>
<td>22.29 (09.63)</td>
<td>22.15 (07.31)</td>
<td>23.51 (09.04)</td>
<td>23.83 (08.48)</td>
</tr>
<tr>
<td></td>
<td>SF</td>
<td>31.17 (10.41)</td>
<td>32.12 (09.76)</td>
<td>29.72 (13.67)</td>
<td>28.76 (11.92)</td>
<td>30.48 (11.80)</td>
<td>33.37 (09.33)</td>
</tr>
<tr>
<td></td>
<td>PL</td>
<td>30.51 (08.27)</td>
<td>29.30 (06.90)</td>
<td>29.35 (08.65)</td>
<td>28.17 (10.28)</td>
<td>28.89 (08.57)</td>
<td>29.70 (10.34)</td>
</tr>
<tr>
<td></td>
<td>CO</td>
<td>20.33 (08.00)</td>
<td>20.35 (08.73)</td>
<td>22.98 (10.60)</td>
<td>23.12 (10.93)</td>
<td>21.94 (09.69)</td>
<td>20.38 (10.68)</td>
</tr>
<tr>
<td>Arm deceleration</td>
<td>VI</td>
<td>14.75 (02.86)</td>
<td>16.11 (03.26)</td>
<td>18.12 (06.54)</td>
<td>14.60 (03.11)</td>
<td>14.71 (02.73)</td>
<td>14.68 (02.51)</td>
</tr>
<tr>
<td></td>
<td>PL</td>
<td>21.27 (07.68)</td>
<td>19.21 (07.24)</td>
<td>18.53 (07.09)</td>
<td>18.02 (07.25)</td>
<td>18.70 (06.53)</td>
<td>18.02 (05.19)</td>
</tr>
<tr>
<td></td>
<td>CO</td>
<td>14.00 (03.26)</td>
<td>17.47 (06.16)</td>
<td>15.96 (05.77)</td>
<td>17.39 (05.43)</td>
<td>16.65 (06.77)</td>
<td>14.98 (03.20)</td>
</tr>
<tr>
<td>Follow-through</td>
<td>VI</td>
<td>23.07 (07.04)</td>
<td>23.54 (07.40)</td>
<td>23.28 (04.78)</td>
<td>20.64 (04.56)</td>
<td>21.98 (08.55)</td>
<td>22.55 (09.03)</td>
</tr>
<tr>
<td></td>
<td>SF</td>
<td>33.30 (15.06)</td>
<td>33.61 (14.39)</td>
<td>32.43 (15.70)</td>
<td>35.75 (14.70)</td>
<td>33.63 (15.42)</td>
<td>35.28 (11.95)</td>
</tr>
<tr>
<td></td>
<td>PL</td>
<td>29.37 (07.33)</td>
<td>28.38 (08.15)</td>
<td>27.85 (08.64)</td>
<td>28.79 (09.24)</td>
<td>28.71 (06.18)</td>
<td>25.65 (05.82)</td>
</tr>
<tr>
<td></td>
<td>CO</td>
<td>22.53 (07.17)</td>
<td>27.00 (07.04)</td>
<td>24.98 (06.37)</td>
<td>24.11 (07.41)</td>
<td>25.62 (08.84)</td>
<td>25.98 (04.91)</td>
</tr>
</tbody>
</table>

**Overall movement**

How well did the participants in the different experimental groups succeeded to approach their throwing arm coordination (shoulder-elbow intra-limb coordination) to the coordination pattern of the model? Figure 5.1 shows in a set of angle-angle plots the shoulder-elbow coordination of the model (top) and the averaged throwing arm coordination of the participants in the four experimental groups (top to bottom) in the pretest, the acquisition phase and the early and late retention tests (from left to right). The graphics shows that: The model begins the pitch action with a shoulder angle of about 35° and an elbow angle of approximately 60°; at the end of movement the shoulder angle is about 80° and elbow is relatively highly stretched with about 140°. The participants in the experimental
groups have showed almost different coordination patterns. For example, the participants in video group have started their movement in the pretest in average with a shoulder angle of approximately 30° and an elbow angle of almost 80° and ended at about 60° and about 120°. In addition, the respective NoRM-D scores is inserted into the graphics; it shows numerically the difference between the throwing arm coordination of the participants and that of the model (remember: The smaller the NoRM-D, the smaller the mean difference between model and experimental group).
Figure 5.1. Intra-limb coordination of the throwing arm: relative change of the shoulder and elbow angles of the model and the participants in the experimental groups across the pretest, the acquisition phase and the early and late retention tests.
The angle-angle plots in Figure 5.1 illustrate the following:

- Shoulder-elbow intra-limb coordination of the participants differs in all experimental groups from that of the model.
- This deviation becomes smaller with increasing practice, i.e., shoulder-elbow intra-limb coordination of the participants approach in all experimental groups to the shoulder-elbow intra-limb coordination of the model. This is both visually (angle-angle plots) and numerically (NoRM-D scores tend to become smaller) recognizable.
- Shoulder-elbow intra-limb coordination of the participants look different depending on the experimental group; video and control groups tend to show more similar coordination to the model rather stick-figure and point-light groups.

The statistical analysis for shoulder-elbow intra-limb coordination came to the following results: In the pretest, there was no significant difference between the experimental groups, $F = 1.76, p > .1$. In acquisition phase, there was no significant main effect for group, $F = 0.26, p > .1$, block, $F = 1.66, p > .1$, or group x block interaction, $F = 0.67, p > .1$. The participants approached their shoulder-elbow coordination to the model from the pretest to the acquisition blocks as proved by a significant main effect for time from pretest to acquisition blocks, $F = 4.73, p < .01$, $\eta^2_{par} = .17$. In the early and late retention tests, then, again no significant difference was observed between the experimental groups, $F = 0.70, p > .1$, and $F = 0.38, p > .1$, respectively. That means all participants achieved a similar level of learning, regardless of the model demonstrations they had previously observed in the acquisition phase, or regardless of observation a model demonstration or no-observation in the acquisition phase. Figure 5.2 represents the deviations of the experimental groups (NoRM-D) from the coordination pattern of the model. It is important to note that the graphics for intra- and inter-limb coordination variables are presented from 25 to 65 in y axis, so that the viewer is able to easily perceive which variable has been closer to the model (remember: The smaller the NoRM-D, the smaller the difference).
Phase 1: Wind-up

The angle-angle plots of shoulder-elbow coordination in wind-up phase illustrate that coordination pattern of the participants differs in all experimental groups from that of the model. Moreover, the deviation does not become smaller with increasing practice (see Figure 5.3).

The statistical analysis for shoulder-elbow coordination in wind-up phase showed no significant difference between the experimental groups in pretest, $F = 0.12, p > .1$. In acquisition phase, there was no significant main effect for group, $F = 0.76, p > .1$, block, $F = 0.67, p > .1$, or group x block interaction, $F = 0.33, p > .1$. No significant main effect was observed for group, $F = 0.32, p > .1$, time, $F = 0.88, p > .1$, or group x time interaction, $F = 1.28, p > .1$, from pretest to acquisition blocks. In the early and late retention tests there was also no significant difference between the experimental groups, $F = 0.62, p > .1$, and $F = 0.84, p > .1$, respectively. Figure 5.4 shows the difference between the participants’ coordination patterns (NoRM-D) from the model. NoRM-D scores are presented from 5 to 75 in y axis.

Figure 5.2. Means of NoRM-D scores of shoulder-elbow intra-limb coordination for the experimental groups across pretest, acquisition blocks and retentions tests.
for all movement phases in all kinematic variables in an attempt to make the difference between phases visually clear for the viewer.

Figure 5.3. Shoulder-elbow intra-limb coordination for wind-up phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.
Figure 5.4. Means of NoRM-D scores of shoulder-elbow intra-limb coordination for wind-up phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.

Phase 2: Stride

The angle-angle plots of shoulder-elbow coordination in stride phase show that coordination pattern of the participants differs in all experimental groups from that of the model. Moreover, the deviation become smaller with increasing practice (see Figure 5.5).

The statistical analysis for shoulder-elbow coordination in stride phase showed no significant difference between the experimental groups in pretest, $F = 2.21$, $p > .1$. In acquisition phase, there was no significant main effect for group, $F = 1.03$, $p > .1$, block, $F = 1.05$, $p > .1$, or group x block interaction, $F = 0.85$, $p > .1$. The participants improved significantly their performance from pretest to acquisition blocks as proved by a significant main effect for time, $F = 4.82$, $p < .01$, $\epsilon_{par}^2 = .17$. In the early and late retention tests there was no significant difference between the experimental groups, $F = 0.50$, $p > .1$, and $F = 0.35$, $p > .1$, respectively. Figure 5.6 shows the difference between the participants’ coordination patterns (NoRM-D) from the model.
Figure 5.5. Shoulder-elbow intra-limb coordination for stride phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.
Phase 3: Arm cocking

The angle-angle plots of shoulder-elbow coordination in arm cocking phase reveal that coordination pattern of the participants differs in all experimental groups from that of the model. In addition, the difference does not become smaller with increasing practice (see Figure 5.7).

The statistical analysis for shoulder-elbow coordination in arm cocking showed no significant difference between the experimental groups in pretest, $F = 0.12, p > .1$. In acquisition phase, no significant main effect was observed for group, $F = 0.25, p > .1$, block, $F = 0.92, p > .1$, or group x block interaction, $F = 0.80, p > .1$. There was no significant main effect for group, $F = 0.20, p > .1$, time, $F = 0.70, p > .1$, or group x time interaction, $F = 0.67, p > .1$, from pretest to acquisition blocks. In the early and late retention tests, no significant difference was also observed between the experimental groups, $F = 0.67, p > .1$, and $F = 1.11, p > .1$, respectively. Figure 5.8 represents the difference between the participants’ coordination patterns (NoRM-D) from the model.
Figure 5.7. Shoulder-elbow intra-limb coordination for arm cocking phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.
Phase 4: Arm acceleration

The angle-angle plots of shoulder-elbow coordination in arm acceleration phase illustrate that coordination pattern of the participants differs in all experimental groups from that of the model. Moreover, the deviation does not become smaller with increasing practice (see Figure 5.9).

The statistical analysis for shoulder-elbow coordination in arm acceleration phase showed no significant difference between the experimental groups in pretest, $F = 2.83, p > .05$. In acquisition phase, there was no significant main effect for group, $F = 1.44, p > .1$, block, $F = 0.65, p > .1$, or group x block interaction, $F = 1.35, p > .1$. No significant main effect was observed for group, $F = 1.84, p > .1$, time, $F = 0.45, p > .1$, or group x time interaction, $F = 1.28, p > .1$, from pretest to acquisition blocks. In the early and late retention tests there also was no significant difference.
between the experimental groups, \( F = 1.43, p > .1 \), and \( F = 2.75, p > .05 \), respectively. Figure 5.10 illustrates the difference between the participants’ coordination patterns (NoRM-D) from the model.

Figure 5.9. Shoulder-elbow intra-limb coordination for arm acceleration phase of pitch for the experimental groups across pretest, acquisition blocks and retention tests.
Phase 5: Arm deceleration

The angle-angle plots of shoulder-elbow coordination in arm deceleration phase illustrate that coordination pattern of the participants differs in all experimental groups from that of the model. Moreover, the deviation does not become smaller with increasing practice (see Figure 5.11).

The statistical analysis for shoulder-elbow coordination in arm deceleration phase showed that there was a significant difference between the experimental groups in pretest, $F = 3.53$, $p < .05$, $\eta_{par}^2 = .31$. In this case, post-hoc test showed no significant differences between groups. In acquisition phase, however, there was no significant main effect for group, $F = 2.01$, $p > .1$, block, $F = 0.67$, $p > .1$, or group x block interaction, $F = 2.05$, $p > .05$. From pretest to acquisition blocks, no significant main effect was observed for group, $F = 1.74$, $p > .1$ and time, $F = 0.49$, $p > .1$, but group x time interaction was significant, $F = 3.00$, $p < .01$, $\eta_{par}^2 = .28$. In the early retention tests there was no significant difference between the
experimental groups, $F = 2.54$, $p > .05$. In the late retention test, however, a significant difference was observed between the experimental groups, $F = 5.66$, $p < .01$, $\epsilon_{par}^2 = .42$. Post hoc test revealed that stick-figure group performed significantly worse than video and control groups, $p < .05$. Figure 5.12 illustrates the difference between the participants' coordination patterns (NoRM-D) from the model.

Figure 5.11. Shoulder-elbow intra-limb coordination for arm deceleration phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.
Phase 6: Follow-through

The angle-angle plots of shoulder-elbow coordination in follow-through phase illustrate that coordination pattern of the participants differs in all experimental groups from that of the model. Moreover, the difference does not become smaller with increasing practice (see Figure 5.13).

