Perception of own and other individuals' movements

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List of Abbreviations

Ball rel	Ball release
EEG	Electroencephalography
fMRI	Functional Magnetic Resonance Imaging
M	Mean
M1	Primary Motoric Cortex
PET	Positron Emission-Tomography
PL	full Point Light Condition
$Pl_{correct}$	correct Information about observed model
PLD	Point Light Display
Pl_{false}	false Information about the observed model
PMd	Dorsal Premotor Cortex
PLr	reduced Point Light Condition
PLW	Point Light Walker
PMC	Prämotoric Cortex
PMv	Ventral Premotor Cortex
RT	Reaction Time
rTMS	repetitive TMS
Shoulder con	Shoulder constant
SD	Standard Deviation
SEM	Standard Error of Mean
ST	Simulation Theory
STS	Superior Temporal Sulcus
TEC	Theory of Event Coding
TMS	Transcranial Magnetic Stimulation
TOM	Theory of Mind
TT	Theory Theory

1. Introduction

It is very important for the human as a highly social creature to perceive movements in the environment and especially that of other individuals. A good example is a sports situation. A soccer player should be able to see where the team-mates and the opponents are and in which direction they are moving. Without the perception of movements it would not be possible to communicate with other players. Nevertheless, the above described example provides evidence that the perception of biological motion, this includes the movement of animals as well as of human beings, is an essential ability to understand other individuals behavior.

Perception is an important topic in research. The classical perception theory (e.g. Fechner, 1860) dealt with the question how the perception of an event in the environment changed when the properties of the perceived event change. For example, a light that varies its brightness. However, one important point that should be considered when thinking about perception is that the movement of the observer is critical for what will be perceived as well (e.g. Gibson, 1979). Therefore, not only stimuli from the environment should be considered but also internal mechanisms of the acting individual.

Throughout the last decade the interaction between perception and action has become a relevant topic in cognitive psychology, as well as in neuroscience. An important milestone that promoted this kind of research was the discovery of so-called mirror neurons in the brain of maquaces (e.g. Rizzolatti, 2004) and the processing of theories that describe perception and action as being the same at a common representational level (e.g. Grèzes & Decety, 2001). A lot of studies deal with the question how perception may influence action and vice versa (e.g. Hecht, Vogt, & Prinz, 2001).

Another important point refers to the question how and to what extend the own motor system is used when observing biological motion. With regard to the present work one line of studies that deals with the perception of own movements (e.g. Knoblich & Flach, 2003) will be reviewed and discussed. The idea behind this kind of experiments refers to the fact that own past movements may be perceived differently from that of other individuals' movements. In this special case the same system that had planned the action now perceives it. In that special case a close match between perception and action could be assumed that should lead to better perception of own movements (e.g. Knoblich, 2003).

Taken together, the objective of the present work will be the interaction of perception and action, or how the own motor system may influence perception. Therefore, not planned or actual executed actions and their influence on perception will be discussed. The question addressed here will be if knowledge about performance of actions influences the perception of exactly those actions. We examined this question according to two approaches: One way is to compare the performance of experts and novices in a sport situation. It is assumed that the performance depends on the motor expertise, namely on the motor and action knowledge of the observer. An expert possesses a high level of motor expertise in reference to a certain action that is the general knowledge about how to perform certain skills. The other way is to refer to the examination of own past actions. The individual possesses high motor competencies, here referred to as the knowledge of one's own motor capabilities. To sum up we examined the influence of the motor system on action perception on different levels of motor knowledge, namely on motor expertise and motor competence. Moreover, we wanted to estimate the influence of the motor system within different kinds of tasks. Therefore, we used an *effect anticipation task* (Experiments 1 and 2), an *action recognition task* as well as an *actor identification task* (Experiment 3).

The first part of the present work will deal with perception (chapter 2). The point light-technique will be introduced as a tool to study the perception of biological motion. Additionally, an overview how and what is perceived when looking at biological motion will be given. Empirical questions and interesting findings derived from behavioral as well as from neuroscientific studies will be discussed.

The second part of the present work will deal with the interaction of perception and action (chapter 3). At first it will be explained how actions are planned. This will be important to understand the implications of the „Common Coding Theory“ (Prinz, 1997), “Theory of event coding” (Hommel, Müsseler, Aschersleben, & Prinz, 2001) and „Simulation Theory“ (Jeannerod, 2001). Those theories will be introduced as useful frameworks for the present work because they provide answers to the question how perception and action may interact and how human beings are able to understand the behavior of other individuals.

Originating from the statements derived from the previous section, the third part of the present work (chapter 4) will deal with the perception of own past movements. First of all, the already described theories will be discussed in the light of the actual question. Afterwards some empirical findings from three different lines of research (*Recognition of own movements, Prediction of own movements effects, Online coordination*) will be presented that try to underline that there might be a difference between the perception of own and other individuals’ movements. Afterwards the results of three own studies will be presented (chapter 5).

The first and second preliminary experiements dealt with the perception of boule throws (*effect anticipation task*). Within these two experiements the aim was to identify what information the observer uses when the task was to judge throwing movements. Observers had to estimate the length of two boule throws. The question was which throw was the longer one. The kind of presentation was manipulated in such a way that the information which was displayed within the point light animations was reduced gradually.

Based on the results of these two prestudies another one was conducted with the aim to test if the perception of own past movements is superior to the perception of other individuals’ movements, that means whether the own motor systems contributes to action perception. The same task as in study one was used except the fact that now own and other individuals’ movements were presented. On the one hand the goal of that study was to replicate the findings of Knoblich and Flach (2001) that the effects of own past movements could be predicted better than the effects of other people actions. On the other hand, the aim was to ascertain if the knowledge about the acting model is an important variable that influences the performance of the observer.

A third study was conducted to test the above described hypothesis with another kind of movement and slightly different tasks. This time we used basketball dribbling because these movements allow to evaluate the interaction of perception and action with another kind of tasks. Now observers had to recognize an up-coming action and to identify the observed model and not to anticipate the effect of an action. This study therefore was divided into two parts and dealt with basketball dribblings. In the first section the observers had to recognize basketball movements within an *action recognition task*. On the one hand we compared the performance of experts and novices. On the other hand we checked the performance within the expert group for own, team-mates and unknown individuals movements. The second part of that basketball study consisted of an *actor identification task*. The observers had to decide if the presented player belongs to the own team or to an unknown team. For the case that the own team was chosen, the observer was asked to name the player. The whole basketball study was designed with the aim to combine an action recognition with an actor identification task. Moreover, different degrees of motor expertise (experts vs. novices) as well as motor competencies (perception of own vs. other individuals' movements) were used to evaluate the influence of the motor system on human motion perception.

The last section of the present work (chapter 6) will discuss the results of the own studies in the light of the above described theories and empirical findings. Additionally, an outlook will be given what else should be done to get further inside into the understanding how perception and action may interact.

2. Background

The aim of the next chapter will be to give an introduction about the perception of biological motion. The most important findings and methodological approaches to study motion perception in reference to the present work will be discussed (see Blake and Shiffrar (2007) for a more detailed overview).

2.1 Perception of biological motion

For the survival of the human being it is very important to perceive movements in the environment. Already newborns therefore have the ability to perceive biological motion quite well. Four months old babies direct their attention much longer to a display when a moving human being is presented instead of a random dot mask (Bertenthal, 1993). Toddlers between the third and the fifth month learn to perceive global structures of biological motion (Booth, Bertenthal, & Pinto, 2002). One study could demonstrade that eight months old babies show a similar pattern of activation within the right hemisphere as adults when looking at biological motion (Hirai & Hiraki, 2005). However, not before the fifth year of life the perception of biological motion is as good as the ability of an adult (Pavlova, Krageloh-Mann, Sokolov, & Birbaumer, 2001).

Taken together, there is a lot of evidence that the perception of biological motion is based on inheritance. Interestingly, in contrast to the perception of moving objects the ability to perceive biological motion does not decrease when people get older (Norman, Payton, Long, & Hawkes, 2004). The authors could demonstrate that older adults were as good as young adults in estimating the performance of walking individuals. Even a reduction of the presentation time of the stimuli does not lead to a decrease in performance.

Although there is a high sensitivity of the inividual for human biological motion, it still can be impaired. The ability to detect a point light walker within a display with additional dots is depressed when the walker is presented at the rim (Ikeda, Blake, & Watanabe, 2005). This result leads to the conclusion that biological motion perception is best when the stimuli are presented in the fovea and decreases when the motion is presented peripherally.

2.1.1 The point light-method

Different techniques were developed to study especially the perception of biological motion. The first analysis of biological motion was performed by the French researcher Etienne-Jules Marey. He was interested in the motion patterns of animals like horses, birds and cats as well as in those of human beings. Marey used photographs with multiple exposures so that several phases of a movement became visible within one picture. The Swedish psychologist Gunnar Johansson (1973) developed the so-called “point light-technique” to study the underlying mechanisms of motion perception more systematically. Small light bulbs were attached to the main joints of the actor and it was filmed in front of a dark background. When representing the videos later, only the shining light bulbs were visible. The advantage of this method refers to the fact that distractors like clothes could be hidden so that only kinematic details of the movement were visible. However, the wires that were used to provide power to the lights hindered the movements of the models. Because of that, Johansson used reflective markers instead of the light bulbs in later attempts. The models therefore had to wear tight dark suits while they were filmed with a video camera. When representing the video the contrast was turned to be high while the level of the brightness was low. However, the possibilities to manipulate such stimuli were limited.

Cutting (1978a, 1978b) therefore established a new method to generate point light displays (PLDs). He used the properties of the normal walk to generate a point light walker synthetically. A walk can be described as a periodic movement. The arms as well as the legs describe pendulum motions. In contrast the hip and the shoulders move elliptically. These regularities established the basis of an algorithm that describes the movement patterns of a walking human being. This method allows manipulating the point light walker systematically.

However, it should be noted that those “synthetic” walkers are different to “real” walkers in such a way that external forces like for instance gravity or the mass of the walker itself remain unconsidered (Runeson, 1994).

Today, video based and opto-electronical motion analysis systems are used to represent the motion patterns. Reflective markers are still used to mark the main joints of the model. To calculate the epicentres of the joints vast numbers of cameras are used. This allows reconstructing the trajectories in three-dimensional space. Modern motion capture systems therefore combine the advantages of the two already described methods used by Johansson (1973) and Cutting (1978a, 1978b). The “real” walker is the basis and can be manipulated in reference to the research questions. For instance, it is possible to manipulate the size of the captured subjects so that all models have the same body height. This is an important feature when observers have to identify or to name point light walkers.

To study the underlying mechanism that guide biological motion perception researchers used different kinds of presentations of the pointlight walker. For instance, not only the joints of the point light walker can be represented, but also additional points that mask the walker. The position of those distractor dots can change unsystematically with every frame and sometimes there is no walker at all in the display (“random dot mask”). Furthermore, so-called “scrambled” point light displays are used. The idea behind this manipulation is that the “form” of the walker is dismissed. The points that represent the joints move in the same way as they naturally would do, but they are presented at a wrong position within the display. With these modifications it is possible to manipulate the movements spatially or temporally.

In short, the point light-method is a useful tool to study the perception of biological motion, because it allows to represend only the kinematics of the moving human being und to manipulate them according to the aim of the experiement. However, it should be considered that this kind of presentation has nevertheless the disadvantage that it is not naturally.

Normally we do not perceive only the kinematics of a moving human being. There are other aspects like the environment around us that influence what and how we perceive.

2.1.2 What is perceived?

When thinking about the perception of biological motion the question arises what we actually perceive. There are two possible answers, namely that we are able to perceive figures and their attributes as well as actions.

Perception of figures and their attributes

As already described above, the Swedish psychologist Gunnar Johansson (1973, 1976) was the first one who investigated if observers were able to identify a walking human being when the movement was presented within a point light display. He could show that observers are very fast in detecting the moving individual. However, within the past few years several studies have been performed to examine which properties of a human being presented within a point light display could be recognized by an observer. Distinct studies could show that it is possible to recognize the gender of a walking individual (Cutting & Kozlowski, 1977; Sumi, 2000; Troje, 2002b) as well as its age (Montpare & Zebrowitz-McArthur, 1988). Even emotions like fear and joy could be recognized within point light displays (Atkinson, Dittrich, Gemmell, & Young, 2004; Clarke, Bradshaw, Field, Hampson, & Rose, 2005; Dittrich, 1996, 2003). With regard to the present work not only the ability to identify an acting human being and its properties within a point light display is interesting. The ability to discriminate among different point light walkers and to name them will be a central topic later.

Perception of actions

A lot of studies deal with the perception of action and not with the actor and its attributes. Already Johansson (1973) could show that it is possible to discriminate between different actions like walking, dancing or drawing within PLDs. Additionally, Hoenkamp (1978a) and Todd (1983) worked out that it is even possible to distinguish between very similar movement patterns like walking and running. Furthermore, the recognition of a certain movement pattern is facilitated when the object which is involved within the action is presented, too. Shipley and Cohen (2000) showed that observers were more likely to identify a basketball movement when the ball was presented. It was much harder for the participants of that study to identify a basketball movement when no ball was included within the PLDs.

Beneath the actor and the action it is possible to identify the kinematics of a movement. A good example is the situation when an individual is looking at another person that is lifting a box. Even if it does not know what is inside the box, it will be able to estimate the lifted weight. Bingham (1987) as well as Runeson and Frykholm (1981, 1983) could confirm this observation. The perception of that specific kinematic pattern allows to guess what a person is doing and what the intention of an action might be. Runeson and Frykholm (1983) worked out that the readjustments a person is performing before lifting the box and that the lead-in movements of the action are enough to estimate the weight of a lifted box. Moreover, the researchers could demonstrate that the observer could not be deceived about the weight being lifted. Even if the person that is lifting the box tries to look much exerted the observer is able to see if this is a deception or not. Runeson and Frykholm (1983) additionally found out that it is possible to estimate the length of a thrown ball. Furthermore, it should be mentioned that it is possible to pick up useful kinematic information even when only one moving body segment is visible. Observers were able to estimate the weight of a handle which was lifted by only seeing one arm (Bingham, 1987).

2.1.3 How is biological motion perceived?

Direct and indirect perception

In general there are two approaches to the perception of biological motion. One is the so-called "direct perception approach". It postulates that the perception of motion happens directly and immediately. No further processing is necessary. Bingham (1995) assumed that movement trajectories allow the estimate the weight of a lifted object. The spatial-temporal pattern of the movement, like for instance changes in velocity, provide enough information to the observer to be able to rate the action. Runeson and Frykholm (1981) followed a similar approach. They postulated the so-called KSD-principle ("kinematic specification of dynamics") which says that forces and accelerations can be perceived directly from kinematic details.

In contrast to this view, an indirect perception of biological motion was postulated as well ("heuristic approach"). The idea of this approach is that further processing stages are necessary to extract the meaning of the perceived event. Gilden and Proffit (1994) therefore assumed that observers have heuristics about velocities and angle changes that allow to estimate kinetic parameters like forces from the kinematic information provided by the movement.

Form and motion

Already Johansson (1973) described the phenomenon that an observer looking at a white screen with some static black dots is not able to recognize what is illustrated. As soon as the dots begin to move the observer immediately has the impression of a walking person. 200 ms are enough to recognize that there is a human moving and 400 ms allow naming the kind of action (Johansson, 1976). A challenging task for further research therefore was from where the observer knows that it was a human being that was moving. Which points are necessary for the identification?

One basic approach to that was formulated by Johansson (1950). The kernel assumption of his “principles of perceptual vector analysis” is that the visual system tries to group similar or simultaneous occurring events like it is postulated by the “Gestaltpsychologie”. “Elements” which are moving in the same direction are classified as being the same. In reference to the perception of biological motion a characteristic hierarchy of the elements is assumed. The upper part of the body, defined by the shoulder and hip points builds the top of this hierarchy. The movements of the arms and legs describe pendulum like motions and both depend on the movements of the upper body. The hands and feet then again depend on the motions of the arms and legs and also describe pendulum like motions. Johansson (1976) manipulated the presentation by systematically blinding out points to find out which ones are important to recognize a human being and its action. The results of this study showed that the points at the hip and the legs are enough to identify the walker. To be able to determine the movement direction of the individual the points of the ankles are important (Troje & Westhoff, 2006). It should be pointed out that the movement of the ankles is the most important cue to identify biological motion as such. From an ecological point of view this result makes sense, because the individual should know when somebody is walking towards him.

Compounded with these kinds of studies is the question whether the observer pays attention to only single dots (local analysis) or to all dots concurrently (global analysis). There are a lot of studies dealing with that question (e.g. Mather, Radford, & West, 1992; Pinto & Shiffrar, 1999). Spatial (“scrambled PLDs), temporal (implementation of so-called “Inter-Stimulus-Interval” (ISI)) as well as spatial-temporal components of the PLDs are manipulated within those kinds of studies. Taken together, the results of those kinds of studies provide evidence that the local as well as the global analysis of biological motion is important to understand the observed action.

Another line of research refers to the question if a walker is identified because of his “form” or because of his “motion”. Does the observer recognize the form of the walker and therefore derivates the motion “walking” (“event-from-form model”) or does the observer recognize the motion “walking” and assumes therefore that this subject must be a walker (“event-from-dynamics model”)? The answer to that question is complicated. On the one hand it seems impossible to assume that an observer is able to detect a point light walker within a scrambled point light display when he has no idea about its form. However, as already described above, it is the motion of the dots which allows identifying the walker. On the other hand it could be shown that static images are enough to induce or to present motion (Heptulla-Chatterjee, Freyd, & Shiffrar, 1996). Pittinger and Shaw (1975) therefore distinguish between kinematic and structural features which are important to recognize an event in the environment.

Troje (2002a, 2002b) conducted a study with the aim to investigate how women and men are recognized when walking. Does the individual use structural information like for instance the shoulder-hip ratio? Or does it use kinematic information like the movements of the upper body? He therefore combined structural and kinematic information in different ways. One possible representation, for instance, was the combination of a womans’ walking pattern and the form of a man. The results showed that it is the kinematic information, the movement pattern that guides the judgement. Interestingly, this result only was found when the walker was observed from frontal view and not from half-profile view (45°). One possible explanation might be that in frontal view differences in kinematics as well as structural features are better visible.

“Top-down” versus “bottom-up” processes

One interesting consideration refers to the question if the perception of biological motion is based on bottom-up (stimulus driven, low-level mechanism) or top-down (conceptually driven, high-level mechanism) processes. The results that the perception of a point light walker, being presented upside-down, is impaired, leads to the assumption that the perception of biological motion is stimulus driven. Sumi (1984) could show that the recognition rate for

PLWs decreased, because the observers confounded the leg with the arm movements and vice versa when the walker was presented up-side down. If the observers had used concepts ("How does it look like when a walker is presented upside down?") the decrements in performance would not be expected.

To test if perception is based on low-level mechanisms Thornton, Rensink and Shiffrar (2002) used a double-task paradigm. The idea behind this manipulation was that a second task should not impair performance when perception is really based on low-level mechanisms. In this study, participants had to look at point light displays while simultaneously solving an additional task. The primary task for the observer was to detect the walking direction of the presented point light model. The secondary task was to identify the positions of four rectangles within the display respectively to monitor if they change their positions or if one of them rotates from one frame to another. Interestingly, the results showed that the performance of the secondary task depends on the difficulty of the primary task. If the primary task was easy, only small decrements were found for the secondary task. If, however, the primary task was more difficult, because the PLW was presented for example within a scrambled PLD, the performance in the secondary task decreased more dramatically. The authors assumed that a shift from passive motion perception to active motion perception had occurred and therefore more attention was needed. However, it should be pointed out that even when the perception of the walker seems to be easy, some attention is nevertheless needed to perceive the motions, otherwise the small decrements within the easier condition cannot be explained. The results therefore indicate that perception of biological motion needs at least some attention and is not a fully automatic process.

Until now, findings based on behavioral data have been presented. These results have implications for future studies. The next chapter will deal with neuroscientific findings that may help to improve our understanding of action perception.

2.1.4 Neuroscientific findings

Human beings possess a very good ability to detect biological motion. Therefore, the question arises if certain areas in the human brain exist that support the perception of especially biological motion and whether these areas are different from those that are relevant for the perception of moving objects. The perception of biological motion therefore was examined using functional magnetic resonance imaging (fMRT), electroencephalography (EEG), positron emission-tomography (PET) and transcranial magnetic stimulation (TMS).

One of the most important areas in the brain for the perception of biological motion is the superior temporal sulcus (STS). It receives input via the dorsal (“vision for action”) and ventral stream (“vision for perception”). This leads to the conclusion that within this area the integration of information regarding the recognition of an action and the information regarding the identification of an object takes place (Goodale & Milner, 1992). The result of a fMRT study conducted by Giese and Poggio (2003) for instance showed that during the perception of “real” biological motion both streams are active. However, if the observer is looking at a PLD, no areas that were associated with the perception of form were activated.

Crucial for the activation pattern in STS is the context in which the movement is presented and if a familiar or unfamiliar movement is presented to an observer. If whole body movements were presented, the activation of STS, the amygdala and the adjoined temporal area is greater compared to the presentation of hand movements only. Additionally, the activation within those areas is greater when the PLW is presented in its normal orientation than in a head over heels position (Grossman & Blake, 2001).

The importance of the STS area for the perception of biological motion could be also shown on the level of single cells. Kenderick and Baldwin (1989) were able to identify single cells within the area STP of monkeys (homologous to human STS) that responded selectively to the movements of conspecifics. The application of repetitive TMS (rTMS) over STS leads to a short-term perturbation regarding the perception of biological motion (Grossman, Battelli, &

Pascual-Leone, 2005; see Allison, Puce and McCarthy (2000) for a review about the role of STS region in reference to perception).

Other important brain regions regarding the perception of biological motion are the premotor cortex (e.g. Rizzolatti, Fagida, Galesse, & Fogassi, 1996), the ventral temporal lobus (e.g. Vaina, 2001), the lateral fusiform gyrus (e.g. Beauchamp, Lee, & Martin, 2002), middle temporal area (MT) (e.g. Huk & Heeger, 2002), the fusiform and occipital face area (e.g. Grossman & Blake, 2002), and the extra striate body area (e.g. Downing, 2001).

The results of the neuroscientific research regarding the perception of action are especially important in the light of the present work, because they could provide evidence for the assumption that there is a link between perception and action respectively action planning. Several studies indicate that during the perception of actions, areas in the brain are activated that are activated during the planning and execution of actions as well. These areas are among others the premotoric cortex (PMC) and the primary motor cortex (M1) (Decety, Grèzes, Costes, Perani, & Jeannerod, 1997; Grèzes, Costes, & Decety, 1998; Hamilton, Wolpert, Frith, & Grafton, 2006).

We have seen that people are highly sensitive to the observation of biological motion. The pointlight method and the possibility to manipulate the pointlight displays to study the underlying mechanisms is a well established tool to examine biological motion perception. Figures and their attributes like the gender or the age of the pointlight walker can be perceived and observers are able to distinguish between different kinds of actions like for instance walking and running. It could be demonstrated that there are different explainations how biological motion is perceived. In reference to the task perception is either due to the form or the motion of a pointlight walker and it can be stimulus or conceptually driven. Local analysis of single points as well as the global analysis of several points support the perception. There are specialized region within the human brain like the STS that are responsible for biological motion perception.

3. Interaction of perception and action

The aim of the following chapter is to describe the interaction of perception and action. Knoblich and Sebanz (2006) postulated that the link between perception and action is fundamental for social understanding and social interaction. The authors discriminate between two lines of research. One the one hand, research on action perception postulates that subjects use their own motor system to understand the action of others and to identify own actions. On the other hand, research on joint action is related to the question how human beings share representations and how it is possible to predict what the other individual will do to interact with one. Therefore, the most important approaches that build the basis for those studies will be discussed first. Afterwards, the results of studies that give evidence for the interaction of perception and action will be presented.

3.1 Theoretical approaches

To understand the implications of the theories that describe the interaction of perception and action it is important to know how actions are planned.

3.1.1 Action planning

“Sensorimotor view” and “Ideomotor view”

There are two theories that try to examine the question how actions are planned. On the one hand, there is the “sensorimotor view” which assumes that actions are responses to a stimulus. That view has its origins in the classic behaviourism. It is assumed that actions are „reactions“ to certain stimuli in the environment. The response therefore is triggered by a stimulus and follows every time after a stimulus and not vice versa. Hommel (2001) postulated that it is the “stimulus triggered hypothesis” that is inherent in all sensorimotor theories. This assumption influences the „linear stage theory of human performance“ (Sanders, 1980) that will be discussed later in the context of action perception coupling.

In contrast the “ideomotor view” postulates that instead of an external stimulus an internal mechanism causes an action. It is the individual itself that wants to achieve or to realize a certain goal. This presupposes that the goal of the action is already represented before the actual movement is carried out. That means that the goal of an action influences the planning of an action and therefore works backward in time. In difference to the sensorimotor view, not the stimulus but the goal of an action can cause the movement. Hommel (2001) therefore used the term “goal triggered hypothesis”. The ideomotor view distinguishes between the goal state itself and the cognitive representation of the goal. It is assumed that the anticipation of an action effect plays a crucial role in the control of upcoming actions. Also, it should be pointed out that this assumption presupposes that the “system” had already learned which movements are necessary to achieve a goal. Therefore the linkage between certain movements and its effects must have already been learned. The important point is that this conjunction can be used in both ways.

The “Theory of internal models” describes these assumptions in much more detail. That approach postulates that the motor system consists of two functionally different systems, namely the “forward model” and the “inverse model”. The “forward model” specifies which motor commands are necessary to achieve a certain effect in the environment. The “inverse model” describes what effect was caused by what actions. Moreover, it is assumed that whenever a movement is planned or executed predictions concerning the sensory consequences of the action are derived from the motor command. This statement has its origins in the so called “reafference principle” (von Holst, 1950). Originally, this principle was established to explain how the visual system is able to produce a stable picture of the environment even if the eye of the observer is moving. However, if a movement is executed the consequences of the movement or the corresponding reaffarences are predicted. Because of this modulation by the forward model it is possible to ascribe perceived sensory events to the self (Blakemore, Frith, & Wolpert, 1999). If the same or very similar sensory events are perceived that were modulated by the own motor system before, it is obvious that the perceived event was caused by the own movement (Frith, 1992). It is important to note that this process is unconscious. The individual does not have access to the reaffarences or even the motor program and most of the processes guiding motor control remain unconscious (Frith, Blakemore, & Wolpert, 2000). The whole process becomes conscious only when there is a difference between the planned and the predicted effect or between the predicted and the real effect. A couple of diseases are linked to the "Theory of internal models". For instance, it is assumed that people who suffer from schizophrenia may have a disorder concerning the prediction of upcoming events and that the forward model provides incorrect predictions (Blakemore, Wolpert, & Frith, 2002; Frith, Blakemore, & Wolpert, 2000).

It should be pointed out that both theories, the "sensorimotor view" as well as the "ideomotor view", account for the generation of certain actions. The difference refers to the fact if they are internally or externally caused. The advantage of the "sensorimotor view“ in comparison to the "ideomotor view" is therefore based on the fact that it is easier to control this effect methodically and to explain an upcoming action in reference to its origin. Stimuli are observable entities which can easily be manipulated whereas mental states are unobservable and only hard to influence. When taking a closer look to simple stimulus-response reaction tasks it becomes obvious that both approaches determine if an action will occur and how it will look like. It is not the stimulus per se that causes a response. The individual still decides how and when to react. Hommel, Gehrke and Knuf (2000) postulated that two conditions exist which have to be fulfilled for a response to occur. First, there has to be a stimulus and second an appropriate intention or volition to respond to that stimulus. However, whenever an individual decides to achieve a certain goal there is a stimulus that determines the action. Grasping for a glass of water to have a drink is a good example within this context. The object as the stimulus predefines the action of the grasping hand. Actions therefore link movements to goals (Prinz, 1997).

3.1.2 Common Coding Theory

A variant of the ideomotor theory is the so-called “Common-Coding Theory” (Prinz, 1997). This framework provides a principle of how action and perception are matched. It refers to action control and action planning but it also contributes to perception. For better understanding the implications of the “Common-Coding Theory”, the traditional approach referring to perception and action, will be discussed first.

Traditional approaches

The early frameworks postulated that perceptual processes are more or less independent from processes of action planning and action control. It was assumed that the components which underlie perception and action are the so-called “sensory codes”, which stand for the simulation of a sense organ, and the “motor codes”, which refer to patterns of excitation in muscles. Already in the 17th century Descartes (1664) proposed that these two codes have nothing in common and that a ”translator” is necessary to link perception and action. The visual stimulus might be for example given in retinal codes whereas the corresponding motor response should be programmed in body coordinates. However, in the 19th century Lozte as well as James assumed that there were no fundamental differences between perceptual and motor representations. The so called “Ideo-Motor Principle”, which was originally formulated to explain voluntary actions, postulates that “every mental representation of a movement awakens to some degree the actual movement which is its object” (James, 1890). Observing or imagining an action for example excites the motor programs that are used to execute that same action (Jeannerod, 2001; Prinz, 1997). The “Common-Coding Theory” also had its origins in the work of Lotze who postulated that perceived or even imagined actions can affect the execution of corresponding movements (1852, as cited in Prinz, 1987). So far both researchers postulated that there is a link between perception and action but the nature and directionality of this link was still unknown. The next chapter therefore will describe how perception may guide action on the hand and how action may guide perception on the other hand.

