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The influence of motor expertise and motor experience on action and actor recognition

Tanja Hohmann[1,2], Nikolaus F. Troje[3], Adriana Olmos[3], and Jörn Munzert[1]

[1]Justus-Liebig University Giessen, Giessen, Germany
[2]German Sport University Cologne, Cologne, Germany
[3]Queen's University, Kingston, Canada

Two experiments examined whether different levels of motor and visual experience influence action perception and whether this effect depends on the type of perceptual task. Within an action recognition task (Experiment 1), professional basketball players and novice college students were asked to identify basketball dribbles from point-light displays. Results showed faster reaction times and greater accuracy in experts, but no advantage when observing either own or teammates' actions compared with unknown expert players. Within an actor recognition task (Experiment 2), the same expert players were asked to identify the model actors. Results showed poor discrimination between teammates and players from another team, but a more accurate assignment of own actions to the own team. When asked to name the actor, experts recognised themselves slightly better than teammates. Results support the hypothesis that motor experience influences action recognition. They also show that the influence of motor experience on the perception of own actions depends on the type of perceptual task.

Keywords: Anticipation; Basketball; Biological motion; Motor experience; Point-light displays; Visual experience.

Research has shown that the perception of human actions provides a rich source of information that can be used to extract a range of different action features. Johansson (1973), for example, introduced the "point-light technique" to study the perception of biological motion. In this technique, small markers are attached to major joints while videotaping the moving body. Observers then view only these markers representing the joints of the body as point-light displays (PLDs). Even when observers see only a few points as PLDs, they can recognise another person's movement and also identify specific features. For instance, they can retrieve a person's gender (Beardsworth & Buckner, 1981; Cutting & Kozlowski, 1977; Sumi, 2000; Troje, 2002), age (Montpare & Zebrowitz-McArthur, 1988), or even emotional state (Atkinson, Dittrich, Gemmell, & Young, 2004; Clarke, Bradshaw, Field, Hampson, & Rose, 2005; Dittrich, Troscianko, Lea, & Morgan, 1996; Pollick, Hill, Calder, & Paterson, 2003). From the actions of an array of individual PLDs, it is even possible to recognise activities (e.g., dancing) involving one or more persons (Mass, Johansson, Janson, & Runeson, 1971), to evaluate the effort involved in an action (Bingham, 1987; Runeson & Frykholm, 1981, 1983), or to predict the throwing distance of a ball when its flight is masked (Munzert, Hohmann, & Hossner, 2010). However, not only the kinematics of joints may be

Correspondence should be addressed to Jörn Munzert, Department of Psychology and Sport Sciences, Justus-Liebig University Giessen, Kugelberg 62, 35394 Giessen, Germany. E-mail: Joern.Munzert@sport.uni-giessen.de

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represented in PLDs, but also the interaction of a model with an object. For example, Shipley and Cohen (2000) have shown that additional cues such as the PLD of the ball within a basketball video facilitate the recognition of actions.

Such results lead us to ask which cues guide this high visual sensitivity to biological motion. Several studies in the field of expertise research have addressed this question by examining how the perception of actions differs between experts and novices. They have demonstrated that experts reveal well-established perception-action coupling and are also faster at detecting relevant movement cues with which to predict upcoming actions (Williams & Ward, 2003). Experts also show superior recall and recognition of movement patterns compared to novices (Starkes & Allard, 1991; Williams & Ward, 2003) and reveal an attunement to appropriate PLDs (Abernethy, Gill, Parks, & Packer, 2001; Ward, Williams, & Bennett, 2002). Nonetheless, all such studies reveal a confounding of the influence of two factors that both contribute to perception: motor experience and visual experience. Experts possess visual experience through observing the actions of teammates and motor experience through repeatedly performing the actions themselves.

There are several theories describing how we use our own motor system while perceiving biological motion. For instance, common coding theory (Prinz, 1997) and mental simulation theory (Jeannerod, 2001, 2006) both refer to the fact that we can draw on our own motor representations (Prinz, 1997; Shiffrar & Pinto, 2002; Viviani & Stucchi, 1992). They each propose that a common medium makes it possible to match perception and action, and assume that the same representations of activation are involved in both perceiving and performing an action. Mapping the perceived action onto one's own motor system enables the observer to understand the goals underlying the action. This also facilitates the prediction of action outcomes. The assumption is that matching an observed action to one's own motor system makes it possible to draw on those mechanisms of the motor system that are normally used to predict the outcomes of one's own actions. The closer the match between the executed and the perceived movement, the better the perception of that movement.

Specific evidence supporting the close match between perception and action comes from research on mirror neurons. Di Pellegrino, Fagida, Fogassi, Gallese, and Rizzolatti (1992) were the first to report on mirror neurons in area F5 of the macaque's brain. These mirror neurons were active both when the monkey watched an actor grasping an object and when it grasped the object itself. Iacoboni et al. (1999) have described a homologue area of the monkey's F5 area in the human brain located in Broca's area. Further evidence for overlapping brain areas for perception and action can be derived from reviews by Blakemore and Decety (2001) and Decety and Grèzes (1999) that have reported activation in the same motor areas when both observing and planning movements.