The statistical analysis for shoulder-elbow coordination in follow-through phase showed no significant difference between the experimental groups in pretest, $F = 2.49$, $p > .05$. In acquisition phase, there was no significant main effect for group, $F = 2.53$, $p > .05$, block, $F = 0.49$, $p > .1$, or group x block interaction, $F = 0.97$, $p > .1$. No significant main effect was observed for group, $F = 1.95$, $p > .1$, time, $F = 0.49$, $p > .1$, or group x time interaction, $F = 1.20$, $p > .1$, from pretest to acquisition blocks. In the early retention test, there also was no significant difference between the experimental groups, $F = 1.80$, $p > .1$. In the late retention test, however, there was a significant difference between the experimental groups, $F =$
3.22, \( p < .05, \ e_{par}^2 = .29 \). In this case, post-hoc test showed no significant differences between groups. Figure 5.14 illustrates the difference between the participants’ coordination patterns (NoRM-D) from the model.

Figure 5.13. Shoulder-elbow intra-limb coordination for follow-through phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.
Figure 5.14. Means of NoRM-D scores of shoulder-elbow intra-limb coordination for follow-through phase of pitch for the experimental groups across pretest, acquisition blocks and retention tests.

Summary

The results of shoulder-elbow intra-limb coordination revealed that there were no significant differences between groups in pretest, acquisition blocks, and retention tests in terms of overall movement. In addition, the participants improved their performances from pretest to acquisition phase in terms of overall movement. Results of pitch phases showed an improvement in stride phase from pretest to acquisition blocks. Moreover, the participants in stick-figure group performed significantly worse than those in video and control group, in late retention test. The mean and standard deviation of NoRM-D values of shoulder-elbow intra-limb coordination are summarized in Table 5.1. From Table 5.1 it is clear that NoRM-D values of stride phase is much higher than other phases of pitch.
5.1.2 Knee-ankle intra-limb coordination

The descriptive data of the knee-ankle intra-limb coordination for overall movement and movement phases are presented in Table 5.2.

Table 5.2. Mean and standard deviation of NoRM-D scores of knee-ankle intra-limb coordination for overall movement and movement phases

<table>
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<th>Block 3</th>
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</tr>
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</table>
Overall movement

Figure 5.15 shows in a set of angle-angle plots the knee-ankle coordination of the model and the averaged striding leg’s coordination of the participants in the four experimental groups across the pretest, the acquisition phase and the early and late retention tests. The graphics show that: The model begins the pitch action with a knee angle of about 180° and an ankle angle of approximately 120°; at end of movement the knee angle is about 130° and ankle is relatively in the same angular position as the start point with about 110°. The participants in different groups performed the pitch very differently from the model in terms of striding leg coordination pattern, although angular positions of start and end points were almost as the model. For example, the participants in video group, have started their movement in the pretest in average with a knee angle of approximately 180° and ankle angle of almost 100° and ended at about 130° and about 110°.
Figure 5.15. Intra-limb coordination of the striding leg: relative change of the knee and ankle angles of the model and participants in the four experimental groups across the pretest, the acquisition phase and the early and late retention tests.
The angle-angle plots in Figure 5.15 illustrate the following:

- Knee-ankle intra-limb coordination of the participants differs in all experimental groups very clearly from that of the model.
- This deviation becomes smaller with increasing practice, i.e., knee-ankle intra-limb coordination of the participants approach in all experimental groups to the knee-ankle intra-limb coordination of the model. This is both visually (angle-angle plots) and numerically (NoRM-D scores tend to become smaller) recognizable.
- Knee-ankle intra-limb coordination of the participants does not look very different depending on the experimental group.

The statistical analysis for knee-ankle intra-limb coordination presents the following results: In the pretest, no significant difference was observed between the experimental groups, $F = 1.43, p > .1$. In acquisition phase, there was no significant main effect for group, $F = 1.42, p > .1$, block, $F = 0.92, p > .1$, or group x block interaction, $F = 1.45, p > .1$. The participants approached their knee-ankle coordination to the model from the pretest to the acquisition blocks, as proved by a significant main effect for time, $F = 4.13, p < .01$, $\eta^2_{\text{par}} = .15$. In the early and late retention tests, then, again no significant difference was observed between the experimental groups, $F = 1.35, p > .1$, and $F = 1.26, p > .1$, respectively. Figure 5.16 represents the deviations of the experimental groups (NoRM-D) from the coordination pattern of the model.
**Phase 1: Wind-up**

The angle-angle plots of shoulder-elbow coordination in wind-up phase illustrate that coordination pattern of the participants differs in all experimental groups very clearly from that of the model. Moreover, the deviation does not become smaller with increasing practice (see Figure 5.17).

The statistical analysis for knee-ankle coordination in wind-up phase showed no significant difference between the experimental groups in pretest, $F = 0.95, p > .1$. In acquisition phase, there was no significant main effect for group, $F = 1.09, p > .1$, block, $F = 0.32, p > .1$, or group x block interaction, $F = 1.90, p > .05$. No significant main effect was observed for group, $F = 1.63, p > .1$, time, $F = 0.75, p > .1$, or group x time interaction, $F = 1.57, p > .1$. In the early and late retention tests there also was no significant difference between the experimental groups, $F = 1.38, p > .1$, and $F = 1.34, p > .1$, respectively. Figure 5.18 illustrates the difference between the participants’ coordination patterns (NoRM-D) from the model.
Figure 5.17. Knee-ankle intra-limb coordination for wind-up phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.
Phase 2: Stride

The angle-angle plots of knee-ankle coordination in stride phase show that coordination pattern of the participants differs in all experimental groups clearly from that of the model. Moreover, the deviation become smaller with increasing practice (see Figure 5.19).

The statistical analysis for Knee-ankle coordination in stride phase showed no significant difference between the experimental groups in pretest, $F = 1.38$, $p > .1$. In acquisition phase, there was no significant main effect for group, $F = 1.04$, $p > .1$, block, $F = 1.39$, $p > .1$, or group x block interaction, $F = 0.59$, $p > .1$. An improvement was observed from pretest to acquisition blocks, $F = 7.81$, $p < .001$, $\varepsilon_{par}^2 = .25$. No significant main effect was observed for group, $F = 1.58$, $p > .1$, or group x time interaction, $F = 0.66$, $p > .1$ from pretest to acquisition blocks. In the early and late retention tests there was no significant difference between the experimental groups, $F = 1.47$, $p > .1$, and $F = 0.86$, $p > .1$, respectively. Figure 5.20

Figure 5.18. Means of NoRM-D scores of knee-ankle intra-limb coordination for wind-up phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.
illustrates the difference between the participants’ coordination patterns (NoRM-D) from the model.

Figure 5.19. Knee-ankle intra-limb coordination for stride phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.
Figure 5.20. Means of NoRM-D scores of knee-ankle intra-limb coordination for stride phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.

**Phase 3: Arm cocking**

The angle-angle plots of knee-ankle coordination in arm cocking phase illustrate that coordination pattern of the participants differs in all experimental groups clearly from that of the model. Moreover, the deviation does not become smaller with increasing practice (see Figure 5.21).

The statistical analysis for knee-ankle coordination in arm cocking phase showed a significant difference between the experimental groups in pretest, $F = 3.28$, $p < .05$, $\eta^2_{par} = .30$. In this case, post-hoc test showed no significant differences between groups. In acquisition phase, the participants improved their performance during the acquisition blocks as proved by a significant main effect for block, $F = 4.04$, $p < .05$, $\eta^2_{par} = .14$. However, no significant main effect was observed for group, $F = 0.83$, $p > .1$, or group x block interaction, $F = 0.52$, $p > .1$. From pretest to acquisition blocks, there was no significant main effect for group, $F = 1.58$, $p > .1$, time, $F = 2.25$, $p > .05$, or group x time interaction, $F = 0.40$, $p > .1$. In the early retention test there was no significant difference between the experimental
groups, \( F = 2.35, p > .05 \). In the late retention test, however, a significant difference was observed between the experimental groups, \( F = 5.64, p < .01, \ \epsilon_{par}^2 = .42 \). In this case, post-hoc test showed no significant differences between groups. Figure 5.22 illustrates the difference between the participants’ coordination patterns (NoRM-D) from the model.
Figure 5.21. Knee-ankle intra-limb coordination for arm cocking phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.
Phase 4: Arm acceleration

The angle-angle plots of knee-ankle coordination in arm acceleration phase show that coordination pattern of the participants differs in all experimental groups from that of the model. Moreover, the deviation become smaller with increasing practice (see Figure 5.23).

The statistical analysis for knee-ankle coordination in arm acceleration phase showed no significant difference between the experimental groups in pretest, $F = 2.80, p > .05$. In acquisition phase, there was no significant main effect for group, $F = 2.30, p > .05$, block, $F = 2.18, p > .1$, or group x block interaction, $F = 1.66, p > .1$. A significant main effect was observed for time, $F = 3.72, p < .05$, $\varepsilon_{par}^2 = .13$, but not for group, $F = 2.77, p > .05$, or group x time interaction, $F = 0.82, p > .1$, from pretest to acquisition blocks. In the early and late retention tests there was a significant difference between the experimental groups, $F = 3.02, p < .05$, $\varepsilon_{par}^2 = .27$, and $F = 3.03, p < .05$, $\varepsilon_{par}^2 = .28$, respectively. In this case, post-hoc test
showed no significant differences between groups. Figure 5.24 illustrates the difference between the participants’ coordination patterns (NoRM-D) from the model.

Figure 5.23. Knee-ankle intra-limb coordination for arm acceleration phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.
Phase 5: Arm deceleration

The angle-angle plots of knee-ankle coordination in arm deceleration phase illustrate that coordination pattern of the participants differs in all experimental groups from that of the model. Moreover, the deviation does not become smaller with increasing practice (see Figure 5.25).

The statistical analysis for knee-ankle coordination in arm deceleration phase showed no significant difference between the experimental groups in pretest, $F = 1.59$, $p > .1$. In acquisition phase, there was no significant main effect for group, $F = 1.93$, $p > .1$, block, $F = 1.58$, $p > .1$, or group x block interaction, $F = 1.00$, $p > .1$. No significant main effect was observed for group, $F = 1.90$, $p > .1$, time, $F = 2.58$, $p > .05$, or group x time interaction, $F = 0.55$, $p > .1$, from pretest to acquisition blocks. In the early and late retention tests there was no significant difference between the experimental groups, $F = 1.56$, $p > .1$, and $F = 1.81$, $p > .1$, respectively.
respectively. Figure 5.26 illustrates the difference between the participants’ co-ordination patterns (NoRM-D) from the model.

Figure 5.25. Knee-ankle intra-limb coordination for arm deceleration phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.
Phase 6: Follow-through

The angle-angle plots of knee-ankle coordination in follow-through phase illustrate that coordination pattern of the participants differs in all experimental groups from that of the model. Moreover, the deviation does not become smaller with increasing practice (see Figure 5.27).

The statistical analysis for knee-ankle coordination in follow-through phase showed no significant difference between the experimental groups in pretest, $F = 1.55$, $p > .1$. In acquisition phase, there was no significant main effect for group, $F = 1.44$, $p > .1$, block, $F = 0.30$, $p > .1$, or group x block interaction, $F = 1.70$, $p > .1$. No significant main effect was observed for group, $F = 1.53$, $p > .1$, time, $F = 1.58$, $p > .1$, or group x time interaction, $F = 1.15$, $p > .1$. In the early and late retention tests there was no significant difference between the experimental groups, $F = 0.87$, $p > .1$, and $F = 1.19$, $p > .1$, respectively. Figure 5.28 illustrates the difference between the participants’ coordination patterns (NoRM-D) from the model.
Figure 5.27. Knee-ankle intra-limb coordination for follow-through phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.
Summary

The results of knee-ankle intra-limb coordination showed no significant differences between groups in pretest, acquisition blocks, and retention tests in terms of overall movement. In addition, there was an improvement from pretest to acquisition phase in terms of overall movement. In terms of NoRM-D values of overall movement, it is clear from Figures 5.2 and 5.16 that the values of knee-ankle coordination are higher than the values of shoulder-elbow coordination. Results of pitch phases revealed the participants improved their performances in stride and arm acceleration phases from pretest to acquisition blocks. In late retention test, the participants in stick-figure group showed worse performances than those in video and point-light groups in arm cocking phase. The mean and standard deviation of NoRM-D values of shoulder-elbow intra-limb coordination are summarized in Table 2. From Table 5.2 it is clear that NoRM-D values of stride phase is much higher than other phases of pitch.
5.1.3 Elbow-knee intra-limb coordination

The descriptive data of the elbow-knee inter-limb coordination for overall movement and movement phases are presented in Table 5.3.

