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Consciousness and Cognition 12 (2003) 620–632

Consciousness and Cognition

www.elsevier.com/locate/concog

Action identity: Evidence from self-recognition, prediction, and coordination

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Received 10 March 2003

Abstract

Prior research suggests that the action system is responsible for creating an immediate sense of self by determining whether certain sensations and perceptions are the result of one's own actions. In addition, it is assumed that declarative, episodic, or autobiographical memories create a temporally extended sense of self or some form of identity. In the present article, we review recent evidence suggesting that action (procedural) knowledge also forms part of a person's identity, an action identity, so to speak. Experiments that addressed self-recognition of past actions, prediction, and coordination provide ample evidence for this assumption. The phenomena observed in these experiments can be explained by the assumption that observing an action results in the activation of action representations, the more so, when the action observed corresponds to the way in which the observer would produce it.

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1. Action identity

There can be no doubt that humans are able to identify the products of their past actions. Often, there are obvious cues. For instance, the authors in this issue can identify the papers they have written by looking for their names. When browsing in an old diary one will recognize one's handwriting and when looking at an old drawing one will recognize one's drawing style. However, in other situations it is less obvious whether one perceives the products of one's own past actions.

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1053-8100/$ - see front matter
doi:10.1016/S1053-8100(03)00070-9

Consider for example Aida who finds an old audiotape without a label. As she listens to the tape she hears a noisy record of a piano piece, which everybody in her family likes to perform. Will she recognize whether it is her who played? If so, why?

It seems that in order to make this judgment she would need to somehow compare what she currently hears to what it would sound like if she performed the heard piece herself (cf. Barresi & Moore, 1996). And if she could identify herself as having played the piece, based on this comparison, her ability to recognize herself would likely result from the fact that the actions she performed earlier and the ones she would perform now are identical or very similar. In other words, her self-recognition ability would be based on identical actions.

Phenomena of action identity are largely unexplored. This is probably due to the following reasons. First, it is obvious how individuals can recognize themselves based on a stable representation of their anatomical features (e.g., their face, Kircher et al., 2001), certain traits they ascribe to themselves (Baumeister, 1998), episodic and autobiographical memories (cf. Tulving, 2002), or narratives (Dennett, 1992). These abilities are some of the main markers for what Neisser (1988) called the Remembered Self. It is less obvious how individuals can recognize themselves based on stable action knowledge, mainly because this knowledge is assumed to be implicit and cognitively impenetrable (cf. Cohen & Squire, 1980; Ryle, 1949).

Second, if one addresses the relationship between self and action, the most obvious questions that come to mind are how intentionality creates phenomenal experience (Metzinger, 2003), how one is able to identify whether a certain perceptual event is caused by one's own actions (Frith, Blakemore, & Wolpert, 2000; Jeannerod, 1999; Leube, Knoblich, Erb, & Kircher, 2003), and whether one's feeling of control reliably reflects the actual amount of control one exerts with one's actions (Wegner, 2002). These issues pertain to a more immediate self that Neisser (1988) referred to as the Perceived Self (see also Rochat, 2003).

Phenomena of action identity, if they exist, would suggest that stable action representations allow one to recognize one's own way of doing things, one's action style, so to speak. And if one thinks about exceptional musicians, dancers, or athletes, it seems quite plausible that they should be able to recognize their action style. However, there is reason to assume that phenomena of action identity also can be observed in less exceptional performers. After all, there are action domains in which almost every adult is more or less of an expert (e.g., walking, throwing, clapping, or handwriting). Also, individuals carry out the same actions in different ways. Possible reasons for inter-individual variability include differences in anatomical constraints, different learning histories, and different levels of expertise. All of these inter-individual differences could give rise to phenomena of action identity, at least if a given individual performs the actions in question in a relatively stable manner.

The first aim of the present paper is to provide a theoretical basis for addressing phenomena of action identity, using current theoretical approaches that postulate a contribution of the action system to perception. These approaches will provide principles to explain how action knowledge becomes activated through perception (even when one has currently no intention to perform the action), and to explain why there could be an asymmetry between observing one's own actions and somebody else's actions. The second aim is to then provide an overview of studies that explored various phenomena of action identity in different action domains. Some of these studies addressed the question of whether individuals can recognize their own past actions. The remaining studies addressed the question of whether one can generate more accurate predictions for one's own past actions and whether the higher accuracy facilitates coordinating new actions with the perceived ones.