From perception to action

Within the 20th century theories were established that postulated that perception and action do not have much in common. The framework of “information-processing approaches to perception” (e.g. Sanders, 1980) for example claims a linear order of information processing with little contact between perception and action. Linear-stage models assume that there is a sequence of different processing stages and that the next stage would begin its work when the preceeding one stopped working. For instance, Sanders (1980) claimed that there are four stages namely: stimulus pre-processing, feature extraction, response choice and motor adjustment. The first two refer to perception, the last two to action. A central topic of these so-called “information-processing approaches to perception” is the assumption that an interaction between the information derived from the stimulus and the information stored in memory exists. It furthermore was postulated that a certain stimulus is identified by matching that stimulus against a set of memory representations. However, it should be noted that there are no studies in this field that refer to the content or the structure of such memory representations. Moreover, in this view action does not play any role and so the impact of action-related knowledge on perception and vice versa remains unclear. Therefore, it seems to be questionable if and how both domains should interact. This leads to the conclusion that linear-stage models do not give an adequate account for the linkage between perception and action.

Results of ongoing research, especially in the neuroscientific field, therefore, lead to the assumption that the processing stages more or less overlap in time or work parallel. Connected to this idea is the assumption that multiple representations exist. Goodale and Humphrey (1998) as well as Milner and Goodale (1995) for example claimed the existence of two separate pathways for perception and action in the human brain. On the one hand there is the so-called "ventral (what) pathway" in the temporal lobe and on the other hand the so-called "dorsal (how) pathway" in the parietal lobe. The first one refers to object identification, the second one to the orientation and location of an object. The authors postulated that vision-for-perception and vision-for-action are probably different. The identification of a certain object in the environment is represented in viewer-independent coordinates. That means that the observer is able to identify an object independent of its orientation. For instance, it should make no difference to see a cup from the top, right or left side, because the observer has a stable representation of the object and so various viewpoints do not make a difference. In contrast, when grasping an object the representation of the distance between the observers hand and the location of the object is permanently updated. Because of that the temporal maintenance of the object representation is limited. This leads to the conclusion that two partially separate representations of the same object may exist.

Further evidence for this assumption derives from lesion studies. Milner and Goodale (1995) for example described a patient who was not able to identify the orientation of a slot, but who was able to put a disk into that slot. Patients with optic ataxia show the opposite pattern. These findings support the assumption that there are two different kinds of representations, namely one for perceptual judgements or identification and one for the guidance of actions. The two representations seem to be more or less independent from each other. To sum up, the above described approaches assume that different levels of representations exist and that it is perception that guides action.

From action to perception

Another line of research dealing with the interaction of perception and action has its origins in the work on attention and on attentional capacity limitations. All theories established in that field (e.g. "early-selection theories", (Broadbent, 1958); "late-selection theories", (Deutsch, 1963); “capacity-free or capacity-demanding processes”, (Shiffrin, 1977); “specific and unspecific capacity limitations”, (Kahneman, 1973)) postulated that capacity limitations are inherent in the processing system. Therefore selection mechanisms are needed to overcome these limitations. Later, this idea was used to describe how the selection of specific relevant features in the environment and the simultaneous rejection of irrelevant information allows to overcome the limitations of the system and to plan an action. It has to be pointed out that the selection of a specific action leads to the limitations and not that the limitations lead to the selection of a specific action. That means that according to the so-called “selection-for-action view” that action planning modulates perception. This leads to the conclusion that action guides perception.

Perception and Action

It should be obvious that a link between perception and action must exist and that both overlap to some extent. The next section will deal with the question how this link or this overlap may look like in more detail.

One possibility might be that a direct link between perception and action exists (‘singel-hypen view’). Another explanation refers to the assumption that there is some kind of “mental representation” which combines both perception and action (‘double-hypen view’). Support for this last assumption derives from the work of Ernst Mach (1922) who hypothesized that the body is perceived in the same way as the environment. What separates action from perception is the fact that actions can be controlled by will. This leads to the conclusion that action and perception are somehow similar and therefore no translation is necessary. Locked to this assumption is the question how they are combined. To solve this issue so-called ‘mapping views’ were introduced. They postulate the existence of learning- and experience-related perceptual-motor or visual-kinaesthetic connections (Bandura & Walters, 1963; Gewirtz & Stingle, 1968). Another approach refers to so called ‘matching views’. The main point is that the interaction of perception and action occurs on the same codes that are used for the perception of the movement as well as for the execution of the movement. Meltzoff and Moore (1977) postulated that visual as well as proprioceptive signals are coded in a common form.

In the end the “Common-Coding Theory” therefore postulates that there is a common medium for perception and action. Perceived events and planned actions share a common representational domain (Prinz, 1997). Perceptual and action representations are somehow equivalent. Action representations should contribute to perception representations and vice versa. Evidence for a close connection between perception and action derives from a variety of observations. Newborn baby imitate the mouth movements of the mother, for instance (e. g. Meltzoff & Moore, 1977). Other examples refer to synchronous and compatible actions. How should it otherwise be possible to dance to the music or with a partner in synchrony, when it is not possible to perceive the music respectively the movements of the partner and to react to him?

Taken together, the “Common-Coding Theory” assumes the existence of so-called “event codes” (former sensory codes) and “action codes” (former motor codes) which are represented in a common medium. Moreover, it is assumed that no translator is necessary because these codes are equivalent and they overlap each other to some extend (Prinz, 1997). The “Common Coding Theory” therefore is a usefull framework to describe how perception and action interact but it can not explain how actions are planned or how it is possible to understand the meaning of observed movements.

Empirical evidence for the “Common Coding Theory”

Evidence for the Common-Coding Theory derives from two classes of paradigms namely the “interference paradigms” and the “induction paradigms”. A methodical strategy is the use of choice reaction tasks to determine the factors for stimulus processing and response generation.

A typical experiment would be that the participants have to press keys in reference to a light. The colour of the stimulus stands for the “event code” and the corresponding action for the “action code”. It is important to note that the events that were presented in these experiments share certain properties with the action that should be executed.

The “interference paradigms” shed light to the question how the bidirectional interference between the perception of certain events and the simultaneous execution of an action could be explained. The “Interference Hypothesis for perception and action” states that a code that is busy with perception cannot be used for action planning or control at the same time (Prinz, 1997). As a consequence on the one hand the perception of concurrent or incongruent stimuli influences action planning (Hommel et al., 2001). Participants had to memorize the direction of arrows and press a key in reference to the arrows later on. The results indicate that the presentation of an additional arrow influences the planning and execution of the response. The observation of an arrow pointing in the same direction as the memorized one leads to increased reaction times (“negative compatibility effect”). On the other hand action planning can impair perception (Müsseler & Hommel, 1997). The task was to identify the pointing direction of an arrow in a masked display while pressing a specific key for right or left. Again the results clearly demonstrated that when the same codes are used for perception and action the performance of the subjects decreased. The participants detected the arrow more often when it pointed to the opposite direction compared to the executed key press. That result confirms the assumption that the same code cannot be used for perception and action at the same time.

The “induction paradigms” try to explain how certain stimuli trigger certain actions. Studies are conducted in the temporal as well as the spatial domain. For example, participants had to synchronize their own finger tapping with an auditory tone. What is interesting here in reference to the Common Coding Theory is the “negative asynchrony” effect which could be found in several studies (Aschersleben & Prinz, 1995). It refers to the fact that the onset of the finger movement is initiated before the tone is represented. This leads to the conclusion that the two events are synchronized in terms of their sensory codes. The finger movement leads to a sensory effect as well as the tone and, because it takes more time to produce these sensory effects with the finger the movement has to start ahead of time.

One example of studies in the spatial domain refers to the well known “Simon-Effect”. Reaction times are faster when the spatial arrangement of the response key and the signal respectively the stimuli correspond. It is assumed that the stimulus and the response sets share some features and therefore, the stimulus will prime the response if they are compatible (Kornblum, 1992, 1994; Kornblum & Lee, 1995).

To summarize the results of these studies it could be demonstrated that on the on hand perception could influence action (“interference paradigms”) and that on the other hand action can influence perception (“induction paradigms”).

3.1.2 Theory of event coding

The results of the above described kinds of studies lead to another important point and extends the assumptions derived from the “Common Coding Theory”. It seems to be plausible to hypothesize that actions are planned in terms of their anticipated or intended effects. This is the kernel assumption of the “Theory of Event Coding” (TEC; Hommel et al., 2001). The next chapter will describe the TEC in more detail and implications for the present work will be discussed.

It was postulated that perceiving and action planning refers to the same aspects, namely the internal representation of external, distal events. Additionally, perceiving presupposes and allows for active behaviour and performing an action relies and produces perceptual information like the “Theory of internal models” would suggest. It therefore can be concluded that action codes as well as stimulus codes represent the result as well as the stimulus for a certain action at the same time. It should be pointed out that this linkage refers to late stages of perception and early stages of action or action planning. TEC does not account for early sensory processes as well as late motor processes.

Another important point concerning TEC refers to the assumption that it is not one common "grandmother cell" that combines action and perception. It is much more plausible to assume that different codes are stored within various cortical brain areas. Visual information, for instance, is stored within different cortical areas and follows distinct pathways (DeYoe & Van Essen, 1988). It can be assumed that actions seem to be presented in a similar way (Hommel et al., 2001). TEC therefore postulates the existence of so-called "feature codes". Theses codes are not specific to a certain stimulus or a certain action and they have to be learned. They receive input from the sensory codes and spread this information to codes of the motor system. "Feature codes" represent more or less the common coding domain.

It has to be considered that some kind of integration mechanism is needed. This assumption refers to the fact that distinct codes which are activated when perceiving an event in the environment have to be connected to each other. It would not make sense if the codes were activated individually. It is much more plausible, for instance, to code the colour and the size of an object together to be able to establish an appropriate perception of an object. On that score TEC assumes that on a first stage the codes are activated and that on a second stage these codes are adequately connected or integrated to each other (Hommel et al., 2001). It is not a single code that represents an event, it is much more a bundle of such codes that define an event. Additionally, it could be proposed that when a certain code becomes activated, the other codes which are connected with this related code becomes activated, too. This assumption is in line with the already mentioned "interference" and "induction paradigms". As long as a code is not connected or integrated within other codes, an action is facilitated ("induction paradigm"). If a certain code becomes integrated it is no longer available for the planning of a certain action and performance will therefore decrease ("interference paradigm"). It should be noted that attention, the situational context as well as the intention play a critical role in this process. The goal of the perceiver specifies what is processed and how it is processed. It depends of the importance of a certain feature if it is processed and if it influences the upcoming action or perception. This leads to the conclusion that features are weighted with regard to their importance (Hommel et al., 2001).

Further evidence for the TEC derives from studies about stimulus-response compatibility (SRC). The main finding refers to the fact that some tasks are easier to solve than other ones (lower reaction times, movement time and frequency of error) depending on the way stimuli and responses are arranged (e.g. Fitts, 1953). Additionally, Michaels (1988) could show that the SCR effects hold for motion stimuli as well. To return to the initial point, the same mechanisms that account for the SCR effect are more or less the same mechanisms described underlying "Common coding theory". The responses in choice reaction time (RT) tasks are assumed to be faster and less error-prone in the case that stimuli and responses are corresponding, because the response is then prespecified. The corresponding codes are already activated.

In short, there is strong evidence that action and perception share a common representational medium. It is suggested that common coding takes place at a high cognitive level, namely at late products of perception and early stages of action (Hommel et al., 2001). The postulated codes cannot be used for perception and action planning at the same time. Additionally, it is assumed that actions are planned and controlled in terms of their effects (Prinz, 1997). However, it still remains indistinct how observers are able to understand other individuals behavior and to judge the outcome of an observerd action. The next chapter will deal with the "Simulation Theory" and the "Theory Theory" as usefull frameworks for the present work.

3.1.3 "Simulation Theory" versus "Theory Theory"

Two approaches that should be considered are „Simulation Theory" (ST) as well as "Theory Theory" (TT) because both try to explain how an observer is able to predict an ongoing movement or even to predict the outcome of an action. Both theories additionally shed light to the question whether observers are able to detect certain mental states within the observed subject.

TT claims that individuals accomplish mind-reading by acquiring and deploying a commonsense “theory of mind” (Gallese & Goldman, 1998). That means they use something like a “scientific theory” and utilize casual or explanatory laws to understand the minds of other individuals. As a consequence TT assumes that it is not possible to observe mental states of other people directly (Davies & Stone, 1995). On the other hand ST suggests that individuals use their own mental mechanisms and motor system to understand the behaviour of others (e.g. Jeannerod, 2001). However, there are different accounts that describe what is meant by “simulation”. The aim of the next chapter will be to discuss these approaches and the implications of ST for the present work will be exposed.

Different accounts for „Simulation Theory“

“Simulation Theory“ seems to be a fruitful framework in the context of the present work. However, it should be noted that there are different basic approaches which belong to different scientific fields like cognitive and social neuroscience as well as philosophy concerning „Simulation Theory“. The term “simulation” is used interchangeably and in different ways by different researches. This leads among others to the conclusion that assumptions derived from simulation theories vary in reference to the degree of how actions are simulated. Nevertheless, all approaches have in common that the own motor system is always involved whenever an action is simulated. It is suggested that the motor system is part of a simulation network. Simulation can generally be described as the conscious reactivation of previously executed actions that are stored in memory (Decety & Ingvar, 1990). This “reactivation” of own past experiences allows the individual to derive information about the action that can be covert or overt.

Hesslow (2002) formulated the „Simulation Theory of cognitive function”. This approach is based on three main assumptions. First the author postulates that simulation works by the activation of motor structures with the restriction that those actions are not executed. This activation of motor structures is very similar for real actions as well as for simulated action. Second, not only behaviour but also perception could be simulated by activating the sensory cortex. Therefore, actually perceiving an event in the environment as well as imagining perceiving something (the perception is generated by the brain itself) is nearly the same. Third the consequences of actions can be perceptually simulated as if the action really had been performed.

The “Motor Simulation Theory“ (Jeannerod, 2001) is very simular to the theories proposed by Decety (1990) and Hesslow (2002) but it goes even further. It also assumes that the motor system is involved in action perception and that every action involves covert stages. These covert stages refer to representations of the future like the goals of certain actions and their associated effects and that the state of simulation and the state of execution of an action are very similar as already declared. Jeannerod (2001) called these states “S-States” and they refer, according to him, to intended as well as imagined actions, prospective action judgments, perceptually based decisions, observation of graspable objects as well as of actions performed by others and actions in dreams. As a consequence this is a much broader understanding about what can be simulated in contrast to Decety (1990) and Hesslow (2002). Additionally, in contrast to the other described theories the “Motor Simulation Theory“ assumes that simulation is an unconscious process.

The interesting question which derives from the postulated similarity between covert and overt actions refers to the fact why overt actions are not executed when it is assumed that similar brain areas are activated. There are two possible explanations. One refers to the fact that the activation of certain brain areas during the simulation of an action is not strong enough to initiate a movement. The other explanation postulates that the signal does not reach the motor neuron level because it is already blocked before. This implies that an inhibitory mechanism is generated in parallel to the motor signal.

Wilson and Knoblich (2005) addressed the question why the motor system is activated at all when only looking at other individuals and no motor movement is intended. The authors argue that the activation of the motor system feeds back into the perceptual processing so that the actions of others can be predicted in a top-down fashion. Covert imitation therefore works like an *emulator*. A *perceptual emulator,* for instance, uses the implicit knowledge derived from own body representations as a model to track actions of conspecifics in real time and to anticipate upcoming actions. That is the reason why the motor system is activated even when no motor action is intended.

Another approach regarding “Simulation Theory“ derives from philosophy. The so-called „Simulation Theory of mind” (Goldman, 2005) tries to explain how an observer is able to understand the mental states such as intentions, desires, feelings and beliefs of other people. The attributor therefore attempts to put himself “in the shoes of the others” to mimic the mental activity of a target (Goldman, 2002). The own psychological resources are used to understand the behaviour of conspecifics by imagining to perform exactly that action on a covert stage. Therefore the term “mind-reading” is used in this context. It describes the circumstances that individuals are able to attribute mental states to the self as well as to others. “Theory of mind” (TOM) postulates that we have metacognitive understandings of our own minds as well as understandings about the minds of other individuals. It should be noted that when trying to impute the mental states of the target, the observer has to substitute his own mental states with that of the observed individual (Goldman, 2005).

Even if all these accounts seem to be very similar there are important differences according to the degree to what is meant by simulation and whether it is an conscious or unconscious process. On the one hand, the simulation theory according to Decety (1990) would suggest that simulation allows to represent the motor intention of an observed subject. An example would be to see how a monkey is grasping for a nut. The observer will understand this action but according to Dectey (1990) nothing is said about the prior intention of the monkey that means why he may grasp for the nut. The „Simulation Theory of mind" (Goldman, 2005) on the other hand, however, not only describes how the motor system is used to understand actions. Additionally, it tries to explain the way how an observer is able to understand the mental states of others and this is therefore not related to motor actions per se. The "Simulation Theory of mind" therefore goes one step further, namely it reveals something about prior (social as well as communicative) intentions of an action. According to that theory the observer would assume that the monkey may be hungry, because he grasps for the nut.

Jacobs and Jeannerod (2005) are sceptical about the approach used by many motor theorists that the simulation process might be the link between human motor cognition (notion that cognition is embodied in action) and human mindreading. They argue that the mirror system is well designed to understand object-oriented actions but not to understand the social intentions of an observed individual.

Another difference concerning the approaches belongs to the extent of automaticity and control the individuals may exert upon the simulation process. Simulation can be automatic and unconscious when an observer is looking at a targets' movement (Grèzes, Frith, Passingham, 2004). But this process could be conscious as well if the individual tries to understand the intentions of the observed target (Ruby & Decety, 2004). However, all approaches are in agreement with theories of embodied cognition, because they postulate that the cognitive representations and operations used to simulate an action are grounded in bodily states and the modality-specific system of the brain (Niedenthal, Barsalou, Winkielman, Krauth-Gruber, & Ric, 2005). That means that cognitive and sensorimotor mechanisms are intimately connected.

Evidence for the hypothesis that real actions are simulated mentally, originate from studies that demonstrade that imagined actions show the same temporal characteristics (e.g. imagined time is equal to real execution time) as a really executed action (Decety, Jeannerod, & Prablanc, 1989; Munzert, 2008). Further evidence that imagined actions are internally simulated derives from a study by Frak, Paulignan and Jeannerod (2001). Subjects had to estimate the feasibility of grasping an object which was located at different distances. The results indicate that the time to respond depends on the orientation of the object. If the arm had to be rotated to reach the object, and therefore more time was needed, the response reflected that time delay.

Evidence for the function of different brain areas for the simulation process also originates from several studies in the neuroscientific field, including lesion studies (for an overview see Jeannerod (2001) and Blakemore and Decety (2001)). Ramnani and Miall (2004) used fMRT to examine the question whether the same brain areas are active when mental states are attributed to others or to the own person. According to „Simulation Theory“ the same brain areas should be involved when preparing own actions as well as when predicting the future actions of an observed individual. Using an associative stimulus-response task they could demonstrate that separated sub-circuits are activated within the premotor system depending on the agent. When own actions are predicted the dorsal premotor cortex (PMd) was more activated whereas the ventral premotor cortex (PMv) was involved when other individuals actions were predicted. The activation of PMd speaks for a simulation process whereas the activation of PMv is in better agreement with suggestions derived from TT. Ramani and Miall (2004) therefore concluded that mental imagery or simulation of own actions is used to understand the actions of others (see also Sebanz and Frith (2004) for more detail).

To sum up “Simulation Theory” as well as “Theory Theory” try to explain how individuals are able to understand the mental states of others. Whereas TT assumes that people use something like a scientific theory to understand the behaviour of others, ST assumes that the observer tries to put himself in the shoes of the observed model. This leads to the conclusion that according to ST the observer uses his own motor system to predict an ongoing action whereas TT would negate this assumption (Gallese & Goldman, 1998). This assumption has strong implications for the present work. According to TT it should make no difference to observe own or other individuals movements whereas according to ST differences could be expected. It depends on the fact whether the own motor system is used or not when people perceive biological motion. The next chapter will provide evidence for the interaction of perception and action that derives from behavioral as well as neuroscientific studies.

3.2 Empirical evidence for the interaction of perception and action

Empirical findings from behavioral studies

The interaction of perception and action can be evaluated in different ways. It is possible to examine how an actual action or even past actions as well as the representation of an action influences perception (Schütz-Bosbach & Prinz, 2007). The next chapter will provide an overview about studies that evaluate the interaction of perception and action.

On-line effects of motor action on perception

Contrast effects

Similar to the above described "interference paradigms" studies that examine the interaction of perception and action assume that an actual action can hinder perceptual encoding processes. That means that an observer may be less sensitive to a stimulus. The result that reaction times of finger movements are slowed down in the case that the participant observes a movement with another finger (Brass, Bekkering, & Prinz, 2001), or the execution of a different grasp (Craighero, Bello, Fadiga, & Rizzolatti, 2002), are examples for so called contrast effects (Schütz-Bosbach & Prinz, 2007). It is assumed that especially when the perceived action and the simultaneous executed action are qualitatively similar, performance should decrease. Kilner, Paulignan and Blakemore (2003) conducted a study to test the hypothesis that the simultaneous execution of an action while looking at a visual stimulus influences the performance of even that action. The task was to make sinusoidal arm movements while looking either to a robot or another human arm. The robot or the other human being carried out congruent or incongruent movements in the horizontal or vertical plane. The variance in the executed arm movement by the observer was measured. It could be shown that the performance of the observers decreased when they were looking at another human beings arm during incongruent arm movements. Interestingly, there was no performance decrement when the observer watched the robot arm performing congruent respectively incongruent movements. This result is in line with the above described interference paradigms and it further confirms the assumption that biological and no biological motion are processed differently. Similarly, mirror-neurons in the premotor cortex discharge differently whether the hand or a tool is used to manipulate an object (Rizzolatti, Fogassi, & Gallese, 2001).

Jacobs and Shiffrar (2005) conducted a serious of psycho-physical experiments to investigate the question how action and perception are linked in more realistic situations. The purpose of the keen and robust sensitivity to human movement is to coordinate the own movements with that of other individuals. Most of the research deals with stationary observers. The authors therefore investigated the question what happens to movement perception when the observer is in motion, too. The task was to judge the relative gait speeds of two different walkers. The results of these studies shed light to the question how action and especially the own motor system contributes to perception. Jacobs and Shiffrar (2005) could demonstrate that the production of similar actions influences the perception of especially these actions. Moreover, performance differed depending on the motor experience. Performance was better for common walking speeds compared to unusual walking speeds. Additionally, the authors concluded that egocentric gait-speed perception depended on the observers’ walking speed, but exocentric gait-speed perception did not and therefore these two types of perception rely on different visual-motor processes. That means that self-relative and other-relative action comparisons are different. The authors worked out that the observers' perception is biased by its own motor effort. Those participants who were fitter or were athletes could predict their own walking speed in reference to a point light walker much more accurate than the participants who were less fit. Additionally, the possibility to coordinate the own movement with that of other actors, differently influences the perception of gait speeds. For instance, individuals perceived themselves walking slower than the point light walker at slow walking speeds.

Another interesting experiment in that context was conducted by Hamilton (2004). The researcher examined the question if the perception of the weight of a box lifted by another person is influenced with reference to the weight the person himself is lifting simultaneously. That means the participants of the study watched short movie clips of someone else lifting a heavy or light box. While watching the movies they lifted or held a light or heavy weight in their own hands. The results showed that the perception of the lifted weight in the movie depends on the weight they were holding. The observers overestimated the weight lifted in the movie when they were holding a light weight and they underestimated it when they were holding a heavy weight in their hands. The above described results are in line with the assumption that a simultaneous action can influence perception and vice versa.

Assimilation effects

On the other hand, actual action can also facilitate concurrent perception. The idea behind these studies is similar to that of the "induction paradigms" used to test the predictions of the "Common Coding Theory" as described above. In experiments conducted by Flanagan and Johansson (2003) the participants had to observe another individual who executed a block stacking task. Interestingly, the coordination between the gaze of the observer and the movement of the models' hand was predictive and not reactive. This leads to the conclusion that the observer already knows what the next movement of the observed model will be.

Further evidence that an action can influence perception derives from a study in the auditory field (Repp & Knoblich, 2007). An expert as well as a novice group heard two tones that were related by a half-octave. Because these two tones are very similar some individuals perceive these tones as an ascending melody while other individuals perceive them as a descending melody. However, the perception of these tones can be manipulated according to the simultaneously performed action. When the participants pressed the keys of a piano or a computer keyboard in a left-to-right sequence, they reported more frequently to hear the two tones in an ascending manner and vice versa. Additionally, it should be pointed out that this result was true for the experts group only. It seems that the extensive active experience of playing the piano was responsible for that effect. The authors of this study suggest that piano players automatically generate expectations and something like an auditory image when they press the keys. It is this expectation that biases the perception of the two tones. The results of this study demonstrate how current action may influence perception.

Reed and Farrow (1995) could show that the own body position influences the perception of others' body postures. The authors used a same-different visual matching task. Observers had to estimate whether the position of an observed body had changed or not while simultaneously performing continuous unconstrained arm or leg movements. The results showed that observers were better able to recognize changes in arm movements when they were simultaneously moving their arms.

To sum up, the above described studies demonstrate that an actual action can hinder as well as facilitate perception. However, it remains unclear why action sometimes disturbs and sometimes supports perception. It is assumed that the time interval between action production and perception may be the critical factor that determines whether concurrent action influences perception in a positive or negative way. As already described above, it is assumed that a code could be used either for action or for perception (Hommel et al., 2001). Time delays between perception and action therefore allow using the same code for both domains and assimilation effects should be found (Schütz-Bosbach & Prinz, 2007).

Off-line effects of motor action on perception

However, not only actual actions influence the perception of actions but also past action or the representation of an action can influence perception (top-down effects).

Fagiolo, Hommel and Schubotz (2007) could demonstrad that the preparation of a certain action can increase the perceptual sensitivity in refrence to that action. In this study subjects had either to reach or to grasp for an object. However, while planning to execute the movement they had to attend to the shape or location of a presented object. The results indicate that individuals were more sensitive to changes according to the shape of an object when they were planning to execute a grasping movement, than when they were planning to execute a reaching movement. On the other hand, they were more sensitive to changes in reference to the location of a presented object when they were planning a reaching movement. Taken together, the results of that experiment support the assumption that motor intentions can influence the perception in a top-down manner.

As already described, it is assumed that the representation of an action should influence the perceptual process. It therefore seems plausible to hypothesize that an improved representation of an action should lead to improved perception and vice versa. Therefore non-visual motor learning should influence perception. To investigate the question whether there is a transfer from action to perception and from perception to action Hecht, Vogt and Prinz (2001) conducted two experiments. In the first study one group of individuals had to learn timed two-cycle arm movements (motor group). They received verbal but no visual feedback on their performance. Another group of participants had to learn to judge the temporal ratios of two-cycle sinusoidal motions of a vertical bar (visual group). A third group sub served as control group. All groups had to perform a motor test as well as a visual test with the tests being similar to the practice conditions. It is not surprising that the motor group should be best in the motor test and the visual group should be best in the visual test, because the tests were in accordance with their specific training. Especially interesting however was how good the performance of the motor and the visual group was in the tests they did not practice for. If there were transfer effects from perception to action and vice versa, the motor group should be better in the visual test than the control group. In contrast the visual group should be better in the motor test than the control group. The analysis of the data according to the total error confirmed these assumptions. Both groups showed best performances in the tests which belonged to their training sessions. The visual group however was better in the motor task than the control group and the motor group was better in the visual test than the control group. Taken together, the results manifest that there are transfer effects from perception to action and vice versa.

In a second study the authors wanted to find out whether the planning or preparatory component to execute the arm movement was responsible for the results in the previous study or if the results were due to kinaesthetic feedback. Hecht et al. (2001) therefore conducted a ‘passive’ kinaesthetic learning condition and an ‘active’ motor practice condition. One individual had to carry out the motor task whereas a partner, who was aligned to the first person, only received kinaesthetic information of the movement. The results demonstrated that both groups, the active as well as the passive learners, showed the same performance in the visual test and that they were better in that test than the control group of study one. On the one hand, this result confirmed the findings of the previous study namely that there are transfer effects from action to perception. On the other hand, the results indicated that kinaesthetic feedback seems to be sufficient to evoke the transfer from action to perception. In the present task the preparation and execution of the motor task does not seem to be responsible for the positive transfer effects.

Support for the assumption that there are transfer effects from action to perception also derives from a study conducted by Casile and Giese (2006). The idea behind this experiment was that the acquisition of a new motor pattern should improve the visual recognition of exactly this pattern. At the beginning of the study the individuals had to perform a discrimination task. Two point light walkers were presented on a screen and the task was to judge whether the walkers used a similar movement pattern or a different one. The walking pattern could vary according to the arm and leg movements. Characteristic for the normal walking pattern is a phase difference of about 180°. The walkers however showed additional phase differences from 225° and 270°. After the pre-test the participants had to learn to perform a new walking pattern (270° phase difference of arm and leg movements). It is important to mention here that they did not get any visual feedback while they learned the movement. After the motor practice they again had to perform the pre-test. The results showed that the individuals improved their performance for the movement patterns they learned during the motor practice. No improvement according to recognition rate was found for the two other walking patterns. This result therefore supports the assumption that there is a transfer from action to perception. It should be pointed out that the degree of improvement correlated with the accuracy of execution of the movement pattern. Those participants who had learned the new walking pattern very good showed better recognition performances than those individuals who had learned the movement pattern less successful.

Another possibility to evaluate so called “off-line effects of motor action on perception” (Schütz-Bosbach & Prinz, 2007) is to look at studies that investigated motor experts. It is assumed that an expert has a very good representation of especially those actions that refer to his domain. Calvo-Merino, Glazer, Grezes, Passingham and Haggard (2005) therefore conducted a study with expert capoeira and classical ballet dancers. The aim of this experiment was to compare the activity within the premotor and parietal brain regions of those two groups when they were looking either at their own dance styles or at that of the other group. The analysis of the data revealed that the motor system was much more activated when individuals watched their own dance styles compared to watching another dance style. However, the results of that study can either be due to the greater motor expertise the individuals have according to their dance style or they could be due to greater perceptual expertise they have in watching those movements.