Table 5.3. Mean and standard deviation of NoRM-D scores of elbow-knee inter-limb coordination for overall movement and movement phases

<table>
<thead>
<tr>
<th>Phase</th>
<th>Group</th>
<th>Pretest</th>
<th>Block 1</th>
<th>Block 2</th>
<th>Block 3</th>
<th>Early Ret</th>
<th>Late Ret</th>
</tr>
</thead>
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<td>43.74</td>
<td>43.44</td>
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<td>43.95</td>
</tr>
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<td>CO</td>
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<td>44.66</td>
<td>43.45</td>
<td>44.42</td>
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</tr>
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<td>43.57</td>
<td>44.48</td>
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<td>44.69</td>
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<tr>
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<td>49.84</td>
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<td>50.16</td>
<td>52.65</td>
<td>53.71</td>
</tr>
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<td>Arm cocking</td>
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<td>25.31</td>
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</tr>
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<td>Follow-through</td>
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<td>31.96</td>
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</tr>
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<td>35.31</td>
<td>35.57</td>
<td>36.11</td>
<td>37.06</td>
</tr>
</tbody>
</table>

Overall movement

The angle-angle plots in Figure 5.29 show that the model begins the pitch action with an elbow angle of about 60° and an knee angle of approximately 180°; at end of movement the elbow angle is about 140° and knee is about 130°. The participants showed almost a similar angular positions at start and end points, but
not during the movement. For example, the participants in video group, have started their movement in the pretest in average with an elbow angle of approximately 70° and a knee angle of almost 160° and ended at about 120° and about 130°.
Figure 5.29. Inter-limb coordination between the throwing arm and the striding leg: relative change of the elbow and knee angles of the model and the participants in the four experimental groups across the pretest, the acquisition phase and the early and late retention tests.
The angle-angle plots in Figure 5.29 illustrate the following:

- Elbow-knee inter-limb coordination of the participants differs in all experimental groups very clearly from that of the model.
- This deviation becomes smaller with increasing practice, i.e., elbow-knee inter-limb coordination of the participants approach in all experimental groups to the elbow-knee inter-limb coordination of the model. This is both visually (angle-angle plots) and numerically (NoRM-D scores tend to become smaller) recognizable.
- Elbow-knee inter-limb coordination of the participants look different depending on the experimental group; video and control groups tend to show similar coordination to the model rather stick-figure and point-light groups.

The statistical analysis for elbow-knee inter-limb coordination came to the following results: In the pretest, there was no significant difference between the experimental groups, \( F = 2.22, \ p > .1 \). In acquisition phase, there was no significant main effect for group, \( F = 1.18, \ p > .1 \), block, \( F = 1.56, \ p > .1 \), or group x block interaction, \( F = 1.31, \ p > .1 \). The participants approached their elbow-knee coordination to the model from the pretest to the acquisition blocks, as proved by a significant main effect for time, \( F = 7.37, \ p < .001, \ \varepsilon_{par}^2 = .24 \). In the early and late retention tests, then, again no significant difference between the experimental groups was observed, \( F = 1.67, \ p > .1 \), and \( F = 0.80, \ p > .1 \), respectively. Figure 5.30 represents the deviations of the experimental groups (NoRM-D) from the coordination pattern of the model.
**Phase 1: Wind-up**

The angle-angle plots of elbow-knee coordination in wind-up phase illustrate that coordination pattern of the participants differs in all experimental groups from that of the model. Moreover, the deviation does not become smaller with increasing practice (see Figure 5.31).

The statistical analysis for elbow-knee coordination in wind-up phase showed no significant difference between the experimental groups in pretest, $F = 1.66$, $p > .1$. In acquisition phase, there was no significant main effect for group, $F = 0.52$, $p > .1$, block, $F = 0.69$, $p > .1$, or group x block interaction, $F = 1.40$, $p > .1$. No significant main effect was observed for group, $F = 1.05$, $p > .1$, time, $F = 1.22$, $p > .1$, or group x time interaction, $F = 0.99$, $p > .1$, from pretest to acquisition blocks. In the early and late retention tests there also was no significant difference between the experimental groups, $F = 1.30$, $p > .1$, and $F = 0.64$, $p > .1$, respectively. Figure 5.32 illustrates the difference between the participants’ coordination patterns (NoRM-D) from the model.
Figure 5.31. Elbow-knee inter-limb coordination for wind-up phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.
Figure 5.32. Means of NoRM-D scores of elbow-knee inter-limb coordination for wind-up phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.

**Phase 2: Stride**

The angle-angle plots of elbow-knee coordination in stride phase illustrate that coordination pattern of the participants differs in all experimental groups from that of the model. However, the deviation becomes smaller with increasing practice (see Figure 5.33).

The statistical analysis for elbow-knee coordination in stride phase showed no significant difference between the experimental groups in pretest, $F = 2.14, p > .1$. In acquisition phase, there was no significant main effect for group, $F = 1.48, p > .1$, block, $F = 1.64, p > .1$, or group x block interaction, $F = 0.85, p > .1$. A significant main effect was observed for time, $F = 9.26, p < .001, \varepsilon_{par^2} = .24$, but not for group, $F = 2.36 p > .05$, or group x time interaction, $F = 0.68, p > .1$, from pretest to acquisition blocks. In the early and late retention tests, there was no significant difference between the experimental groups, $F = 1.38, p > .1$, and $F =$
0.85, \( p > .1 \), respectively. Figure 5.34 illustrates the difference between the participants’ coordination patterns (NoRM-D) from the model.

Figure 5.33. Elbow-knee inter-limb coordination for stride phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.
Phase 3: Arm cocking

The angle-angle plots of elbow-knee coordination in arm cocking phase illustrate that coordination pattern of the participants differs in all experimental groups from that of the model. Moreover, the deviation does not become smaller with increasing practice (see Figure 5.35).

The statistical analysis for elbow-knee coordination in arm cocking phase showed no significant difference between the experimental groups in pretest, $F = 0.68, p > .1$. In acquisition phase, there was no significant main effect for group, $F = 0.38, p > .1$, block, $F = 0.75, p > .1$, or group x block interaction, $F = 1.29, p > .1$. No significant main effect was observed for group, $F = 0.57, p > .1$, time, $F = 0.15, p > .1$, or group x time interaction, $F = 0.44, p > .1$, from pretest to acquisition blocks. In the early and late retention tests there also was no significant difference between the experimental groups, $F = 1.14, p > .1$, and $F = 2.91, p > .05$, respectively. Figure 5.36 illustrates the difference between the participants’ coordination patterns (NoRM-D) from the model.
Figure 5.35. Elbow-knee inter-limb coordination for arm cocking phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.
Phase 4: Arm acceleration

The angle-angle plots of elbow-knee coordination in arm acceleration phase illustrate that coordination pattern of the participants differs in all experimental groups from that of the model. Moreover, the deviation does not become smaller with increasing practice (see Figure 5.37).

The statistical analysis for elbow-knee coordination in arm acceleration phase showed a significant difference between the experimental groups in pretest, $F = 4.17, p < .05, \varepsilon_{par}^2 = .35$. In this case, post-hoc test showed no significant differences between groups. In acquisition phase, there was a significant main effect for group, $F = 3.95, p < .05, \varepsilon_{par}^2 = .33$, and group x block interaction, $F = 3.13, p < .05, \varepsilon_{par}^2 = .28$, but not for block, $F = 1.54, p < .1$. Post hoc test revealed that stick-figure group performed significantly worse than control group in acquisition phase, $p < .05$. A significant main effect was observed for group, $F = 4.47, p < .05, \varepsilon_{par}^2 = .36$, but not for time, $F = 2.21, p > .05$, or group x time interaction, $F =
1.68, \( p > .05 \), from pretest to acquisition blocks. Here, stick-figure group performed, again, significantly worse than control group, \( p < .05 \). In the early and late retention tests there also was a significant difference between the experimental groups, \( F = 4.00, \ p < .05, \ \eta^2_{\text{par}} = .33 \), and \( F = 4.01, \ p < .05, \ \eta^2_{\text{par}} = .34 \), respectively. Stick-figure group performed significantly worse than control group in early retention test and worse than video group in the late retention test, \( p < .05 \). Figure 5.38 illustrates the difference between the participants’ coordination patterns (NoRM-D) from the model.
Figure 5.37. Elbow-knee inter-limb coordination for arm acceleration phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.
Figure 5.38. Means of NoRM-D scores of elbow-knee inter-limb coordination for arm acceleration phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.

Phase 5: Arm deceleration

The angle-angle plots of elbow-knee coordination in arm deceleration phase illustrate that coordination pattern of the participants differs in all experimental groups from that of the model. Moreover, the deviation does not become smaller with increasing practice (see Figure 5.39).

The statistical analysis for elbow-knee coordination in arm deceleration phase showed no significant difference between the experimental groups in pretest, $F = 2.51, p > .1$. In acquisition phase, there was a significant main effect for group, $F = 3.01, p < .05$, $\varepsilon_{par}^2 = .27$, but not for block, $F = 1.63, p > .1$, or group x block interaction, $F = 0.98, p > .1$. No significant main effect was observed for group, $F = 2.59, p > .05$, time, $F = 1.45, p > .1$, or group x time interaction, $F = 0.53, p > .1$. In the early and late retention tests there was no significant difference between the experimental groups, $F = 2.74, p > .05$, and $F = 3.33, p > .05$, respectively.
Figure 5.40 illustrates the difference between the participants’ coordination patterns (NoRM-D) from the model.

Figure 5.39. Elbow-knee inter-limb coordination for arm deceleration phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.
Phase 6: Follow-through

The angle-angle plots of elbow-knee coordination in follow-through phase illustrate that coordination pattern of the participants differs in all experimental groups from that of the model. Moreover, the deviation does not become smaller with increasing practice (see Figure 5.41).

The statistical analysis for elbow-knee coordination in follow-through phase showed a significant difference between the experimental groups in pretest, $F = 3.14, p < .05, \eta^2_{par} = .29$. In this case, post-hoc test showed no significant differences between groups. In acquisition phase, there was no significant main effect for group, $F = 2.73, p > .05$, block, $F = 0.49, p > .1$, or group x block interaction, $F = 0.96, p > .1$. No significant main effect was observed for group, $F = 2.46, p > .05$, time, $F = 1.72, p > .1$, or group x time interaction, $F = 1.09, p > .1$. In the early and late retention tests there was no significant difference between the experimental group, $F = 1.53, p > .1$, and $F = 2.28, p > .05$, respectively. Figure 5.42
illustrates the difference between the participants’ coordination patterns (NoRM-D) from the model.

Figure 5.41. Elbow-knee inter-limb coordination for follow-through phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.
Summary

The results of elbow-knee inter-limb coordination showed that there were no significant differences between groups in pretest, acquisition blocks, or retention tests in terms of overall movement. In addition, the participants improved their performances from pretest to acquisition phase in terms of overall movement. In terms of NoRM-D values of overall movement, it is clear from Figures 5.2, 5.16, and 5.30 that the values of elbow-knee coordination are higher than the values of shoulder-elbow coordination and the values of knee-ankle coordination. Results of pitch phases showed an improvement in stride phase from pretest to acquisition blocks. Moreover, participant in the stick-figure group performed significantly worse than participant in control group, in acquisition phase and early retention test. The mean and standard deviation of NoRM-D values of shoulder-elbow intra-limb coordination are summarized in Table 5.3. From Table 5.3 it is clear that NoRM-D values of stride phase is much higher than other phases of pitch.
5.2 Movement form

The descriptive data of the movement form scores for overall movement and movement phases are presented in Table 5.4.