2. Action identity as a marker for the action systems contributions to perception

Exploring phenomena of action identity allows one to address the important theoretical question of whether and how the action system contributes to action perception in a new way. Several theoretical frameworks have postulated that such contributions exist, e.g., Gibson's (1979) ecological theory of perception, and the motor theory of speech perception (Liberman & Whalen, 2000). In the following, we will concentrate on the common coding approach to perception and action (Hommel, Müsseler, Aschersleben, & Prinz, 2001; Prinz, 1997) and on action simulation approaches (Blakemore & Decety, 2001; Dokic & Proust, 2002; Gallese & Goldman, 1998; Jeannerod, 2001; Knoblich, Seigerschmidt, Flach, & Prinz, 2002).

The common coding theory applies James' ideomotor principle (James, 1890) to the domain of event perception, action perception, and imitation (Greenwald, 1970; Hommel et al., 2001; Prinz, 1997, 2002). The original principle was postulated to explain voluntary action. It states that imagining an action will create a tendency to carry it out. This tendency will automatically lead to the execution of the action when no antagonistic mental images are simultaneously present (James, 1890, Vol. II, 526). In addition, the common coding theory claims that the mental images (or representations in more modern terms) do not code actions per se (Prinz, 1997). Rather, it is assumed that the early mental antecedents of an action are coded, more specifically, the distal perceptual events that an action should produce. If the activation of a common code exceeds a certain threshold the corresponding motor codes are automatically triggered.

An important implication of this assumption is that there is a common medium for perception and action. In other words, the common coding theory postulates a functional equivalence or commensurability of perceptual and action representations. Accordingly, perceptual representations should contribute to action, and action representations should contribute to perception. Most importantly for the present purpose, the perception of an action should activate action representations to the degree that the perceived and the represented action are similar.

A growing body of neuro-physiological evidence suggests that common coding of perception and action is also a principle that applies to the neuronal implementation of perception action links. There are a number of areas in the brain that are active during planning and controlling an action as well as perceiving the actions of others (Blakemore & Decety, 2001; Decety & Grèzes, 1999). Rizzolatti and his colleges provided evidence for "mirror neurons" in the pre-motor area of the macaque monkey (Metzinger & Gallese, 2003; Rizzolatti, Fogassi, & Gallese, 2001). These neurons fire when the monkey carries out object-directed actions. They also fire when the monkey observes the experimenter carrying out the same specific action. Recent positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) studies suggest that humans possess a similar mirror system (e.g., Iacoboni et al., 1999; Koski et al., 2002). Further "motor" areas, which are often active while perceiving actions include the left parietal cortex (Decety & Chaminade, 2003), and the SMA (Elsner et al., 2002).

At first glance, the common coding theory mainly seems to provide a principle for how one can match actions one observes others doing to one's own action repertoire. And indeed, it has been successfully applied to explain many phenomena of ideo-motor action and imitation (e.g., Bekkering & Prinz, 2002; Knuf, Aschersleben, & Prinz, 2001). However, the similarity principle inherent in the theory also suggests that common codes should be more activated when observing one's own past actions and their consequences than when observing others'. The reason is that there are inter-individual differences in performing actions or action sequences. For instance, people have different ways of walking, throwing, writing, etc. Thus, whenever one perceives one's own past actions, the similarity between the perceptual events observed and the common event representation should be maximal, because one perceives a sequence of events one would produce in exactly the same way. If one perceives the actions of others' the perceptual events observed and the common event representations should be less similar. The degree of activation of the common codes should vary depending on whether the other person performs the observed actions in a similar way as one would perform them oneself, or in a different way. Thus, one could identify the consequences of one's own past actions based on the differential activation of these codes.