An fMRI study by Calvo-Merino, Glaser, Grèzes, Passingham, and Haggard (2005) points to the particular influence of motor expertise on the perception of actions. Ballet dancers and capoeira dancers watched videos of both ballet and capoeira sequences. Results showed a stronger activation of the premotor cortex when observing actions from the observer's own expert motor domain compared with actions from that domain in which the observer had no specific expertise. A study conducted by Aglioti, Cesari, Romani, and Urgesi (2008) revealed that athletes are better at predicting the success of basketball free shots than visual experts such as coaches or sports journalists. Moreover, both visuomotor (athletes) and visual experts (coaches or sports journalists) showed selective increases of motor-evoked potentials. The striking finding is that only athletes showed a time-specific increase in motor excitability during observation of throws that missed the basket. The authors interpret this result as evidence for better anticipatory skills based on motor experience within the motor expert group.

Additionally, Sebanz and Shiffrar (2009) have recently provided evidence that motor expertise influences the ability not only to anticipate actions but also to infer the intentions of the observed person. The performance of an expert group was compared to a novice group within a deception task in basketball. Whereas performance did not differ between the two groups when presented with postural cues, the expert group showed superior performance when dynamic movement information was provided. The authors concluded that members of the expert group showed better perceptual performance because the observed actions referred to their own action repertoire. Calvo-Merino, Ehrenberg, Leung, and Haggard (2010) have recently provided further evidence that the quality of perception is linked closely to one's own action repertoire. Observers (men, women) had to judge actions that are usually performed only by female dancers. Results revealed a gender effect: Female observers were slightly better than male experts at discriminating the females' actions. The authors took this as evidence for an additional role of motor familiarity above and beyond visual experience. Both male as well as female actors possess visual experience on the observation of females' actions, but only the females have the specific motor experience with these kinds of actions.

Another line of research has examined the role of motor experience in movement perception when observing own past actions. The rationale underlying these studies is that expert observers possess particular motor experience of their own actions along with specific knowledge about their own motor constraints. This line of research compares performances when observing one's own past action versus those of friends and/or strangers. This makes it possible to disentangle the influence of motor experience from that of visual experience. Better performance when observing own actions is assumed to be due to greater motor experience, whereas better performance when observing friends compared to unknown persons is assumed to be due to visual experience. Several studies have demonstrated an ability to discriminate between own and other individuals' actions. For instance, Cutting and Kozlowski (1977) have shown that it is possible to recognise own actions and those of friends from their gait. However, they did not find any difference in performance between self and friends. Within a similar study, Beardsworth and Buckner (1981) have demonstrated that it is possible to discriminate between one's own gait, that of friends, and that of unknown persons when observing PLDs. However, it should be noted that the differences in recognition rates within these studies were very small. Loula, Prasad, Harber, and Shiffrar (2005) have replicated the finding that observers are able to discriminate between own actions, those of friends, and those of strangers, and extended this successfully to a wider range of skills. This was the first study to reveal that the recognition of models depends on the type of skill. The model actor, and, more specifically, the own person, was recognised more frequently when models performed expressive actions such as dancing and boxing than when walking or greeting. Even if those latter tasks are observed more frequently, they are thought to be more uniform, thereby allowing less scope for an easy discrimination of individual differences. Additionally, Prasad and Shiffrar (2009) have shown that when participants judge actions from a back view, they can recognise their own actions better than those of others. This indicates specifically that motor experience plays a major role in the recognition of actors.

Knoblich and Prinz (2001) have shown that participants can identify their own characters written on a graphics tablet even when they view only a single dot representing the trajectory of the tip of a pencil. When given acoustic stimuli, participants can also accurately identify their own hand clapping from that of others (Flach, Knoblich, & Prinz, 2004). Similarly, pianists can recognise a piece of music they have previously played themselves among piano pieces played by others (Repp & Knoblich, 2004). In another study, Knoblich and Flach (2001) asked participants to predict the landing position of darts on a board when watching videos depicting only the actions without any perception of the dart. Again, predictions based on perceiving one's own actions were better than those based on perceiving other people's throws. One could argue that these studies provide strong support for the motor view of action perception, because, normally, people do not perceive their own actions visually. One possible exception is top athletes who sometimes train with video feedback of their own performance. But even top athletes have more visual experience of other athletes' actions than of their own.

The present study has two aims: The first is to provide further evidence that perceptual performance is modulated not only by visual but also by specific motor experience. We analysed whether experts reveal two advantages: one for actions on which they are experts and one for their own actions. Predictions of movement outcomes should be superior when experts perceive own actions compared to the actions of other experts. Second, up to now, researchers have always used only one kind of observation task within the same study: Either actor recognition (Loula et al., 2005) or effect anticipation tasks (Knoblich & Flach, 2001) have been used to measure the influence of individual motor experience on action perception. It should be noted that both types of task have been found to support the motor view of action perception (Knoblich & Flach, 2001; Loula et al., 2005), but to a different extent. Therefore, it remains unclear whether visual and motor experience influence action perception to the same extent, or whether the impact of motor and visual experience depends on the type of observation task. Differences can be expected in light of fMRI studies showing that the same stimulus material can lead to different neural activation of motor areas when the observation task context is varied (Zentgraf et al., 2005). Therefore, we combined an action and an actor recognition task using the same stimulus material within one study to examine whether the influence of visual and motor expertise is modulated by the task. Experiment 1 and Experiment 2 assessed both action recognition and actor recognition under PLD conditions. Specifically, we used different kinds of basketball dribble as stimuli. To examine the influence of visual and motor experience, we compared the performance of experts with that of novices within an action recognition task and the performance of different expert teams within an actor recognition task.