Table 5.4. Means and standard deviations of movement form scores for overall movement and movement phases

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<thead>
<tr>
<th>Phase</th>
<th>Group</th>
<th>Pretest</th>
<th>Block 1</th>
<th>Block 2</th>
<th>Block 3</th>
<th>Early Ret</th>
<th>Late Ret</th>
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<td>9.53 (1.31)</td>
<td>10.22 (1.35)</td>
<td>10.07 (1.22)</td>
<td>9.90 (0.97)</td>
<td>9.80 (1.18)</td>
</tr>
<tr>
<td></td>
<td>CO</td>
<td>10.51 (1.43)</td>
<td>10.45 (1.37)</td>
<td>10.66 (1.27)</td>
<td>10.33 (1.49)</td>
<td>9.90 (2.10)</td>
<td>9.95 (1.38)</td>
</tr>
<tr>
<td>Stride</td>
<td>VI</td>
<td>6.42 (0.60)</td>
<td>6.42 (0.96)</td>
<td>6.33 (1.29)</td>
<td>6.90 (0.99)</td>
<td>6.31 (0.97)</td>
<td>6.73 (0.65)</td>
</tr>
<tr>
<td>(3 items)</td>
<td>SF</td>
<td>4.89 (1.40)</td>
<td>5.55 (1.39)</td>
<td>5.72 (1.63)</td>
<td>5.75 (1.44)</td>
<td>5.85 (1.33)</td>
<td>5.51 (1.32)</td>
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<tr>
<td></td>
<td>PL</td>
<td>6.03 (0.96)</td>
<td>6.14 (1.17)</td>
<td>6.50 (0.80)</td>
<td>6.55 (0.89)</td>
<td>6.50 (0.63)</td>
<td>6.52 (0.65)</td>
</tr>
<tr>
<td></td>
<td>CO</td>
<td>6.54 (0.97)</td>
<td>7.10 (1.23)</td>
<td>7.20 (0.83)</td>
<td>7.25 (0.90)</td>
<td>6.40 (1.82)</td>
<td>6.89 (1.05)</td>
</tr>
<tr>
<td>Arm cocking</td>
<td>VI</td>
<td>7.38 (1.12)</td>
<td>7.42 (0.96)</td>
<td>7.57 (1.04)</td>
<td>8.11 (0.84)</td>
<td>7.23 (0.80)</td>
<td>7.84 (0.96)</td>
</tr>
<tr>
<td>(3 items)</td>
<td>SF</td>
<td>5.60 (1.91)</td>
<td>6.33 (1.24)</td>
<td>6.50 (1.41)</td>
<td>6.33 (1.28)</td>
<td>6.31 (1.65)</td>
<td>5.76 (1.53)</td>
</tr>
<tr>
<td></td>
<td>PL</td>
<td>7.54 (1.24)</td>
<td>7.90 (0.90)</td>
<td>7.59 (1.12)</td>
<td>7.61 (1.08)</td>
<td>7.52 (0.82)</td>
<td>7.75 (0.60)</td>
</tr>
<tr>
<td></td>
<td>CO</td>
<td>7.91 (0.96)</td>
<td>7.79 (1.05)</td>
<td>7.95 (0.84)</td>
<td>7.58 (1.31)</td>
<td>7.34 (1.54)</td>
<td>7.16 (1.51)</td>
</tr>
<tr>
<td>Arm acceleration</td>
<td>VI</td>
<td>9.32 (1.37)</td>
<td>9.16 (0.54)</td>
<td>9.48 (1.19)</td>
<td>9.50 (0.97)</td>
<td>9.00 (0.97)</td>
<td>8.80 (1.15)</td>
</tr>
<tr>
<td>(4 items)</td>
<td>SF</td>
<td>7.13 (2.86)</td>
<td>7.62 (2.51)</td>
<td>7.77 (2.50)</td>
<td>7.50 (2.18)</td>
<td>7.67 (1.89)</td>
<td>7.53 (2.22)</td>
</tr>
<tr>
<td></td>
<td>PL</td>
<td>8.90 (1.97)</td>
<td>8.70 (1.77)</td>
<td>8.50 (1.74)</td>
<td>8.25 (2.01)</td>
<td>8.16 (1.55)</td>
<td>8.78 (0.85)</td>
</tr>
<tr>
<td></td>
<td>CO</td>
<td>8.95 (1.13)</td>
<td>9.45 (1.34)</td>
<td>8.83 (1.30)</td>
<td>9.33 (1.39)</td>
<td>9.18 (2.00)</td>
<td>8.51 (1.52)</td>
</tr>
<tr>
<td>Arm deceleration</td>
<td>VI</td>
<td>3.76 (0.70)</td>
<td>4.12 (1.09)</td>
<td>4.25 (1.30)</td>
<td>4.18 (0.74)</td>
<td>4.24 (0.74)</td>
<td>4.31 (0.46)</td>
</tr>
<tr>
<td>(2 items)</td>
<td>SF</td>
<td>2.33 (1.70)</td>
<td>2.77 (1.66)</td>
<td>3.20 (1.20)</td>
<td>2.92 (1.72)</td>
<td>3.08 (1.50)</td>
<td>2.63 (1.39)</td>
</tr>
<tr>
<td></td>
<td>PL</td>
<td>3.30 (1.12)</td>
<td>3.70 (1.26)</td>
<td>3.62 (1.28)</td>
<td>3.42 (1.92)</td>
<td>3.61 (1.35)</td>
<td>3.46 (0.95)</td>
</tr>
<tr>
<td></td>
<td>CO</td>
<td>3.60 (1.16)</td>
<td>3.27 (1.58)</td>
<td>3.37 (1.54)</td>
<td>3.75 (1.41)</td>
<td>3.64 (1.52)</td>
<td>3.63 (1.62)</td>
</tr>
<tr>
<td>Follow-through</td>
<td>VI</td>
<td>3.82 (1.53)</td>
<td>5.20 (1.72)</td>
<td>5.51 (1.55)</td>
<td>4.75 (1.46)</td>
<td>5.88 (1.23)</td>
<td>5.26 (1.48)</td>
</tr>
<tr>
<td>(3 items)</td>
<td>SF</td>
<td>3.37 (1.93)</td>
<td>3.55 (1.61)</td>
<td>4.09 (1.63)</td>
<td>4.24 (2.11)</td>
<td>4.02 (1.84)</td>
<td>3.56 (1.74)</td>
</tr>
<tr>
<td></td>
<td>PL</td>
<td>3.62 (1.50)</td>
<td>4.01 (1.56)</td>
<td>4.31 (1.36)</td>
<td>4.70 (2.20)</td>
<td>4.16 (1.84)</td>
<td>3.91 (1.63)</td>
</tr>
<tr>
<td></td>
<td>CO</td>
<td>4.38 (1.67)</td>
<td>4.68 (1.89)</td>
<td>4.45 (1.87)</td>
<td>5.29 (1.79)</td>
<td>4.96 (1.90)</td>
<td>4.97 (2.25)</td>
</tr>
<tr>
<td>Overall evaluation</td>
<td>VI</td>
<td>3.01 (0.69)</td>
<td>3.25 (0.95)</td>
<td>3.33 (0.72)</td>
<td>3.42 (0.78)</td>
<td>3.47 (0.85)</td>
<td>3.37 (0.69)</td>
</tr>
<tr>
<td>(2 items)</td>
<td>SF</td>
<td>2.13 (1.01)</td>
<td>2.40 (0.96)</td>
<td>2.81 (1.06)</td>
<td>3.01 (1.21)</td>
<td>2.90 (0.96)</td>
<td>2.41 (1.14)</td>
</tr>
<tr>
<td></td>
<td>PL</td>
<td>3.08 (0.71)</td>
<td>3.25 (0.95)</td>
<td>3.40 (0.85)</td>
<td>3.61 (0.93)</td>
<td>3.35 (0.60)</td>
<td>3.16 (0.84)</td>
</tr>
<tr>
<td></td>
<td>CO</td>
<td>3.29 (0.95)</td>
<td>3.14 (0.87)</td>
<td>3.16 (0.79)</td>
<td>3.08 (0.95)</td>
<td>3.22 (0.85)</td>
<td>3.17 (1.10)</td>
</tr>
</tbody>
</table>
Test of objectivity

Two raters evaluated the video recording of the throws of the participants. The descriptive data of the raters’ scores for overall movement are presented in Table 5.5.

Table 5.5. The mean and standard deviation of the rating scores for two raters.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Min.</th>
<th>Max.</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rater A – Pretest</td>
<td>18.50</td>
<td>53.00</td>
<td>41.728</td>
<td>8.146</td>
</tr>
<tr>
<td>Rater A – Acquisition Block 1</td>
<td>28.00</td>
<td>53.00</td>
<td>43.217</td>
<td>7.361</td>
</tr>
<tr>
<td>Rater A – Acquisition Block 2</td>
<td>28.67</td>
<td>55.00</td>
<td>44.048</td>
<td>7.071</td>
</tr>
<tr>
<td>Rater A – Acquisition Block 3</td>
<td>28.00</td>
<td>57.00</td>
<td>44.464</td>
<td>7.599</td>
</tr>
<tr>
<td>Rater A – Early Retention</td>
<td>22.00</td>
<td>54.40</td>
<td>43.454</td>
<td>7.427</td>
</tr>
<tr>
<td>Rater A – Late Retention</td>
<td>26.40</td>
<td>54.40</td>
<td>43.092</td>
<td>7.235</td>
</tr>
<tr>
<td>Rater A – Overall Evaluation</td>
<td>173.73</td>
<td>317.87</td>
<td>257.524</td>
<td>40.352</td>
</tr>
<tr>
<td>Rater B – Pretest</td>
<td>25.60</td>
<td>61.00</td>
<td>53.371</td>
<td>7.705</td>
</tr>
<tr>
<td>Rater B – Acquisition Block 1</td>
<td>40.00</td>
<td>62.33</td>
<td>54.767</td>
<td>5.016</td>
</tr>
<tr>
<td>Rater B – Acquisition Block 2</td>
<td>48.33</td>
<td>62.00</td>
<td>56.133</td>
<td>4.071</td>
</tr>
<tr>
<td>Rater B – Acquisition Block 3</td>
<td>46.00</td>
<td>61.33</td>
<td>56.543</td>
<td>4.156</td>
</tr>
<tr>
<td>Rater B – Early Retention</td>
<td>43.00</td>
<td>62.50</td>
<td>56.007</td>
<td>4.450</td>
</tr>
<tr>
<td>Rater A – Late Retention</td>
<td>44.20</td>
<td>61.60</td>
<td>55.381</td>
<td>4.655</td>
</tr>
<tr>
<td>Rater B – Overall Evaluation</td>
<td>269.27</td>
<td>366.37</td>
<td>337.062</td>
<td>22.920</td>
</tr>
</tbody>
</table>

Normal distribution

Normal distribution is a prerequisite for Pearson correlation test. The results of Kolmogorov-Smirnov test showed that all variables are normally distributed (Table 5.6).
Table 5.6. Results of the Kolmogorov-Smirnov-test for the rating scores of rater A and B

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
<th>Test value</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rater A – Pretest</td>
<td>41.728</td>
<td>8.15</td>
<td>1.157</td>
<td>.137</td>
</tr>
<tr>
<td>Rater A – Acquisition Block 1</td>
<td>43.217</td>
<td>7.36</td>
<td>.597</td>
<td>.869</td>
</tr>
<tr>
<td>Rater A – Acquisition Block 2</td>
<td>44.048</td>
<td>7.07</td>
<td>1.211</td>
<td>.106</td>
</tr>
<tr>
<td>Rater A – Acquisition Block 3</td>
<td>44.464</td>
<td>7.60</td>
<td>1.075</td>
<td>.198</td>
</tr>
<tr>
<td>Rater A – Early Retention</td>
<td>43.454</td>
<td>7.43</td>
<td>.810</td>
<td>.527</td>
</tr>
<tr>
<td>Rater A – Late Retention</td>
<td>43.092</td>
<td>7.24</td>
<td>.649</td>
<td>.794</td>
</tr>
<tr>
<td>Rater A – Overall Evaluation</td>
<td>257.524</td>
<td>40.35</td>
<td>.770</td>
<td>.594</td>
</tr>
<tr>
<td>Rater B – Pretest</td>
<td>53.371</td>
<td>7.71</td>
<td>1.355</td>
<td>.051</td>
</tr>
<tr>
<td>Rater B – Acquisition Block 1</td>
<td>54.767</td>
<td>5.02</td>
<td>.489</td>
<td>.971</td>
</tr>
<tr>
<td>Rater B – Acquisition Block 2</td>
<td>56.133</td>
<td>4.07</td>
<td>.838</td>
<td>.484</td>
</tr>
<tr>
<td>Rater B – Acquisition Block 3</td>
<td>56.543</td>
<td>4.16</td>
<td>1.058</td>
<td>.213</td>
</tr>
<tr>
<td>Rater B – Early Retention</td>
<td>56.007</td>
<td>4.45</td>
<td>.942</td>
<td>.337</td>
</tr>
<tr>
<td>Rater A – Late Retention</td>
<td>55.381</td>
<td>4.66</td>
<td>1.264</td>
<td>.082</td>
</tr>
<tr>
<td>Rater B – Overall Evaluation</td>
<td>337.062</td>
<td>22.92</td>
<td>.858</td>
<td>.453</td>
</tr>
</tbody>
</table>

*Pearson correlations*

The Pearson correlation tests the direction of two variables (the bigger one variable, the bigger the other variable). The results of Pearson correlations of rater A and B are summarized in Table 5.7. The results showed that all correlation values are good to very good. Most of them are over .80.