To examine whether the results were due to motor or visual expertise, the researcher conducted a follow-up study (Calvo-Merino, Grezes, Glaser, Passingham, & Haggard, 2006). This time the members of the ballet group watched gender specific ballet movements. The idea behind this manipulation was that now the female ballet dancers should have the most motor experience with their own gender specific movements but that they should have a comparable amount of visual experience with male and female ballet moves. The same should be true for the males. The finding that there was a greater activation within the motor regions of the brain as well as the cerebellum when subjects looked at their own gender-specific actions, supports the assumption that the motor system is most engaged in visual observation when the own class of movements is observed.

Affiliated with motor expertise is the idea that experts should posses high motor competencies. That means that they should have a great knowledge about constraints of human movements in general and especially for those movements they are experts. For instance, it could be shown that observers utilized the so called “two-third power law” when predicting the movement of a single dot (Viviani, 2002). This law describes the interrelation between the velocity of a moving dot and the radius of curvature of the trajectory. This is one law that is typical for biological motion. The other one is called “Fitts’ law” and describes the relation between speed and accuracy in performed and imagined movements. It postulates that the time needed to move as quickly as possible between two targets depends on the width of the targets and the distance between them.

Already Decety and Jeannerod (1993) could show that Fitts law is used during the imagination of a movement. Grosjan, Shiffrar & Knoblich (2007) further examined this result, because they wanted to find out whether this law holds for action perception as well. Subjects in this study looked at another person who was moving his arm with different speeds between two targets of different sizes and at different distances. Apparent motion displays were used instead of videos to avoid that the result was due to different movement trajectories. The task was to evaluate whether the model was able to move with the perceived speed without missing the targets. The result revealed that the participants utilized Fitts' law to come to their decisions. That means that those movement times were reported as being possible that were predicted according to Fitt's law. Additionally Grosejan et al., (2007) could show that the same results were due to the movement of a robot arm and to movements of non-biological agents.

Another important point that influences the perception of action is the present and past experience the observer has, as well as his age, fatigue and physical fitness (Proffitt, Bhalla, Gossweiler, & Midgett, 1995; Proffitt, Stefanucci, Banton, & Epstein, 2003). For instance, the infants` perception of hill safety improves when their ability to crawl increases (Adolph, 2003). Moreover, it could be shown that the impairment of the motor system can affect the perception negatively. Bosbach, Cole, Prinz and Knoblich (2005) could show that individuals who lost their sense of cutaneous touch and proprioception showed deficits when they had to interpret the movement of another person lifting a box. That means that they were not able to recognize if the observed person had a false expectation regarding the lifted weight or not.

Empirical findings from neuroscientific studies

Additional support for the interaction of perception and action derives from studies in the neuroscientific field. PET as well as fMRI-studies could show that the premotor cortex, the posterior parietal cortex as well as the cerebellum are activated during the actual executed or imagined action and the observation of the same action (Decety & Grèzes, 1999; Ruby & Decety, 2001). The same brain areas are activated when observing a certain action as well as when performing exactly that action (Gallese & Goldman, 1998; Jackson & Decety, 2004). These brain areas refer primarily to the motor system involving the primary motor and premotor cortex, the basal ganglia, the cerebellum as well as the corticospinal pathway. Furthermore, associative cortical areas like for instance the parietal and prefrontal cortex show a specific activation while observing as well as performing different actions. It should be noted that even if the same brain areas seem to be activated when watching other conspecifies' movements or performing the movement itself that sharedness does not mean identicality. Otherwise it would not be possible to distinguish between self and others if exactly the same brain areas were activated. There is also a large body of literature concerning the question how the self can be delimited from the other (e.g. Decety & Sommerville, 2003).

With the discovery of so-called "mirror neurons" in area F5 in the brain of macaques a neurophysiologic correlate was found where perception and action are represented within single cells (e. g. Di Pellegrino, Fagida, Fogassi, Gallese, & Rizzolatti, 1992; Fadiga, Fogassi, Gallese, & Rizzolatti, 2000; Gallese, Fadiga, Fogassi, & Rizzolatti, 1996). These neurons discharge when the monkey performs hand movements as well as when he is watching at another monkey or even a human being performing the same task. However, it should be emphasized regarded these findings that mirror neurons are restricted to movements with the hand or mouth towards an object so far. It is questionable whether these neurons discharge in the same way when looking at whole body movements and whether monkeys really imitate (Wilson, 2005). There is evidence that a similar structure exists in the human brain (Gallese, et al., 1996; Hari, Forss, Avikainen, Kirveskari, Salenius, & Rizzolatti, 1998). It could be shown that during the observation of a specific action, like a hand movement for example, the motor-evoked potentials from the hand muscle increases (Fadiga, Fogassi, Pavesi & Rizzolatti, 1995). Additionally, different cortical areas within the brain of monkeys show activity at the same point in time as a temporary synchronization of cell activity (Eckhorn, Frien, Bauer, Woelbern, & Kehr, 1993; Gray, Engel, Koenig, & Singer, 1992). This supports the above described idea of binding of certain codes.

We have seen that behavioral as well as neuroscientific experiements analyzed the interaction of perception and action using different kinds of paradigms. It was evaluated how present or past actions may facilitate or hinder perception. Evidence for the interaction of perception and action does not only derive from behavioral studies. With the discovery of the so-called “mirror neurons” a neurophysiological correlate was found were perception and action may interact.

3.3 Conclusion

What is the meaning of “action planning”, “Common-Coding Theory”, “Theory of Event Coding”, “Simulation Theory“ and the described studies in the context of the present work? First of all it should be obvious that there is a strong link between perception and action and that they obviously influence each other. Second, derived from the “Common Codig Theory” it could be assumed that perception and action are represented within one common domain. It was postulated that the “mirror neurons” might represent these common medium. An important implication deriving from the “Common-Coding Theory” is the fact that when the activation of a common code exceeds a certain threshold the corresponding motor codes are triggered. The activation of a motor representation while perceiving a movement depends on the degree to which both are similar. There is a set of scientific results which verifies that what someone perceives depends upon his motor experience. As a consequence, perception is embodied meaning that the own body or the representation of the body is used for perception. It is the similarity and the dissimilarity between the representations for perception and action that specifies the quality of the actual perception and action. Third, the “Theory of event coding” postulated that actions are planned in terms of their intended effects. The individual is not only able to plan a movement in order to achieve a certain goal (forward model) but it is also able to infer from a certain effect which action is necessary to cause even that effect (inverses model). Fourt, because of the perceptual resonance to an observed action individuals are able to understand the actions and possibly the intentions of other people. “Simulation Theory“ therefore assumes that individuals are able to understand the intention of other human beings because they mentally simulate the perceived action. This leads to the conclusion that observing an action activates the same mechanisms in the brain of the observer which are activated when the observer imagines that action or even intends to perform this action on his own. Derived from this hypothesis it could be assumed that when someone perceives his own past actions, more information about the intention of the acting individual should be available. Moreover, this should lead to even better predictions of the outcome of own actions.

Taken together, there is strong evidence from a theoretical as well as from an empirical point of view for the assumption that perceiving own movements is qualitatively different from perceiving movements of strangers. It is important in this context to remember the distinction between on-line and off-line perception. The first type refers to the situation when an individual perceives the effect of its actions while it is actively performing it. This includes visual as well as kinaesthetic information about the outcome of an action. The second type refers to the perception of own movements after they have been performed; that means that there will be a time delay between the execution and the observation of the movement. The later type is the objective of the present work.

When a person perceives the own movement, the same “system” that had planned the action is now perceiving it and therefore the “resonance” should be very high. If the movement of a stranger is perceived, the overlap between perception and action should be smaller because of the different styles of performance of persons. The matching of the above describes “motor codes” and “perception codes” will be smaller and that should lead to a worse performance.

This assumption implies that if more “motor codes” are activated performance and perception will be better. For instance Grezes, Frith and Passingham (2003) could show that the activity within the parietal premotor circuit, which is used for action perception, starts earlier when own movements are judged in reference to other individuals’ movements.

It moreover is assumed that the individual compares the perceived actions to what it would look or feel like when it performs exactly that movement on its own. First, this presupposes that the action performed earlier and the way it would be executed now is very similar. The self-recognition ability is therefore more or less based on identical actions. This leads to the conclusion that it should be very easy to identify own actions because the individual is an expert for its own actions and possesses about a good representation of that actions. Support for that hypothesis is the assumption that the same movement is carried out very differently by different persons but that there is a very stable movement style within one person. The inter-individual variability derives from the fact that there are different learning histories, skill levels and anatomical constraints which determine how the movement will look like.

However, it seems to be questionable if this advantages also refers to the fact that someone is able to predict the effects of own movements better than that of other individuals. As the TEC stated, there is a link between late perception and early action respectively action planning. Nothing is said about the effects on the complex machinery of the late motor processes (Hommel et al., 2001). Therefore is also seems plausible to assume that there is no difference between the anticipation of action effects when perceiving the own movement or that of other individuals. From an ecological point of view it should not make a difference because normally the own movement is not perceived from a third-person perspective.

To sum up, based on the differential activation of the codes when watching different persons, one should be able to identify the own movement among that of others. The own action should awake some kind of familiarity in the observer. Moreover, it is assumed that individuals’ have the best motor competencies for their own movements. That is they possess the best knowledge of their own motor capabilities and they are experts for own movements. Because of that the coordination with past own movements should be facilitated compared to the movements of other people. However it remains ambiguous whether individuals are also better to predict the outcome of own actions compared to other human beings movements.

It will be interesting to further investigate the question whether individuals are able to recognize the own past movement and if they are able to predict the effects of the own movement better than that of other people. Before presenting the results of two own experiments, an overview about studies will be given that already employed similar questions.

4. Perception of own past movements and their effects

Human beings are able to identify the products of past actions in some situations very easily. For example, one can recognize the handwritings or drawings of himself when watching it later. Or in a more obvious case, one can recognize himself when watching a video of own actions. In that case the good identification of own movements refers to the fact that someone has a better representation of his own anatomical features, like for example his face. It is also thinkable that one simply remembers being the author of an action. But there are also examples where it is less obvious whether one perceives the products of own past actions. This might be the case when hearing an old recording of a piece of music for example. Is it possible to identify the musician who played the music and what cues may help the individual to choose the right decision? Is the recognition of the author of an action even better, when someone perceives the own movement? Does the perception of own and other individuals actions therefore differ or are they equal?

The next part of the work will provide an overview of studies that explored the phenomenon of self identification in different kinds of actions. The aim of those kind of studies is to prove that the motor system is involved in actor and action recognition. The experimental approach has therefore to ensure that not anatomical features (e.g. the face), object features (e.g. the trajectories of the ball) or episodic knowledge leads to actor identification. Most of the studies therefore use the above described point-light technique, to provide only kinematic information about the acting person. Overall, the studies can be divided into three main sections. One line of research deals with the identification of the actor. The aim of those studies is to find out if someone can recognize the own movement among that of other individuals movements and if it is possible to identify friends among strangers. Another kind of research deals with the anticipation of action effects. The idea addressed here concerns the question if someone can anticipate the effect of own movements faster or better than the effects of other people movements. A third line of research deals with the question if someone can coordinate his own actions better with perceived past actions of himself than with actions of other human beings.

4.1 Actor identification

These studies address the question if someone is able to identify the own movements or the products of own movements among that of other people. The phenomena of action identity were demonstrated in a variety of domains. The first one who was interested in person identification was Wolff (1931). In this study the task for the participants was to walk up and down in a room and perform different kind of actions. To avoid that someone identifies itself due to its clothes or other easily recognizable cues, he asked every person to wear exactly the same clothes. Additionally, he manipulated the faces in the video tapes in a way that they were not visible anymore. The results gave a first hint that it is possible to recognize the own movement among that of other individuals, like friends for instance. Nevertheless, there were some inaccuracies in that study. The size of the people was not equal and it seems questionable if the clothes really avoid individual characteristics. To solve that problem the so called “point light technique” was established by Johansson (1973) as already described above.

Cutting and Kozlowski (1977) enhanced the question about the identification of a point light walker. They wanted to find out if it is not only possible to identify a walker within a point light display but also to give him the correct name. Therefore, they captured the motions of six walkers. Later they presented these movements as point light displays on a screen. The formerly walkers were now the observers. After some difficulty at the beginning of the experiment, the participants were quite well able to distinguish the own movement from that of other individuals. Gait parameters like the walking frequency, speed and stride length seemed to provide enough information for the observers to make their decision.

Beardsworth and Buckner (1981) replicated this study with some modifications. In contrast to the study of Cutting and Kozlowski (1977), they limited the number of answers according to their own movement. That means it was not allowed to name the own person several times. Additionally, each movement was presented for a longer time. The results showed a statistically significant difference between the perception of own and other individuals movements. That is, observers were able to distinguish between the movements of their friends and that of strangers.

The finding that the observer shows his best performances for the own movements is especially interesting as normally a person does not see himself walking. In contrast it is the norm that we perceive other people and particularly our friend walking. Therefore, it is questionable were this advantage for the own movement and that for friends in reference to strangers may come from. There are in general two answers. First it seems that movement perception is based on experience. According to the traditional view (Johansson, 1973) these experiences may be based on the fact that we often see our friends walking and we therefore have a lot of "visual experience". This would explain why we are able to distinguish between friends and strangers. Support for this assumption derives from a study of Stevenage, Nixon and Vience (1999) who could show that it is possible to learn to differentiate between formerly unknown point light walkers after a certain amount of practice. Second Prinz (1997) claimed that the difference between the perception of own movements and that of friends as well as strangers refers to fact that the individual has better motor representations (knowledge about a movement) for its own movements than for those of other human beings ("motor view"). This view could therefore explain why subjects are better suited to perceive their own movements.

Jokisch, Daum and Troje (2006) conducted a study to test these predictions. The authors argumented that if the perception of own movements depends on the own motor representations, then it should make no difference from which perspective a person will see its own movements. On the other hand, if the perception of friends is based on perceptual experience, the perspective should play an important role. In a first session the researchers therefore captured the movements of two groups of twelve individuals who were all familiar to each other. In the second session the participants saw either their own or their friends movements from profile, half-profile or frontal view. The task was to assign the correct name to each walker. The results indicate that the recognition of the own movement was independent from the view point, whereas the recognition of friends was better for the frontal view and worst for the profile view. These findings support the assumptions that we use our own motor system when we perceive movements (Prinz, 1997).

Loula, Prasard, Harber and Shiffrar (2005) used an actor identification as well as a discrimination task to extend the results according to actor identification. In a first experiment the authors examined the question how well observers were able to identify themselves, friends and strangers within PLDs. Different actions, like for instance walking, jumping, greeting gestures by shaking hands, dancing and table tennis playing were presented. Within the test session the observers saw only three different actors (self, friend, stranger) so that the amount of visual experience within the test was the same for each actor. The results showed that the performance was best for the self-trials. Friends were better recognized than strangers. Additionally, performance was depending on the presented actions. Observers gave more correct answers when they saw dance or table tennis movements compared to actions like walking or running.

The second experiment referred to the same stimuli as the previous experiment. Now an actor discrimination task was used instead of an actor identification task. This manipulation allowed for an unbiased measure of actor identification, because the observer never explicitly named the presented actor. Two different actions were presented. The task was to decide whether the two movements come from the same actor or from different ones. Again the analysis of the data showed that observers were most accurate when the own movement was presented and that they were better for friends' trials than for the trials where strangers were presented. A further experiment using the same stimuli revealed that identity perception is orientation specific. When the PLDs are presented up-side down no better performance for the own movement was found compared to friends and strangers. When only static cues were presented identity perception for all presented actors was at chance level (Loula et al., 2005).

Handwriting

Knoblich und Prinz (2001a) conducted a series of studies about person identification in the domain of handwriting. The advantage of this approach lays in the fact that the information provided by a handwritten trajectory can be manipulated very easyly. The trajectory consists of only two spatial and one temporal dimension. Additionally, writing and drawing are complex skills and action planning is important for that kind of action. It seems to be obvious that a person can identify past handwritten signs when she is looking at the finished product. The interesting question here is, if this ability to identify the own past handwriting is as good as when only action-related information is given like the presentation of one moving point that reflects the trajectory of the written sign. Overall there were five studies which addressed the question whether the participants can recognize their own actions among that of other people when seeing the visual effect. Each study was divided into two sessions. In the first session the participants had to produce writing samples of a number of familiar (numbers and letters of the Latin script) and unfamiliar (letters from Thai and Mongolian scripts) symbols. While they were performing the task their hand was videotaped from view. The participants did not receive visual feedback about the emerging trajectories. To standardize the writing, the stroke sequence and the stroke direction was stipulated. If the task was for instance to draw the letter 'P', the participants needed to start with a down-stroke, then lift the pen to produce the bended stroke from top to bottom. The second session took part one week later in each case. Therefore, it was unlikely that the individuals could remember certain aspects of the first session which would allow for better self-recognition in the second session. The participants saw two kinematic displays of the same symbol. The symbols were presented by a moving dot that appeared on the screen. This dot symbolized the tip of the pen. Only the moving dot was visible, what means the whole trajectory was invisibly. The task was to identify the one that was the product of the own movement. The order of self and other produced symbols was randomized. No feedback was given about the correctness of the judgement. The results showed that the participants were able to identify their own past actions even so only the moving dot was presented.

To gain further into the mechanism by which the participants were able to identify own movements, the size as well as the overall duration of the drawing movement was standardized. Again the results indicated that participants were able to recognize their own movements. As an exception the performance broke down when the differential velocity information was removed. In that case the dot moved with constant velocity. Further support for the importance of the velocity derives from the fact that those symbols were recognized much more often as products of own past actions which were associated with larger velocity changes. It seems that velocity changes provide a rich source of information about the actor of a past movement, especially in the case of self-recognition. Symbols with a lot of velocity changes therefore were identified easier. Another interesting result was that no difference was found between familiar and unfamiliar symbols. It is assumed that this result could be explained by a stronger activation of the event codes when watching own former produced symbols. This stronger activation may be due to an increased resonance process or because of the internal simulation of the action (Knoblich & Flach, 2003).

Clapping

To gain further insight into the perception of movements and the mechanisms underlying especially the perception of own movements, Repp (1987) conducted another series of experiments. The aim was to explore whether individuals were able to identify their own past clappings. In difference to the studies conducted by Knoblich and Prinz (2001b) this type of movement allowed to additionally remove all spatial information so that only acoustic information (tempo, relative timing) survived. Again the results showed that individuals were able to recognize their own clapping.

Flach, Knoblich and Prinz (2004) tried to replicate the findings of Repp (1987). The aim was to determine how action-related timing information is used to recognize the own movement. This study was divided in two sessions separated by one week. In the first study the participants were asked to clap rhythmic patterns of varying complexity. The performance of each individual was recorded. The second session was the real test session. Each individual was matched with another participant. That means for every person half of the presented trials were self generated and half of them the result of another person's movements. Additionally, two participants watched exactly the same stimulus material. The task was to decide whether a certain sequence of clapping was a past product of an own movement. The results of this study clearly demonstrated that individuals can recognize their own past clapping and therefore replicated the findings of Repp (1987). However, the accuracy of the judgements was unaffected by the rhythmic complexity of the clapping pattern.

A follow up study dealt with the question if the individuals would still be able to recognize the own movement when only simple tones (beeps) were presented. That means that the general tempo and the relative timing is unaffected but other cues, for instance, acoustic differences that may evolve because of different hand configurations while clapping, were removed. Interestingly, the results showed no difference compared to the results of the previous study. This leads to the conclusion that the general tempo as well as the rhythmic information provides sufficient information to identify the own movement.

To gain further insight into the question which cues allow the individuals to recognize their own clapping, the next study further manipulated the sequences of the tones. The original timing was still unaffected but the tones were replayed in the tempo of the other participant or the partner (change of relative timing). The results indicated that this manipulation leads to a decreased performance, that is the participants were not able to identify their own clapping. In the case that the participants had used the general tempo information no decrements would be expected. If the participants on the other hand had used the relative timing they simple should confound own and other individuals movements. Taken together, the general tempo as well as the relative timing of the tones are important cues for self-recognition.

Piano playing

Repp and Knoblich (2004) tested the hypothesis whether skilled performers were able to recognize the products of own past movements within the domain of piano playing. It was postulated that within this expert group a strong connection between actions and their resulting action effects exist. The authors therefore asked 12 piano players with several years of experience to play different music sequences (duration 15 to 20 s) they were not familiar with, on a keyboard. On half of the trials a silent keyboard was used so that the piano players did not hear the music. After about two months the piano players were invited back to the lab. This time they heard the pieces of music which were recorded during the first test session. The task for the individuals was to rate on a 5-point scale (1= not me, 5= me) how sure they were whether the presented piece of music was a product of their own actions or that of another player, respectively. Interestingly, the piano players rated own past products higher than those of other participants. This result underscores the findings described above, namely that individuals are able to recognize the products of own past actions. The authors therefore concluded that when hearing own performances the resonance within the motor system might be greater compared to hearing other individuals' music pieces. Therefore, the match between anticipated and perceived action effects is better. Repp and Knoblich (2004) argue that the piano players internally simulate the actions as well as their consequences and this simulation is more or less similar to what they hear, depending on the performer of the action (own vs. other).

Again the question arises what cues had been used by the piano players to discriminate between own past products and other players' movements. To clarify this question, Repp and Knoblich (2004) conducted a serious of follow up experiments. They manipulated the speed as well as the overall dynamic level of the captured music pieces. Additionally, they removed dynamic nuances which may be responsible for the high recognition performances. The results of that study showed that none of these manipulations led to a decrement in performance of the participants. This leads to the conclusion that all information necessary to discriminate between an own movement and that of another person's movement is still there. The authors therefore postulated that the expressive timing as well as the articulation might be important to solve the task. It should be pointed out that even if the piano players did not hear the sound during the recording sessions and even if they had to play music excerpts they were not familiar with, they were still able to recognize own past action products. This result was interpreted as strong evidence for the assumption that the own motor system is more activated when a person perceives own past movements than when it perceives other people movements. However, it should be pointed out that this assumption might be true only for the perception of own past movements (off-line effects).

Schütz-Bosbach, Mancini, Aglioti and Haggard (2006) could show that the opposite is true for on-line perception of own movements. The crucial question concerning this study was whether own and other individuals' movements are represented in the same or in a different way. Obviously own movements differ from that of other people. The individuals take in different viewpoints when perceiving own and others individuals' movements or they simply receive kinaesthetic feedback from their own movements which is missing when they are watching others, for instance. The authors used the so-called "rubber-hand illusion" to manipulate the sense of ownership. Participants were sitting in front of a table. One hand was placed on the table while they were looking at a rubber hand which was placed in front of them. If the rubber hand as well as the own hand is stimulated simultaneously, the illusion arises that the rubber hand is the own hand. If however the stimulation was asynchrony, no such illusion would arise. TMS was used to test whether motor facilitation was stronger when participants attribute the rubber hand to themselves or to another agent. Interestingly, the results showed that motor facilitation was stronger when participants attributed the hand to another person compared to the situation when they attributed the hand to themselves. On the one hand this result confirms the assumption that the observation of other individuals' movements facilitates the own motor system. On the other hand it could be shown that when looking at putative own movements the motor system is less active.

Taken together, this result leads to the conclusion that other human's action and own actions are presented differently within the human motor system when talking about on-line effects of perception. Moreover, during the on-line observation of own movements the own motor system is less active. This finding is, in contrast to the results of other experiments, dealing with off-line effects were the own motor system seems to be stronger activated.

4.2 Prediction of own movements effects

Another line of research is concerned with the question whether it is possible to predict the consequences of a self-generated action better than the effects of other individuals' actions. Current theories assume that observing an action triggers action simulation, and therefore mechanisms in the motor system are used to predict the future consequences of an observed action.

Handwriting

To test the hypothesis that someone is able to predict the consequences of ones own movements better than that of other people movements Knoblich, Seigerschmidt, Flach and

Prinz (2002) conducted an experiment in the field of handwriting. The study was divided into two separated sessions, one week apart. The task in the first recording session was to write different versions of the digit ‘2’ on a writing pad. That number was chosen, because it can be divided easily into two separate parts, namely the bended and the straight stroke. The participants on the one hand were asked to write the whole digit and on the other hand to only produce the first stroke in isolation. The hand of the individuals was videotaped from view. The individuals were not able to see their hand while writing and they did not receive any feedback about the trajectories of their movements. However, in this case the production and the observation perspective are equal. In the second session the participants saw a moving dot on the screen that reproduced the first bended stroke of the digit ‘2’. Only the small dot representing the tip of the pen was visible, the trajectories were invisible. The task for the individuals was to decide whether this first stroke was part of the whole number; that means that the individual that produced the movement planned to complete the drawing or it planned to only produce this first stroke in isolation. Half of the presented strokes were self-produced while the other half was produced by another participant. No feedback about the performance was given. The results showed that when watching strokes that were produced by another individual the participants were at chance level, meaning that they were not able to decide if the trajectory was part of the digit ‘2’ or an isolated stroke. However, if the participants observed own movements they were above chance level with their predictions. That means that individuals were better able to generate predictions of the consequences of own movements than for other people movements. The variability of movements between the individuals is high and therefore the motor system is best able to predict the effects of the own movements. This is in line with the above discussed assumption that when watching own movements the activation of the event codes leads to the simulation of an action which then leads to better predictions of an upcoming event.

Another experiment was conducted with the difference that the participants had to write the number within two horizontal lines. The idea behind this manipulation was to restrict the height of the drawing und therefore test the predictions that the differences between the movements of individuals are responsible for better predictions of own movements. Interestingly, even with that manipulation the results did not change in reference to the first study. But when the individuals had to write the number within a field that was restricted by horizontal as well as vertical auxiliary lines, the performance broke down for self-generated trajectories as well. This result derives from the fact that this manipulation constrained the trajectories in a way that no inter-individual differences among the individuals were possible. This explanation is in line with the assumption of the „Common Coding Theory“. If the movements are restricted, the anticipation of the results for own movements is as good as for the movements of other individuals.

Dart throwing

The aim of a study of Knoblich and Flach (2001) was to examine the question if the advantages in prediction of action effects of own movements could also be found when the production and the observation perspective were different. Therefore, a dart throwing task was chosen. Again, there were two sessions which were separated by one week. In the first capture session the individuals were asked to throw darts at the upper, middle and lower third of a target board. All of the participants were beginners, meaning they had no experience with dart throwing. After a short training session, 10 videos of each throwing movement to a certain target height were recorded. The task in the test session was to predict the landing position of the dart after a certain video clip was presented. The videos presented either their own movements or that of a partner. Exactly the same stimulus material was used for both individuals. Each presentation started with the participant picking up the dart and ended with the dart leaving the hand. No feedback was given about the accuracy of the judgments. The participants were able to predict the landing positions of the darts quite well. Interestingly, performance increased in the second half of the trials when the own movement was presented but it did not increase when the movement of an other individual was presented. To gain further insight into the question what cues the observers use to predict the landing positions of the darts and what the reasons areb for the better performance for own in comparison to other human beings movements, the mode of presentation was manipulated. There was one experiment in which the amount of information provided about the person throwing was restricted to the upper body and the throwing arm. The head was invisible. Only the throwing arm was visible in a third study. Taken all together, the three experiments showed that the overall accuracy of the prediction decreased proportional to the amount of information that was given. Interestingly, the pattern for self-other judgements remained unaffected.

All three studies demonstrated that the advantage for better prediction of own movements selectively increases in later trials. According to the authors, the reason for the lack of a difference in early trials between own and other individuals' movements may refer to the fact that a certain time is needed to adjust action simulation to the new perspective. It needs time to change from a third-person perspective to the first-person perspective. Additionally, it was assumed that the presented self-other difference refers to the fact that action timing in that mode of movement is an important cue. This invariant might have differed across the different participants. The results demonstrate that action perception is indeed based on action simulation and this allows for action prediction.

4.3 Online coordination

A series of experiments addressed the question whether the simulation of an observed action provides information in a way that is fast enough to allow the coordination with past actions. Would an individual be its own best dance partner or accompanist when playing a certain piece of music.

Flach, Knoblich and Prinz (2003) performed a study about handwriting. The aim was to investigate whether one can coordinate new actions more accurately with the products of own past movement products. Again the experiment was divided into two sessions. In the first recording session the individuals were asked to draw zigzag and sinusoidal line patterns with constant or alternating amplitudes on a writing pad. During the second session the participants watched at a point light display that reproduced either the own movement or that of another person. In this study the task was not to identify the author of the presented action but to coordinate the own movement with the one presented on the screen. The individuals were instructed to press a button every time the dot turned from moving upward to moving downwards and vice versa. To solve the task the participants had to internally predict the next turning point. While the task was difficult at the beginning of the experiment, all individuals improved their performance later. Interestingly, they improved more when a difficult line pattern was presented with alternating, irregular patterns compared to the presentation of constant, regular patterns. Only when own movements were presented, the performance for both types of presented patterns reached a comparable level. For the case that other individuals' movements were presented, the constant timing error remained higher for irregular patterns throughout the experiment.

To sum up, the results of that study indicate that an individual could better coordinate her actions with own past actions. It is important to note that the task has to be sufficiently difficult and that practice is needed. The lack of a self-other difference in the initial trial might occur, because time was needed to identify the inter-individual differences concerning the point light display. Another possible explanation might be that those differences were already detected at the beginning of the presentation, but that the individuals were not able to use it for the online action control.