EXPERIMENT 1: ACTION RECOGNITION

The aim of our first experiment was, first, to further examine the finding that expertise on a task influences the recognition of actions. Therefore, we used an expert–novice paradigm to analyse the impact of specific motor expertise on perceptual decisions. We hypothesised that experts would recognise basketball dribbles better and faster than novices. Second, because it hardly seems possible to differentiate between perceptual and motor expertise at this level of analysis, we analysed the experts' recognition performance for dribbles involving either their own actions, those of teammates, or those of unknown players. The recognition of own movement effects does not benefit from perceptual experience, because players do not watch their own actions regularly. Therefore, the predicted advantage for recognising own movement effects (cf. Knoblich & Flach, 2001) can be attributed to better motor experience. If a discrimination between teammates' dribbles were to be superior, this could be interpreted as a perceptual expertise advantage, because teammates' actions can be viewed extensively during training sessions.

In light of the results of a study by Shipley and Cohen (2000), we were also interested in whether the kind of presentation (with or without the ball or the dribbling sound) of the basketball dribbles would have any influence on the observers' performance. We anticipated that additional information like the presentation of the ball or the sound of the bouncing ball would lead to better recognition compared with a depiction of the moving body alone.

Methods

Participants. Two groups with different expertise levels worked on the experimental tasks. Expert basketball players were recruited from two male basketball teams in Kingston (Canada) whose players did not know each other. These were 10 players from Queen's University and eight players from the Royal Military College with a mean age of 20.2 years (range: 18–24 years). All players were right handed, and had been playing basketball for an average of 12.6 years. They spent an average of 14.3 hours playing basketball each week, and had belonged to their team for at least 2 years. The novices were 19 students (12 male, 7 female) of physical education at Justus-Liebig University, Giessen (Germany), who had no specific experience of playing basketball or played it only on a recreational level.

All participants were paid for their services. They were naive to the purpose and the hypotheses of the study. All had normal or corrected-to-normal vision and provided informed consent before beginning the experiment. None of the participants had a medical condition that prohibited them from taking part. The studies were conducted in accordance with the Declaration of Helsinki.

Material (apparatus). Stimuli for the action recognition task were recorded using a motion capture system (Vicon; Oxford Metrics, Oxford, UK). Movement trajectories were captured with 12 infrared cameras (Vicon) with a sampling rate of 120 Hz and a spatial accuracy of 1 mm when tracking the positions of markers. The capture area for recording actions was approximately 25 m^2. We calculated the functional joint centres with Visual3D (C-Motion) software. The sound of the ball touching the ground was captured with a microphone placed above the player (sound sampling rate: 46,200 Hz). Finally, the stimuli for the visual testing phase were created with MatLab 6.1 and the PsychToolbox (Brainard, 1997). Stimuli were presented on a 17-inch monitor, and responses were collected with a keyboard.

Stimulus generation. Motion capture data were recorded individually. Each expert player was dressed in tight black clothes. A total of 53 markers (marker size: 1.4 cm) were fixed to the body of the player. Additionally, three soft markers were fixed to the ball. These markers did not influence the dribbling actions. Before recording, all expert players were given time to familiarise themselves with the setting. To start with, they were recorded while walking. They were instructed to walk through the volume several times at their own preferred speed. Then, we recorded five different dribbling actions. These were speed, crossover, between-the-legs, behind-the-back, and spin dribbling. Five trials were captured for each dribble. The expert players were instructed to bounce the ball five times while standing on the spot at one side of the volume before starting to move through it. They were asked to move naturally and to dribble as if they were playing in a real game. They were not informed about the aim of the study to ensure that they would not stress any specific movement feature that might make it easier for them to identify their own actions later.

The height of all model players was standardised for all PLDs. The PLDs for each player consisted of 15 dots representing the joints of the body. The ball was represented by a single dot. Stimulus dots were approximately 2 mm in diameter. Each recording was clipped to a total length of 1.6 s encompassing 1.45 s before and 0.15 s after a reference point representing the switchover from one hand to the other. This reference point was set at the moment when the ball hit the ground. Because there is no hand switch in spin dribbling, the reference point was set at the moment when the ball hit the ground during the rotation of the body. Because there is also no hand switch in speed dribbling, the reference point here was set to the first moment when the ball hit the ground after the model started running through the capture volume. For each observer, we used two point-light display sequences for each type of dribble and two additional walking trials. This resulted in a total of 12 videos of each expert player.