Table 5.7. The results of Pearson correlations between two raters

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pearson correlation</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>.863</td>
<td>.000</td>
</tr>
<tr>
<td>Acquisition Block 1</td>
<td>.667</td>
<td>.000</td>
</tr>
<tr>
<td>Acquisition Block 2</td>
<td>.833</td>
<td>.000</td>
</tr>
<tr>
<td>Acquisition Block 3</td>
<td>.840</td>
<td>.000</td>
</tr>
<tr>
<td>Early Retention</td>
<td>.788</td>
<td>.000</td>
</tr>
<tr>
<td>Late Retention</td>
<td>.830</td>
<td>.000</td>
</tr>
<tr>
<td>Overall Evaluation</td>
<td>.873</td>
<td>.000</td>
</tr>
</tbody>
</table>
**Intra-class correlation coefficient**

The intra-class coefficient checks the average level of two variables. The results indicated that the values for intra-class correlation between two raters are very bad. The reason is that the expert B has given more points on average than the expert A. The results of intra-class correlation coefficient are summarized in Table 5.8.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Intra-class correlation</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>.177</td>
<td>.160</td>
</tr>
<tr>
<td>Acquisition Block 1</td>
<td>-.140</td>
<td>.775</td>
</tr>
<tr>
<td>Acquisition Block 2</td>
<td>-.189</td>
<td>.847</td>
</tr>
<tr>
<td>Acquisition Block 3</td>
<td>-.107</td>
<td>.721</td>
</tr>
<tr>
<td>Early Retention</td>
<td>-.171</td>
<td>.834</td>
</tr>
<tr>
<td>Late Retention</td>
<td>-.426</td>
<td>.738</td>
</tr>
<tr>
<td>Overall Evaluation</td>
<td>-.568</td>
<td>.849</td>
</tr>
</tbody>
</table>

For later statistical analysis of movement form, the rating scores of Rater A has been considered.
**Overall Movement**

The statistical analysis of movement form scores showed a significant difference between the experimental groups in pretest, $F = 3.85, p < .05, \varphi_{par}^2 = .27$. Stick-figure group performed significantly worse than control group in pretest, $p \leq .05$. In acquisition phase, there was no significant main effect for group, $F = 2.24, p > .1$, block, $F = 1.58, p > .1$, or group x block interaction, $F = 0.19, p > .1$. A significant main effect was observed for time, $F = 5.54, p < .01, \varphi_{par}^2 = .17$, but not for group, $F = 2.80, p > .05$, or group x time interaction, $F = 0.42, p > .1$, from pretest to acquisition blocks. In the early retention test there was no significant difference between the experimental groups, $F = 1.61, p > .1$. However, in the late retention test there was a significant difference between the experimental groups, $F = 3.43, p < .05, \varphi_{par}^2 = .25$. In late retention test, video group performed significantly better than stick-figure group, $p < .05$ (see Figure 5.43).

![Figure 5.43. Means of movement form scores for the experimental groups across pretest, acquisition blocks and retentions tests.](image-url)
**Phase 1: Wind-up**

The statistical analysis of movement form scores in wind-up phase showed no significant difference between the experimental groups in pretest, $F = 1.36, p > .1$. In acquisition phase, there was no significant main effect for group, $F = 0.46, p > .1$, block, $F = 2.55, p > .05$, or group x block interaction, $F = 0.78, p > .1$. No significant main effect was observed for group, $F = 0.69, p > .1$, time, $F = 1.71, p > .1$, or group x time interaction, $F = 0.75, p > .1$. In the early and late retention tests there was no significant difference between the experimental groups, $F = 0.04, p > .1$, and $F = 0.52, p > .1$, respectively (see Figure 5.44).

![Figure 5.44](image-url)

Figure 5.44. Means of movement form scores for wind-up phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.
Phase 2: Stride

The statistical analysis of movement form scores in stride phase showed a significant difference between the experimental groups in pretest, $F = 5.43$, $p < .01$, $\eta^2_{par} = .35$. In pretest, stick-figure group showed significantly worse performance than video and control groups, $p < .05$. In acquisition phase, there was no significant main effect for group, $F = 2.92$, $p > .05$, block, $F = 2.30$, $p > .1$, or group $\times$ block interaction, $F = 0.59$, $p > .1$. A significant main effect was observed for group $F = 3.99$, $p < .05$, $\eta^2_{par} = .30$, and time, $F = 5.12$, $p < .01$, $\eta^2_{par} = .16$, but no group $\times$ time interaction, $F = 0.83$, $p > .1$, from pretest to acquisition blocks. Control group performed significantly better than stick-figure group from pretest to acquisition blocks, $p < .05$. In the early retention test, there was no significant difference between the experimental groups, $F = 0.55$, $p > .1$. In the late retention test, however, there was a significant difference between the experimental groups $F = 4.45$, $p < .05$, $\eta^2_{par} = .30$ (see Figure 5.45). Stick-figure group showed a significantly worse performance than control group, $p < .05$.

![Figure 5.45. Means of movement form scores for stride phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.](image-url)
Phase 3: Arm cocking

The statistical analysis of movement form scores in arm cocking phase showed a significant difference between the experimental groups in pretest, $F = 5.52, p < .01$, $\varepsilon_{par}^2 = .35$. Stick-figure group performed significantly worse than point-light and control groups, $p < .05$. In acquisition phase, there was a significant main effect for group, $F = 3.74, p < .05$, $\varepsilon_{par}^2 = .29$, but not for block, $F = 0.03, p > .1$, or group x block interaction, $F = 1.37, p > .1$. A significant main effect was observed for group, $F = 4.61, p < .01$, $\varepsilon_{par}^2 = .33$, but not for time, $F = 2.04, p > .1$, or group x time interaction, $F = 1.35, p > .1$, from pretest to acquisition blocks. Control group showed significantly better performance than stick-figure group, $p < .05$. In the early retention test, there was no significant difference between the experimental groups, $F = 1.70, p > .1$. In the late retention test, however, there was a significant difference between the experimental groups $F = 5.47, p < .01$, $\varepsilon_{par}^2 = .37$. Stick-figure group performed significantly worse than video and point-light groups, $p < .05$ (see Figure 5.46).

![Figure 5.46](image-url)

Figure 5.46. Means of movement form scores for arm cocking phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.
**Phase 4: Arm acceleration**

The statistical analysis of movement form scores in arm acceleration phase showed no significant difference between the experimental groups in pretest, $F = 2.50, p > .05$. In acquisition phase, there was no significant main effect for group, $F = 2.32, p > .05$, block, $F = 0.06, p > .1$, or group x block interaction, $F = 0.61, p > .1$. No significant main effect was observed for group, $F = 2.44, p > .05$, time, $F = 0.65, p > .1$, or group x time interaction, $F = 0.65, p > .1$, from pretest to acquisition blocks. In the early and late retention tests there was no significant difference between the experimental group, $F = 2.19, p > .1$, and $F = 1.56, p > .1$, respectively (see Figure 5.47).

![Figure 5.47](image-url)
**Phase 5: Arm deceleration**

The statistical analysis of movement form scores in arm deceleration phase showed no significant difference between the experimental groups in pretest, $F = 2.34, p > .05$. In acquisition phase, there was no significant main effect for group, $F = 1.32, p > .1$, block, $F = 0.20, p > .1$, or group x block interaction, $F = 0.37, p > .1$. No significant main effect was observed for group, $F = 1.59, p > .1$, time, $F = 1.66, p > .1$, or group x time interaction, $F = 0.51, p > .1$, from pretest to acquisition blocks. In the early retention test, there was no significant difference between the experimental group, $F = 1.36, p > .1$. In the late retention test, however, there was a significant difference between the experimental groups $F = 3.08, p < .05$, $\eta^2_{par} = .23$. Video group performed significantly better than stick-figure group in late retention test, $p < .05$ (see Figure 5.48).

![Graph showing movement form scores](image-url)

*Figure 5.48. Means of movement form scores for arm deceleration phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.*
Phase 6: Follow-through

The statistical analysis of movement form scores in follow-through phase showed no significant difference between the experimental groups in pretest, $F = 0.59$, $p > .1$. In acquisition phase, there was no significant main effect for group, $F = 1.02$, $p > .1$, block, $F = 1.12$, $p > .1$, or group x block interaction, $F = 1.10$, $p > .1$. A significant main effect was observed for time, $F = 4.41$, $p < .01$, $\eta_{par}^2 = .14$, but not for group, $F = 1.07$, $p > .1$, or group x time interaction, $F = 0.78$, $p > .1$, from pretest to acquisition blocks. In the early and late retention tests there also was no significant difference between the experimental groups, $F = 2.40$, $p > .05$, and $F = 2.07$, $p > .1$, respectively (see Figure 5.49).

![Graph showing movement form scores across pretest, acquisition blocks, and retention tests for different groups.](image)

Figure 5.49. Means of movement form scores for follow-through phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.
**Overall evaluation**

The statistical analysis of movement form scores in overall evaluation showed a significant difference between the experimental groups in pretest, $F = 3.39, p < .05$, $\eta_{par}^2 = .25$. In this case, post-hoc test showed no significant differences between groups. In acquisition phase, there was no significant main effect for group, $F = 1.19, p > .1$, block, $F = 2.66, p > .05$, or group x block interaction, $F = 0.83, p > .1$. A significant main effect was observed for time, $F = 6.93, p < .001$, $\eta_{par}^2 = .20$, but not for group, $F = 1.62, p > .1$, or group x time interaction, $F = 0.98, p > .1$. In the early and late retention tests there was no significant difference between the experimental group, $F = 0.87, p > .1$, and $F = 1.65, p > .1$, respectively (see Figure 5.50).

![Figure 5.50. Means of movement form scores for overall evaluation for the experimental groups across pretest, acquisition blocks and retentions tests.](image-url)
Summary

The results of movement form revealed that stick-figure group performed significantly worse than control group in pretest and worse than video group in late retention test in terms of overall movement. There were no significant differences between experimental groups in acquisition phase and early retention test in terms of overall movement. In addition, the participants improved their performances from pretest to acquisition phase in terms of overall movement. Results of pitch phases showed an improvement in stride and follow-through phases and overall evaluation from pretest to acquisition blocks. Moreover, participant in the stick-figure group performed significantly worse than participant in video and control group in arm cocking and arm deceleration phases in late retention test. The mean and standard deviation of movement form scores are summarized in Table 5.4. From Table 5.4 it is clear that movement form scores of overall movement are in the range of rather performed to completely performed (42-63). Moreover, in early phases of pitch the participants received better movement form scores (almost between rather performed to completely performed) than in later phases of pitch (almost between rather not performed to rather performed).
5.3 Movement time

The descriptive data of the movement time scores for overall movement and movement phases are presented in Table 5.9.

Table 5.9. Mean and standard deviation of absolute movement time difference for overall movement and movement phases