Keller, Knoblich and Repp (2007) examined the question whether musical ensemble players were better able to synchronize with their own former performances than with those of another player and if they were able to identify own past recordings. Within a first recording session nine skilled piano players were asked to play one part of four different piano duets. Three to four months later the task was to play the converse part of exactly those music pieces. The piano players either had to synchronize with own earlier recordings or with those of another player. The important point was that they were not informed whether they had to synchronize with own past recordings or not. However, they were asked to identify their own former recordings. The results showed that the piano players were better able to synchronize with their own earlier performances and they were able to identify their own past recordings. Interestingly, those participants who showed high performance accuracy to synchronize with own past recordings were also better to identify their own performances. The authors concluded that the piano players simulated the concurrent actions of the other player to make temporal predictions about when to act to be synchronous. This simulation was best when they had to synchronize with themselves.

4.4 Conclusion

The aim of the above described studies was to test the prediction whether there is a link between perception and action and to what degree both are similar. All experiments examined the influence of motor competencies on action perception. It was assumed that someone should have the best motor competencies for his own movements, because the same system that had planned and executed the movement is now watching it. There is a lot of evidence that the perception of own movements differs from the perception of other individuals' movements. In the first place, individuals were able to identify their own past actions among those of other individuals. That was shown in several studies dealing with various kinds of movements (e.g. Beardsworth & Buckner, 1981; Cutting & Kozlowski, 1977; Loula et al., 2005). In the second place, an advantage for the prediction of action effects when the own movement is presented could be found (e.g. Knoblich & Flach, 2001). In the third place, the coordination with own past actions seems to be easier compared to the coordination with other individuals' actions (e.g. Keller et al., 2007). Moreover, Daprati, Wriessenegger & Lacquaniti (2006) demonstrated that the detection of fine kinematic variations regarding hand gestures is better and faster when watching own movements compared to watching other individuals.

The next chapter will deal with three own experiments that were designed for the purpose to extend the previous findings. Derived from the results described above several questions arise. First, it would be interesting to evaluate whether the result that the effects of own past movements could be better anticipated than the effects of other people refer to the fact that the observer knews the identity of the observed model. Second, it remains unclear whether observers are not only able to identify own past actions but also if they are also better able to recognize an upcoming action earlier when own movements are presented. Third, it seems to be worthwhile to examine the influence of motor expertise and motor competence within one experiement to further gain insight the question to what extend visual and motor experience determine perception. Fourth, the influence of motor competence could be analyzed within different task and one group of participants to test whether the task determines to what extent the individual motor knowledge determines perception.

5. Studies

The purpose of the present investigation was to find out whether an individual uses its own motor system when looking at biological motion. To examine this question we used participants with different kinds of expertise levels and motor competencies as well as different kinds of tasks (*effect anticipation*, *action recognition* and *actor identification tasks*).

The goal of the first experiments about effect anticipation was to find a task respectively a certain kind of presentation where the use of the motor system seems to be a critical variable. Additionally, we wanted to find out under which conditions we could assume that a better motor representation leads to a better prediction of the movement.

In reference to the dart study of Knoblich & Flach (2001) a discrete movement was used in the first two experiments, because here we were able to separate the movement and its effect temporally as well as spatially. We decided to use the boule underhand throw as experimental task. Within the first two pre-studies we manipulated the kind of presentation in such a way that we reduced the information provided to the learner systematically.

Based on these results we conducted a third experiment with the aim to test the hypothesis that the effects of own movements could be better anticipated than the effects of other individuals movements. If the assumption that the own motor system is used when perceiving biological motion is correct, then the observer should have an advantage when looking at own movements because of the high motor competence for own movements. We used two different kinds of tasks, namely a discrimination task and a length task. Observers had either to judge which of two throws the longer one was or how long a single throw was. Moreover, we manipulated the knowledge about the presented model to test whether this manipulation affects the performance of the observers. PLD as well as videos were used to present the actions. Within the three PLD conditions we gave no information, the right or the wrong information about the observed model.

To get further inside that question, a third study about action recognition and actor identification was realized. Here the influence of motor experience was tested with regard to motor expertise and motor competencies. Experiment 1 examined the question whether experts show superior performance compared to novices within an *action identification task*, namely to identify different kinds of basketball dribblings (effect of motor expertise). Additionally, the performance of the expert group was analyzed separately with regard to the observed model (own movement, friend, stranger; effect of motor competencies). The aim of Experiment 2 was to clarify the question if observers (here: member of the expert group from experiment 1) were able to recognize themselves, friends or strangers within an *actor identification task* (effect of motor competencies).

Finally the results of all three studies will be discussed in conjunction and implications for the theoretical background as well as future research directions will be discussed.

5.1 Perception of throwing ranges from point light displays[1]

First of all, the results of two preliminary explorative studies will be presented. They were designed with the main purpose to evaluate which would be the best stimulus material according to the later experiments.

5.1.1 Preliminary experiement 1

Main objectives

The main objective of the present work is the question in what way an individual uses its own motor system when looking at biological motion. Incorporated with this question is the assumption that we predict the outcome of actions with the assistance of our own motor system. As described above individuals internally simulated observed movements to be able to understand these actions (e.g. Jeannerod, 2001).

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[1] Munzert & Hohmann: Discrimination of throwing differences from Pointlight Displays without seeing the object. Submitted to Europ. J. of Cogn. Psychol. (07/2008)

The starting point of the present experiments was a study conducted by Knoblich and Flach (2001). They could demonstrate that observers were better able to predict the landing position of a thrown dart when looking at own past actions compared to looking at past actions of another individual. This result was discussed as strong evidence for the assumption that individuals use their own motor system to understand other people movements. Additionally, the result of Knoblich and Flach (2001) underscores the assumption that observers internally simulate movements and do not use pure heuristics like "Theory Theory" would assume to estimate the outcome of an action. In the late case one would expect that there would be no difference between looking at own or other individuals' movements.

However, critical concerning this dart study is the fact that the authors used video displays as stimuli. Thus the observers could easily recognize if they were the presented model or someone else. It therefore remains indistinct if the above described advantage when looking at own movements really derives from the fact that there was a greater resonance process between perception and action for own movements or if the results were influenced by the fact that observers knew which model belonged to themselves. It is therefore for instance imaginable that the results are based simply on differences concerning the motivation of the observers.

The question was whether the knowledge about the model ("me or stranger?") may influence or bias the performance of the observers. Therefore, the aim of the present study was to replicate the findings of Knoblich and Flach (2001), but to use another kind of stimuli presentation. Observers should not be able to identify the presented model. Instead of video clips PLD were used to represent the movements. Similar to the dart study a discrete task, namely boule throwing, was used. This task allows separating the effect from the movement. In contrast to the dart study the task was not to judge the result of a single movement ("landing position of the dart"). The task concerning the present study was to compare two throws and to estimate which one was the longer one.

To evaluate whether the results of Knoblich & Flach (2001) were due to a simple response bias, the first aim was to find the appropriate kind of presentation of the boule throws. The own motor system should play a crucial role for the performance of the observers. Therefore, the performance of the participants should be a bit higher than chance level. If the task would be too easy it could be assumed that the expected advantage when looking at own movements and the therefore postulated greater resonance process between perception and action would not be visible. The presentation was manipulated in two ways. The first manipulation refers to the differences concerning the length of the two throws. The aim was to find out which is the minimal difference between two throws that could be distinguished by the observer. The other manipulation refers to the movement itself. We wanted to find out how much information an observer needs to discriminate the length of two throws.

Runeson and Frykholm (1983) could show that observers could estimate the length of throwing movements. Our hypothesis therefore was that observers are able to discriminate between the length of different throws and that the performance of the observers decreases when the difference between the two presented throws decreases, too. Additionally, we await that the reduction of information within the displays should lead to poorer performances, because it could be shown that the sensitivity to human movement increases the more information is given to the observer (Neri, Morrone, & Burr, 1998; Poom & Olsson, 2002; Thornton, Pinto, & Shiffrar, 1998).

5.1.1.1 Method

Participants

A total of 61 students of physical education (26 male, 35 female) at the University of Giessen, Germany took part in Experiment 1. They were aged 20-37 years (*M* = 22.6; *SD* = 2.87), 55 of them were right-handed, and 6 were left-handed. Participants were recruited from different classes in the Physical Education program. All had normal or corrected-to-normal vision.

Although they were familiar with the game of *boules* and had played it at least once before, none of them was an expert in this field. Participants were not paid for their services.

Material (Apparatus)

The movements of the models were captured with a high-speed firewire camera (Basler). The movement analysis software Simi Reality Motion System (Version 7.3) as well as the video software Pinnacle Software (Version 9.1) was used to create the videos, PLDs and the test procedure. Stimuli were presented with a DVD-Player on a TV screen. The answers of the observers were collected via a computer keyboard.

Stimuli generation

Five different students of physical education (three males, two females) who were familiar with *boules* but revealed no expert competence served as models. They performed throws with distances ranging from 5 m to 12 m. Targets were defined as a zone of 15 cm around a full meter distance, so that, for example, the target field for 8 m ranged from 7.85 m to 8.15 m. The weight of the ball was 600 g and had a diameter of 6.5 cm.

Nine reflective markers were attached to body joints (shoulder, elbow, wrist, hip, knee, ankle, heel, and toe) plus the head. A distance of approximately 5 m between the model and the camera was chosen to optimize the display window for the depicted movements. Only the moving body was videotaped but not the ball flight. Both videos and PLD showed models from a lateral perspective while throwing. Depicted movements started with the hand at the hip followed by a forward-backward movement with the arm and were visible until the hand reached the highest point after ball release. Point-light figures were presented in the middle of the screen. The image size of point-light and video movies was 720 x 480 pixels. The distance between the monitor and the participant was approximately 1 m.

Task and Design

The task always consisted of a discrimination between the distances of two throws shown within one trial. Observers had to decide whether the first or second throw was longer. Each trial contained throws by the same model. Half the trials showed the longer distance first; the other half, the shorter one. Differences between two throws ranged from 1m to 5m, with full meter distances in between. Each difference was presented 10 times resulting in a total of 50 trials. Throwing differences were presented in randomized order.

Each test block was preceded by a short, five-trial training block to familiarize participants with each specific condition. A single trial within a condition contained the following steps: It started with a black screen with the white title “Trial x” presented mid-screen (for 2 s), followed by a white cross (for 2 s) mid-screen. Then the first throw was presented. Afterwards the screen went black again (for 1 s) before the second throw was displayed. The final screen showed the question “1 or 2?” (for 5 s), thus focusing participants on the discrimination task. Using a forced-choice paradigm, participants were instructed that if they were not certain about their answer, they should make an intuitive guess, because there was a good chance that this would be correct. After the presentation of the test stimuli, participants had to complete a questionnaire tapping personal data and strategies used during the experiment. The total time for the test procedure was approximately 45 min.

Participants had to perform the discrimination task under three different viewing conditions. The video condition (Video) presented the full video. It begins with the staring position (hand beneath the hip) and stopped when the hand reached the highest point after release of the ball. The full point-light condition (PL) displayed only nine points of the whole body, and the reduced point-light condition (PL-r), only the three points representing the arm (shoulder, elbow, and wrist). The sequence of blocked conditions was balanced for participants.

This resulted in a 3 x 5 within-subject design with participants exposed to three conditions (Video, PL, PL-r) when comparing five different throwing distances (1 m, 2 m, 3 m, 4 m, 5 m). The sequence of conditions was balanced across subjects, while order of distance differences was almost completely randomized, the only exception being no direct repetition of the same distance differences.

Dependent Variables and Statistical Analysis

The dependent variable was the number of correct discriminations. Data are reported as the percentage of correct answers.

5.1.1.2 Results

Figure 1 represents the mean percentage of correct discriminations for conditions and differences.

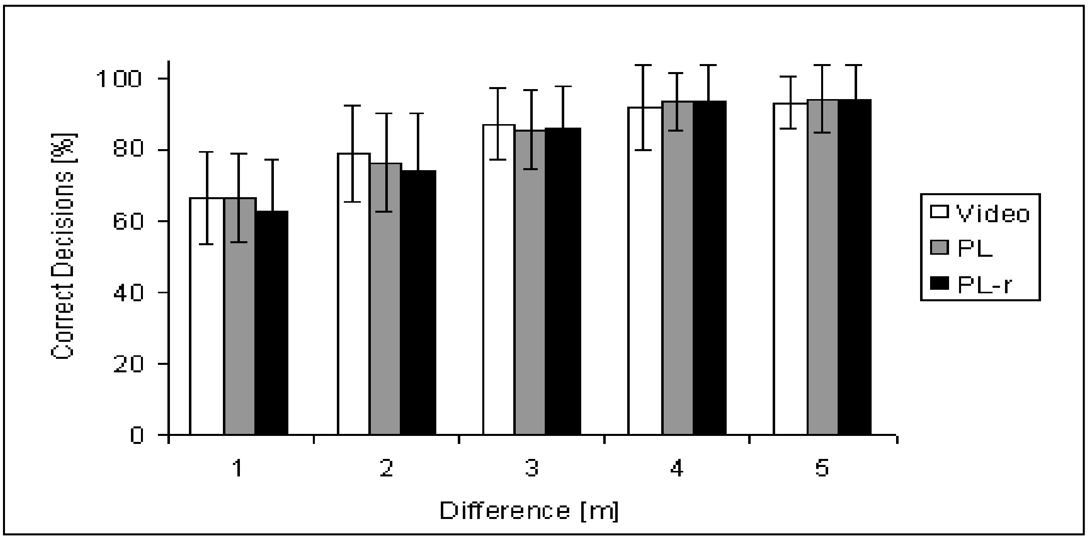

Figure 1

Correct Decisions [%] of the observers regarding the Differences and Conditions (Video: video, PL: point-light, PL-r: point-light reduced).

Performance on the discrimination task was above chance for all conditions and distances. A 3 x 5 ANOVA with repeated measures for both variables revealed a significant effect of differences, $F(4, 240) = 199.77$, $p < .001$, $\eta^2 = .77$, indicating that discrimination was better for larger differences. There was no significant effect for conditions, $F(2, 120) = 1.46$, $p = .24$, $\eta^2 = .02$, and no significant interaction effect, $F(8, 480) = 1.39$, $p = .20$; $\eta^2 = .02$.

5.1.1.3 Discussion

Whereas the percentage of correct discriminations is sensitive to task difficulty (differences between 1m and 5m), no significant differences are found for conditions. Point-light conditions supply observers with approximately the same information as video displays in reference to the discrimination task. This is even the case for the reduced point-light condition providing the observer with information on the kinematics of shoulder, elbow, and hand alone. Evidently, the dynamics of these three points contain the full movement information just like the video presentations. It seems to be plausible to assume that observers attend to the points representing the arm (local analysis) and not to the whole body (global analysis). Participants are able to anticipate the throwing distance and compare the two distances with a better than chance ratio for small differences and almost perfectly for larger differences.

Post-hoc questioning of the participants reveals that two aspects of the movements are subjectively important for the discrimination task: the up-down movement of the body during the shot, primarily caused by a flexion of knees, and the extent of the arm swing after ball release. If both aspects are really so critical for discriminating between throwing distances, this might explain the lack of significant differences between conditions. Apparently, these aspects can be extracted to a similar degree under all three conditions. This is clearly the case for the up-down movement in the PL compared with the Video condition, because the former contains information on the trajectories of knee, hip, and shoulder. Although information on knee and hip trajectories is not available in the PL-r condition, it still contains essential information about the up-down movement. The trajectory of the shoulder represents the endpoint of an anatomical chain in which the resulting impulse is transmitted to the arm. The range of the arm swing after the ball is released can be extracted to the same degree from all three conditions. Both PL and PL-r provide information about the relative position of shoulder and hand in a similar way as the Video condition. Therefore, in Experiment 2, we decided to further reduce the information provided in the point-light displays.

5.1.2 Preliminary experiement 2

Main objectives

The results of experiment 1 indicate that the performance of observers regarding the discrimination task depend at least on the presented differences between the two throws. The greater the distance between two throws, the higher is the probability that the observer will be able to name which one was the longer one. However, no differences regarding the kind of presentation of the movement itself were found. The reduced point light condition (PLr) was as good as the video condition.

The aim of the second experiment was to find out what might be the critical cue of a throwing movement which is absolutely needed to estimate the length of a throw. Based on the statements of the observers of the previous study we further manipulated the PLDs respectively reduced the number of presented points within the displays. Generally, we focused on two aspects, namely the up-down shoulder movement and the range of arm swing. The critical question was whether an observer can really perceive these relevant movement aspects that differ as a function of throwing distances. If the subjective impression on the importance of these movement features is valid, the extent of up-down movements or the range of arm swing should correlate with throwing distances. Therefore, models' movement trajectories were further analyzed in terms of the range of the shoulder movement in the Y and X direction and the angle at the highest point of the arm swing. The range of the Y-movement component of the shoulder (Y-shoulder) stands for the up-down movement, and the angle of the arm (Angle) represents the arm swing. Range of X direction of the shoulder movement (X-shoulder), which participants had not emphasized in the post experimental reports, was included as a control variable, because it also relates to the shoulder movement. Angle of the arm (Angle) provides a measure of the extent of the arm swing. Spearman rank correlations between distances and Y-shoulder, X-shoulder, and Angle respectively revealed significant correlations for Y-shoulder and distances, Rho = .666, p < .001, and for Angle and distances, Rho = .428, p < .01, but not for X-shoulder and distances, Rho = -.083, p = .61). This validates participants' subjective reports on which important features they might rely on when performing the discrimination task.

Therefore, the second experiment analyzed whether a reduction of information on these aspects would have a detrimental effect on performance in the discrimination task. Additionally, a further reduction of point-light displays offering only the kinematics of the single hand point was introduced. This also involved an elimination of the up-down movement of the shoulder, but retained its effect at the end of the biomechanical chain.

We expected that a further reduction of perceivable information would lead to a decrease in the percentage of correct discriminations. This should hold not only for the aspects mentioned in the post-hoc interviews but also for the reduction depicting only one point. Derived from the results of experiement 1 we expected to replicate the finding that the performance of the observer decreases when the difference between the two presented throws decreases, too.

5.1.2.1 Methods

Participants

A second, independent sample containing a total of 66 sport students (42 male, 24 female) at the University of Giessen, Germany took part in the second study. They were aged 19-27 years (*M* = 21.6; *SD* = 2.00), 60 were right-handed, and 6 were left-handed. The students were recruited from different classes in the Physical Education program. All had normal or corrected-to-normal vision. Although they were familiar with the game of *boules*, none of them were recognized experts in this sport. Participants were not paid for their services.

Material (Apparatus)

The same material and apparatus as in experiment 1 were used.

Stimuli generation

The stimulus set for the second experiment was constructed with the same recording procedure as in Experiment 1. Again five physical education students served as models. Although they had some experience in the *boules* technique, they were not experts in this domain. Trajectories of the movements were captured using the Simi Reality Motion System (Version 7.3). Coordinates of the shoulder, elbow, and wrist were used to standardize the length of the arm segments of each model by calculating an average arm length on the basis of the coordinates from the five models. This procedure eliminated differences in height, which could be a potential factor in the discrimination task. This was first processed for a reduced point-light condition (PL-r). In order to eliminate the up-down movement, we set the shoulder point to a fixed coordinate and recalculated the movement trajectories of the elbow and the wrist relative to this coordinate (Shoulder-constant). To mask the movement of the arm after the ball release, we cut out the display at this point (Ball-release). To further reduce movement information, we also depicted the wrist only in its time course (Hand).

Task and Design

The task was the same as that in Experiment 1. Participants had to discriminate whether the first or the second throw would travel a greater distance. Four conditions were tested in a within-subject design presenting the arm (PL-r), the arm without an up-down movement (Shoulder-constant), the arm only to the point of ball release (Ball-release), and a more reduced display with only the trajectory of the wrist (Hand) but the full range of the arm swing. Once again, five different throwing distances between 1m and 5m had to be compared within each condition. A 4 (Conditions) x 5 (Distances) design was applied in this study. A total of 50 pairs of throws was presented in each condition.

Similar to experiment 1 a training session of five trials was administered before the examination of each condition to familiarize participants with the stimuli. This time each test session consisted of four blocks of 50 trials. The order of the blocks was counterbalanced.

The test setting was similar to Experiment 1. Observers’ responses were collected with paper and pencil. After the test procedure, participants had to answer a questionnaire on personal data and the task. The total time for the test session was approximately 60 min.

Dependent Variables and Statistical Analysis

The dependent variable was the number of correct discriminations. Data are again reported as the percentage of correct answers. Statistical analyses were based on ANOVAs with repeated measures. Significance level was set to .05.

5.1.2.2 Results

Figure 2 presents the mean percentage of correct discriminations for conditions and distances.

The question was whether the performance of the observer depended on the presented action and the difference between the length of the two throws. Performance should be better if more information was given to the observer and if the difference between the tow presented throws was large. A 4 (Conditions) x 5 (Distance differences) ANOVA with repeated measures for both variables revealed significant effects for conditions, $F(3, 195) = 29.21$, $p < .001$, $\eta^2 = .31$, for differences, $F(4, 260) = 186.80$, $p < .001$, $\eta^2 = .74$, and for the interaction, $F(12, 780) = 9.45$, $p < .001$, $\eta^2 = .13$.

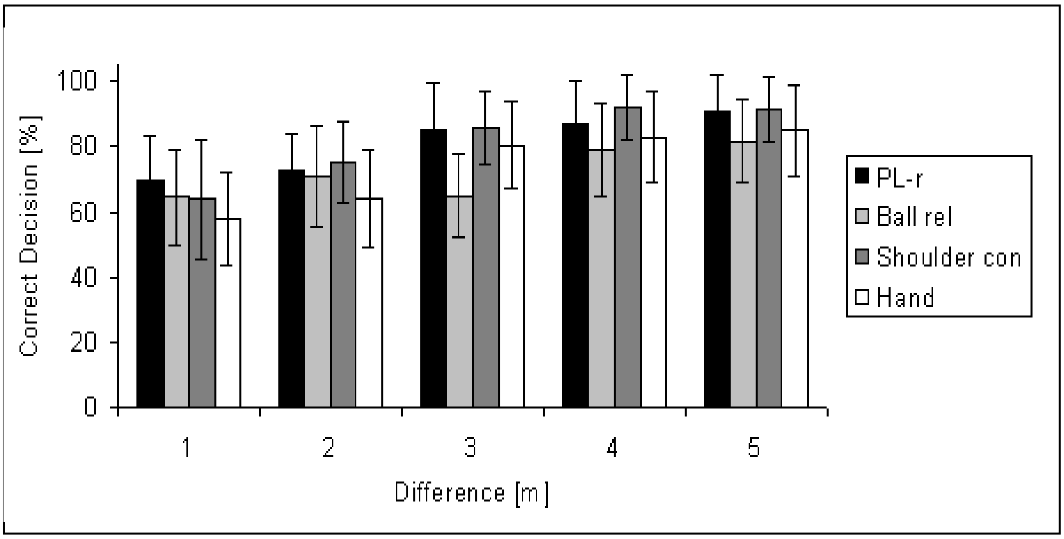

Figure 2

Correct Decisions [%] of the observers regarding the Differences and Conditions (PL-r: reduced point-light, Ball rel: ball release, Shoulder con: shoulder constant, Hand: hand).

Mean correct discriminations for conditions pooled over distances were *M* = 81.12 (*SD* = 8.57) for PL-r, *M* = 74.12 (*SD* = 9.45) for Hand, *M* = 72.33 (*SD* = 8.51) for Ball-release, and *M* = 81.76 (*SD* = 6.99) for Shoulder-constant. Scheffé tests for repeated measures revealed significant differences on the 5% level between PL-r and both Hand and Ball-release, as well as between Shoulder-constant and both Hand and Ball-release. Differences between PL-r and Shoulder-constant, and between Hand and Ball release were not significant (the critical Scheffé difference on the 5% level was 2.56%).

5.1.2.3 Discussion

The aim of Experiment 2 was to examine the consequences of further reducing the displayed kinematic information compared with the PLD conditions in Experiment 1. The choice of the conditions Shoulder-constant and Ball-release is derived from the post-hoc statements of the participants in Experiment 1, who considered these parameters to be most important for the discrimination task. It can be demonstrated that both parameters correlate positively with throwing distance. A third PLD condition was also introduced that reduces the kinematic information to only one point (Hand).

Two conditions, Ball-release and Hand, caused a decrement in the amount of correct discriminations, whereas PL-r and Shoulder-constant revealed a similar percentage of correct discriminations to that in Experiment 1. Although reduction of PLD to one point led to a significant decrease in the percentage of correct discriminations, the proportion of correct answers was still above chance even for the most difficult task of comparing differences of only 1m. The same was true for the Ball-release condition. With only one exception (3m difference for Ball release) all other conditions show a regular increase in correct discriminations with larger differences.

Different results were found when the up-down movement was eliminated in the Shoulder-constant condition and when the second part of the arm swing was removed in the Ball-release condition. Both parameters were emphasized as being subjectively important for the discrimination task and both correlate positively with actual throwing distance. Nonetheless, only the Ball-release condition leads to a decrement in distance discrimination. Although both parameters correlated with distance to different degrees, information about the arm swing may substitute the missing up-down information, but not vice versa.

In contrast to our expectations and to participants' verbal reports in Experiment 1, elimination of the up-and-down movement in the Shoulder-constant condition did not cause a decrement on the discrimination task. From a biomechanical point of view, it might be argued that this condition also contains the full information necessary to anticipate throwing distances. It provides information on the velocity and the angle of the object relative to the horizontal plane at the point of release. The physical parameters defining the motion of the ball have to be considered as a prerequisite for anticipating throwing distances. The trajectory of the ball is determined by the release speed, release angle, and release height. Air resistance is disregarded in this model. Throwing to a certain target can be implemented through different combinations of release speed, release angle, and release height. If this really is the basic information processed during the discrimination task, then the Ball-release condition should measure up to or even show better results than Shoulder-constant, because the above-mentioned information can be seen most effectively when the movement is observable up to the point in time at which the display is cut out in this condition. Moreover, one could argue that the angle of the initial ball curve can be recognized optimally in the Ball-release condition.

The difference between biomechanical plausible calculations and the discrimination performance of participants agrees with findings reported by Hoenkamp (1978b). He showed that observers do not identify different gait patterns through a single kinematic variable, but through complex relations of variables. In this case, the global parameter was based on the ratio of durations of the forward and the back swing of the lower leg. Our data show that single parameters like the velocity of the hand/ball cannot explain the full range of discrimination performance. Conditions providing the best opportunity to pick up information on velocity, like the Hand condition, result in decrements in the discrimination task. Therefore, we propose that it is the global dynamics of the arm movement, relying on a rough image of the arm and including the full arm swing, that contain the relevant information for the discrimination task. Therefore, this result speaks for global and not for local analysis of biological motion.

5.2 Perception of own and other individuals' throwing movements[2]

Main objectives

The aim of the present work is to find evidence for the assumption that the own motor system is used when individuals look at biological motion. This assumption is associated with the idea that we internally simulate the observed movements (e.g. Jeannerod, 2001). Whereas the aim of the first two studies was to find a task which might be useful to test these assumptions,

this study was conducted to test this hypothesis directly with even that task.

As already described in the preliminary chapters of this work it is assumed that there is as strong linkage between perception and action. The "Common Coding Theory" (Jeannerod, 2001) for instance postulates that perception and action are represented in a common medium and that they even share the same features. This leads to the conclusion that the perception of a movement should be best when the same system that had planned and executed an action is now watching it. According to that an individual should perceive its own movements better than movements of other human beings respectively, the individual should be able to estimate the outcome of own past actions better than the outcome of other individuals' actions.

The aim of this study was to find out whether the knowledge of the observed model has an influence on the performance of the observed models. To test these assumptions we used the boule throwing task of the first two experiments. We decided to use the PLr Condition and the 1m difference. The results of the previous experiments showed that observers were a little bit above chance level when using this kind of presentation.

Beneath the discrimination task used in the previous studies a slightly different task was used this time. In contrast to the previous studies only one throwing movement was presented to the observer. The task was to judge the length of that single throw. The idea behind this manipulation was that this task may force the observer to use his own motor system and to

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[2] Hossner, Hohmann & Munzert: Predicting the effects of actions: No self-other differences in throwing movements. Article in prep.

simulate the action to a higher degree. The discrimination task may allow the observer to base his judgements on more objective cues like for instance the range of the arm swing. Such a comparison would not be possible if only one movement was presented.

The other difference between the present study and the previous ones is that the observers were now confronted with their own movements and with that of one other person. Because the aim was to find out whether the knowledge about the identity of the observed model is important to find the expected self/other differences, a full video and a point light condition was used this time. While during the full video condition the identity of the model is obvious, it was possible to manipulate this information within the PLD condition. Either the correct or the wrong information could be given about the observed model. This manipulation allows to test the influence onto the observers' performance. If perception is based on so-called "bottom up processes" and according to an "direct perception approach" (Gibson, 1979) additional information about the observed model should not influence perception. In that case the stimulus provides all information and no further knowledge is needed. If, however, perception of biological motion is based on "top-down processes" and according to an "indirect perception approach" (e.g. Gilden & Proffitt, 1994) information about the observed model might help to estimate the length of the throws.

Nevertheless, according to the dart study of Knoblich (2001) we assume that observers were better able to judge the length of two throws or that of one single throw when they see own movements and not that of another individual.

5.2.1 Method

Participants

A total of 36 students of physical education (18 male, 18 female) at the University of Greifswald, Germany took part in this experiment. All participants were right-handed. Participants were recruited from different classes in the Physical Education program. All had normal or corrected-to-normal vision. Although they were familiar with the game of *boules* and had played it at least once before, none of them was an expert in this field. Participants were not paid for their services.

Material (Apparatus)

The same material and apparatus as in experiment 1 were used.

Stimuli generation

Every participant (the later observers) performed the boule throwing task. The task was to hit targets that were located 7m respectively 8m away from the starting line. Targets were defined as a zone of 15 cm around a full meter distance, so that, for example, the target field for 8 m ranged from 7.85m to 8.15m. Participants had to hit each target eight times and the number of attempts they needed to complete the task was recorded. The weight of the ball was 600g and had a diameter of 6.5cm.