Design and procedure. Experiment 1 employed a mixed design. Two groups (experts, novices) completed a perceptual decision task based on the within-subject factor action (spin, behind-the-back, between-the-legs, crossover dribbles) and condition (player only, player with ball, player with sound); that is, all participants assessed all actions and all conditions. The speed dribble was analysed separately because there was no need to switch hands in this action and also no significant change of direction. The displays of walking trials were not used in Experiment 1.

Participants were seated approximately 0.7 m in front of a monitor in a dimly lit room. They performed three recognition task blocks (one for each condition). Three different models were presented in each block. Experts watched videos of their own actions, those of a familiar other player (teammate), and those of an unfamiliar other player (from the other team). Twenty trials were presented for each model (two different five-action trials presented twice). This resulted in a total of 60 trials in each block and 180 trials overall. Trials were randomised across actors and dribbles within each block, and the order of blocks was balanced across all participants. Participants were not told the identity of the models in advance, and received no feedback on their performance. A short training session was conducted to familiarise them with the experimental setting.

Stimulus material was matched between experts and novices; that is, each expert observer was paired with one novice observer who worked on exactly the same set of trials. Because only 18 experts but 19 novices participated in this experiment, one expert player was presented twice. Naturally, all players were unfamiliar for the novices.

The presentation of each trial started with a white cross on a blue screen (5 s) followed by one of the PLDs (half-profile view). The model moved from the left or right side toward the middle of the screen. Maximum trial length was 1.57 s. The presentation of actions stopped either when the participant pressed the spacebar to indicate that she or he had recognised the dribble or after the complete movement had been presented. Participants then reported which type of dribble they had observed with a mouse click on the appropriate item in a list. Reaction time was taken from the beginning of the video sequences. Participants were instructed to respond as quickly as possible while keeping the number of errors low. They were also informed that the participant with the highest number of correct answers and the fastest reaction times would receive a prize.

The entire experimental session took approximately 20 min.

Dependent variables and statistical analysis

The number of correct answers and the reaction times for correct action recognition were recorded as dependent variables. Separate analyses of expertise and the own/other factor were conducted only for experts. Statistical analyses were based on ANOVAs with repeated measures using a significance level of $p < .05$. Speed dribbling was analysed separately, because no hand change and no significant change of movement direction occurs as in the other dribbles. Therefore, reaction times were not comparable to the other dribbles.

Results

Expert–novice differences

To evaluate differences in the recognition of actions between experts and novices and the influence of motor experience on movement perception, we analysed the number of correct responses as well as the reaction times in relation to the factors action and condition. We will report only data in detail that refer to our hypotheses.

Analysis of correct decisions. A 2 (group) $\times$ 3 (condition) $\times$ 4 (dribble) ANOVA with repeated measures revealed a significant effect of group, $F(1, 32) = 10.05$, $p < .01$, $\eta^2 = .24$. Experts ($M = 86.02\%$, $SD = 7.85\%$) were better at recognising the dribbles than novices ($M = 77.35\%$, $SD = 8.05\%$). There was also a significant main effect of dribble, $F(3, 96) = 24.46$, $p < .001$, $\eta^2 = .43$ and a significant Expertise $\times$ Dribble interaction, $F(3, 96) = 7.42$, $p < .01$, $\eta^2 = .19$. No significant differences were found for condition, $F(2, 64) < 1$, *ns*. An additional analysis of speed dribbling revealed no significant differences in the number of correct answers for any of the variables.

Analysis of reaction times. A mixed ANOVA with repeated measures for reaction times revealed a significant effect of group, $F(1, 32) = 8.99$, $p < .01$, $\eta^2 = .22$. Experts ($M = 1.31$ s, $SD = 0.09$ s) showed faster reaction times than novices ($M = 1.40$ s, $SD = 0.09$ s).

There was a significant effect of dribble, $F(3, 96) = 53.29$, $p < .001$, $\eta^2 = .63$ and a significant Expertise $\times$ Dribble interaction, $F(3, 96) = 6.14$, $p = .001$, $\eta^2 = .16$. There was also a nonsignificant effect of condition, $F(2, 64) = 2.44$, $p = .09$, $\eta^2 = .07$. The analysis of reaction times for speed dribbling revealed a significant difference for condition, $F(2, 64) = 4.07$, $p < .05$. Reaction times were faster within the player-and-sound condition ($M = 1.44$ s, $SD = 0.16$ s) than in the player-only ($M = 1.54$ s, $SD = 0.16$ s) and player-with-ball conditions ($M = 1.50$ s, $SD = 0.16$ s). Paired *t*-tests revealed a significant difference between the player-only and player-with-sound conditions, $t(33) = 2.50$, $p < .05$. None of the other differences attained significance.

Experts' action recognition of own, familiar, and unfamiliar actions

Motor experience was analysed for the expert group in terms of the own/other distinction. A 3 (model) $\times$ 3 (condition) $\times$ 4 (dribble) design was implemented to assess the influence of motor representations on perceptual decisions within the expert group. We conducted an arcsine transformation of the percentage data before performing the statistical analysis.