<table>
<thead>
<tr>
<th>Phase</th>
<th>Group</th>
<th>Pretest</th>
<th>Block 1</th>
<th>Block 2</th>
<th>Block 3</th>
<th>Early Ret</th>
<th>Late Ret</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall movement</td>
<td>VI</td>
<td>-0.66 (0.23)</td>
<td>-0.67 (0.15)</td>
<td>-0.71 (0.21)</td>
<td>-0.66 (0.16)</td>
<td>-0.65 (0.13)</td>
<td>-0.70 (0.17)</td>
</tr>
<tr>
<td></td>
<td>SF</td>
<td>-0.65 (0.29)</td>
<td>-0.77 (0.20)</td>
<td>-0.71 (0.29)</td>
<td>-0.63 (0.21)</td>
<td>-0.67 (0.21)</td>
<td>-0.61 (0.25)</td>
</tr>
<tr>
<td></td>
<td>PL</td>
<td>-0.73 (0.28)</td>
<td>-0.67 (0.25)</td>
<td>-0.68 (0.17)</td>
<td>-0.63 (0.17)</td>
<td>-0.63 (0.20)</td>
<td>-0.80 (0.27)</td>
</tr>
<tr>
<td></td>
<td>CO</td>
<td>-0.50 (0.54)</td>
<td>-0.42 (0.55)</td>
<td>-0.47 (0.57)</td>
<td>-0.40 (0.58)</td>
<td>-0.42 (0.57)</td>
<td>-0.45 (0.33)</td>
</tr>
<tr>
<td>Wind-up</td>
<td>VI</td>
<td>-0.34 (0.11)</td>
<td>-0.35 (0.06)</td>
<td>-0.37 (0.16)</td>
<td>-0.37 (0.09)</td>
<td>-0.36 (0.08)</td>
<td>-0.37 (0.13)</td>
</tr>
<tr>
<td></td>
<td>SF</td>
<td>-0.29 (0.17)</td>
<td>-0.38 (0.11)</td>
<td>-0.38 (0.12)</td>
<td>-0.35 (0.09)</td>
<td>-0.37 (0.12)</td>
<td>-0.33 (0.12)</td>
</tr>
<tr>
<td></td>
<td>PL</td>
<td>-0.34 (0.21)</td>
<td>-0.30 (0.18)</td>
<td>-0.29 (0.11)</td>
<td>-0.29 (0.12)</td>
<td>-0.28 (0.18)</td>
<td>-0.38 (0.14)</td>
</tr>
<tr>
<td></td>
<td>CO</td>
<td>-0.24 (0.25)</td>
<td>-0.20 (0.28)</td>
<td>-0.26 (0.24)</td>
<td>-0.20 (0.27)</td>
<td>-0.20 (0.25)</td>
<td>-0.23 (0.19)</td>
</tr>
<tr>
<td>Stride</td>
<td>VI</td>
<td>-0.33 (0.11)</td>
<td>-0.25 (0.10)</td>
<td>-0.25 (0.13)</td>
<td>-0.22 (0.16)</td>
<td>-0.23 (0.11)</td>
<td>-0.27 (0.09)</td>
</tr>
<tr>
<td></td>
<td>SF</td>
<td>-0.34 (0.11)</td>
<td>-0.38 (0.11)</td>
<td>-0.31 (0.12)</td>
<td>-0.27 (0.14)</td>
<td>-0.28 (0.12)</td>
<td>-0.35 (0.16)</td>
</tr>
<tr>
<td></td>
<td>PL</td>
<td>-0.18 (0.11)</td>
<td>-0.33 (0.12)</td>
<td>-0.33 (0.10)</td>
<td>-0.29 (0.09)</td>
<td>-0.31 (0.06)</td>
<td>-0.19 (0.12)</td>
</tr>
<tr>
<td></td>
<td>CO</td>
<td>-0.27 (0.25)</td>
<td>-0.18 (0.22)</td>
<td>-0.16 (0.28)</td>
<td>-0.16 (0.22)</td>
<td>-0.15 (0.25)</td>
<td>-0.27 (0.18)</td>
</tr>
<tr>
<td>Arm cocking</td>
<td>VI</td>
<td>-0.02 (0.03)</td>
<td>-0.06 (0.03)</td>
<td>-0.06 (0.03)</td>
<td>-0.05 (0.02)</td>
<td>-0.05 (0.04)</td>
<td>-0.02 (0.03)</td>
</tr>
<tr>
<td></td>
<td>SF</td>
<td>-0.03 (0.05)</td>
<td>-0.01 (0.05)</td>
<td>-0.03 (0.04)</td>
<td>-0.02 (0.05)</td>
<td>-0.01 (0.05)</td>
<td>-0.05 (0.03)</td>
</tr>
<tr>
<td></td>
<td>PL</td>
<td>-0.03 (0.03)</td>
<td>-0.03 (0.01)</td>
<td>-0.03 (0.02)</td>
<td>-0.04 (0.01)</td>
<td>-0.03 (0.02)</td>
<td>-0.02 (0.02)</td>
</tr>
<tr>
<td></td>
<td>CO</td>
<td>-0.05 (0.05)</td>
<td>-0.02 (0.04)</td>
<td>-0.02 (0.03)</td>
<td>-0.01 (0.05)</td>
<td>-0.02 (0.05)</td>
<td>-0.04 (0.05)</td>
</tr>
<tr>
<td>Arm acceleration</td>
<td>VI</td>
<td>-0.02 (0.01)</td>
<td>-0.03 (0.01)</td>
<td>-0.03 (0.01)</td>
<td>-0.03 (0.01)</td>
<td>-0.03 (0.01)</td>
<td>-0.01 (0.01)</td>
</tr>
<tr>
<td></td>
<td>SF</td>
<td>-0.02 (0.01)</td>
<td>-0.02 (0.01)</td>
<td>-0.02 (0.01)</td>
<td>-0.02 (0.01)</td>
<td>-0.02 (0.01)</td>
<td>-0.02 (0.02)</td>
</tr>
<tr>
<td></td>
<td>PL</td>
<td>-0.02 (0.01)</td>
<td>-0.02 (0.01)</td>
<td>-0.02 (0.01)</td>
<td>-0.02 (0.01)</td>
<td>-0.02 (0.01)</td>
<td>-0.02 (0.01)</td>
</tr>
<tr>
<td></td>
<td>CO</td>
<td>-0.03 (0.01)</td>
<td>-0.02 (0.01)</td>
<td>-0.02 (0.01)</td>
<td>-0.02 (0.01)</td>
<td>-0.02 (0.01)</td>
<td>-0.03 (0.01)</td>
</tr>
<tr>
<td>Arm deceleration</td>
<td>VI</td>
<td>0.00 (0.02)</td>
<td>-0.01 (0.01)</td>
<td>-0.01 (0.02)</td>
<td>-0.01 (0.01)</td>
<td>0.01 (0.03)</td>
<td>0.00 (0.01)</td>
</tr>
<tr>
<td></td>
<td>SF</td>
<td>-0.01 (0.02)</td>
<td>0.00 (0.02)</td>
<td>0.00 (0.02)</td>
<td>0.01 (0.02)</td>
<td>0.00 (0.01)</td>
<td>-0.01 (0.01)</td>
</tr>
<tr>
<td></td>
<td>PL</td>
<td>-0.02 (0.01)</td>
<td>0.00 (0.01)</td>
<td>-0.01 (0.01)</td>
<td>0.00 (0.01)</td>
<td>0.00 (0.01)</td>
<td>0.00 (0.01)</td>
</tr>
<tr>
<td></td>
<td>CO</td>
<td>-0.01 (0.01)</td>
<td>0.00 (0.02)</td>
<td>-0.01 (0.01)</td>
<td>-0.01 (0.01)</td>
<td>-0.01 (0.01)</td>
<td>-0.01 (0.02)</td>
</tr>
<tr>
<td>Follow-through</td>
<td>VI</td>
<td>0.01 (0.04)</td>
<td>0.01 (0.05)</td>
<td>0.00 (0.05)</td>
<td>0.01 (0.05)</td>
<td>0.01 (0.03)</td>
<td>0.02 (0.04)</td>
</tr>
<tr>
<td></td>
<td>SF</td>
<td>0.00 (0.06)</td>
<td>0.00 (0.06)</td>
<td>0.03 (0.07)</td>
<td>0.01 (0.03)</td>
<td>0.02 (0.04)</td>
<td>0.00 (0.03)</td>
</tr>
<tr>
<td></td>
<td>PL</td>
<td>-0.02 (0.02)</td>
<td>0.00 (0.04)</td>
<td>0.00 (0.03)</td>
<td>0.01 (0.05)</td>
<td>0.00 (0.04)</td>
<td>0.00 (0.06)</td>
</tr>
<tr>
<td></td>
<td>CO</td>
<td>0.03 (0.05)</td>
<td>0.01 (0.07)</td>
<td>-0.02 (0.05)</td>
<td>-0.01 (0.07)</td>
<td>0.00 (0.08)</td>
<td>0.01 (0.08)</td>
</tr>
</tbody>
</table>
**Overall movement**

The statistical analysis of absolute movement time difference showed no significant difference between the experimental groups in pretest, $F = 0.72$, $p > .1$. In acquisition phase, there was no significant main effect for group, $F = 1.58$, $p > .1$, block, $F = 2.59$, $p > .05$, or group x block interaction, $F = 0.73$, $p > .1$. No significant main effect was observed for group, $F = 1.30$, $p > .1$, time, $F = 1.62$, $p > .1$, or group x time interaction, $F = 0.84$, $p > .1$, from pretest to acquisition blocks. In the early retention test there was no significant difference between the experimental group, $F = 1.27$, $p > .1$. However, in the late retention test, there was a significant difference between the experimental groups, $F = 3.00$, $p < .05$, $\eta^2_{\text{par}} = .21$. Control group performed significantly better than point-light group in the late retention test, $p \leq .05$ (see Figure 5.51).

![Figure 5.51](image_url)

Figure 5.51. Means of absolute movement time difference for the experimental groups across pretest, acquisition blocks and retentions tests.
Phase 1: Wind-up

The statistical analysis of absolute movement time difference in wind-up phase showed no significant difference between the experimental groups in pretest, $F = 0.56$, $p > .1$. In acquisition phase, there was no significant main effect for group, $F = 1.88$, $p > .1$, block, $F = 1.20$, $p > .1$, or group x block interaction, $F = 0.52$, $p > .1$. From pretest to acquisition blocks, no significant main effect was observed for group, $F = 1.35$, $p > .1$, time, $F = 0.46$, $p > .1$, or group x time interaction, $F = 0.84$, $p > .1$. In the early and late retention tests there was no significant difference between the experimental groups, $F = 1.96$, $p > .1$, and $F = 2.03$, $p > .1$, respectively (see Figure 5.52).

![Figure 5.52. Means of absolute movement time difference for wind-up phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.](image-url)
**Phase 2: Stride**

The statistical analysis of absolute movement time difference in stride phase showed no significant difference between the experimental groups in pretest, $F = 2.12$, $p > .1$. In acquisition phase, there was a significant main effect for block, $F = 4.20$, $p < .05$, $\eta^2_{par} = .11$, but not for group, $F = 2.48$, $p > .05$, or group x block interaction, $F = 0.93$, $p > .1$. A significant main effect was observed for time, $F = 3.15$, $p < .05$, $\eta^2_{par} = .09$, but not for group, $F = 2.44$, $p > .05$, or group x time interaction, $F = 0.58$, $p > .1$. In the early and late retention tests there also was no significant difference between the experimental groups, $F = 1.79$, $p > .1$, and $F = 2.08$, $p > .1$, respectively (see Figure 5.53).

---

**Figure 5.53.** Means of absolute movement time difference for stride phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.
**Phase 3: Arm cocking**

The statistical analysis of absolute movement time difference in arm cocking phase showed no significant difference between the experimental groups in pretest, $F = 0.53$, $p > .1$. In acquisition phase, there was no significant main effect for group, $F = 2.33$, $p > .05$, block, $F = 0.34$, $p > .1$, or group x block interaction, $F = 2.14$, $p > .05$. No significant main effect was observed for group, $F = 1.58$, $p > .1$, time, $F = 0.10$, $p > .1$, or group x time interaction, $F = 1.53$, $p > .1$, from pretest to acquisition blocks. In the early and late retention tests there was no significant difference between the experimental groups, $F = 1.28$, $p > .1$, and $F = 1.32$, $p > .1$, respectively (see Figure 5.54).

![Figure 5.54](image)

Figure 5.54. Means of absolute movement time difference for arm cocking phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.
**Phase 4: Arm acceleration**

The statistical analysis of absolute movement time difference in arm acceleration phase showed no significant difference between the experimental groups in pre-test, $F = 0.67, p > .1$. In acquisition phase, there was no significant main effect for group, $F = 1.30, p > .1$, block, $F = 1.65, p > .1$, or group x block interaction, $F = 0.77, p > .1$. No significant main effect was observed for group, $F = 1.22 p > .1$, time, $F = 1.04, p > .1$, or group x time interaction, $F = 0.64, p > .1$, from pretest to acquisition blocks. In the early and late retention tests there also was no significant difference between the experimental groups, $F = 1.65, p > .1$, and $F = 1.23, p > .1$, respectively (see Figure 5.55).

![Figure 5.55. Means of absolute movement time difference for arm acceleration phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.](image)
**Phase 5: Arm deceleration**

The statistical analysis of absolute movement time difference in arm deceleration phase showed no significant difference between the experimental groups in pretest, $F = 1.52, p > .1$. In acquisition phase, there was no significant main effect for group, $F = 0.67, p > .1$, block, $F = 2.68, p > .05$, or group x block interaction, $F = 2.04, p > .05$. From pretest to acquisition blocks, no significant main effect was observed for group, $F = 0.62, p > .1$, time, $F = 1.87, p > .1$, or group x time interaction, $F = 1.69, p > .1$. In the early and late retention tests there also was no significant difference between the experimental groups, $F = 0.69, p > .1$, and $F = 0.52, p > .1$, respectively (see Figure 5.56).

![Figure 5.56. Means of absolute movement time difference for arm deceleration phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.](image-url)
**Phase 6: Follow-through**

The statistical analysis of absolute movement time difference in follow-through phase showed no significant difference between the experimental groups in pretest, $F = 1.62, p > .1$. In acquisition phase, there was no significant main effect for group, $F = 0.21, p > .1$, block, $F = 0.10, p > .1$, or group x block interaction, $F = 1.43, p > .1$. From pretest to acquisition blocks, no significant main effect was observed for group, $F = 0.36, p > .1$, and time, $F = 0.08, p > .1$, but group x time interaction was significant, $F = 2.09, p < .05, \epsilon_{par}^2 = .16$. In the early and late retention tests there also was no significant difference between the experimental groups, $F = 0.21, p > .1$, and $F = 0.19, p > .1$, respectively (see Figure 5.57).