Three reflective markers were attached to the arm (shoulder, elbow, and wrist). A distance of approximately 5m between the model and the camera was chosen to optimize the display window for the depicted movements. Only the moving body was videotaped but not the whole ball flight. Both videos and PLD showed models from a lateral perspective while throwing. Depicted movements started with the hand at the hip followed by a forward-backward movement with the arm and were visible until the hand reached the highest point after ball release. Point-light figures as well as the full videos were presented in the middle of the screen. The image size of point-light and video movies was 720 x 480 pixels. The distance between the monitor and the participant was approximately 1m.

Procedure and Design

Participants had to perform two different tasks which were organized into two separated blocks of 64 trials each. The first task refers to the discrimination task we used in the previous experiments (discrimination task). The observers had to decide whether the ball in the first or the second throw traveled further. Half the trials showed the longer throw first. The second task was to estimate the length of a single throw (length task). This throw was either a 7m or 8m throw. Participants had to evaluate if the presented throw was the "long" or the "short" one. Half of the presented trials belonged to the 7m and half of the trials belonged to the 8m throw.

Within each of the two tasks half of the presented actions derived from recordings of their own throwing performances while the other half derived from recordings of a partner (Actors). The order of presented model self/other was counterbalanced across all observers. The arrangement of the two actors was based on the results of a pre-study about discrimination of two presented models (data not reported here). Because we wanted to manipulate the knowledge about the presented model, we had to find combinations of models were the difference between the throwing performances should be similar, so that even misinformation about the models' identity should be believable.

Each test block (discrimination task, length task) was preceded by a short, five-trial training block to familiarize participants with each specific condition. The order of events within each trial (black screens, instructions, PLS and so on) was similar to that used in the previous study. The only difference according to the sequences of trials belongs to the task the participants had to solve. Within a trial either one (length task) or two throws (discrimination task) were presented. Using a forced-choice paradigm, participants were instructed that even if they were not certain about their answer, they should make an intuitive guess, because there was a good chance that this would be correct. After the presentation of the test stimuli, participants had to complete a questionnaire tapping personal data and strategies used during the experiment. The total time for the test procedure was approximately 60 min.

Participants had to perform the discrimination task and the length task under four different viewing Conditions. The video condition (Video) presented the full video. In total there were three point-light conditions (PL) were only the moving arm (shoulder, elbow, and wrist) was presented. The difference between these conditions belongs to the fact that we gave either no information about the presented model (PL), the correct information about the model ($\mathrm{Pl}_{\mathrm{correct}}$) or misinformation about the identity of the model ($\mathrm{PL}_{\mathrm{false}}$). Every presentation began with the starting position (hand beneath the hip) and quitted when the hand reached the highest point after the ball released the hand after a forward-backward-forward movement. Overall the participants had to complete four test sessions, one for every Condition, which were separated by at least one day. All observers started with the point light condition without information about the actor. The second session belonged to the full video condition. The session three and four were again point light conditions with either the correct or wrong information about the actor. The order of correct and misinformation was counterbalanced. This resulted in a 4 (Conditions) x 2 (Actors) x 2 (Task) design. Additionally, we included the performance level of the participants according to the number of attempts they had needed to hit each target eight times in the capture session in our analysis. Based on that data, we splited the group into an expert and a novices group. Additionally, we took into consideration whether the observers first saw their own movements or that of the partner.

Dependent Variables and Statistical Analysis

The dependent variable was the number of correct discriminations. Data are reported as the percentage of correct answers. Statistical analyses were based on ANOVAs with repeated measures. Significance level was set to .05.

5.2.2 Results

Overall Analysis of both Tasks, all Conditions, Actors, Expertise Level and Order

To study differences concerning the perception of own and other individuals' movements and the influence of information about the observed model, the number of correct answers given by the observers were analyzed in reference to the discrimination task and the length task. Moreover, we were interested in the question whether participants who showed good throwing performances were better able to recognize the length of a throw than participants who showed bad throwing performances. Additionally, we wanted to find out whether the order of presented models (own movement first or other individuals movement first) influences the performance of the observers. Figure 3 and 4 illustrate the results for both Tasks in reference to Condition and Actor.

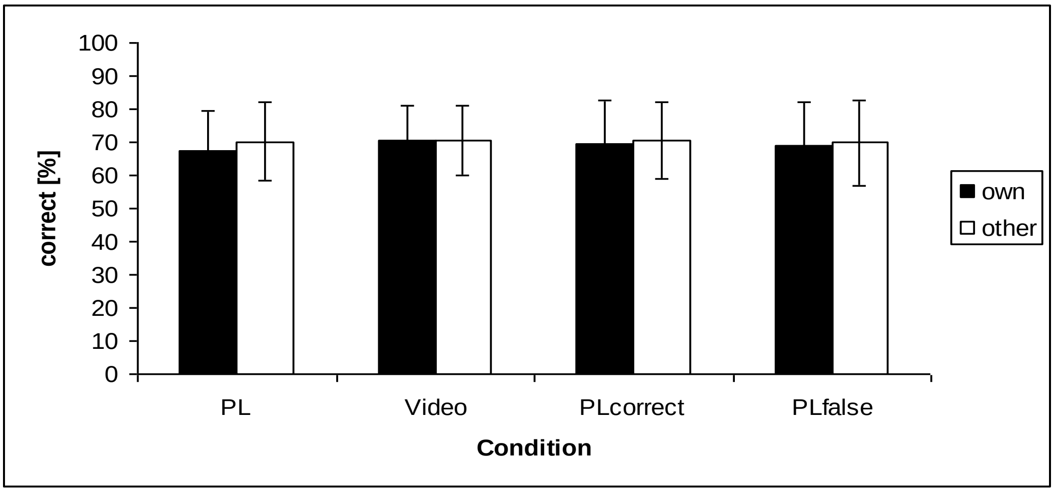

Figure 3

Correct Decisions [%] of the observers regarding the discrimination task depending on the Actor and the Conditions. Error bars indicate standard deviations (SD).

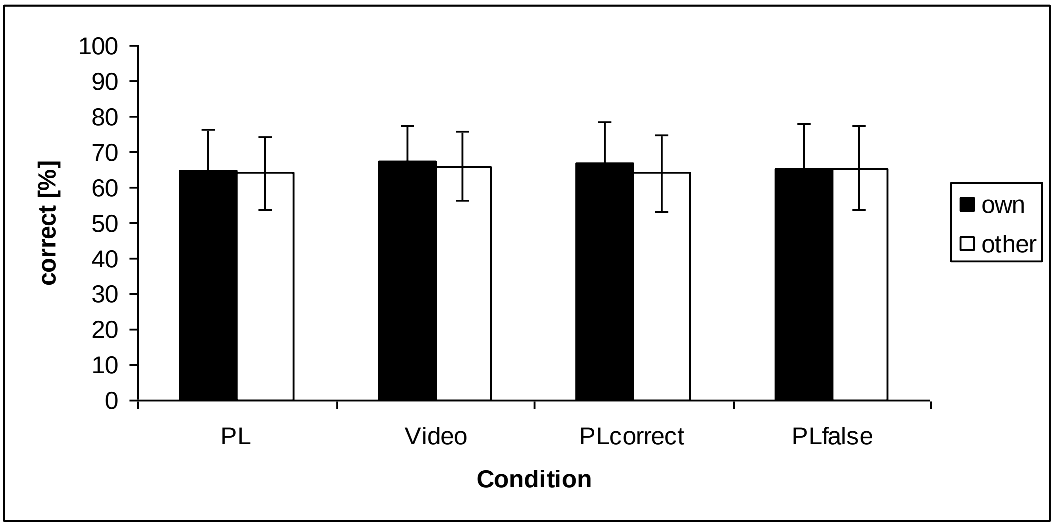

Figure 4

Correct Decisions [%] of the observers regarding the length task depending on the Actor and the Conditions. Error bars indicate standard deviations (SD).

Data were analyzed concerning the Actor (self, other), the Condition (PL, Video, $PL_{correct}$, PL_{false}), the Task (length task, discrimination task), the order (selfother, otherself) and the expertise level (novice, expert).

A 4 (Conditions) x 2 (Tasks) x 2 (Actors) MANOVA with repeated measures and the between subject factors Order (selfother vs. otherself) and Expertise Level (novice vs. expert) revealed significant differences concerning the Task, $F(1,32) = 42.98$, $p <. 001$, $\eta^2 = .57$ and the Order, $F(1,32) = 5.69$, $p = .02$, $\eta^2 = .15$ as well as a nearly significant effect for Expertise Level, $F(1,32) = 4.11$, $p = .05$, $\eta^2 = .11$. Additionally, the interactions Condition x Expertise Level, $F(3,96) = 4.48$, $p = .005$, $\eta^2 = .12$ and Condition x Task x Order, $F(3,96) = 3.14$, $p = .03$, $\eta^2 = .09$ were significant. However, the factors Actor, $F(1,32) = .00$, $p = .97$, $\eta^2 = .00$ and Condition, $F(3,96) = 1.28$, $p = .29$, $\eta^2 = .04$ were statistically significant. This leads to the conclusion that it makes no difference to the observer to see the own past movements or those of another individual in reference to the discrimination task (own movements, $M = 69.10\%$, $SD = 12.28\%$; other individuals' movements, $M = 70.24\%$, $SD = 11.72\%$) and the length task (own movements, *M* = 66.15%, *SD* = 11.28%; other individuals' movements, *M* = 64.85%, *SD* = 10.70%). Differences were found regarding the Task (discrimination task, *M* = 69.67%, *SD* = 12%; length task, *M* = 65.50%, *SD* = 10.99%) meaning that the discrimination task seems to be easier than the length task. Moreover, Expertise level had an influence. Experts are better than novices to solve the two tasks (experts, *M* = 69.52%, *SD* = 10.51%; novice, *M* = 65.65%, *SD* = 12.17%). No differences were found regarding the Conditions (PL, *M* = 66.60%, *SD* = 11.31%; Video, *M* = 68.67%, *SD* = 10.22%; $PL_{correct,}$ *M* = 67.64%, *SD* = 11.80%; Pl_{false}, *M* = 67.43%, *SD* = 12.65%). Information about the observed model does not seem to have an influence on performance.

Separate analysis for the two tasks

Analysis of the discrimination task (all Conditions, both Actors, Expertise Level and Order)

To evaluate the performance of the observers separately for the discrimination task, a 4 (Conditions) x 2 (Actors) x 2 (Orders) x 2 (Expertise level) MANOVA was conducted. The analysis showed that there were significant effects for Order, $F(1,32) = 6.40$, $p = .02$, $\eta^2 = .17$ and for the interaction Condition x Expertise level, $F(1,32) = 2.79$, $p = .05$, $\eta^2 = .08$. No significant difference was found concerning the factors Actor, $F(1,32) = .21$, $p = .65$, $\eta^2 = .01$ and Expertise level, $F(1,31) = 1.84$, $p = .18$, $\eta^2 = .05$. As can be seen in Figure 5 participants performed better when they first saw the movements of another person (*otherown M* = 72.44%, *SD* = 13.44%) compared to seeing the own movement first (*ownother M* = 66.90 %, *SD* = 12.36%). Figure 6 illustrates that experts (*M* = 71.15%, *SD* = 11.31%) are better than novices (*M* = 68.18%, *SD* = 12.35%) especially for the PL Conditions.

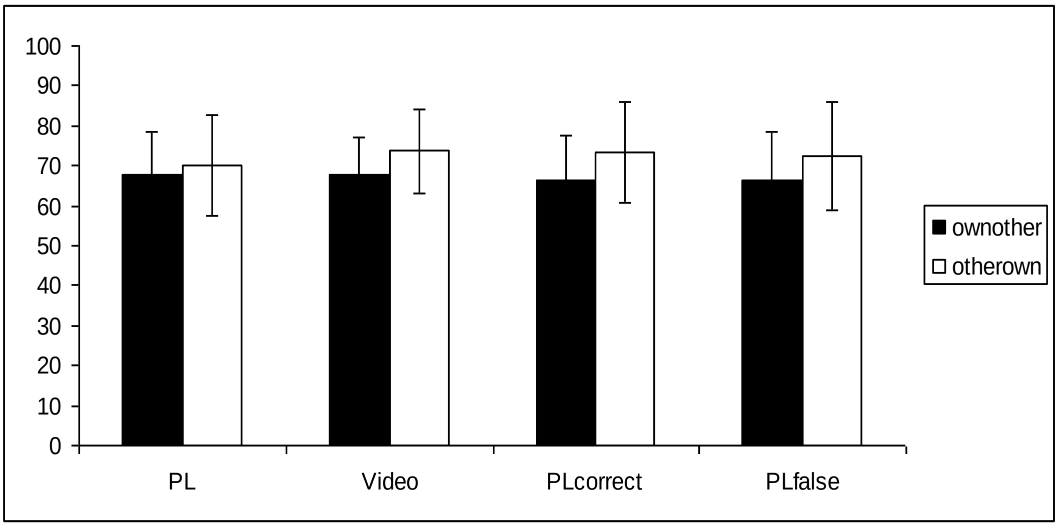

Figure 5

Correct Decisions [%] of the observers regarding the discrimination task depending on the Order and the Conditions. Error bars indicate standard deviations (SD).

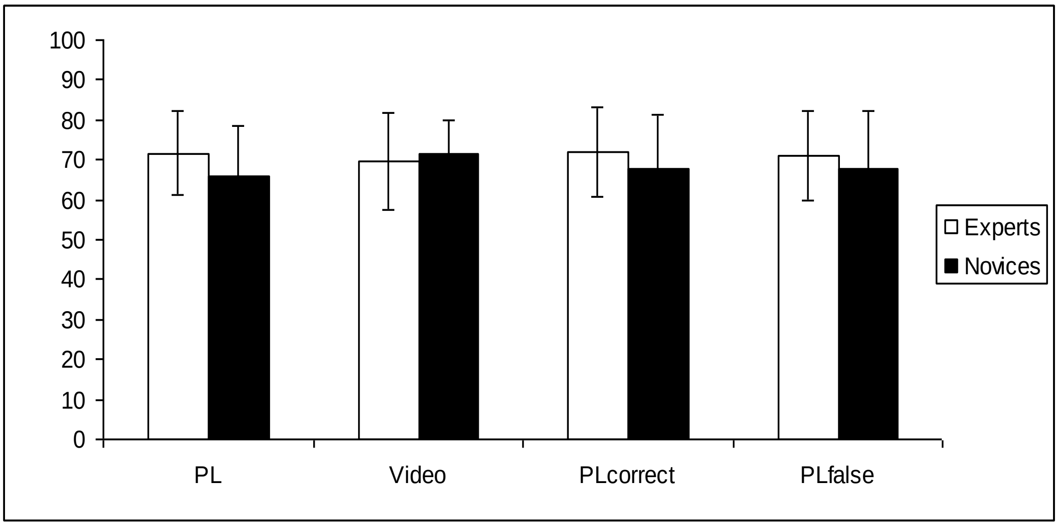

Figure 6

Correct Decisions [%] of the observers regarding the discrimination task depending on the Expertise level and the Conditions. Error bars indicate standard deviations (SD).

Analysis of the length task (all Conditions, both Actors, Expertise Level and Order)

To evaluate the performance of the observers separately for the length task, a 4 (Conditions) x 2 (Actors) x 2 (Orders) x 2 (Expertise level) MANOVA was conducted. The analysis showed that there was a nearly significant effect for Order, *F*(1,32) = 3.85, *p* = .06, η^2 = .12 and a significant effect for Expertise level, *F*(1,32) = 6.89, *p* = .01, η^2 = .18. No significant effect was found for Actor, *F*(1,32) = .41, *p* = .53, η^2 = .01. However, we found significant differences for the interactions, Condition x Order *F*(3,96) = 3.35; *p* = .02, η^2 = .10, Conditions x Expertise level, *F*(3,96) = 3.73; *p* = .01, η^2 = .10 and a nearly significant effect for the interaction Expertise level x Order, *F*(1,32) = 3.95; *p* = .06, η^2 = .11. Observers were better when they first saw the movements of another person (*M* = 67.28, *SD* = 10.40%) compared to seeing the own movement first (*M* = 63.02, *SD* = 11.31%) (see Figure 7 for details). Experts (*M* = 67.88, *SD* = 8.99%) performed better than novices (*M* = 63.12, *SD* = 11.89%). This result is illustrated in Figure 8.

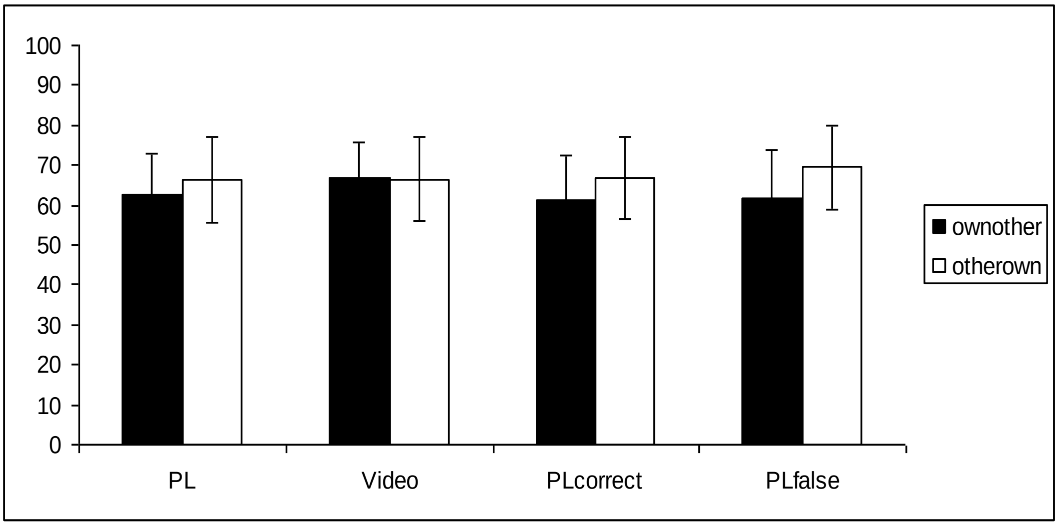

Figure 7

Correct Decisions [%] of the observers regarding the length task depending on the Order and the Conditions. Error bars indicate standard deviations (SD).

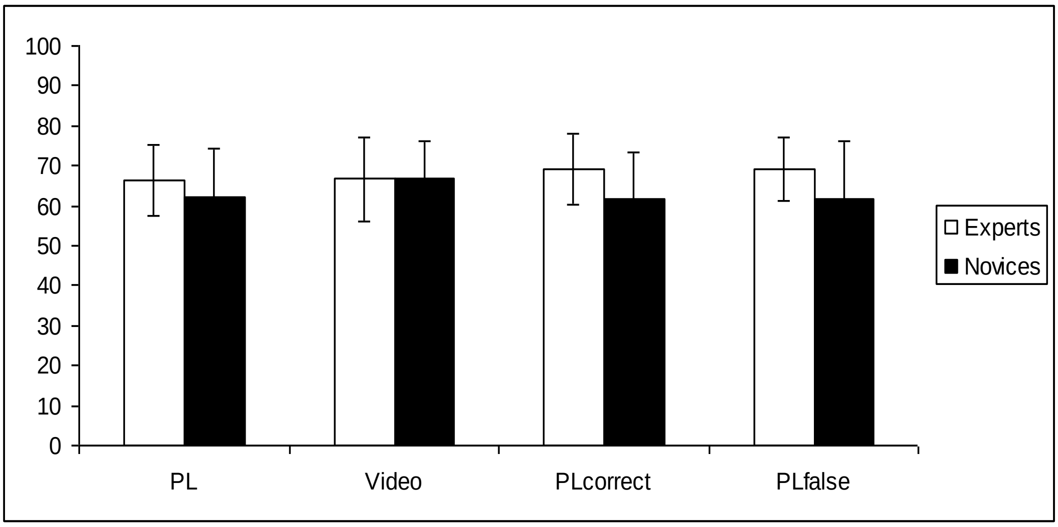

Figure 8

Correct Decisions [%] of the observers regarding the length task depending on the Expertise Level and the Conditions. Error bars indicate standard deviations (SD).

Further analysis

To evaluate the influence of information about the observed model we decided to evaluate the performance for the PL Condition without any information about the observed model and that of the Video Condition separately from the two other PL Conditions ($PL_{correct}$ and $PL_{false)}$. Later on we compared the performance for the $PL_{correct}$ and PL_{false} Condition separately. Taken together we analysed how information about the observed model influences the performance of the participants in reference to the actual observed model.

Analysis of the PL and Video Condition within the discrimination and length task-effects according to no prior information and knowledge about the observed model

To reveal the performance of the observers for the PL Condition without any prior information about the observed model and the Video Condition separately a 2 (Conditions) x 2 (Actors) ANOVA was conducted for both tasks separately. The results showed that there were no significant differences concerning the Conditions, $F(1,35) = 2.11$, $p = .16$, $\eta^2 = .06$, the Actor, *F*(1,35) = .25, *p* = .62, η^2 = .01 and the interaction Conditions x Actor, *F*(1,35) = 1.71, *p* = .20, η^2 = .05 for the discrimination task. Paired t-tests reveal no significant differences between observing own movements and those of another individual for the Pl Condition (*t*(36) = -.89, *p* = .38) and the Video Condition (*t*(36) = .10, p = .92). Moreover, there were no significant differences concerning the Conditions, *F*(1,35) = 2.56, *p* = .12, η^2 = .07, the Actor, *F*(1,35) = .30, *p* = .59, η^2 = .01 and the interaction Condition x Actor, *F*(1,35) = .17, *p* = .68, η^2 = .01 for the length task. Again paired t-tests show no differences between the observation of own movements (*t*(36) = .29, *p* = 78) and those of another individual (*t*(36) = .74, *p* = .47).

To evaluate the effect of expertise level we conducted a MANOVA with repeated measures for Condition and Actor and the between subject factor expertise level for both tasks.

For the discrimination task there were no significant effects for Actor, *F*(1,34) = .24, *p* = .63, η^2 = .01, nor for Condition, *F*(1,34) = 2.34, *p* = .14, η^2 = .06 and not for Expertise level, *F*(1,34) = .01, *p* = .94, η^2 = .00. However, the interactions Condition x Expertise level, *F*(1,34) = 4.86, *p* = .03, η^2 = .13 and Condition x Actor x Expertise level, *F*(1,34) = 6.34, *p* = .02, η^2 = .16 revealed significant effects. For the alternative task there were no significant effects for Actor, *F*(1,34) = .30, *p* = .59, η^2 = .01, Condition *F*(1,34) = 2.55, *p* = .12, η^2 =. 07 nor for Expertise level, *F*(1,34) = 01, *p* = .94, η^2 =.00.

Taken together, there is no effect of expertise level for both task and the first two Conditions. There are only significant interaction effects for the discrimination tasks for Condition x Expertise level (*p* =.03) and for Condition x Expertise level x Actor (*p* =.02). As can be seen in Figure 6 and 8 novices seem to be better or as good as experts in the Video Condition and Experts are better within the Point light Condition.

To evaluate the interaction of Condition x Expertise level x Actor we decided to analyze the discrimination task separately for experts and novices. For experts a MANOVA with the factors Condition and Actor revealed no effect for Actor, *F*(1,17) = .55, *p* = .47, η^2 = .03 nor for Condition, *F*(1,17) = .21, *p* = .66, η^2 = .01 but a significant interaction effect Condition x Actor, *F*(1,17) = 7.65, *p* = .01, η^2 = .31. Experts performed better for the PL Condition when they saw another individual (other individual *M* = 73.18% , *SD* = 10.15%; own movement *M* = 66.85%, *SD* = 12.33%), but for the Video Condition they performed better when they saw own movements (*M* = other individual 68.40%, *SD* = 12.95%; *M* = own movement 70.07%, *SD* = 10.45%). For Novices a MANOVA with the factors Condition and Actor revealed a significant effect for Condition, *F*(1,17) = 7.88, *p* = .01, η^2 =.32 but no effect for Actor, *F*(1,17) = .00, *p* = .98, η^2 = .00 and the interaction Condition x Actor, *F*(1,17) = .62, *p* = .44, η^2 = .04. Novices are better for the Video Condition (*M* = 71.97%, *SD* = 9%) than for the PL Condition (*M* = 67.63 %, SD = 12.78%).

Analysis of the $PL_{correct}$ and PL_{false} Condition within the discrimination and length task- effects of correct/wrong information about the observed model

To evaluate the effect of correct and wrong information about the observed model in reference to the performance of the observers we analyzed the Pl_{correct} and PL $_{\text{false}}$ separately from the PL Condition and the Video Condition.

To analyze if the performance of the observers differs between the two Conditions a MANOVA with the factors Information (correct, false information about the observed model), Task and Actor was conducted. The results showed that there was no effect of Information, *F*(1,35) = .05, *p* = .82, η^2 = .00 and no effect for Actor, *F*(1,35) = .01, *p* = .95, η^2 = .00 but a significant effect for Task, *F*(1,35) = 23.30, *p* = .00, η^2 = .40. No interaction was significant (Information x Task, *F*(1,35) = .14, *p* = .71, η^2 =.00; Information x Actor, *F*(1,35)= 1.15, *p* = .29, η^2 =.03; Task x Actor, *F*(1,35) = 1.92, *p* = .17, η^2 = .05; Information x Task x Actor, *F*(1,35) =1.68, *p* =.20, η^2 =.05).

Observers were better according to the discrimination task (*M* = 69.63%, *SD* = 12.82%) than for the length task (*M* = 65.44%, *SD* = 11.63%). However, they were not better when they observed own movements (*M* = 67.62%, *SD* = 12.63%) compared to looking at movements of another individual (*M* = 67.45%, SD = 11.82%). Additionally, we did not find differences concerning the information (correct or wrong) given to the participants about the observed model. Correct information about the model (*M* = 67.64%, SD = 11.8%) as well as wrong information (*M* = 67.43 %, SD = 12.65%) does not influence observers' performance.

Analysis of all PL Condition (both Tasks, all PL Conditions, both Actors, Expertise Level and Order)

To evaluate if there is an influence about the knowledge of the observer regarding the Pl-Conditions at all we decided to analyze all PL-Conditions together and excluded the Video Condition. That analysis allows comparing the performance of the observers when they had no information about the observed model, the correct or the wrong information about the observed model.

A 3 (Conditions) x 2 (Tasks) x 2 (Actors) MANOVA with the between subject factors Order and Expertise Level (novice vs. expert) revealed significant differences concerning the Task, *F*(1,32) = 38.48, $p < .001$, η^2 = .55 and the Order, *F*(1,32) = 6.29, *p* = .02, η^2 = .16 as well as a significant effect for expertise level, *F*(1,32) = 7.15, *p* = .01, η^2 = .18. No significant effect was found for the main factor Actor, *F*(1,32) = 0.01, *p* = .93, η^2 = .00 and for Condition, *F*(2,64) = .58, *p* = .57, η^2 = .02.

The performance of the observers was better for the discrimination task (*M* = 69.36%, *SD* = 12.50%) than for the length task (*M* = 65.09%, *SD* = 11.35%) and experts (*M* = 69.95%, *SD* =

9.74%) were better than novices (*M* = 64.50%, *SD* = 13.21%). Participants were better when they first saw another individual (*M* = 69.78%, *SD* = 11.67%) compared to seeing the own movements first (*M* = 64.20%, *SD* = 11.43%). However, it does not make a difference to see the own movement (*M* = 67.12%, *SD* = 12.28%) or that of another person (*M* = 67.33%, *SD* = 11.56%). Additionally, the knowledge about the observed model does not make a difference. The participants performed as good as in the PL Condition without any knowledge about the observed model (*M* = 66.60%, *SD* = 11.31%), correct information about the observed model (*M* = 67.64%, *SD* = 11.8%) and for the Condition when the information about the observed model was wrong (*M* = 67.43%, *SD* = 12.65%).

5.2.3 Discussion

On the one hand the aim of the present study was to replicate the findings of Knoblich et al. (2001) that effects of own movements can be better anticipated than the effects of other individuals' movements. It was assumed that the degree of the "resonance process" depends on the expertise level as well as on the motor competencies of the observer (Schütz-Bosbach & Prinz, 2007). The perception of own movements and their effects should be better because there is a greater "resonance process" between perception and action that facilitates effect anticipation (Knoblich, 2003).

On the other hand we wanted to find out whether the knowledge about the observed model had an influence on the performance of the observer. The question was whether the observer had to know that he was the presented model to get the result that the effects of own actions can be better anticipated compared to the observation of another person or whether performance is independent from that knowledge.

From a theoretical point of view the effects of better anticipation when looking at own movements should be independent from that knowledge. The direct perception approach (Gibson, 1979) would assume that perception is a direct process and that no further processing of information is necessary. The stimulus itself provides all the information that is necessary (bottom-up process) so that no additional knowledge is needed. Moreover, “Common-Coding Theory” (Prinz, 1997) as well as „Simulation Theory“ (Jeannerod, 2001) would predict that the activation of the common codes respectively the simulation of an observed action refers to unconscious and automatic processes. The conscious knowledge about the identity of the observed model should therefore have no influence.

On the other hand there might be different results concerning the observation of own or other individuals’ movements, because the observer is simply more “motivated” when looking at own movements. Additionally, it can be speculated that observers try to match the observed movement more directly to their own motor system, because they have a lot of experience with own movements and know how to perform own throws of different length. This would be in line with the “indirect perception approach” (e.g. Gilden & Proffitt, 1994) meaning that observers possess heuristics how they perform movements and what actions lead to what effect. That is they try to use their “forward model” to solve the task.

In contrast to the study of Knoblich et al. (2001) the result of the present study indicates that observers were not better to anticipate the effects of own movements compared to those of other individuals independent of the presented task and the presented conditions. Although we also used a discret task, a similar design and we presented the action within a video we cannot replicate the finding that participants performed better when they observed own movements. Moreover, there was no difference between own and other individuals’ movements within any of the PL Conditions. This leads to the second main result of the present study. We cannot find any influence of the knowledge about the observed model. Even if it is hard to reveal whether information about the observed model influences perception because we did not find any difference between the observation of own or other individuals’ past movements, it can be speculated that information might not influence the performance of the observers at all. It neither hinders nor facilitates performance.