Analysis of correct decisions. A 3 (model) $\times$ 3 (condition) $\times$ 4 (dribble) ANOVA with repeated measures for rate of correct action recognition revealed neither a significant main effect of model, $F(2, 30) < 1$, *ns*, nor a significant effect of condition, $F(2, 30) < 1$, *ns*. On average experts showed $M = 88.7\%$ ($SD = 20.27\%$) correct decisions for own movements, $M = 86.20\%$ ($SD = 21.52\%$) for teammates' movements, and $M = 87.30\%$ ($SD = 20.60\%$) for others' movements. Again, we found a significant effect of dribble, $F(3, 45) = 5.24$, $p < .05$, $\eta^2 = .26$. None of the interactions with the factor model attained significance (all $F < 1$, *ns*).

Analysis of reaction times. An ANOVA for reaction times revealed no significant main effects of model, $F(2, 22) < 1$, *ns*, or condition, $F(2, 22) < 1$, *ns*. Reaction times for own movements were $M = 1.31$ s ($SD = 0.19$ s), for teammates $M = 1.36$ s ($SD = 0.36$ s), and for others $M = 1.31$ s ($SD = 0.23$ s). None of the interactions with the factor model attained significance.

Once again, there was a significant main effect of dribble, $F(3, 33) = 36.29$, $p < .001$, $\eta^2 = .77$. An ANOVA with repeated measures for reaction times for speed dribbling showed a significant effect of condition, $F(2, 26) = 6.02$, $p = .01$, $\eta^2 = .32$. Observers were faster in the player-with-sound condition ($M = 1.49$ s, $SD = 0.05$ s) than in the player-only ($M = 1.52$ s, $SD = 0.05$ s) and player-with-ball conditions ($M = 1.49$ s, $SD = 0.05$ s). Paired t-tests revealed significant differences between the player and player-with-sound conditions, $t(13) = 3.14$, $p = .01$, and between the player-with-ball and player-with-sound conditions, $t(13) = 2.21$, $p = .05$.

Discussion

Results clearly showed that experts were better at recognising basketball dribbles than novices. This can be seen in terms of both the rate of correct classifications of dribbles and in reaction times. It should be pointed out that even the novices pressed the button before the hand change occurred, indicating that they were also able to anticipate the upcoming action and did not wait until the presentation stopped. A closer look at the results revealed that the expert-novice differences generalised to most of the different dribbles.

The expertise advantage for perceptual judgements 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 to be found in biological motion perception. This demonstrates that the kinematics of actions build a basis for perceptual recognition and decision making that is relevant for experts' decisions. However, the differences between experts and novices could be explained by both superior motor expertise and better perceptual representations. The two mechanisms cannot be separated in an expert–novice design. Nonetheless, either both mechanisms together or one of them in particular must have been responsible for the expert–novice differences in the present action recognition task.

To address this issue, we also compared performance on the factor model (self, teammate, unknown player). Observing different models did not result in any differences in the rates of either correct responses or reaction times. However, it should be pointed out that this result was not due to the task at hand. The differences found between experts and novices clearly demonstrated that the task is sensitive enough to distinguish between groups with varying levels of expertise. Action recognition therefore works just as well for own actions as it does for other humans' actions. On the one hand, finding any difference between the perception of own actions and that of friends and strangers might be due to a ceiling effect. The performance within the expert group was already very high, and any further improvement would seem to be difficult. On the other hand, there might be no difference between motor expertise for basketball dribbling at all and for motor experience with own movements for that kind of task. One could argue that the representation of the movement can be used in the same way for the perception of both own actions and those of other individuals. Additionally, we did not find a speed–accuracy tradeoff within one of the groups. This leads to the conclusion that experts and novices did not differ in their strategies for solving the task. Nonetheless, experts did produce more correct answers as well as shorter reaction times, which further underlines their superior performance.

Action recognition did not depend on the presentation condition. In other words, it made no difference whether participants observed only the body of the player, the player with the ball, or the player combined with the sound of the bouncing ball. Only speed dribbling reaction times were faster in the body-and-sound condition. We assume that participants recognised these more quickly because of the more pronounced rhythm in ball bouncing compared with the other four dribbles. However, the lack of differences between the three conditions contradicts the findings reported by Shipley and Cohen (2000). This might be because the participants in our study knew in advance that they were going to be observing basketball actions. Only the player-and-sound condition provided participants with further information that could help them to recognise speed dribbling. In this case, we assume that a top-down process guided the perception of the actions, so that additional information on conditions played only a minor role.

EXPERIMENT 2: ACTOR RECOGNITION

Experiment 2 focused on actor recognition when presenting PLDs of actions. It addressed the question *who* is acting and not *what* is the outcome of the action as in Experiment 1. Only the expert group from Experiment 1 took part in this experiment, because the novices were not familiar with the other participants, making it impossible to assume any visual experience of their actions. We decided to use a hierarchically organised decision task that would allow us to examine performance on identifying own past actions both indirectly and directly. Because observers may feel uncomfortable about naming themselves (Beardsworth & Buckner, 1981) or naming strangers explicitly (Loula et al., 2005), we used two types of questions: First, participants had to assign the presented player to a team. If they assigned this player to their own team, they were then asked to identify the player. That is, observers now had to recognise own actions and that of friends explicitly.