![Figure 5.57](image)

Figure 5.57. Means of absolute movement time difference for follow-through phase of pitch for the experimental groups across pretest, acquisition blocks and retentions tests.
Summary

The results of shoulder-elbow intra-limb coordination revealed that there were no significant differences between groups in pretest, acquisition blocks, and early retention test, but control group performed significantly better than point-light group in late retention test, in terms of overall movement. Results of pitch phases showed an improvement in stride phase from pretest to acquisition blocks. The mean and standard deviation of absolute movement time difference are summarized in Table 5.9. From Table 5.9 it is clear that movement time values of wind-up and stride phases are much higher than other phases of pitch.

5.4 Summary of the results

The results of the present study have been presented in this chapter. The results of kinematic analysis (intra- and inter-limb coordination) revealed no significant differences between groups across pretest, acquisition phase, and retention tests in terms of overall movement. In addition, the participants improved their performances from pretest to acquisition phase in terms of overall movement in all three kinematic measurements. According to Figures 5.2, 5.16, and 5.30, the participants showed lower NoRM-D values for shoulder-elbow intra-limb coordination than knee-ankle intra-limb coordination and elbow-knee inter-limb coordination. The NoRM-D values of knee-ankle intra-limb coordination were lower than the values of elbow-knee inter-limb coordination. Results of kinematic analysis of pitch phases showed a common improvement in stride phase from pretest to acquisition blocks in all kinematic measurements. Moreover, stick-figure group showed worse performances than other groups in later phases of pitch such as arm acceleration and arm deceleration in late retention test.

The results of movement form revealed that although stick-figure group had worse performance than control group in pretest, but in acquisition phase and early retention test there were no significant differences between the groups in terms of overall movement. In late retention test, the stick-figure group showed again worse performances than video group. Moreover, the participants improved
their performances from pretest to acquisition blocks. The movement form scores revealed that the participants in all groups (an exception is stick-figure group) achieved relatively high movement form scores in terms of overall movement (rather-completed to completely-completed). Similar to kinematic analysis, the results of pitch phases showed an improvement from pretest to acquisition blocks in stride phase. There were also improvements from pretest to acquisition blocks in follow-through phase and overall evolution. The movement form scores of pitch phases showed that the participants in all group (but not stick-figure group) achieved relatively high scores (rather performed to completely performed) in early phases of pitch and medium scores (rather not performed to rather performed) in later phases of pitch.

The analysis of absolute movement time difference scores showed no significant differences between groups in pretest, acquisition blocks, and early retention test. However, control group performed better than point-light group in late retention test. The analysis of pitch phases revealed that the participants improved their timing scores in stride phase from pretest to acquisition blocks. Moreover, the main timing error scores were occurred in wind-up and stride phase of pitch.

To summarize, the participants have showed almost similar kinematic, movement form, and movement time performances in pretest, acquisition blocks, and retention tests. Stick-figure group generally showed higher values of deviation in almost all measured variables, however usually not in a significant extent. A summary of the results with emphasizing on differences between groups across the time of measurement is presented in Table 5.10. The participants improved their performances from pretest to acquisition blocks in stride phase of pitch in all measured variables.

Table 5.10. A summary of results of the study for all measured variables

<table>
<thead>
<tr>
<th></th>
<th>Pretest</th>
<th>Acquisition phase</th>
<th>Early retention</th>
<th>Late retention</th>
</tr>
</thead>
<tbody>
<tr>
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<td>No sig.</td>
<td>No sig.</td>
<td>No sig.</td>
</tr>
<tr>
<td>Knee-ankle</td>
<td>No sig.</td>
<td>No sig.</td>
<td>No sig.</td>
<td>No sig.</td>
</tr>
<tr>
<td>Movement form</td>
<td>Sig.</td>
<td>No sig.</td>
<td>No sig.</td>
<td>Sig.</td>
</tr>
<tr>
<td>Movement time</td>
<td>No sig.</td>
<td>No sig.</td>
<td>No sig.</td>
<td>Sig.</td>
</tr>
</tbody>
</table>
5.5 Test of statistical hypotheses

In this study two main hypothesis were considered. First hypothesis is as the following:

H 1  Model demonstrations, in which relative motion information is highlighted, lead to a better motor performance and learning in comparison to classic video model demonstrations.

Statistical hypotheses driven from H 1 are as the following:

H 1.1 Participants in point-light group perform significantly better than participants in video group in acquisition phase in terms of all dependent variables (intra- and inter-limb coordination, movement form, and movement time).

This hypothesis is rejected because statistical analysis has revealed no significant difference between the participants in point-light group and the participants in video group in acquisition phase in all dependent variables ($p < .05$).

H 1.2 Participants in point-light group perform significantly better than participants in video group in early retention test in terms of all dependent variables (intra- and inter-limb coordination, movement form, and movement time).

This hypothesis is rejected because statistical analysis has revealed no significant difference between the participants in point-light group and the participants in video group in early retention test in all dependent variables ($p < .05$).

H 1.3 Participants in point-light group perform significantly better than participants in video group in late retention test in terms of all dependent variables (intra- and inter-limb coordination, movement form, and movement time).
This hypothesis is rejected because statistical analysis has revealed no significant difference between the participants in point-light group and the participants in video group in late retention test in all dependent variables ($p < .05$).

H1.4 Participants in stick-figure group perform significantly better than participants in video group in acquisition phase in terms of all dependent variables (intra- and inter-limb coordination, movement form, and movement time).

This hypothesis is rejected because statistical analysis has revealed no significant difference between the participants in stick-figure group and the participants in video group in acquisition phase in all dependent variables ($p < .05$).

H1.5 Participants in stick-figure group perform significantly better than participants in video group in early retention test in terms of all dependent variables (intra- and inter-limb coordination, movement form, and movement time).

This hypothesis is rejected because statistical analysis has revealed no significant difference between the participants in stick-figure group and the participants in video group in early retention test in all dependent variables ($p < .05$).

H1.6 Participants in stick-figure group perform significantly better than participants in video group in late retention test in terms of all dependent variables (intra- and inter-limb coordination, movement form, and movement time).

This hypothesis is rejected because statistical analysis has revealed no significant difference between the participants in stick-figure group and the participants in video group in late retention test in all dependent variables ($p < .05$).
H 2  Model demonstration groups perform better than no-demonstration control group in acquisition phase and retention tests in all dependent variables.

Statistical hypotheses driven from H 2 are as the following:

H 2.1  Participants in model demonstration groups perform significantly better than participants in control group in acquisition phase in terms of all dependent variables (intra- and inter-limb coordination, movement form, and movement time).

This hypothesis is rejected because statistical analysis has revealed no significant difference between the participants in demonstration groups and the participants in control group in acquisition phase in all dependent variables ($p < .05$).

H 2.2  Participants in model demonstration groups perform significantly better than participants in control group in early retention test in terms of all dependent variables (intra- and inter-limb coordination, movement form, and movement time).

This hypothesis is rejected because statistical analysis has revealed no significant difference between the participants in demonstration groups and the participants in control group in early retention test in all dependent variables ($p < .05$).

H 2.3  Participants in model demonstration groups perform significantly better than participants in control group in late retention test in terms of all dependent variables (intra- and inter-limb coordination, movement form, and movement time).

This hypothesis is rejected because statistical analysis has revealed no significant difference between the participants in demonstration groups and the participants in control group in late retention test in all dependent variables ($p < .05$).
6 Discussion

The present study was designed to investigate the hypothesis of the Visual Perception Perspective (Scully and Newell, 1985). Scully and Newell proposed that the observers extract mainly relative motion information while watching a model demonstration and later use the information for reproduction of the observed action. Visual Perception Perspective assumed that highlighting the relative motion information within a model demonstration through generating point-light or stick-figure displays could lead to better motor performance and learning than presenting the observers with a classic video demonstration containing all the structural information.

In this study it was hypothesized that the participants who observed point-light or stick-figure model demonstration would perform better than those who observed a classic video model demonstration.

Generally, the results of kinematic analysis, movement form and movement time provided no support for this hypothesis, because there was no significant difference between demonstration groups in terms of intra- and inter-limb coordination patterns, movement form values, and absolute movement time difference of overall movement in the acquisition phase or the retention tests. In fact, the participants in the point-light and stick-figure groups did not perform better than those in the video group after observing the model demonstration (i.e., in the acquisition phase). Moreover, observing a point-light or stick-figure model demonstration did not result in better motor learning than a video model demonstration (i.e., in retention tests). In addition, some evidence revealed that highlighting relative motion information through stick-figure model demonstration led to even worse performance than video group in the late retention test in terms of overall movement. For example, the stick-figure group showed significantly lower movement form scores than the video group in the late retention test in terms of overall movement.

However, lack of significant differences between demonstration groups (at least between point-light and video) is generally in accordance with results of previous
studies (Breslin et al. 2005; Horn et al. 2005). For example, Horn et al. (2005) found no significant difference between video and point-light groups in the acquisition phase and the retention test in intra-limb coordination of lower-limb of a soccer chipping motor task. Moreover, Breslin et al. (2005) found no significant difference between the video and point-light groups in the acquisition phase and the retention test in terms of intra- and inter-limb coordination of upper- and lower-body by using a cricket bowling action. Other existing evidence shows that saliency of relative motion information within a display is not superior to classic demonstration (see Hodges et al. 2007, for more information).

The results of the current study and previous studies reveal that making salience the relative motion information by generating point-light or stick-figure displays do not necessarily result in any performance superiority in comparison to not making salience the information in classic video display. These results may question the importance of highlighting relative motion information within a model demonstration in the process of observational motor learning (see Horn et al. 2005, too).

In the present study, a no-demonstration control group was also involved in an attempt to examine the effects of action observation itself. This was done by comparing participants’ motor performance and learning in the model demonstration groups with those in the no-demonstration control group. In this regard, it was hypothesized that model demonstration groups would have significantly better performance than the no-demonstration control group in the acquisition phase and the retention tests.

The findings of this study surprisingly provided no support for this hypothesis. The participants in the model demonstration groups did not outperform the participants in the no-demonstration control group in either the acquisition phase or the retention tests. In other words, these results indicate that the video-based demonstration of the Baseball-pitch, in whichever form of demonstration, had no positive effects on motor performance and learning and the participants in the model demonstration groups did not improve their performance more than control group. Moreover, some evidence showed that the participants in no-demonstration control group performed significantly better than those in model demonstration
groups. For example, the participants in control group performed significantly better than those in point-light group in late retention test in terms of absolute movement time difference of overall movement. These findings are in contradiction with the results of Al-Abood, Davids, and Bennett (2001), Horn, Williams et al. (2005) and Breslin, Hodges et al. (2005, 2009) who found a superiority for observing a model demonstration over no-observation in observational motor learning (see Ashford, Davids, & Bennett, 2006, Wulf, Shea, & Lewthwaite, 2010, too).

The present contradiction might be interpreted in terms of the experimental method used in the present study. One possibility might be the amount of action observation during the acquisition phase. Although the present experiment was oriented in regard to the previous studies (Breslin et al., 2005, 2006), it might be possible that three times observation of a complex throwing skill was not sufficient to provoke any significant differences between model demonstration groups and no-demonstration control group. This may indicate that the participants in model demonstration groups might have needed more amount of action observation to show an approximation of the modeled action significantly better than no-demonstration control group.

Moreover, lack of superiority of model demonstration groups over no-demonstration control group might be due to instruction of the Baseball pitch the participants were given in the beginning of the experiment. The participants were given an instruction to the Baseball pitch before performing the pretest trials which consisted of a series of static images of six phases of pitch and additional notes describing each phase as well. A detailed examination of the results of coordination profile of groups in pretest reveals that the participants were able to become relatively similar to the modeled action by observing a series of static images of the movement sequences, at least in terms of throwing arm intra-limb coordination (according to NoRM-D scores and angle-angle plots). Moreover, movement form scores show that the participants of all groups, an exception is stick-figure group, have achieved relative high scores (> 42) in the pretest which indicate that the participants performed the Baseball pitch rather completely.
In the present study, although the instruction was used to introduce the to-be-
learnt action to the participants, it might be possible that showing the participants
a series of static images in the instruction prevented the influences of observing
the model demonstrations in the acquisition phase, because the to-be-learnt ac-
tion has been already learnt in the pretest.

Although the results show that presenting the participants with a set of static im-
ages of movement sequences led to relatively accurate learning of a very dy-
namic and complex action, we hesitate to make any conclusion in regards to
these results. However, the results raise the question whether relative motion
information really is extractable from a set of static images of movement se-
quences. To consider this question, I refer to the theoretical basis of Visual Per-
ception Perspective.

Scully and Newell´s (1985) proposal that relative motion information is picked-up
from a model demonstration for later reproduction was theoretically based on the
According to Johansson, perception of biological motion presented in a point-light
display occurs by perception of motion of the points over time, i.e., in terms of
form-from-motion perception (Lappe, 2012).