One critical point why the results of the present study might not replicate the previous findings of Knoblich and Flach (2001) may refer to the chosen task and kind of presentation. Someone could assume that the arm swing (representation of three points) when throwing a boule is too much constrained, meaning that all participants performed the action in a similar way. If this would be true, no better “resonance process” could be assumed, because the same amount of codes should be activated when looking at own and other subjects’ movements. However, the pre-study which was about actor identity (data not reported here) showed that observers were able to discriminate between different individuals. This result therefore indicates that even if only three points are represented, different movement patterns and movement trajectories emerge. Additionally, when comparing a dart throwing movement and a boule throw, someone would not expect that one action might be more constrained than the other one.

Another critical point may refer to the difficulty of the two tasks. Even if the results showed that the discrimination task seems to be easier than the length task, both tasks are solved well above chance level. That means that observers tried to solve the task, otherwise the performance would have been at chance level. Therefore, its plausible to belief that the observers had at least the impression to be able to solve the task. It is not surprising that performance did not increases across the different test sessions, because the participants never got feedback about their performances. Moreover, the result that performance depends on the task underscores that each task is sensitive to measure the perception of biological motion somehow. It is not surprising that the performance for the discrimination task is better, because here two throws are presented consecutively that could be simply compared with each other. The length task did not allow for that “direct” matching, meaning that the individual had to match it against a set of throws it had in memory.

The result that the Conditions be it point light or video had no influence on the performance of the observers at all speaks for the assumption that the perception of biological motion is an automatic process. The observer picks up the relevant information independent of the kind of presentation. This result confirms the results of our own previous study that there is no difference between the presentation of the full video and that of only three points representing the arm. It is therefore toilsome to discuss whether the presentation of the full point light display (nine dots representing the body, see previous study) might have lead to other results.

However, even if we did not find any differences in performance regarding the presented model nor for the presented condition, we nevertheless could show that motor experience has an influence on action perception. Those participants that needed less attempts to hit the target during the capture session performed better within both tasks and especially within the PL Conditions. Their own motor experience allows them to better perceive the observed action. This result is in line with previous studies that could show that experts performed better than novices in a perception task (e.g. Calvo-Merino et al., 2005; Calvo-Merino et al., 2006) and that motor experience has an influence on action perception (Schütz-Bosbach & Prinz, 2007).

However, it remains inexplicit why there is no difference between novices and experts within the video condition. The result that the novices overall performed better within the video condition than within the PL condition in reference to the discrimination task underscores that the video condition seems to be somehow easier for novices. Although it remains unclear what the reasons are for that effect.

The result that the performance of the observers was better within both task and nearly all Conditions when they first saw the movements of another individual remains unclear. On the one hand this result cannot be a simple effect of order, because then the same results should have emerged when they first saw own movements and then those of another participant. On the other hand this result contradicts the findings of several other studies that there is an advantage when seeing the own movement (e.g. Knoblich, 2003; Knoblich & Prinz, 2001b). The only study that showed that during the perception of other individuals' movement the activation of the motor system was more facilitated compared to watching own movements, was the study of Schütz-Bosbach et al. (2006). On the one hand the authors interpreted their result in that way that the motor system differentiated between own and other individuals' movements. On the other hand they assume that the suppression of the motor system is functional. Human beings try to imitate observed movements and this tendency is assumed to be very strong when looking at own movements. It is therefore plausible to assume that there is a network in the brain that suppresses even that tendency to prevent inappropriate responses when looking at own current movements (Brass, Zysset, & von Cramon, 2001). It should be stressed at this point that Schütz-Bosbach et al. (2006) used an on-line paradigm to study self and other differences within the human motor system while we used an off-line paradigm instead. From an ecological point of view there is no reason why the suppression of the motor system which might be useful during the on-line perception of movements should also be useful during the offline-perception of movements. Moreover, this assumption would be completely diametral to the above described theories and assumptions that there is a greater resonance process for the perception of movements someone is an expert in or even familiar with (e.g. Calvo-Merino et al., 2006; Knoblich & Flach, 2003; Loula et al., 2005; Schütz-Bosbach & Prinz, 2007). It therefore remains unclear what the reasons are for that effect in the present study.

To sum up, we cannot replicate the findings of Knoblich et al. (2001) about effect anticipation that the outcome of own actions can be better anticipated than the results of other individuals movements. However, there is a whole body of literature about actor identification that shows, that it is possible to identify the own movements (e.g. Beardsworth & Buckner, 1981; Cutting & Kozlowski, 1977; Loula et al., 2005). It therefore seems to be plausible to assume that the expected difference between the observation of own and other people movements are among others due to the task the individual had to solve.

5.3 Action discrimination and actor identification[3]

The third study was designed for the main purpose to assess the influence of visual and motor expertise respectively motor competencies on perception of biological motion using an off-line paradigm to examine perception-action coupling. Specifically we wanted to evaluate whether the task modulates the extent to which motor or visual experience might be used. It should be pointed out that within the present study motor experience was examined for the first time with regard to motor expertise on the one hand and to motor competencies on the other hand. Additionally, we used two types of tasks, namely an *action recognition task* (Experiment 1) and an *actor identification task* (Experiment 2) which are also normally examined in different studies. Action recognition and actor identification were assessed for the same observation task under PLD conditions. Most of the evidence for the motor view of biological motion comes from studies on actor identification. We combined this task with an additional *action recognition task,* where participants had to anticipate different actions from own and others' movements. Particularly, we used different kinds of basketball dribbling as stimuli. Task complexity should provide participants with an opportunity to express an individual style of performance, which could be used for recognition of actions (Loula et al., 2005). Additionally, we wanted to find out whether the kind of presentation at all influences the perception of movements (Shipley & Cohen, 2000).

5.3.1 Experiment 1: Action recognition

Main objectives

The aim of our first experiment about action identification was to reassure that individual experience with the task had an influence on recognition of actions. We therefore used the expert-novice paradigm to analyze the impact of specific motor expertise on perceptual decisions.

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[3] Hohmann, Munzert & Troje: The observationof own movements shows different results in action recognition and actor identification in a gross motor skill. Article in prep.

Because on that level of analysis no differentiation between perceptual and motor expertise seems possible we analyzed the experts' performance for recognition of dribbling for their own movements, that of teammates and that of unknown players. We wanted to test the influence of motor competence, that is the general knowledge of motor constraints in reference to biological motion and in our case that of own movements, on perception. Recognition of own movement effects is not supported by perceptual experience, since players do not watch own movements regularly. An expected advantage of assessing own movements (Knoblich & Flach, 2001) could be attributed to better motor competencies. If a discrimination between teammates' dribbling would be superior, this could be taken as a perceptual expertise effect, because teammates' movements can be viewed extensively during training sessions (Loula et al., 2005). Moreover, it would be interesting to see whether the kind of presentation of the basketball dribbling influences the performance of the observers at all.

We hypothesized that experts can recognize dribbling better and faster than novices (Williams, 2003). Observers should be best to recognize own movements and better for the actions of friends compared to strangers (e.g. Beardsworth & Buckner, 1981; Cutting & Kozlowski, 1977; Loula et al., 2005). Additional information like the presentation of the ball or even the sound of the bouncing ball should lead to better performance compared to seeing only the moving body (Shipley & Cohen, 2000).

5.3.1.1 Method

Participants

Two groups with different expertise levels completed the experimental tasks. Expert basketball players were recruited from two male basketball teams from Kingston (Canada). Ten players from the Queen's University and eight players from the Royal Military College took part in the study (age M = 20.2 years, age range: 18-24 years). All players were right hander. They were playing basketball on average for 12.6 years. On average they spent 14.3 hours playing basketball each week and they had been team members for at least 2 years. Additionally 19 students (12 male, 7 female) of Physical Education at Justus-Liebig University, Giessen (Germany), without specific experience in playing basketball or only playing basketball on a recreational level served as novices. Participants from the novices group were matched with expert players with reference to the stimulus material.

All participants were paid for their services. They were naïve to the hypotheses of the study. Everyone provided informed consent before beginning the experiment. None of the participants had a medical condition that prohibited him from taking part in the study, all participants had normal or corrected-to-normal vision.

Material (Apparatus)

Stimuli for the action identification task were recorded using a motion capture system (Vicon; Oxford Metrics, Oxford, UK). Movement trajectories were captured with 12 infra-red cameras (Vicon) with a sampling rate of 120 Hz. Positions of the markers were tracked with a spatial accuracy of 1mm. The capture area for recording movements was 90 m². Movement trajectories were captured and pre-processed with the software Workstation, IQ2 and Cmotion Visual3D software. A biomechanical model was fitted to each individual to determine the joint locations. The sound of the ball touching the ground was captured with a microphone which was placed above the player (sound sampling rate: 46200). To create the stimuli for the visual testing phase we used MatLab 6.1 and the Psychtoolbox (Brainard, 1997). Stimuli were presented on a monitor (17 inches). Reactions were collected with a keyboard.

Stimulus generation

All basketball players were recorded individually. Each participant was dressed in tight black clothes. 53 markers (marker size: 1.4 cm) were fixed to the body of the player or to specific shells, an additional number of three markers was fixed to the ball. Before recording time was given to each player to familiarize with the setting of the recording. First of all, the participants were captured while walking. They were instructed to walk through the volume several times with a preferred speed. Participants did not know when they were captured to avoid a change of their walking style. Additionally, five dribbling skills were recorded including speed dribbling, cross over, between the legs, behind the back and spin dribbling. Five trials of each dribbling were captured. The players were instructed to bounce the ball five times while standing in place at one side of the volume before they started to move through the volume. Players were asked to move naturally and to perform the dribbling as in a real game. They were not informed about the aim of the study to prevent them to perform a certain aspect of movement which might help them to identify their own movements later on.

After motion capturing was completed, data were edited. The experimenter decided to use only those movements which looked naturally. Each recording was clipped to a total length of 1.6 s which included 1.45 s before and 0.15 s after a reference time that represented the change from one hand to the other. This reference time was set to the point when the ball hit the ground. For each participant, we created two clips of each type of the dribbling and two additional walking trials. A total of 12 videos of each expert player was created. The height of all models was standardized for the PLD. The PLD of the player consisted of 15 dots representing the joints of the body. The ball was represented by a single dot.

Procedure and Design

In Experiment 1 we employed a mixed factorial design. Two Groups (experts, novices) completed a perceptual decision task that was based on the within-subject variables Action (spin, behind the back, between the legs and cross over dribbling) and Condition (player only, player with ball, player with sound); that is all participants assessed all actions and all conditions. Participants were seated in front of a monitor in a dimly lit room. The distance to the monitor was approximately 0.7 m. The observers were instructed to watch PLDs of basketball dribbling to identify the actions as fast and as exact as possible. The task therefore required a speeded decision concerning the change of the movement pattern. Five different basketball dribbling (Actions) were presented namely the speed, spin, behind the back, between the legs and cross over dribbling. Dribbling were presented under three observational conditions: PLD of the moving player, player with ball visible, and player and sound of the ball but with the ball invisible (Conditions). Participants performed three blocks within the recognition task, one block for each Condition. Within each block three different models (Actors) were presented. Experts watched videos of own movements, that of a team-mate and that of an unknown player from another team. Novices only watched movements of unknown players. Stimulus material was matched for experts and novices. 20 trials of each model were presented (two different trials of five actions presented twice). This resulted in a total of 60 trials for each block and in 180 trials overall. Trials were randomized across actors and dribbling within each block. The order of blocks was balanced across all participants. No knowledge about the identity of the observed actors and no feedback about their performance was given. A short training session was conducted to familiarize the participants with the experimental setting. The presentation of each trial started with a white cross on a blue screen (5 s). Then one of the PLD (half-profile view) was presented. The stimulus dots were approximately 2 mm in diameter. The model moved from the left or right side towards the middle of the screen. The maximal trial length was 1.57 s. The presentation of actions stopped when the space bar was pressed, indicating the participant had recognized the dribbling or after the movement had been presented completely. Then a blue screen appeared for 5 s. Subsequently participants had to select the dribbling from a list. Participants were instructed to respond as quickly as possible while keeping the number of errors low. We conducted a competition between participants considering correct answers and reaction times. The entire experimental session took approximately 20 minutes.

Dependent Variables and Statistical Analysis

Statistical analyses were based on repeated measures of variance (MANOVA). Between subject variables were depending on analysis Expertise (Expert, Novice) or Actor (own, familiar, other) and the within-subject variables were Action (speed, cross over, behind the back, between the legs and spin dribbling) and Condition (player, player with ball, player with sound). Separate analyses of expertise and the own/other factor for experts only were conducted. The speed dribbling served as a catch trial and was analyzed separately. The depended variables were the rate of correct answers and the reaction time. A significance criteria of p =.05 was established for the analysis of the speed dribbling and a p=.05/12= .004 was established for all other analyses (Bonferroni corrected). The analysis includes the data of 16 experts because two did not show up in the lab again for the visual test.

5.3.1.2 Results

Expert-Novices Differences

We hypothesized that experts can recognize dribbling better and faster than novices. To evaluate differences in recognition of movements between experts and novices we analyzed the number of correct answers as well as the reaction times with regard to Action and Condition. The results can be seen in Figure 9 and 10.

The question was whether experts differ in the performance compared to novices in reference to the number of correct answers. Experts (86.02%,) showed better performances for the recognition of the dribbling than novices (77.35%).

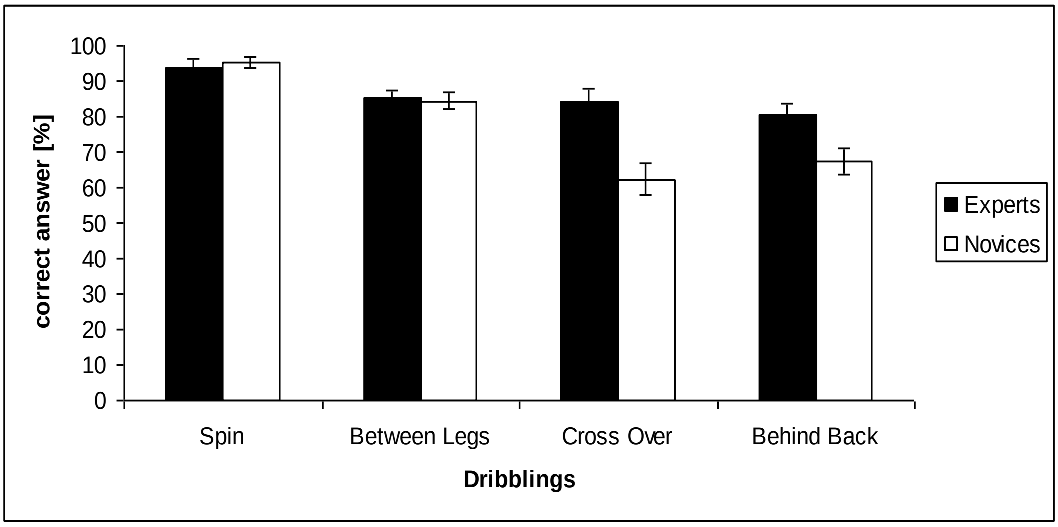

Figure 9

Rate of Correct Answers [%] for the action recognition task depending on Expertise Level and Dribbling. Error bars indicate the standard error of mean (SEM).

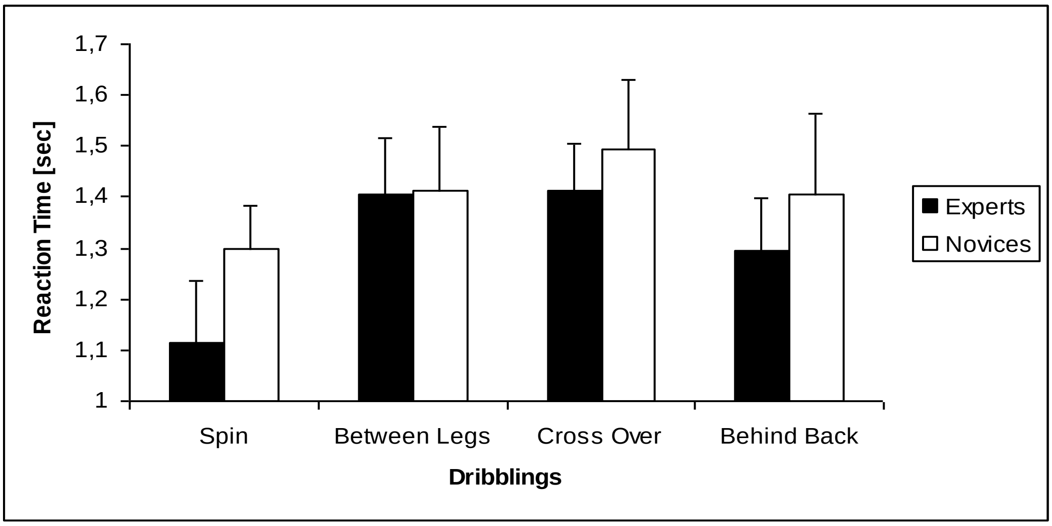

Figure 10

Reaction times for the action recognition task depending on Expertise Level and Dribbling. Error bars indicate the standard error of mean (SEM).

The total number of correct answers was analyzed according to a 2 x 4 x3 (Expertise x Action x Condition) repeated measures of variance (ANOVA). Group served as between subject factor, whereas Condition and Action served as within-subject variables. The analysis revealed a statistically significant main effect of Group, $F(1,32) = 10.05$, $p < .004$, $\eta^2 = .24$, Cohens' $f = 1.11$. Additionally, the performance of the observers depended on the presented Dribbling ($F(3,96) = 24.46$, $p < .004$, $\eta^2 = .43$, Cohens' $f = .82$). A post hoc analysis revealed that participants performed significant better for the spin dribbling (94.61%) compared to the between the legs dribbling (84.81%) $t(33) = 5.41$, $p < .05$, the cross over dribbling (72.70%) $t(33) = 5.91$, $p < .05$ and the behind the back dribbling (73.61%), $t(33) = 7.68$, $p < .05$. Additionally, a significant effect was found between the between the legs and behind the back dribbling, $t(33) = 3.55$, $p = .05$.

The interaction Expertise x Dribbling revealed a significant effect, $F(3,96) = 7.42$, $p < .05$, $\eta^2 = .19$, Cohens' $f = .87$. Paired t tests showed better recognition for experts compared to novices concerning the cross over, $t(32) = -3.61$, $p < .05$, and the behind the back dribbling, $t(32) = -2.74$, $p < .05$. No significant differences were found for Condition, $F(2,64) = 0.52$, $p = .60$, $\eta^2 < .05$. Thus, It makes no difference to see only the player (82.65%), the player with the ball (81.12%) or to see the player and hear the sound of the bouncing ball (80.51%).

Analysis of reaction times

Our hypothesis was that experts are faster to detect certain movements than novices. Therefore, we analyzed the reaction times of both groups. Experts (1.31 s) showed faster reactions than novices (1.40 s).An ANOVA with repeated measures and the between subject factor Group and the within-subject factors Condition and Action for reaction times revealed a significant effect for Group, $F(1,32) = 8.99$, $p < .05$, $\eta^2 = .22$, Cohens' $f = 3.58$. Additionally, a significant effect for Dribbling, $F(3,96) = 53.29$, $p < .05$, $\eta^2 = .63$, Cohens' $f = .58$ was found. Observers were significant fastest to detect the spin dribbling (1.21 s) compared to the between the legs dribbling (1.41 s), $t(33) = -7.74$, $p < .05$, the cross over dribbling (1.45 s),

$t(33) = -10.65$, $p < .05$, and the behind the back dribbling (1.35 s), $t(33) = -6.39$, $p < .05$. Additionally, the reaction times for the between the legs dribbling was significant different from the cross over dribbling, $t(33) = -2.80$, $p < .05$, and the behind the back dribbling, $t(33) = 2.27$, $p < .05$. Furthermore, reaction times significantly differed between the cross over and behind the back dribbling, $t(33) = 4.89$, $p < .05$. The performance of the observers regarding the reaction times therefore depends on the presented action. Whereas the detection of the spin dribbling was very fast, the detection of the cross over dribbling and behind the back dribbling was slower.

Moreover, the interaction Expertise x Dribbling showed a significant effect, $F(3,96) = 6.14$, $p < .004$, $\eta^2 = .16$, Cohens' $f = 1.29$. Paired t-tests showed an advantage for the experts for the spin dribbling, $t(32) = 5.16$, $p < .05$ and a nearly significant effect for the cross over dribbling, $t(32) = 2.03$, $p = .051$. Thus, experts are faster to recognize the spin and the cross over dribbling compared to novices. There is no significant difference between both groups regarding the behind the back and the between the legs dribbling.

Analysis of catch trials

An additional analysis of the speed dribbling, which served as catch trial, revealed neither significant differences on rates for correct answers for Group, $F(1,32) = .11$, $p = .74$, $\eta^2 = .003$, nor for the interaction Actor x Condition, $F(2,64) = .30$, $p = .74$, $\eta^2 = .01$. Experts and Novices did not differ in their performance to identify the speed dribbling. However, the analysis of the reaction times for the speed dribbling revealed a significant difference for Conditions, $F(2,64) = 4.07$, $p < .05$, Cohens' $f = .35$. Reaction times were significant faster within condition player+sound (1.44 s) compared to the Condition player only (1.54 s), $t(33) = 2.50$, $p < .05$. No statistical difference was found between the Conditions player with ball (1.50 s) and player with sound, $t(33) = 1.85$, $p = .07$. The sound of the bouncing ball therefore seems to help the observer to recognize the speed dribbling faster.

Experts' perception of own, familiar and unknown movements

We hypothesized that observers give more correct answers when they look at own movements and are also better when a familiar movements was presented compared to looking at an unfamiliar movement. To evaluate the effect of motor experience in reference to the action recognition task we analyzed the performance within the expert group. The differences between experts and novices might have been due to better motor or visual experience. Now we tested the influence of motor familiarity on action perception. This allows us to test the influence of motor experience more directly because better performance for own movements can only be due to better motor familiarity or to the influence of the motor system. We therefore evaluated the data of the expert group separately for own, teammates' and unknown players' movements. Performance was analyzed depending on the presented Actor (own, team mates' and others' movement). A 3 (Actor) x 3 (Conditions) x 4 (Dribbling) design was conducted to assess the influence of motor representations on perceptual decisions within the expert group.

Figure 11 represents the rate of correct responses and figure 12 the reaction times for correct pesponses depending on the different Actors and Dribblings. Our hypothesis was that observers differ in the performance according to the observation of own, teammates or strangers movements. Own movements should be recognized better than those of teammates and strangers. Therefore, we analyzed the total number of correct answers. The analysis of the data revealed that the performance of the observers did not depend on the presented model. Therefore, observer had no advantage when own (86.46 %), familiar (86.20 %) or unfamiliar (85.42 %) actions were presented.

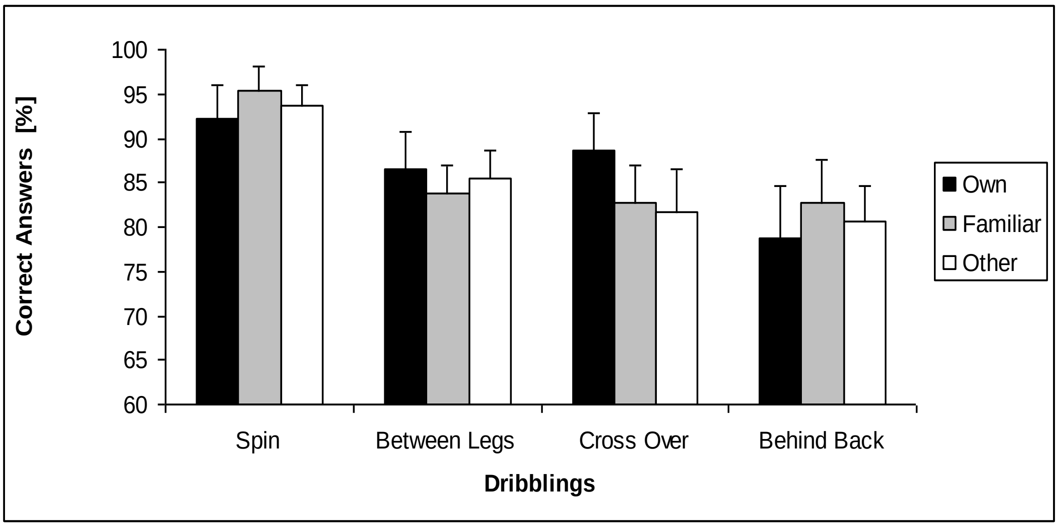

Figure 11

Rate of correct answers [%] for the action recognition task depending on Actor and Dribbling. Error bars indicate the standard error of mean (SEM).

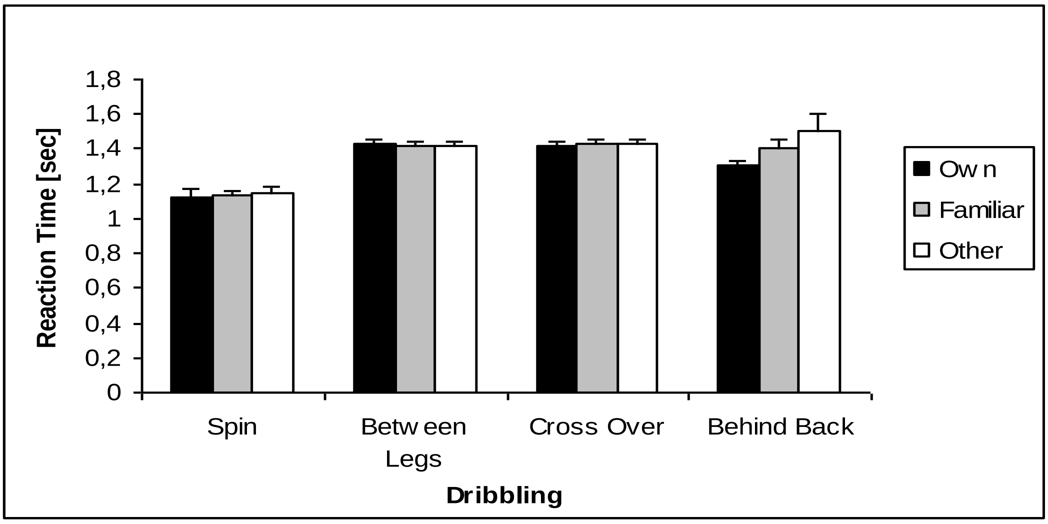

Figure 12

Reaction times for the action recognition task depending on Actor and Dribbling. Error bars indicate the standard error of mean (SEM).

A 3 (Actor) x 3 (Condition) x 4 (Dribbling) ANOVA with repeated measures for rate of correct answers revealed no significant main effect for Actor, $F(2,30) = .06$, $p = .94$, $\eta^2 =$

.004. Additionally, we hypothesized that additional information like the ball or even the sound of the bouncing ball should facilitate recognition of actions. However, additional information like the ball (87,37%) or the sound of the ball (83,20%) did not lead to better performance compared to no further information (87,5%), ($F(2,30) = 0.73$, $p = .43$, $\eta^2 = .05$). Again there was a significant effect for Dribbling, $F(3,45) = 4.97$, $p < .004$, $\eta^2 = .25$, Cohens' $f = .62$ within the expert group. This result can be attributed to significant better recognition of the spin dribbling (93.75%) compared to the between the legs (85.25%), $t(15) = 4.39$, $p < .05$, the behind the back (80.73%) , $t(15) = 4.58$, $p < .05$ and the cross over dribbling (84.23%), $t(15) = 2.34$, $p < .05$. The performance of the experts depends on the presented action. The interaction Actor x Dribbling failed significance level ($F(6,30) = .47$, $p = .83$, $\eta^2 = .03$. Experts did not recognize certain actions faster when own, teammates or strangers movements were presented.

Analysis of reaction times

Our hypothesis was that observes are faster to recognize own movements compared to that of familiar players and strangers. However, the analysis of the data revealed that the participants were not faster for own movements (1.32 sec.), that of familiar players (1.34%) or even strangers (1.37%). An ANOVA for reaction times revealed no significant main effects for Actor, $F(2,22) = 1.03$, $p = .37$, $\eta^2 = .08$. Additionally, it makes no difference to see the player only (1.36 sec), the player with ball (1.34 sec.) or to hear the bouncing ball (1.33 sec.), $F(2,22) = .51$, $p = .61$, $\eta^2 = .04$. There was no differences in reaction times whether experts watched own, teammates or strangers movements. Moreover, additional information like the ball or the sound of the bouncing ball did not lead to faster reaction times. Again there was a significant main effect for Dribbling, F(3,33) = 36.29, $p < .05$, $\eta^2 = .77$, Cohens' $f = 1.81$. This effect is due to significant shorter reaction times for spin dribbling (1.13 s) compared to the between legs (1.42 s), $t(14) = -10.34$, $p < .05$, the behind back (1.37 s), $t(14) = -5.30$, $p < .05$ and the cross over dribbling(1.41 s) ,$t(13) = 9.88$, $p < .001$. The interaction Actor x Dribbling failed significance level ($F(6,66) = 1.47$, $p = .21$, $\eta^2 = .12$). The experts did not recognize certain dribbling faster when they observed own performances of those actions.