We anticipated better recognition of the own person compared with other players (see Loula et al., 2005). With reference to Loula et al. (2005), we also assumed that participants would more frequently recognise a player who performs a movement that is less constrained and therefore permits more individual style.

Method

The same group of 18 experts from Experiment 1 took part in Experiment 2. The stimuli used to test the observers' ability to identify models were also the same as those described in Experiment 1.

Design and procedure. Participants watched videos of 16 players (own movement, seven teammates, and eight players in the other team) at a time. We decided to present 16 players, because we had only eight players in one of the teams. We exchanged the presentation of two players from the other 10-player team when necessary to ensure that all players saw their own actions. The decision task was organised hierarchically. First, participants had to identify the player's team. When they reported "other team", the next stimulus was presented. When they reported "own team", they had to select the name of a teammate from a list of all team members' names including their own.

The within-subjects variables action (walk, speed dribble, and spin dribble) and condition (player only, player with ball, player with sound) were also included; that is, all participants assessed PLDs covering both teams, all actions, and all conditions. As a result, half of the presented stimuli consisted of own team's actions (including the participant); the other half, actions by the other team. Three different actions were presented: speed dribbling, spin dribbling, and normal walking. We used these skills in Experiment 2, because they represent a different range of complexity. Walking was the most constrained action, whereas the speed and spin dribbling allowed a larger degree of variability and individuality.

The condition variable was blocked, and the order of blocks was counterbalanced across participants. Within each block, sequences were presented twice for each model and each action. This resulted in a total of 96 trials per block (16 models $\times$ 3 actions $\times$ 2 trials). The length of each presentation was approximately 1.6 s. A short training session was conducted to familiarise participants with the task.

Dependent variables and statistical analysis. The dependent variables were the rates for the correct classifications to teams and for the recognition of members of the own team. Statistical analyses were based on ANOVAs with repeated measures, and the significance level was set at $p < .05$.

Results

Accuracy of assignments to own or other team

Participants first had to identify whether the display showed a member of their own or the other team. This two-alternative forced-choice task had a chance level of .50. A binominal test showed that classification into teams was better than chance ($p < .05$) for the actions speed dribbling ($M = 54.38\%$, $SD = 8.75\%$) and spin dribbling ($M = 54.44\%$, $SD = 7.9\%$), but not for walking ($M = 52.29\%$, $SD = 7.4\%$). A 3 (condition) $\times$ 3 (action) ANOVA with repeated measures showed no significant effect for either action, $F(2, 28) = 1.06$, $p = .36$, $\eta^2 = .07$, or condition, $F(2, 28) = 1.60$, $p = .22$, $\eta^2 = .10$. The Action $\times$ Condition interaction also failed to attain significance, $F(4, 56) = 1.68$, $p = .17$, $\eta^2 = .11$. Furthermore, we did not find the expected performance differences for the different actions. Spin dribbling ($M = 54.45\%$, $SD = 4.73\%$) did not provide more information about the presented team than speed dribbling ($M = 54.38\%$, $SD = 6.23\%$) or walking ($M = 52.29\%$, $SD = 4.32\%$).

Accuracy of assignments of own actions to the own team

We analysed the rate of correct assignments of own actions to the own team. This analysis again referred to the first task (own or other team), therefore providing an indirect measure of how well observers were able to recognise their own movement as a familiar movement, because they were not asked to identify the player directly.

We collapsed the data across conditions, because prior analyses did not reveal any differences between them. Figure 1 presents the rates of correct assignments of other players' (teammates as well as members of the other team) actions and the own movement to the right team as a function of the presented action. An ANOVA with repeated measures showed a significant effect of action, $F(2,\ 28) = 10.90$, $p < .001$, $\eta^2 = .44$, and actor, $F(1,\ 14) = 12.16$, $p < .001$, $\eta^2 = .47$. The latter was due to better recognition of own actions. There was also a significant Action × Actor interaction, $F(2, 28) = 10.75$, $p < .001$, $\eta^2 = .43$.

An analysis with binominal tests showed that the accuracy of correct assignments of actions to a team differed significantly from chance for own actions ($p < .001$) but not for the actions of other players ($p = .33$). As shown in Figure 1, the rate of correct assignments varied significantly not only for model (own movement: $M = 66.67\%$, $SD = 14.55\%$; other players: $M = 53.70\%$, $SD = 3.53\%$) but also for the actions walking ($M = 52.26\%$, $SD = 12.89\%$), speed dribbling ($M = 68.30\%$, $SD = 7.81\%$), and spin dribbling ($M = 60\%$, $SD = 11.43\%$). Paired *t*-tests revealed significant differences for own movement between walking and speed dribbling, $t(14) = 4.10$, $p < .001$; between walking and spin dribbling, $t(14) = 2.35$, $p = .03$; and between spin and speed dribbling, $t(14) = 2.96$, $p = .01$.