Over the last decade, a relatively different approach has been emerged from a
number of studies in biological motion perception, i.e., motion-from-form percep-
tion (Lappe, 2012). Beintema and Lappe (2002) questioned the classical notion
of form-from-motion perception of biological motion and showed that individuals
can immediately percept a moving human body without local image motion. They
used a technique called limited lifetime in which a few light points were attached
not on the major joints of the body, but rather between joints randomly. It means
that the points were randomly replaced onto another point of the respective body
limb after a short period of time. Using this method, they isolated the form and
motion of the body within a display, because every single frame of the display
represents a static posture of the human body and a sequence of the frames
represents the form and motion of the human body. They proposed that the mo-
tion of the point in a point-light display is not crucial for perception of biological
motion, rather the form information of the body/posture is perceived over time (see Lappe, 2012 too).

Those findings debate the importance of relative motion as a primary source of information within a display which used by observers to constrain the later action production. If the perception of biological motion is driven by the changes of body posture over time and if individuals perceive the motion from form and not inversely form from motion, then it might be the form of the body which is extracted and used by the observers from a model demonstration.

Findings of our study and other studies (Horn et al. 2005, Breslin et al. 2005) indicate that the saliency of relative motion information in form of point-light or stick-figure model demonstrations does not necessarily lead to superior learning compared with traditional video demonstration. Moreover, results of the present study revealed that observing a set of images of movement phases, which in my opinion is hardly possible that relative motion information could be driven from, led to relatively accurate modeling of the to-be-learnt motor skill. Therefore, it might be possible that individuals perceive body/posture information from static images of movement sequences and used to reproduce the modelled action rather than relative motion information. Future research should consider the role of body/posture form information for observational motor learning.

A precise look at the NoRM-D scores of intra- and inter-limb coordination reveal that the participants in all groups showed numerically lower deviations in performing the shoulder-elbow intra-limb coordination rather than knee-ankle intra-limb coordination or elbow-knee inter-limb coordination (see Figures 5-2, 5-16, and 5-30). The above results seem to be in line with the results of Breslin et al. (2009) and Hodges et al. (2006) who found that in actions like kicking a soccer ball or cricket bowling, individuals are able to perform the action similar to that demonstrated by the model through observing the information of “end-effector”, i.e. toe in kicking and arm throwing actions. According to Breslin et al. (2009), end-effector information plays an important role in early stages of observational learning and learners focus on end-effectors’ information even a full-body display is presented. In the present study, the lower NoRM-D scores of shoulder-elbow intra-
limb coordination, which is considered as end-effector in Baseball-pitch, indicate that the participants may have focused more on end-effector information than other information such as intra-limb coordination of striding leg or inter-limb coordination of throwing arm and striding leg in the early stages of learning the Baseball-pitch.

A differentiated analysis of six phases of pitching during test periods revealed interesting results. For shoulder-elbow intra-limb coordination there was an improvement in stride phase from pretest to acquisition blocks. In addition, the participants in video and control group performed significantly better than those in stick-figure group in late retention test. For knee-ankle intra-limb coordination the participants showed an improvement in stride and arm acceleration phases from pretest to acquisition blocks. In late retention test the participants in stick-figure group showed worse performances than those in video and point-light groups in arm cocking phase. For elbow-knee inter-limb coordination there was an improvement in stride phase from pretest to acquisition blocks. Moreover, participant in the stick-figure group performed significantly worse than participant in control group in acquisition phase and early retention test. For movement form scores an improvement was observed in stride and follow-through phases and overall evaluation from pretest to acquisition blocks. Moreover, the participant in the stick-figure group performed significantly worse than those in video and control group in arm cocking and arm deceleration phases in late retention test. An analysis of absolute movement time difference of movement phases revealed that there was an improvement in stride phase from pretest to acquisition blocks.

Apart from the poor performances of stick-figure group compared with other groups in the later phases of Baseball-pitch, there was a common finding for all measured variables. That finding was that the participants improved the performances in stride phase from pretest to acquisition phase in all measured variables. From the mentioned results it seems that if there were any significant improvement in coordination or control variables from pretest to acquisition phase that was mostly occurred in stride phase. Dillman, Fleisig, and Andrew (1993) described that the stride phase in pitching involves the moving of striding leg.
downward and toward the plate (i.e., intra-limb coordination of “non-end-effector”), throwing arm moves in a down/upward direction (i.e., intra-limb coordination of “end-effector”) with a proper synchronization with striding leg (i.e., inter-limb coordination). They also mentioned that the coordination between throwing arm and striding leg in second phase is one of the most crucial features of the pitching action (Dillman, Fleisig, & Andrew, 1993). According to the results of this study the complexity of within a limb or between limbs in stride phase of the Baseball-pitching is what is mostly improved from pretest to acquisition blocks and it might be the most difficult phase of Baseball-pitching which might have needed more amount of practice rather than other phases of Baseball-pitching.

Also, it is obvious from NoRM-D scores and angle-angle plots of intra- and inter-limb coordination for movement phases presented in previous chapter that participants showed numerically and visually a large difference with the model in stride phase than in other phases. According to the results of the current study, complexity of within or between limbs in stride phase is what is mostly improved from pretest to acquisition blocks and it might be the most difficult phase of pitch that needs more amount of practice than other phases. From a practical point, Baseball coaches might to pay more attention to the stride phase of pitching while teaching novices.
7 Summary and Conclusion

7.1 Summary

The skill demonstrations are extensively used by coaches and instructors as an instructional strategy to facilitate learning new motor skills. A main question in observational learning is the nature of information extracted by the observers from the model demonstration for reproducing the modeled action. Scully and Newell (1985) proposed Visual Perception Perspective to address this question and suggested that while observing a demonstration, relative motion information of the action is directly extracted and perceived by the visual system and later used to reproduce the action of the model. According to the Visual Perception Perspective, a demonstration would be particularly more effective when relative motion information of the movement is highlighted by removing the structural information such as shape, color and so on from a demonstration through generating point-light or stick-figure display than classical video demonstration.

The present study was designed to address this issue by comparing the effects of observing point-light and stick-figure model demonstrations with observing classical video model demonstration on motor performance and learning of a Baseball-pitch. A no-demonstration control group was also involved in the experiment to examine whether observing model demonstrations would lead to better motor performance and learning than no-observation.

A total of 41 female and male students were randomly assigned into the video, the stick-figure, the point-light and the control groups. A Baseball-pitch was used as the learning task. The participants performed five trials in the pretest, three blocks each ten trials in the acquisition test, and five trials in each early and late retention tests. The participants in model demonstration groups watched the respective model three times before each acquisition block. The measured varia-
bles were included intra-limb coordination of shoulder-elbow and knee-ankle, inter-limb coordination of elbow-knee, movement form evaluation, and absolute movement time difference.

The results of kinematic analysis (intra- and inter-limb coordination) revealed no significant differences between groups across pretest, acquisition phase, and retention tests in terms of overall movement. However, the participants improved their performances from pretest to acquisition phase in all the kinematic measurements. The participants showed lower NoRM-D scores for shoulder-elbow intra-limb coordination than knee-ankle intra-limb coordination and elbow-knee inter-limb coordination. Results of kinematic analysis of pitch phases showed a common improvement in stride phase from the pretest to the acquisition blocks in all kinematic measurements.

The results of movement form revealed no significant differences between the groups in terms of overall movement in the acquisition phase and the early retention test. In the late retention test, the stick-figure group showed worse performances than the video group. Moreover, the participants improved their performances from pretest to acquisition blocks. The movement form scores revealed that the participants in all groups (an exception is stick-figure group) achieved relatively high movement form scores in terms of overall movement (rather-completed to completely-completed). The results of pitch phases showed an improvement from pretest to acquisition blocks in stride and follow-through phases and overall evaluation.

The analysis of absolute movement time difference scores showed no significant differences between groups in pretest, acquisition blocks, and early retention test. However, control group performed better than point-light group in late retention test. The analysis of pitch phases revealed that the participants improved their timing scores in stride phase from pretest to acquisition blocks.

Generally, the results of kinematic analysis, movement form, and movement time provided no support for the proposition of Visual Perception Perspective, because the participants in point-light and stick-figure groups did not perform better than those in video group in acquisition phase or retention tests. Moreover, the
results showed that the participants in model demonstration groups did not out-perform the participants in no-demonstration control group in the acquisition phase or the retention tests.

The lack of superiority of observation groups over no-observation might be due to instruction the participants were given in the beginning of the experiment. In fact, the participants were able to become relatively similar to the modeled action by observing a series of static images of the movement sequences. These findings debate the importance of relative motion and raise the question whether relative motion information is extracted from static images. In this regards, it has been suggested that the participants might extracted the body/posture information from static images rather relative motion information.

The lower NoRM-D scores of shoulder-elbow intra-limb coordination than other kinematic variables might be because the participants focused in the early stages of learning on the “end-effector” of the to-be-learnt action.

A differentiated analysis of six phases of pitching during test periods revealed that the participants improved the performances in stride phase from pretest to acquisition phase in all measured variables. From the mentioned results it seems that if there were any significant improvement in coordination or control variables from pretest to acquisition phase that was mostly occurred in stride phase. In addition, the participants showed numerically and visually a large difference with the model in stride phase than in other phases.

### 7.2 Conclusions

In conclusion, results of this study provide no support for the hypothesis that relative motion information is extracted during observing model demonstration. In addition, our findings show that participants were able to perform the modeled action relatively accurate only by observing a set of static images of movement sequences. Moreover, the participants in demonstration groups did not show any
improvements in acquisition phase. Following the recent evidence in favor of perception of form-posture information from a display (L appe, 2012), it has been suggested that body/posture information might be extracted for later reproduction. Further studies may examine the nature of picked-up information from a display by focusing on form/body information rather than relative motion information. Analysis of movement phases revealed that the participants improved the performances in all measured variables form the pretest to the acquisition phase in stride phase of Baseball-pitch which might be due to the complexity and difficulty of stride phase of Baseball-pitch rather than other phases.
References


http://bodb.usc.edu/bodb/module/903/.


Liebe Studierende, lieber Studierender!

Beim Erlernen einer neuen Bewegung kann es nützlich sein, ein „Modell“ zu beobachten, das die Bewegung demonstriert. Allerdings weiß man noch recht wenig darüber, wie das Modell aussehen muss. Eine offene Frage ist z.B.: Muss das Modell eigentlich als Vollkörper-Figur dargestellt werden (wie in einem Video) oder ist vielleicht die reduzierte Darstellung als Punkte- oder Strich-Figur besser?


Außerdem werden wir Dich im Laufe der Untersuchung 3 x bitten, an einem Computer einen Bildtest zu bearbeiten. Dazu erhältst Du später eine gesonderte Instruktion.

Wie läuft die Untersuchung genau ab?
Die Untersuchung gliedert sich in mehrere Phasen:
2. Danach werden wir Dir einige Marker auf Gelenkpunkte Deines Körpers aufkleben. Dies ist für die Analyse Deiner Bewegung notwendig (Tag 1).
3. Dann bekommst Du zu dem Ballwurf („Pitch“) eine Bewegungsbeschreibung und Du kannst zur Gewöhnung 2 Würfe machen (Tag 1).
4. Prüftest: 5 Würfe (Tag 1).
5. Bildtest I (Tag 1).
6. Übungsschritt: 3 Übungsböcke a 10 Würfe mit jeweils vorgeschalteter Modell-Demonstration (Tag 1).
7. Bildtest II (Tag 1).
8. Früher Retentionstest (nach 10 Minuten): 5 Würfe (Tag 1).
9. Später Retentionstest (nach 1 Woche): 5 Würfe (Tag 8).

Vielen Dank, dass Du an dieser Untersuchung teilnimmst !!!

Wenn Du Fragen hast, wende Dich bitte an den Versuchsleiter

Saeed Ghorbani, Frank Schuster
Appendix 2. Self-report questionnaire

Forschungsprojekt
Modelllernen im Baseball

Personenbogen

So, jetzt geht es los!

Dein Code:

- Anfangsbuchstaben des Geburtsnamens Deiner Mutter
- Geburtsdatum Deiner Mutter
- Geburtsmonat Deiner Mutter

Nun brauchen wir einige Angaben zu Deiner Person und Deinen sportlichen Vorerfahrungen:

- Dein Alter: _____ Jahre
- Geschlecht: o weiblich o männlich
- Handdominanz (EHI): o Rechts o Links
- Hast Du Vorerfahrungen im Baseball?
  - o ja, viel (öfter als 10 mal gespielt)
  - o ja, ein wenig (1-10 mal gespielt)
  - o nein, gar nicht

- Ich betreibe z.Zt. aktiv Sport: o ja o nein
- Meine Hauptsportart:

Vom Versuchsleiter auszufüllen:

VG: _______
Curriculum vitae

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