Analysis of speed dribbling

Speed dribbling that served as catch trial was analyzed separately from the other skills within the expert group according to the number of correct answers and reaction times. A 3 (Actor) x 3 (Condition) ANOVA for the rate of correct answers did not reveal any statistically relevant difference for Actor, $F(2,30) = .58$, $p = .57$, $\eta^2 = .04$ nor for Condition $F(2,30) = .66$, $p = .53$, $\eta^2 = .04$). The number of correct answers within the experts group did not depend on the presented actor nor on the presented condition. An ANOVA with repeated measures for reaction times for the speed dribbling revealed no effect for Actor, $F(2,26) = .50$, $p = .61$, $\eta^2 = .04$, nor for the interaction Actor x Condition, $F(4,52) = .74$, $p = .57$, $\eta^2 = .05$. Thus, reaction times according to the speed dribbling did not depend on the presented actor nor on the presented condition. However, a significant effect for Condition was found, $F(2,26) = 6.02$, $p < .05$, $\eta^2 = .32$. Observers were significant faster for the Condition player with sound (1.49 s) than for the Conditions player only (1.52 s) ,$t(13) = 3.14$, $p = .01$, and for Player with ball (1.49 s) , $t(15) = .85$, $p = .41$.

5.3.1.3. Discussion

One aim of the first experiment was to compare the performance of experts and novices and to examine whether motor and visual experience had at all an influence on the given task. The results showed that experts are superior in recognizing basketball dribblings compared to novices. This holds for the rate of correct classifications of the dribblings as well as for reaction times. A closer look at the results revealed that the expert-novice differences can be generalized to most of the dribblings. Experts showed better results than novices in three of four movements for the rate of correct action recognition and reaction times, though no such differences were found for the catch trials. No differences for groups were found for classification of the behind the back dribbling and for reaction times of the between the leg dribbling.

The expertise advantage for perceptual judgments in the experts' domain is in line with the body of literature in expertise research (e.g., Starkes & Allard, 1991; Williams & Ward, 2003). Here we can add new evidence, that expertise effects are also applicable for biological motion perception. This demonstrates that the kinematics of movements build a basis for perceptual recognition and decision.

However, differences between experts and novices can be explained by superior motor expertise as well as by better perceptual representations for the experts. Both mechanisms cannot be separated in an expert-novice design. Nevertheless, either mechanism or one of them in particular must have been responsible for the expert-novice differences in our task.

To answer this question we analyzed the performance depending on the observed model within the expert group (self, teammate and unknown player). Now the motor familiarity according to own movements and not motor expertise at all should influence perception. No differences for rates of correct responses nor for reaction times were found for the observation of different Actors. Neither an advantage for observing own movements (influence of motor competencies, motor view) nor an advantage for observing team mates (perceptual view) occurred for the different actions. However, it should be pointed out that this result is not due to the task at hand. The detection of differences between experts and novices clearly demonstrates that the task is sensitive enough to measure differences concerning groups of different levels of motor experience. It therefore seems to be plausible that within this kind of task, namely an action recognition task, the experience to see such movements at all and to match it to the own movement is in depended of the observed model. From an ecological point of view it might make no qualitative difference to see own or other individuals movements and to match the observed movement to the own motor system to understand its implications. Action recognition therefore works for own movements as good as for other humans movements, however, motor expertise modulates this process.

Furthermore, performance did not depend on the presented Condition. It makes no difference whether participants observed only the body of the player, the player with the ball or the player in combination with the sound of the bouncing ball. Only for speed dribbling reaction times were faster in the condition player and sound. We assume that the participants recognized the speed dribbling earlier because of the more pronounced rhythm in ball bouncing compared with the other four dribblings. However, the reason why we did not find the expected differences between the three conditions might be that contrary to the study of Shipley and Cohen (2000) the observer knows already at the beginning of the test session that basketball movements will be presented. As a result the presentation of the ball or its sound provides no more information to the observer. We assume that the perception of the actions is in this case guided by a top-down process. This could explain why we did not find any significant differences with respect to Conditions. However, the result that there is an advantage according to the reaction times for the speed dribbling supports the view that action results are part of motor representations (Repp & Knoblich, 2004).

Moreover, we found a significant main effect for Dribbling. The spin dribbling was identified better and faster than the other three movements. The spin dribbling has qualities, which are different from the other skills. It includes a full turn, whereas the other dribblings are qualified as movements straight ahead without a turn, but with the ball crossing in front of the body, between the legs or behind the body, resulting in similar movements of hand and arm. Another reason for the faster recognition of the spin dribbling depends on methodological issues of setting of the reference frame. It was set for the change between hands. Observers can anticipate the following change of the hand earlier, because it takes more time to prepare a full turn than to prepare one of the other dribblings with no body rotation. Probably, the onset of the movement can be detected earlier.

5.3.2 Experiment 2: Actor identification

Main objectives

Experiment 2 focused on actor identification. This time observers had to answer to questions: 1. "Was this a player of your team or the other team?" and in case the own team was chosen, 2. "Who is the presented model?". We first asked the observers to assign the presented player to the own team or to the other team because this enables us to implicitly measure the influence of visual and motor experience. If perception relies on visual and motor experience observers should be able to discriminate between the own team and the other team because they possess visual experience for the movements of teammates and motor experience for own movements. Additionally, we were able to analyze how often they implicitly assign the own movement to the own team. This enables us to evaluate how familiar observers were with their own movements. The aim of the second question, to explicitly name the player, allows us to distinguish between visual experience (assign a name to the teammate) and motor experience (assign a name to the own movement). As actor identification in PLD depends on skill complexity (Loula et al., 2005) different stimuli with increasing complexity were used. Therefore, we now presented only three movements namely the speed dribbling, the spin dribbling and normal walking. This manipulation enables us to measure performance with reference to certain tasks that are more or less constrained. We hypothesize that observers show better results according to the identification of the own person compared to other observed models (e. g. Loula et al., 2005). We also assume that observers gain relative advantage to recognize the presented player when he performs a movement that is less constrained and therefore permits more individual style. Because the same group of participants and nearly the same stimuli are used as in experiment 1 the current investigation allows us to draw conclusion from the question whether the extent to which visual and motor experience contribute to perception depends on the task.

5.3.2.1 Method

15 participants from the expert group from Experiment 1 took part in the study. One participants did not take part due to private reasons. To test the observers’ ability to identify actors we used the same stimuli as in Experiment 1.

Procedure and Design

Participants watched PLD videos of both teams (own team, other team) and all 16 players (own movement, seven teammates and eight players of the other team) within a perceptual decision task, which was organized in a hierarchical way. They had first to identify the model’s team. After a response “other team”, the next stimulus was presented. In case that the “own team” was chosen, participants had to select a name from a list (names of teammates and own name). Additionally, the within-subjects variables Action (walk, speed and spin dribbling) and Condition (player only, player with ball, player with sound) were included; that is all observers assessed PLDs from both Teams, all Actors, all Actions and all Conditions. This implies that half of the presented stimuli consisted of own team’s actions (including the participant), the other half consisted of the other teams’ actions. Three different actions were presented: speed dribbling, spin dribbling and normal walk (Action). It should be pointed out that these three actions are more or less constrained and therefore allow more or less for an individual performance. Sequences were presented twice for each model and each action. This resulted in a total of 96 items for each Condition (16 models x 3 actions x 2 trials). The order of Conditions was balanced across participants. The length of each video was approximately

1.6 s. A short training session for this task was conducted to familiarize participants with the task.

Dependent Variables and Statistical Analysis

Statistical analyses were based on repeated measures of variance (ANOVA). The between subject variable was Actor (own, other) and the within-subject variables were Action (speed, cross over, behind the back, between the legs and spin dribbling) and Condition (player, player with ball, player with sound). The depended variables were the rate of correct answers and the reaction time. Significance criteria of p = .05/9 = .006 were established for all analyses (Bonferroni corrected). Separate analyses of expertise and the own/other factor for experts only were conducted. The speed dribbling served as a catch trial and was analyzed separately.

5.3.2.2 Results

Performance accuracy for the assignment of a player to the own or other team

First, participants had to identify whether the presented model belonged to the own or the opponent team. Chance level was at .50 in this two-alternative forced choice task. The rates of correct assignments for Action and Condition are presented in Figure 13.

Our hypothesis was that observers were able to distinguish between team-mates and players of another team and that the type of presented action (more or less complex actions) influences the performance of observers. However, the results indicate that the observers were not able to discriminate between players of the own team (53.73%) and that of the team (54.42%). Furthermore, we did not find the expected differences in performance regarding to the presented action. Walking (52.29%) did not give more information about the presented Team than the speed (54.38%) or spin dribbling (54.45%). Additionally, performance was independed from the presented Condition (player (53.75%), player with ball (52.29%) and player with sound (55.07%)).

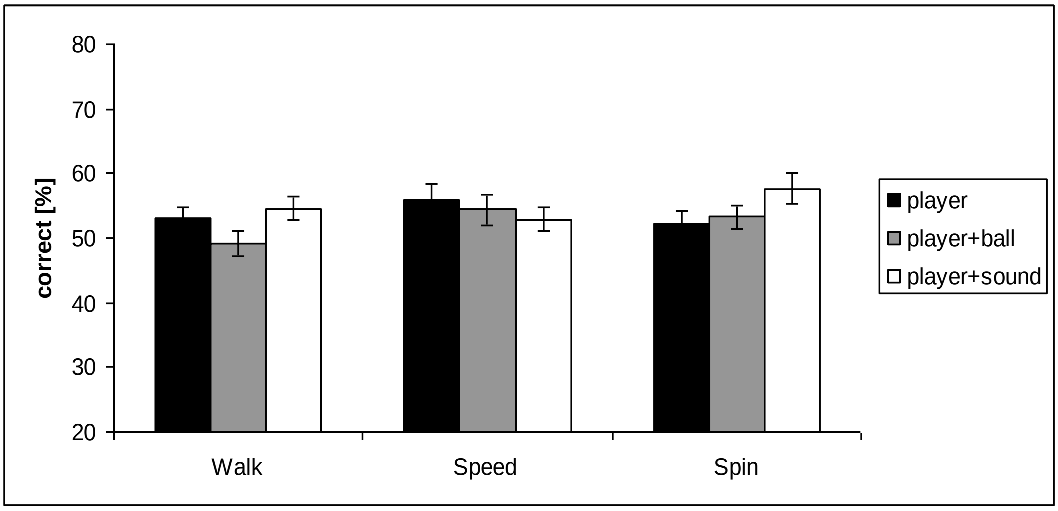

Figure 13

Rate of Correct Assignments [%] for Actors to a Team depending on the presented Action and Condition. Error bars indicate standard error of mean (SEM).

A 3 (Conditions) x 3 (Actions) ANOVA with repeated measures for both variables showed neither a significant effect for Action $F(2,28) = 1.06$, $p = .36$, $\eta^2 = .07$, nor for Condition, $F(2,28) = 1.60$, $p = .22$, $\eta^2 = .10$. The interaction Action x Condition, $F(4,56) = 1.68$, $p =.17$, $\eta^2 = .11$, did also fail significance. Moreover, performance did not depend on the presented Condition. To see only the player (53.75%), the player with ball (52.29%) or to see the player and hear the sound of the bouncing ball (55.07%) did not lead to different performances.

Performance accuracy for assignment of own movement to own team

To examine whether the observers were at least familiar with their own movements the rate of correct assignments of own movements to the own team was analyzed. This analysis again refers to the first task (own or other team). It is therefore an indirect measure how well the observers were able to recognize their own movement as a familiar movement, because they were not asked for the identity of the player directly.

We collapsed the data for Conditions because prior analyses did not reveal any difference for Conditions. Figure 14 represents the rates of correct assignments of other players (teammates as well as opponents) and the own movement to the team depending on the presented action.

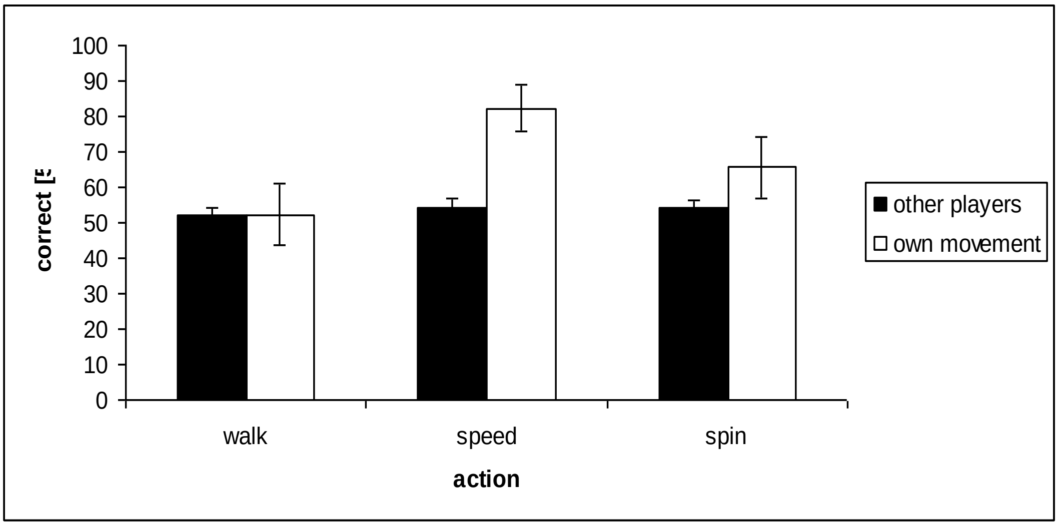

Figure 14

Rate of correct assignments [%] of any other player (teammate, player of the other team) or the own movement to the right Team depending on the presented Action. Error bars indicate standard error of mean (SEM).

The number of correct assignments of the own movement to the own team compared to the number of correct assignments of all other players was analyzed in the next step. Own movements (66.67%) were assigned more often correct to the own team than all other players were assigned correct to the own or other team (53%). An ANOVA with repeated measures showed a significant effect for Actor, $F(1,14) = 12.16$, $p = .004$, $\eta^2 = .47$, Cohens' $f = .93$. Moreover, we found a significant effect for Action F(2,28) = 10.90, $p < .05$, $\eta^2 = .44$, Cohens' $f = .88$. Performance was best for the speed dribbling (68,30%). Actor identification was better for the spin dribbling (60%) compared to the action walk (52,26%). Additionally, the interaction Action x Actor, $F(2,28) = 10.75$, $p <.05$, $\eta^2 = .43$, Cohens' $f = .88$, revealed also a significant difference. Paired t-tests revealed significant differences between the Actions walk and speed dribbling for the own movement $t(14) =-4.10$, $p < .05$, between walk and spin for the own movement $t(14) = -2.35$, $p = .03$ and between spin and speed dribbling for own movement $t(14) = 2.96$, $p < .05$. Furthermore, there was a significant difference between the own and all other players movements for the speed dribbling $t(14) = -6.59$, $p < .05$ and a nearly significant effect between the own and teammates' movements for the spin dribbling $t(14) = -2.07$, $p = .057$.

A further analysis with binominal tests showed that the performance accuracy did significantly differ from chance level for the own movement ($p < .05$) but not for the movements of other players ($p = .33$).

Performance accuracy for assignment of a name to a teammate as well as to the own movement (identification of the Actor)

When participants classified a model to their own team, they subsequently had to identify the model. According to the results of the first part of analysis it has to be considered that participants could not discriminate between teammates and players of the other team. Therefore performance to assign the correct name to a presented player was analyzed for only those players who were correctly assigned as teammates. Chance level was as 12.5 % because decisions were based on eight names (seven teammates and own name).

Because the results revealed no differences for Condition we collapsed data for this factor. Results are summarized in Figure 15.

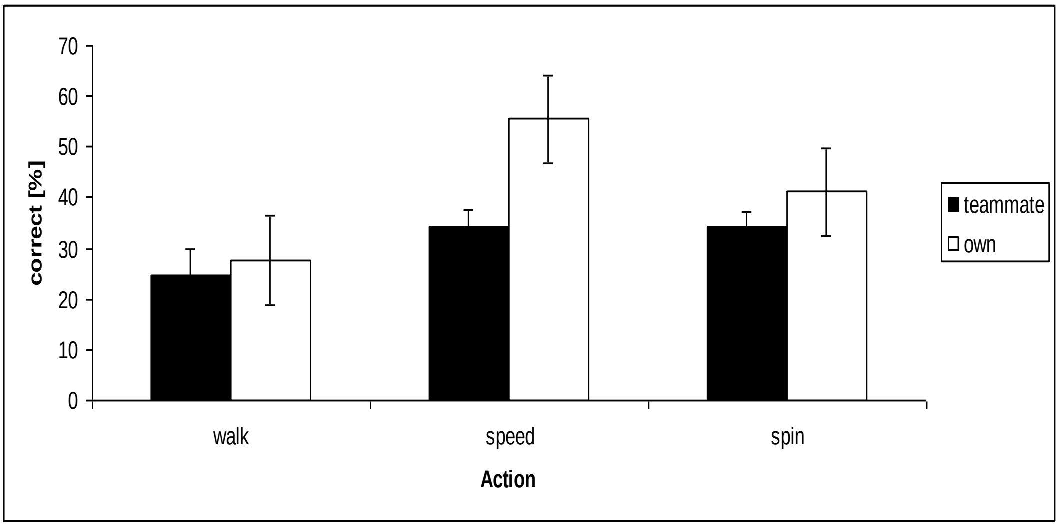

Figure 15

Rate of correct assignments [%] of names to a teammate or to the own movement depending on the presented Action. Error bars indicate standard error of mean (SEM).

The hypothesis was that observers should be better able to assign the own name to the own movements. However, observers were not better able to assign the correct name to the own movement (41.48 %) than to assign the correct name to a teammate (31.15 %). An ANOVA with repeated measures showed no significant effect for Actor $F(1,14) = 1.65$, $p = .22$, $\eta^2 = .11$. However, we found a significant effect for Action $F(2,28) = 5.37$, $p < .05$, $\eta^2 = .27$. Observers were better able to assign the correct name when a speed dribbling (44.92%) was presented compared to watching the spin dribbling (37.71%) or the walk (26.31%). Moreover, paired t-tests revealed significant differences between the Actions walk and speed dribbling $t(14) = -3.43$, $p < .05$. This results furthermore showed that accuracy to assign the correct name to the presented player did significantly differ from chance level for the own movement ($p < .05$) as well as for movements of teammates ($p < .05$).

5.3.2.3 Discussion

The aim of the second study was to examine whether participants were able to discriminate between the own movements, that of teammates and that of strangers. Within a first step we therefore analysed whether observers were able to discriminate between players of the own team and that of another team. To evaluated the impact of motor experience we analyzed how often observers assigned the own movement to the own team. Additionally, we asked observers to name the presented player to be able to test the impact of motor and visual experience more direct. Results show a differentiated picture for decisions on actor ship (own/other and own team/other team).

First, results show that participants can hardly differentiate between members of the own and another team when PLDs are presented. The result that they could not discriminate between teammates' and opponents' movements is inconsistent with the assumption that visual experience may have an influence on actor recognition according to the actor identification task.

Second, participants are more successful in classification of own movements to their own team. It has to be emphasized that this task does not rely on an explicit recognition of the participant himself. Own actions were classified more often to the own team irrespectively if they had recognized themselves. This result provides a strong argument that motor experience plays a major role in actor recognition. Athletes normally do not have visual experience with their own movements. Therefore, visual experience can be excluded as a reason for this result. However on the other hand they have extensive experience and familiar with their own actions.

Third, when athletes were asked to identify the player, whom they had classified correctly into the own team, they were above chance level to assign the correct name to the own movement as well as to a teammate. Results for teammates may be put down to visual experience, whereas results for own movements support the significant role of motor experience. Though no significant differences between recognition of own and teammates' actions were found, our results support the hypothesis that motor experience is helpful for perception of human movements.

Fourth we found support for the assumption that actions allowing an individual style assigned to a team more effectively than for more constrained movements. This holds for the classification of own movements into the own team. The same results were found for the task to identify a player who had been assigned correctly to the own team. Actor identification so far seems to be easier when complex movements like basketball specific actions as the speed and the spin dribbling were represented. Results for actor identification do not show any advantage for perceptual experience, but for some conditions an advantage for motor familiarity. This is seen as support for the motor view of perception of biological movements.

In sum, it appears that motor experience might have a greater influence than visual experience at least on identity perception and that the task somehow modulates whether visual or motor experience play a role.

6. General Discussion

The results of the present studies provide further evidence that individuals are highly sensitive to the perception of human biological motion. Even if there are only subtle differences within the presented actions the observers are well able to recognize these actions. As could be shown in study 1 and 2 about the perception of boule throws, individuals were able to estimate the length of throws even if only a 1m difference between two throws was presented. Moreover, the reduction to only three points that represent the arm of the thrower did not lead to a significant decrease in performance. It can be assumed that observers try to group the simultaneous moving dots in such a way that they see the “real arm” as the “Gestaltpsychologie” or even the “principle of perceptual vector analysis” (Johansson, 1950) would suggest. Additionally, the “pendulum like motion” allows the observer to recognize the movement as biological motion. The result that the perception of the throwing length is still above chance level when seeing only one point representing the hand, further provides evidence that the local analysis of a single dot provides enough information to solve the task.

Additionally, the basketball dribblings could be discriminated above chance level even if the movements were very similar especially when looking at the cross over, between the legs and behind the back dribbling. The difference merely concerns whether the ball changes in front of the body, between the legs or behind the back. Even if the expert group was superior in reference to the novices within the basketball study, the novices were also well above chance to recognize the dribbling although they were not familiar with those movements.

Moreover, we could add new evidence that the point light-technique is a useful tool to study the perception of actions. As demonstrated within the boule studies 1 and 2 there is no difference to see the full video or only the moving dots that represent the kinematics of the acting model. Therefore, the point light technique allows assuring that the observer is looking towards the presented action and is not distracted by certain features within the environment.

The aim of the present studies was to examine the influence of the motor system on the perception of human actions and to find evidence for the motor view of biological motion perception (Knoblich & Flach, 2001; Prinz, 1997). We therefore used an off-line paradigm to test the influence of action on perception. Participants with different kinds of motor expertise (experts vs. novices) and motor competencies (perception of own movements) took part in the studies. Additionally, different kinds of task were examined. An *effect anticipation*, an *action recognition* as well as an *actor identification task* were used to test the influence of the motor system on biological motion perception. All types of task have been quoted as support for the motor view of biological motion (Knoblich & Flach, 2001; Loula et al., 2005).

First of all the results regarding the different kinds of motor expertise as well as motor competencies should be discussed. The results of the basketball study about action recognition reveal that there are differences regarding the recognition of basketball dribbling between expert and novice. Experts achieve a higher rate of correct classification of basketball dribbling and also shorter reaction times for this task than novices. However, it should be pointed out that this expertise effect cannot be attributed to either superior motor or perceptual representations exclusively, because experts have more experience of both observing and practicing basketball skills. That means motor expertise might not be the only aspect responsible for the present result.

Therefore, we used participants with different kinds of motor competencies, here referred to as the knowledge of own motor capabilities. On the one hand the results of the boule study do not provide evidence that individuals perceive own movements better than those of other people within an *effect anticipation task*. This is in contrast to the findings of Knoblich and Flach (2001). Additionally, the same was true for the *action recognition task* within the basketball study. There was no difference in performance to see the own past movements or those of teammates as well as strangers within that task. On the other hand better performances of the observers were found for the actor identification task. Participants more often assigned the own movement to the own team and they were also better to assign the correct name to the own movement. This result could be explained in terms of better motor competencies for own movements, because normally the individual does not see herself performing the dribbling. Therefore, the advantage to see own movements seems to be based on the influence of the motor system.

This leads to the second aim of the studies. It seems to depend on the task to what degree motor experience influences perception. As described above there is a whole body of literature providing evidence that the perception of own movements is superior to the perception of others' actions. However, when taking a closer look most of the studies that support these assumptions derive from studies about actor identification in the domain of walking (Beardsworth & Buckner, 1981; Cutting & Kozlowski, 1977; Jacobs & Shiffrar, 2005; Wolff, 1931), handwriting (Knoblich & Prinz, 2001b), hand clapping (Flach et al., 2004; Repp, 1987), piano playing (Repp & Knoblich, 2004) and the identification of own body parts like the hand (Daprati et al., 2006). This would be in line with the results of the basketball study about actor identification. Participants were better in assigning own PLD to the own team than PLD of their teammates. They could also identify the own person slightly better than teammates, when they had to name the actor. On the other hand participants in our study did not show better results to assign a teammate or another player to one of the teams correctly. This is in contrast to the findings of Loula et al. (2005) and negates the influence of visual experience on perception.

Adjunctive with these findings is the result that the presented action itself provides more or less information to the observer about the presented model. If the movement is less constrained like in the present study where spin dribbling is compared to walking, the identification of the observer seems to be easier. This is in line with the findings of Loula et al. (2005) who could show that the identification is easier when presenting movements like dancing or table tennis compared to greeting and running for example. Further evidence that the relative timing of the movement is crucial for identification derives from studies about drawing or writing (Knoblich & Prinz, 2001b; Knoblich et al., 2002).

However, the results of the *action recognition task* (basketball) are harder to classify. This task demands a direct interaction of the observer with the actions of others. More or less in line with the present study are tasks used in the studies of Flach et al. (2003) and Keller et al. (2007). Participants' had to synchronize their movements with own earlier actions or with other individuals' movements in a drawing task or while playing piano. Individuals in those studies showed better results for synchronization with own movements than for actions produced by other individuals. In contrast, the aim of the basketball task is to react to that movement and not to synchronize the own movement with the presented movement. Normally players have to react in 1:1 situations to players of another team. It therefore can be argued that an advantage of more general representations might be functional for the present task, as it is discussed by Ramnani and Miall (2004). It would be of no advantage to use knowledge about the specific movement features of teammates or of the own movement to a greater extent, because all this information has to be adapted to the movement characteristics of a player of another team. Quite opposite, an orientation on specific features of the own movement skill could cause a detrimental effect for the perception of others' movements. A switch in the movement pattern should be anticipated independently of the model. It can be argued, that motor and perceptual representations can support the anticipation of a dribbling skill like in the present perceptual decision task. Nevertheless, they are used in a generalized form and can be employed for the prediction of others' skills as well as for the perception of own skills.

Additionally, we cannot find evidence for better effect anticipation for own past actions. Up to now the dart study of Knoblich and Flach (2001) is one of the rare experiments that could show that there is a positive influence of high motor competencies on perception within an *effect anticipation task*. On the one hand the results of the boule study provide evidence that experts are better than novices to anticipate effects of actions, that means motor expertise does at least have some influence on the task. On the other hand we cannot provide evidence that motor competence has an influence as well. It therefore seems to be plausible to assume that motor expertise and motor competence affect movement perception and effect anticipation differently. As described by the “Theory of event coding” it is assumed that the goal of the perceiver specifies what is processed and how it is processed (Prinz, 1997). It might be that the task to anticipate an effect and the task to identify a model leads to different processing forms.

In contrast to the study of Knoblich and Flach (2001) video and PLDs were used within our boules study to present the movements. It should be pointed out that the best results within the dart experiment were achieved when the head and eyes were visible. That means the participants could see were the observed models are looking at. It might be that this allows to predict the landing position of the darts but that this information is not useful or meaningful enough to predict the landing of the ball within the video condition.

When taking a closer look at the results of the dart study, the better effect anticipation for own actions could only be found within later trials. The authors explain this circumstance with the assumption that the observers need time to change from a third-person perspective to a first-person perspective. On the one hand it might be that observers within the boule study were not able to change their point of view. On the other hand this argument seems to be less believable, because there were four test sessions in total. Enough time was given to familiarize with the movement.

Knoblich and Flach (2001) postulate that the amount of information given to the observer influences how long it takes to change from a third-person perspective to a first-person perspective. They report that the effect of better anticipation for own movements is present earlier when only minimal information like the arm is visible. Therefore, it additionally remains unclear why we cannot replicate the findings when we also provide only minimal information, namely the throwing arm.

With regard to the results of our basketball study as well as the experiments of Loula et al. (2005) and Cutting and Kozlowski (1977) it does not seem to be necessary to provide only minimal information about the actor. Even if the whole body is presented, actor identification is possible. Moreover, none of these studies reported that it needs time to change from a third-person perspective to a first person perspective. From an ecological point of view this additionally would not make sense. It seems to be much more plausible to believe that according to a direct perception approach (Gibson, 1979) no further processing stages are necessary to understand the perceived movements.

On the one hand it might be that the participants used heuristics to judge the length of the boule throws like "Theory Theory" would suggest. If that would be true someone could not expect to find differences according to the perception of own and other individuals' movements. On the other hand it should be considered what is denoted by "simulation". As described above, there are several accounts that differ according to their statements what is meant by "simulation" and what is "simulated". Does it refer to the movement only (Decety & Ingvar, 1990) or to the intention of the observed model and to prospective action judgments as well (Jeannerod, 2001)? In both cases the motor system is involved during action simulation but only the later one would lead to the conclusion that upcoming actions can be anticipated. According to the results of the present studies it seems to be plausible to use the concept of simulation in a narrow sense. However, up to now it remains indistinct what observers are doing to solve the task.

Unexpectedly we found only a marginal impact of condition on perception of human motion within the boule studies as well as the basketball studies. This result is somewhat surprising, because positive effects of seeing an object in biological motion perception have been reported (Shipley & Cohen, 2000). It can also be expected, that additional acoustic cues might support action recognition (Flach et al., 2004; Repp & Knoblich, 2004). However, no effect for Condition was found for the anticipation of throwing length nor for the recognition of dribblings or the identification of actors. It might be that in that case perception is driven" top-down", that means that observers already have expectations of what they will see and so additional information like for instance the ball during basketball dribbling does not provide further information.