Accuracy of assignments of the model to own actions or that of teammates

When participants classified a model to their own team, they subsequently had to identify him. As shown by the results reported earlier, participants could not discriminate between members of the own team, including themselves, and players of the other team. Therefore, performance was analysed only for those players who were assigned correctly as members of the own team. The chance level was 12.5% here, 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 variable. Results for the correct assignment of the name to a teammate and the own movement are summarised in Figure 2.

An ANOVA with repeated measures showed no significant effect of actor, $F(1,\ 14) = 1.65$, $p = .22$, $\eta^2 = .11$, but a significant effect of action, $(2,\ 28) = 5.37$, $p = .01$, $\eta^2 = .27$. It was harder to identify a person walking ($M = 26.31\%$, $SD = 16.81\%$) compared with a person performing speed dribbling ($M = 44.92\%$, $SD = 4.39\%$) or spin dribbling ($M = 37.71\%$, $SD = 17.82\%$). Paired *t* tests revealed significant differences between the actions walking and speed dribbling $t(14) = 3.43$, $p < .01$. The results showed that recognition of players did differ significantly from chance for both the own movement ($p < .001$) and the actions of teammates ($p < .001$).

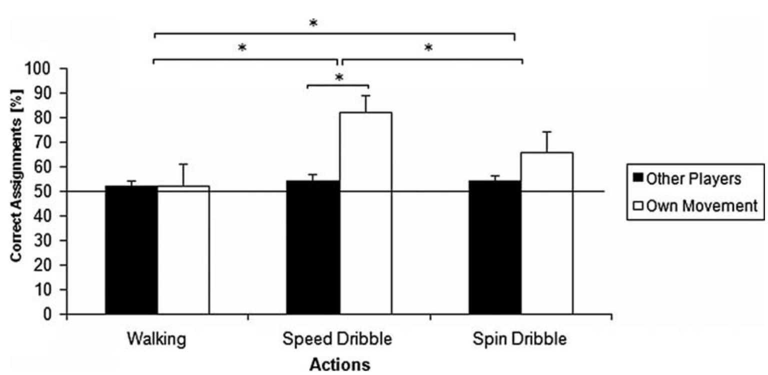

Figure 1. Rate of actor recognition (%) to any other player (teammate, member of other team) or of the own movement to one of the teams as a function of the presented action. Error bars indicate the standard error of the mean (*SE*).

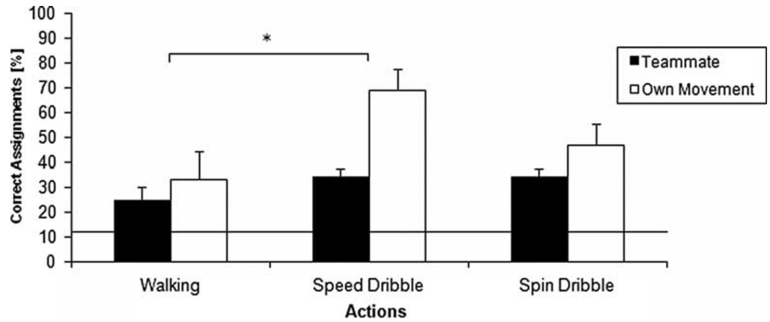

Figure 2. Rate of actor recognition (%) as a function of the presented action. Error bars indicate the standard error of the mean (*SE*).

Discussion

The first question in Experiment 2 was whether observers are able to differentiate between own actions, those of teammates, and those of unknown players on the basis of the amount of motor and visual experience they have with those kinds of actions. Results showed that participants could hardly differentiate between members of the own team and another team when PLDs of actions were presented and the task was to assign them to the correct team. Therefore, we were unable to provide evidence that a certain visual experience with the actions of well-known players leads to an advantage when observing those actions. However, it should be pointed out that participants were better at classifying their own actions to their own team. It has to be emphasised that this task does not rely necessarily on an explicit recognition of the participant. This result provides a strong argument that motor experience plays an important role in actor recognition. Athletes normally do not have visual experience of their own actions. Therefore, visual experience can be excluded as a reason for this result. However, they do have extensive motor experience of and familiarity with their own actions.

When athletes were asked to identify the player whom they had classified correctly to their own team, their ability to assign the correct name to their own movement as well as to that of a teammate was above chance. Results for teammates may be attributed to visual experience, whereas results for own actions support the significant role of motor experience. However, when the task was to name the player directly, no significant differences were found between recognition of own and teammates' actions (see also Cutting & Kozlowski, 1977). Given this result, it can be assumed that both motor and visual experience influence perception within this task. In general, results for actor recognition did not show a major advantage of perceptual experience, but, under indirect conditions, a considerable advantage of motor experience. However, it should be pointed out that we could not replicate Loula et al.'s (2005) finding that observers were able to discriminate between own, familiar, and unknown persons. This might be because we presented actions for a much shorter time (approximately 1.6 s) than the 5 s in Loula et al. Our participants had less time to ''put themselves in the shoes'' of the observed model and to familiarise themselves with the observed actions.

The second question in Experiment 2 was whether the performance of observers depended on the presented action. Results supported the assumption that actions with enough variability to permit an individual style can be assigned to a team more effectively than more constrained actions. Assignments of a player to a certain team were above chance for the two dribbles but not for walking. The same results were found on the task of identifying a player who had been classified correctly to the own team. Actor recognition seems to be easier for complex actions such as basketball-specific speed and spin dribbling actions than for more constrained actions like walking.

GENERAL DISCUSSION

The aim of the present experiments was to examine the influence of both motor and visual experience on the perception of human actions, and to look for evidence in favour of the motor view of biological motion perception (Knoblich & Flach, 2001; Prinz, 1997). It also analysed whether the impact of motor processes on action perception depends on the requirements of the perceptual tasks.

Experiment 1 revealed expert–novice differences in action recognition, but no differences for the recognition of own, familiar, or unknown actions. Therefore, it can be assumed that expertise has an influence on the action recognition task. On the other hand, neither motor experience nor specific perceptual experience of familiar actors showed the expected advantage. In contrast to other studies (Flach, Knoblich, & Prinz, 2003; Keller, Knoblich, & Repp, 2007; Knoblich & Flach, 2001; Knoblich, Seigerschmidt, Flach, & Prinz, 2002), we did not find better action recognition when participants observed their own actions compared to other individuals' actions. Nonetheless, it should be pointed out that our tasks differed significantly from those used elsewhere: Knoblich and Flach (2001) examined the prediction of landing positions of darts on a target board, and Knoblich et al. (2002) asked participants to predict handwriting trajectories. None of these tasks required observers to interact directly with the actions of others. All they had to do was to predict the outcome of an action that had no relevance for their own reactions. In contrast, the present basketball task was relevant for own reactions. Normally, players have to react in one-to-one situations to players of another team. Therefore, it can be argued that more general representations might be functionally advantageous for the present task—as discussed by Ramnani and Miall (2004). Probably, knowledge about the specific movement features of teammates and about one's own movement is not advantageous, because this information has to be adapted to the movement characteristics of a player of another team. Indeed, an orientation towards specific features of one's own movement skill might well have quite the opposite impact and impede the perception of others' actions. Any switch in the movement pattern needs to be anticipated independently of the model. We assume that motor and perceptual representations can support the anticipation of a dribbling skill as in the present perceptual decision task (Jeannerod, 2001, 2006). Nonetheless, they are used in a generalised form, and can be applied to predict others' skills as well as to perceive one's own skills. Any advantage through observing own actions may depend essentially on whether the task requires an interaction or a synchronisation with other actions. This is in line with research showing a higher activation within the human mirror neuron system during the preparation of complementary actions than during imitative actions (Newman-Norlund, van Schie, van Zuijlen, & Bekkering, 2007).

Contrary to the *action* recognition task, we found a limited, but relevant impact of viewing own PLD videos on *actor* recognition. Participants were slightly better at classifying their own PLDs to their own team than the PLDs of their teammates. They also identified themselves slightly better than they identified their teammates. Even though this difference failed to attain significance, it should be noted that it directly contradicts the perceptual view of action perception. This would predict that teammates are identified better than own person due to the extensive visual experience with their actions. Our results are in line with research on self-identification in handwriting (Knoblich & Prinz, 2001), hand clapping (Flach et al., 2004; Repp, 1987), piano playing (Repp & Knoblich, 2004), and the recognition of own body parts like the hand (e.g., Daprati & Sirigu, 2002; Daprati, Wriessnegger, & Lacquaniti, 2006), but contradict studies in the domain of walking (Beardsworth & Buckner, 1981; Cutting & Kozlowski, 1977; Jacobs, Pinto, & Shiffrar, 2004; Wolff, 1931).

A comparison of the results of both experiments confirms the assumption that motor representations possess a specific relevance for perceptual decisions on different kinds of perceptual tasks. We consider that generalised perceptual and motor experience support the recognition of actions in the *action recognition task*. In contrast, the *actor recognition task* seems to depend more strongly on motor experience.

Unexpectedly, we found only a marginal impact of condition (player only, player with ball, player with sound) on the perception of human motion. This is somewhat surprising in light of reports on the positive effects of seeing an object in biological motion (Shipley & Cohen, 2000), and we had also expected additional acoustic cues to support action recognition (Flach et al., 2004; Repp & Knoblich, 2004). However, we found no effect of condition in expert–novice comparisons or in the assessment of own and others' actions. We only found one effect on action recognition for speed dribbling: Reaction times were faster for the player-with-sound condition. We interpret this as a task-specific effect of speed dribbling, because the sound related closely to the very specific rhythm of the movement.

Results show that both motor and visual experience may play an important role in the perception of actions. The differences between experts and novices reported here support this view. No self/other effect is found for the action recognition task. Nonetheless, we are able to demonstrate a facilitation effect of observing own actions for actor recognition. This supports arguments in favour of a dissociation of different perceptual tasks for biological motion perception. The advantage of viewing own actions seems to be more relevant for identifying the actor than for recognising the action.

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