In conclusion, the results show that motor as well as visual experience may play an important role in perception of movements. Expert-novices differences from the basketball study support this view. No self/other effect was found for the *effect anticipation task* or for the *action recognition task*. Nevertheless, we could demonstrate a facilitation effect of observing own movements for actor identification. This supports arguments for a dissociation of different perceptual tasks for biological motion perception. We argue for the *action recognition task* as well as for the *effect anticipation task* that generalized perceptual and motor experience support the recognition of actions. In contrast the *actor identification task* seems to depend on motor representations and motor competencies. This finding is in line with Loula et al. (2005) as it supports the result that motor experience plays a more important role for actor identification than visual experience. An advantage of viewing own movements is more relevant for actor identification than for recognition of action. Nevertheless, if an advantage of perception of own movements does occur, it depends on functional affordances of the specific recognition task and not on the kind of presentation at all. This result is in line with the findings of Zentgraf, Stark, Reiser, Künzell, Schienle, Kirsch, Walter, Vaitl & Munzert (2005). They could demonstrade that different instructions lead to different neural activations of motor areas, even if the stimulus material was identical.

As described above we examined the question to what degree the motor system influences perception with regard to motor experience, namely motor expertise as well as motor competence. The results of the present studies have implications for further research. Within the next step it will be interesting to manipulate the motor experience of the observers to see how this might influence perception and to replicate the findings of Casile and Giese (2006). The current series of experiments can be extended in such a way, that naïve subjects have to learn the movements, namely the boule throw. The performance of the participants should increases due to motor learning (e. g. Casile & Giese, 2006; Hecht et al., 2001).

To support the results of the present basketball study, another experiment should be conducted that tests motor competence within the same actions but with different tasks to provide evidence for the notation of different influences of the motor system with regard to the task. Loula et al. (2005) showed that observers are well able to identify the presented model playing table tennis. It seems to be plausible to again combine an *actor identification task* with an *effect anticipation task*. The task might be to identify the observed model and to judge whether a cross or down the line hit was presented.

It seems to be worthwhile to analyze the gaze behavior of the observers. Even if it will not be possible to clearly indicate what cues observers pay their attention to, different gaze behaviors may provide evidence that individuals use different strategies to solve the task. Moreover, it could be evaluated whether observers rely on single points (local analysis) or if they look more or less at all points (global analysis). It would also be possible to evaluate if observers within a video condition really use the information derived from the head and eyes of the observed model to anticipate the effects of an action as postulated within the dart study (Knoblich & Flach, 2001).

A challenging task for further research will be to evaluate the influence of the motor system within neuroscientifc methods. On the one hand it would be interesting to further evaluate whether the overlap of brain regions that are responsible for perception as well as those for action really rely on the same neurons. Up to now it has not been demonstrated that this "overlap" relies on exactly the same brain structures. The "overlap" might originate, because different neuron populations just simply are located within the same brain regions, but have nothing in common.

So far it is not really clear whether observers use heuristics or really simulate the movement to anticipate the effect of an action for instance. Additional research is needed to modulate this process due to different kinds of instructions and to see whether the simulation network in the brain is more or less active.

7. References

Adolph, K. E. (2003). Specificity of learning: Why infants fall over a veritable cliff. *Psychological Science, 11*, 290–295.

Aschersleben, G., & Prinz, W. (1995). Synchronizing actions with events: The role of sensory information. *Perception and Psychophysics, 57*, 305–317.

Atkinson, A. P., Dittrich, W. H., Gemmell, A. J., & Young, A. W. (2004). Emotion perception from dynamic and static body expressions in point-light and full-light displays. *Perception, 33*, 717-746.

Bandura, A., & Walters, R. H. (1963). *Social learning and personality development*. New York: Holt, Rinehart & Winston.

Beardsworth, T., & Buckner, T. (1981). The ability to recognize oneself from a video recording of one's movements without seeing one's body. *Bulletin of the Psychonomic Society, 18*, 19-22.

Beauchamp, M. S., Lee, K. E., Haxby J. V., & Martin, A. (2002). Parallel visual motion processing streams for manipulable objects and human movements. *Neuron, 34*, 149-159.

Bertenthal, B. I. (1993). Perception of biomechanical motions by infants: Intrinsic image and knowledge-based constraints. In C. Granrud (Ed.), *Carnegie symposium on cognition: Visual perception and cognition in infancy* (pp. 175-214). Hillsdale, NJ: Erlbaum.

Bingham, G. P. (1987). Kinematic form and scaling: Further investigations on the visual perception of lifted weight. *Journal of Experimental Psychology: Human Perception and Performance, 13*, 155-177.

Bingham, G. P. (1995). Dynamics and the problem of visual event recognition. In R. F. Port & T. v. Gelder (Eds.), *Mind as motion: Explorations in the dynamics of cognition*. Cambridge, MA: MIT Press.

Blake, R., & Shiffrar, M. (2007). Perception of human motion. *Annual Review of Psychology, 58*, 47-73.

Blakemore, S.-J., & Decety, J. (2001). From the perception of action to the understanding of intention. *Nature Reviews Neuroscience, 2*, 561-567.

Blakemore, S. J., Frith, C. D., & Wolpert, D. M. (1999). Spatiotemporal prediction modulates the perception of self-produced stimuli. *Journal of Cognitive Neuroscience, 11*, 551-559.

Blakemore, S. J., Wolpert, D. M., & Frith, C. D. (2002). Abnormalities in the awareness of action. *Trends in Cognitive Sciences, 6*, 237-242.

Booth, A. E., Bertenthal, B. I., & Pinto, J. (2002). Perception of the symmetrical patterning of human gait by infants. *Developmental Psychology, 38*, 554-563.

Bosbach, S., Cole, J., Prinz, W., & Knoblich, G. (2005). Inferring another's expectation from action: The role of peripheral sensation. *Nature Neuroscience, 8*, 1295-1297.

Brass, M., Bekkering, H., & Prinz, W. (2001a). Movement observation affects movement execution in a simple response task. *Acta Psychologica, 106*, 3-22.

Brass, M., Zysset, S., & von Cramon, D. Y. (2001b). The inhibition of imitative response tendencies. *NeuroImage, 14*, 1416–1423.

Broadbent, D. E. (1958). *Perception and communication*: Pergamon Press.

Calvo-Merino, B., Glaser, D. E., Grezes, J., Passingham, R. E., & Haggard, P. (2005). Action observation and acquired motor skills: An fmri study with expert dancers. *Cereb Cortex, 15*, 1243-1249.

Calvo-Merino, B., Grezes, J., Glaser, D. E., Passingham, R. E., & Haggard, P. (2006). Seeing or doing? Influence of visual and motor familiarity in action observation. *Current Biology, 16*, 1905-1910.

Casile, A., & Giese, M. A. (2006). Non-visual motor learning influences the recognition of biological motion. *Current Biology, 16*, 69-74.

Clarke, T. J., Bradshaw, M. F., Field, D. T., Hampson, S. E., & Rose, D. (2005). The perception of emotion from body movement in point-light displays of interpersonal dialogue. *Perception, 34*, 1171-1180.

Craighero, L., Bello, A., Fadiga, L., & Rizzolatti, G. (2002). Hand action preparation influences the responses to hand pictures. *Neuropsychologia, 40*, 492-502.

Cutting, J. E. (1978a). Generation of synthetic male and female walkers through manipulation of a biomechanical invariant. *Perception, 7*, 393-405.

Cutting, J. E. (1978b). A program to generate synthetic walkers as dynamic point-light displays. *Behavior Research Methods & Instrumentation, 10*, 91-94.

Cutting, J. E., & Kozlowski, L. T. (1977). Recognizing friends by their walk: Gait perception without familiarity cues. *Bulletin of the Psychonomic Society, 9*, 353-356.

Daprati, E., Wriessnegger, S., & Lacquaniti, F. (2006). Knowledge of one's kinematics improves perceptual discrimination. *Consciousness and Cognition, 16*, 178-188.

Davies, M., & Stone, T. (1995). *Folk psychology*. Oxford: Blackwell.

Decety, J., & Grèzes, J. (1999). Neural mechanisms subserving the perception of human actions. *Trends in Cognitive Science, 3*, 172–178.

Decety, J., Grèzes, J., Costes, N., Perani, D. & Jeannerod, M. (1997). Brain activity during observation of actions: Influence of action content and subject’s strategy. *Brain, 120,* 1763-1777.

Decety, J., & Ingvar, D. H. (1990). Brain structures participating in mental simulation of motor behavior: A neuropsychological interpretation. *Acta Psychologica, 73*, 13-24.

Decety, J., Jeannerod, M., & Prablanc, C. (1989). The timing of mentally represented actions. *Behavioral Brain Research, 34*, 35-42.

Decety, J., & Jennerod, M. (1993). Mentally simulated movements in virtual reality: Does fitts' law hold in motor imagery? *Behavioral Brain Research, 72,* 127-134.

Decety, J., & Sommerville, J. A. (2003). Shared representations between self and other: A social cognitive neuroscience view. *Trends in Cognitive Science, 7,* 527-533.

Descartes, R. (1664). *Traitée de l'homme*. Paris: Girard.

Deutsch, J. A. D., D. (1963). Attention: Some theoretical considerations. *Psychological Review, 20*, 80–90.

DeYoe, E. A., & Van Essen, D. C. (1988). Concurrent processing streams in monkey visual cortex. *Trends in Neuroscience, 11*, 219–226.

Di Pellegrino, G., Fagida, L., Fogassi, L., Gallese, V., & Rizzolatti, G. (1992). Understanding motor events: A neurophysiological study. *Experimental Brain Research, 91*, 176-180.

Dittrich, W. H., Troscianko, T., Lea, S. E. G. & Morgan, D. (1996). Perception of emotion from dynamic point-light displays represented in dance. *Perception*, *25*, 727-738.

Downing, P., Jiang, Y., Shuman, M. & Kanwisher, N. (2001). A cortical area selective for visual processing of the human body. *Science, 293*, 2470-2473.

Eckhorn, R., Frien, A., Bauer, R., Woelbern, T., & Kehr, H. (1993). High frequency (60–90hz) oscillations in primary visual cortex of awake monkey. *NeuroReport, 4*, 243–246.

Fadiga, L., Fogassi, L., Gallese,V., & Rizzolatti, G. (2000). Visuomotor neurons: Ambiguity of the discharge or 'motor' perception? *International Journal of Psychophysiology, 35,* 165-177.

Fadiga, L., Fogassi, L., Pavesi, G., & Rizzolatti, G. (1995). Motor facilitation during action observation: A magnetic stimulation study. *Journal of Neurophysiology, 73*, 2608-2611.

Fagiolo, S., Hommel, B., & Schubotz, R. I. (2007). Intentional control of attention: Action planning primes action-related stimulus dimensions. *Psychological Research*, *71*, 22–29.

Fechner, G. T. (1860). *Elemente derPpsychophysik*. Leipzig: Breitkopf & Hartel.

Fitts, P. M., & Seeger, C. M. (1953). S-r compatibility: Spatial characteristics of stimulus and response codes. *Journal of Experimental Psychology, 46*, 199–210.

Flach, R., Knoblich, G., & Prinz, W. (2003). Off-line authorship effects in action perception. *Brain and Cognition, 53*, 503-513.

Flach, R., Knoblich, G., & Prinz, W. (2004). Recognizing one's own clapping: The role of temporal cues. *Psychological Research, 69*, 147-156.

Flanagan, J. R., & Johansson, R. S. (2003). Action plans used in action observation. *Nature, 424*, 769–771.

Frak, V. G., Paulignan, Y., and Jeannerod, M. (2001). Orientation of the opposition axis in mentally simulated grasping. *Experimental Brain Research, 136,* 120–127.

Frith, C. D. (1992). *The cognitive neuropsychology of schizophrenia*. Hillsdale: Lawrence Erlbaum Associates.

Frith, C. D., Blakemore, S.-J. & Wolpert, D. M. (2000). Abnormalities in the awareness and control of action. *Philosophical Transactions of the Royal Society of London B, 355,* 1771-1788.

Gallese, V., Fadiga, L., Fogassi, L., & Rizzolatti, G. (1996). Action recognition in the premotor cortex. *Brain, 119*, 593-609.

Gallese, V., & Goldman, A. (1998). Mirror neurons and the simulation theory of mind-reading. *Trends in Cognitive Sciences, 2,* 493-501.

Gewirtz, J. L., & Stingle, K. G. (1968). Learning of generalized imitation as the basis for identification. *Psychological Review, 75,* 374-397.

Gibson, J. J. (1979). *The ecological approach to visual perception*. Boston: Houghton Mifflin.

Giese, M. A., & Poggio, T. (2003). Neural mechanisms for the recognition of biological movements. *Nature Reviews Neuroscience, 4,* 179-192.

Gilden, D. L., & Proffitt, D. R. (1994). Heuristic judgement of mass ratio in two-body collisions. *Perception & Psychophysics, 56,* 708-720.

Goldman, A. I. (2002). *Simulation theory and mental concepts*. Amsterdam: Johan Benjamins Publishing Company.

Goldman, A. I. (2005). *Imitation, mind reading, and simulation.* (Vol. 2). Cambridge: MIT press.

Goodale, M. A., & Humphrey, G. K. (1998). The objects of action and perception. *Cognition, 67*, 181-207.

Goodale, M. A., & Milner, A. D. (1992). Separate visual pathways for perception and action. *Trends Neurosci, 15*, 20-25.

Gray, C. M., Engel, A. K., Koenig, P., & Singer, W. (1992). Synchronization of oscillatory neuronal responses in cat striate cortex: Temporal properties. *Visual Neuroscience, 8,* 337–347.

Grèzes, J., Costes, N. & Decety J. (1998). Top-down effect of strategy on the perception of human biological motion: A pet investigation. *Cognitive Neuropsychology, 15*, 553-582.

Grèzes, J., & Decety, J. (2001). Functional anatomy of execution, mental simulation, observation and verb generation of actions: A meta-analysis. *Human Brain Mapping, 12*, 1–19.

Grezes, J., Frith, C. D., & Passingham, R. E. (2003). Inferring false beliefs from the action of oneself and others: An fmri study. *NeuroImage, 21,* 777-750.

Grosjean, M., Shiffrar, M., & Knoblich, G. (2007). Fitts's law holds for action perception. *Psychological Science, 18,* 95-99.

Grossman, E. D., Battelli, L., & Pascual-Leone, A. (2005). Repetitive tms over stsp disrupts perception of biological motion. *Vision Research, 45,* 2847-2853.

Grossman, E. D., & Blake, R. (2002). Brain areas active during visual perception of biological motion. *Neuron, 35,* 1157-1165.

Grossman, E. D., & Blake, R. (2001). Brain activity evoked by inverted and imagined biological motion. *Vision Research, 41,* 1475-1482.

Hamilton, A. (2004). Your own action influences how you perceive another person's action. *Current Biology, 14*, 157-169.

Hamilton, A., Wolpert, D. M., Frith, U., & Grafton, S. T. (2006). Where does your own action influence your perception of another person's action in the brain? *NeuroImage*, *29*, 524-535.

Hari, R., Forss, N., Avikainen, S., Kirveskari, E., Salenius, S., & Rizzolatti, G. (1998). Activation of human primary motor cortex during action observation: A neuromagnetic study. *Proceedings of the National Academy of Sciences, USA, 95*, 15061-15065.

Hecht, H., Vogt, S., & Prinz, W. (2001). Motor learning enhances perceptual judgment: A case for action-perception transfer. *Psychological Research, 65*, 3-14.

Heptulla-Chatterjee, S., Freyd, J., & Shiffrar, M. (1996). Configural processing in the perception of apparent biological motion. *Journal of Experimental Psychology: Human Perception and Performance, 22*, 916-929.

Hesslow, G. (2002). Conscious thought as simulation of behavior and perception. *Trends in Cognitive Sciences, 6*, 242-247.

Hirai, M., & Hiraki, K. (2005). An event-related potential study of biological motion perception in human infants. *Cognitive Brain Research, 22,* 301-304.

Hoenkamp, E. (1978a). Perceptual cues that determine the labelling of human gait. *Journal of Human Movement Studies, 4,* 59-69.

Hoenkamp, H. (1978b). Perceptual cues that determine the labeling of human gait. *Journal of Human Movement Studies, 4,* 59-69.

Hommel, B., Gehrke, J., & Knuf, L. (2000). Hierarchical coding in the perception and memory of spatial layouts. *Psychological Research, 64,* 1-10.

Hommel, B., Müsseler, J., Aschersleben, G., & Prinz, W. (2001). The theory of event coding (tec): A framework for perception and action planning. *Behavioral and Brain Sciences*, *24*, 849-878.

Huk, A. C., & Heeger, D. J. (2002). Pattern-motion responses in human visual cortex. *Nature Neuroscience, 5*, 72-75.

Ikeda, H., Blake, R., & Watanabe, K. (2005). Eccentric perception of biological motion is unscalably poor. *Vision Research, 45*, 1935-1943.

Jackson, P. L., & Decety, J. (2004). Motor cognition: A new paradigm to study self-other interactions. *Current Opinion in Neurobiology, 14*, 259-263.

Jacob, P., & Jeannerod, M. (2005). The motor theory of social cognition. A critipue. *Trends in Cognitive Sciences, 9*, 21-25.

Jacobs, A., & Shiffrar, M. (2005). Walking perception by walking observers. *Journal of Experimental Psychology: Human Perception and Performance, 31*, 157.

James, W. (1890). *The principles of psychology* (Vol. 1&2). New York: Holt.

Jeannerod, M. (2001). Neural simulation of action: A unifying mechanism for motor cognition. *Neuroimage*, *14*, 103-109.

Johansson, G. (1950). *Configurations in event perception*. Uppsala, Sweden: Almqvist & Wiksell.

Johansson, G. (1973). Visual perception of biological motion and a model for its analysis. *Perception and Psychophysics, 14*, 201-211.

Johansson, G. (1976). Spatio-temporal differentiation and integration in visual motion perception. *Psychological Research, 38*, 379-393.

Jokisch, D., Daum, I., & Troje, N. F. (2006). Self recognition versus recognition of others by biological motion: Viewpoint-dependent effects. *Perception, 35,* 911-920.

Kahneman, D. (1973). *Attention and effort*: Prentice Hall.

Keller, P. E., Knoblich, G., & Repp, B. H. (2007). Pianists duet better when they play with themselves: On the possible role of action simulation in synchronization. *Consciousness and Cognition, 16*, 102.

Kendrick, K. M., & Baldwin, B. A. (1989). Visual responses of sheep temporal cortex cells to moving and stationary human images. *Neuroscience Letters, 100*, 193-197.

Kilner, J. M., Paulignan, Y., & Blakemore, S. J. (2003). An interference effect of observed biological movement on action. *Current Biology, 13*, 522-525.

Knoblich, G. (2003). Wahrnehmung eigener Handlungen und ihrer Konsequenzen. *Psychologische Rundschau, 54*, 80-92.

Knoblich, G., & Flach, R. (2001). Predicting the effects of actions: Interactions of perception and action. *Psychological Science, 12*, 467-472.

Knoblich, G., & Flach, R. (2003). Action identity: Evidence from self-recognition, prediction, and coordination. *Consciousness and Cognition, 12*, 620-632.

Knoblich, G., & Prinz, W. (2001a). Recognition of self-generated actions from kinematic displays of drawing. *Journal of Experimental Psychology: Human Perception and Performance, 27*, 456-465.

Knoblich, G., & Prinz, W. (2001b). Recognition of self-generated actions from kinematic displays of drawing. *Journal of Experimental Psychology: Human Perception and Performance, 27*, 456-465.

Knoblich, G., & Sebanz, N. (2006). The social nature of perception and action. *Current Directions in Psychological Sciences, 15*, 99-104.

Knoblich, G., Seigerschmidt, E., Flach, R., & Prinz, W. (2002). Authorship effects in the prediction of handwriting strokes: Evidence for action simulation during action perception. *Quarterly journal of experimental psychology, 55*, 1027-1046.

Kornblum, S. (1992). Dimensional overlap and dimensional relevance in stimulus- response and stimulus- stimulus compatibility. In G. E. Stelmach & J. Requin (Eds.), *Tutorial in motor behavior* (pp. 743- 777). Amsterdam: North-Holland.

Kornblum, S. (1994). The way irrelevant dimensions are processed depends on what they overlap with: The case of stroop- and simon-like stimuli. *Psychological Research, 56,* 130-135.

Kornblum, S., & Lee, J. W. (1995). Stimulus- response compatibility with relevant and irrelevant stimulus dimensions that do and do not overlap with the response. *Journal of Experimental Psychology: Human Perception and Performance, 21,* 855- 875.

Loula, F., Prasad, S., Harber, K., & Shiffrar, M. (2005). Recognizing people from their movement. *Journal of Experimental Psychology: Human Perception and Performance, 31,* 210-220.

Mach, E. (1922). *Die Analyse der Empfindungen und das Verhältnis des physischen zum psychischen* (Vol. 9). Jena: Gustav Fischer.

Mather, G., Radford, K., & West, S. (1992). Low-level visual processing of biological motion. *Proceedings of the Royal Society of London Series B, 249,* 149-155.

Meltzoff, A. N., & Moore, M. K. (1977). Imitation of facial and manual gestures by human neonates. *Science, 198,* 75-78.

Michaels, C. F. (1988). S-r compatibility between response position and destination of apparent motion: Evidence of the detection of affordances. *Journal of Experimental Psychology: Human Perception and Performance, 14,* 231-240.

Milner, A. D., & Goodale, M. A. (1995). *The visual brain in action* (1st ed.). Oxford; New York: Oxford University Press.

Montpare, J. M., & Zebrowitz-McArthur, L. (1988). Impressions of people created by age-related qualities of their gaits. *Journal of Personality and Social Psychology, 55,* 547-556.

Munzert, J. (2008). Does level of expertise influence imagined durations in open skills? Played versus imagined durations of badminton sequences. *IJSEP, 6*, 24-38.

Müsseler, J., & Hommel, B. (1997). Blindness to response-compatible stimuli. *Journal of Experimental Psychology: Human Perception and Performance, 23,* 861-872.

Neri, P., Morrone, C., & Burr, D. C. (1998). Seeing biological motion. *Nature* (395), 894-896.

Niedenthal, P. M., Barsalou, L. W., Winkielman, P., Krauth-Gruber, S., & Ric, F. (2005). Embodiment in attitudes, social perception, and emotion. *Personality and Social Psychology Review*, 9, 184-211.

Norman, J. F., Payton, S. M., Long, J. R., & Hawkes, L. M. (2004). Aging and perception of biological motion. *Psychology and Aging, 19,* 219-225.

Pavlova, M., Krageloh-Mann, I., Sokolov, A., & Birbaumer, N. (2001). Recognition of point-light biological motion displays by young children. *Perception, 30,* 925-933.

Pinto, J., & Shiffrar, M. (1999). Subconfigurations of the human form in the perception of biological motion displays. *Acta Psychologica, 102*, 293-318.

Pittenger, J. B., & Shaw, R. E. (1975). Aging faces as viscal-elastic events: Implications for a theory of nonrigid shape perception. *Journal of Experimental Psychology: Human Perception and Performance, 1,* 374-382.

Pollick, F. E., Hill, H., Calder, A. & Paterson, H. (2003). Recognising facial expression from spatially and temporally modified movements. *Perception, 32*, 813-826.

Poom, L., & Olsson, H. (2002). Are mechanisms for perception of biological motion different from mechanisms for perception of nonbiological motion? *Perceptual and Motor Skills, 95*, 1301-1310.

Prinz, W. (1997). Perception and action planning. *European Journal of Cognitive Psychology, 9*, 129-154.

Proffitt, D. R., Bhalla, M., Gossweiler, R., & Midgett, J. (1995). Perceiving geographical slant. *Psychonomic Bulletin & Review, 2,* 409–428.

Proffitt, D. R., Stefanucci, J., Banton, T., & Epstein, W. (2003). The role of effort in perceiving distance. *Psychological Science, 14,* 106–112.

Ramnani, N., & Miall, C. R. (2004). A system in the human brain for predicting the actions of others. *Nature Neuroscience, 7,* 85-90.

Reed, C. L., & Farah, M. J. (1995). The psychological reality of the body schema: A test with normal participants. *Journal of Experimental Psychology: Human Perception and Performance, 21,* 334-343.

Repp, B. H. (1987). The sound of two hands clapping: An exploratory study. *Journal of the Acoustical Society of America, 81,* 1100-1109.

Repp, B. H., & Knoblich, G. (2004). Perceiving action identity: How pianists recognize their own performances. *Psychological Science, 15,* 604-609.

Repp, B. H., & Knoblich, G. (2007). Action can affect auditory perception. *Psychological Science, 18,* 6-7.

Rizzolatti, G., Fagida, L., Galesse, V., & Fogassi, L. (1996). Premotor cortex and the recognition of motor actions. *Brain research. Cognitive brain research, 3,* 131-141.

Rizzolatti, G., Fogassi, L., & Gallese, V. (2001). Neurophysiological mechanisms underlying the understanding and imitation of action. *Nature Reviews Neuroscience, 2,* 661-670.

Rizzolatti, G., & Craighero, L. (2004). The mirror-neuron system. *Annual Review of Neuroscience, 27,* 169-192.

Ruby, P., & Decety, J. (2001). Effect of subjective perspective taking during simulation of action: A pet investigation of agency. *Nature Neuroscience, 4,* 546-550.

Ruby, P., & Decety, J. (2004). How would you feel versus how do you think she would feel? A neoroimaging study of perspective taking with social emotions. *Journal of Cognitive Neuroscience, 16,* 988-999.

Runeson, S. (1994). Perception of biological motion: The ksd-principle and the implications of a distal versus proximal approach. In G. Jansson , W. Epstein,& S. S. Bergström (Ed.), *Perceiving events and objects* (pp. 383-409). Hilldale, NJ: Erlbaum.

Runeson, S., & Frykholm, G. (1981). Visual perception of lifted weight. *Journal of Experimental Psychology: Human Perception and Performance, 7*, 733-740.

Runeson, S., & Frykholm, G. (1983). Kinematic specification of dynamics as an informational basis for person-and-action perception: Expectation, gender recognition, and deceptive intention. *Journal of Experimental Psychology: General, 112*, 585-615.

Sanders, A. F. (1980). Stage analysis of reaction processes. In G. E. Stelmach & J. Requin (Ed.), *Tutorials in motor behavior* (pp. 331-354.). Amsterdam: North-Holland.

Schütz-Bosbach, S., Mancini, B., Aglioti, S. M., & Haggard, P. (2006). Self and other in the human motor system. *Current Biology, 16*, 1830-1834.

Schütz-Bosbach, S., & Prinz, W. (2007). Perceptual resonance: Action-induced modulation of perception. *Trends in Cognitive Sciences, 11*, 349-355.

Sebanz, N., & Frith, C. (2004). Beyond simulation? Neural mechanisms for predicting the actions of others. *Nature Neuroscience, 7,* 5-7.

Shiffrin, R. M., & Schneider, W. (1977). Controlled and automatic human information processing, ii. *Psychological Review*(84), 127–190.

Shipley, T. F., & Cohen, L. R. (2000). Affordances for coordinated action in point-light walker displays. *Ecological Psychology, 12,* 87-92.

Starkes, J. L., & Allard, J. (1991). Motor-skill experts in sports, dance, and other domains. In K. A. Ericsson & J. Smith (Eds.), *Toward a general theory of expertise: Prospects and limits* (pp. 126-152). Cambridge: Cambridge University Press.

Stevenage, S. V., Nixon, M. S., & Vince, K. (1999). Visual analysis of gait as a cue to identity. *Applied Cognitive Psychology, 13,* 513-526.

Sumi, S. (1984). Upside-down presentation of the johansson moving light-spot pattern. *Perception, 13,* 283-286.

Sumi, S. (2000). Perception of point-light walker produced by eight lights attached to the back of the walker. *Swiss Journal of Psychology, 59*, 126-132.

Thornton, I. M., Pinto, J., & Shiffrar, M. (1998). The visual perception of human locomotion. *Cognitive Neuropsychology, 15*, 535-552.

Thornton, I. M., Rensink, R. A., & Shiffrar, M. (2002). Active versus passive processing of biological motion. *Perception, 31*, 837-853.

Todd, J. T. (1983). Perception of gait. *Journal of Experimental Psychology: Human Perception and Performance, 9,* 31-42.

Troje, N. F. (2002a). Decomposing biological motion: A framework for analysis and synthesis of human gait patterns. *Jounal of Vision, 2*, 371-387.

Troje, N. F. (2002b). The little difference: Fourier based synthesis of gender specific biological motion. In R. P. Würtz & M. Lappe (Ed.), *Dynamic perception* (pp. 115-120). Berlin: AKA Verlag.

Troje, N. F., & Westhoff, C. (2006). Inversion effect in biological motion perception: Evidence for a "life detector"? *Current Biology, 16,* 821-824.

Vaina, L. M., Solomon, J., Chowdhury, S., Sinha, P. & Belliveau, J. W. (2001). Functional neuroanatomy of biological motion perception in humans. *Proceedings of the National Academy of Sciences USA, 98,* 11656-11661.

Viviani, P. (2002). Motor competence in the perception of dynamic events:A tutorial. In W. H. Prinz & B. Hommel (Ed.), *Common mechanisms in perception and action (attention and performance)* (pp. 406–442). Oxford: University Press.

von Holst, E., & Mittelstaedt, H. (1950). Das Reafferenzprinzip. *Naturwissenschaften, 37,* 464-476.

Williams, M., & Ward, P. (2003). Perceptual expertise: Development in sport. In J. L. Starkes & K. A. Ericsson (Eds.), *Expert performance in sports. Advances in research on sport expertise* (pp. 219-251). Champaign, IL: Human Kinetics.

Wilson, M., & Knoblich., G. (2005). The case of motor involvment in perceiving conspecifics. *Psychological Bulletin, 131*, 460-473.

Wolff, W. (1931). Zuordnung individueller Gangmerkmale zur Individual-Charakteristik. *Beihefte zur Zeitschrift für angewandte Psychologie, 58*, 108-122.

Zentgraf, K., Stark, R., Reiser, M., Künzell, S., Schienle, A., Kirsch, P., Walter, B., Vaitl, D., & Munzert, J. (2005). Differential activation of pre-sma and sma proper during action observation: Effects of instructions. *NeuroImage, 26*, 662-672.

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