Like the common coding theory, recent action simulation theories assume that the motor system contributes to action perception (Blakemore & Decety, 2001; Dokic & Proust, 2002; Jeannerod, 2001). These theories claim that when one observes the actions of others, one concurrently simulates carrying out the same action. Such simulations use the same predictive mechanisms of the motor system that generate predictions about the consequences of one's own actions in online action control. The functional value of such simulations is obvious. They could generate predictions that are useful for shifting one's attention or for directing one's actions to critical locations, for anticipating the appearance of critical events, or for coordinating one's own actions with somebody else's (Knoblich & Jordan, 2002, 2003; Sebanz, Knoblich, & Prinz, 2003). Neuro-physiological evidence supports the action simulation assumption. First, the mirror neurons in the monkey pre-motor cortex already discharge in early phases of the movement (Umiltà et al., 2001). Moreover, several regions in the human brain are activated during action generation, action imagination, and action observation. These areas include the pre-motor cortex, the posterior parietal cortex, and the cerebellum (Decety & Chaminade, 2003; Ruby & Decety, 2001).

If one combines the action simulation hypothesis with the assumption of a parity or commensurability between perception and action, as postulated by the common coding theory, one would expect that the similarity of an observed action with the common codes might also affect the accuracy of action simulations. Specifically, action perception might initiate simulations in the following manner: first, common event representations become activated by the perceptual input. Second, there is an automatic activation of the motor codes attached to these event representations. Third, the activation of the motor codes results in a prediction of the action results in terms of expected perceptual events on the common coding level.

This raises the possibility that certain common codes are already pre-activated through a simulation, when they first occur in the perceptual input, and that they are pre-activated to a larger extent when one observes one's own past actions. Thus, the match between pre-activated and actually perceived codes might contribute to self-recognition. In addition, observing self-produced actions and their consequences should result in a more accurate prediction of future events. More accurate predictions could also ameliorate action coordination. In the following we will address empirical evidence supporting these assumptions. We start with studies addressing self-recognition and then proceed to studies addressing prediction and coordination.

3. Recognition

Until recently, only few studies investigated whether individuals are able to identify past actions. Wolff (1931) conducted the first study addressing this issue. He filmed individuals while they walked up and down in a room and carried out different actions. They were all dressed in the same loose clothing to disguise anatomical cues. Also, he manipulated the films to disguise each person's face. When he showed these films to the walkers they could recognize themselves much better than they could recognize other persons whom they all knew well. He concluded from these results that persons are able to recognize their "individual gait characteristics." However, there are many alternative explanations for this result. For instance, it is unlikely that the loose clothing really disguised all anatomical characteristics (think for instance of the size of a person).

Two more recent studies tried to replicate Wolff's result using Johansson's (1973) point-light technique. With this technique one can isolate the movement (kinematic) information from the form information. The results were controversial. Whereas Cutting and Kozlowski (1977) found that their participants were not better able to recognize themselves than their acquaintances, Beardsworth and Buckner (1981) reported a small advantage for recognizing oneself from a point-light-display of gait. But even if one takes the latter result seriously, it could be explained by the assumption that one can derive the anatomical structure from the multiple moving objects in the point-light-displays (structure from motion, cf. Wallach & O'Connell, 1953).

Thus, the earlier results do not provide unambiguous evidence that action-related knowledge contributes to recognize one's own past actions or their products. In order to avoid such ambiguities we turned to the handwriting domain in a first series of experiments. The product of handwriting is a simple trajectory with two spatial dimensions and one temporal dimension. Thus, it is relatively easy to control the information provided in such a trajectory. Nevertheless, drawing is a complex skill and action planning ought to play an important role in drawing productions (Van Sommers, 1984).

3.1. Handwriting

In a series of experiments, we addressed the question of whether one can recognize the kinematics of one's own handwriting (Knoblich & Prinz, 2001). It is obvious that persons can identify the products of their handwriting when they are confronted with a finished product (e.g., a page from their diary). However, it is less obvious whether they can identify themselves based on action-related information. Therefore, we isolated this type of information from handwriting samples and investigated whether participants can still identify their own handwriting.

The participants came for two individual sessions that were at least 1 week apart. During the first session, they produced writing samples of a number of familiar symbols, like numbers and letters from the Latin script, and unfamiliar symbols, like letters from Thai and Mongolian scripts. We recorded the kinematics of their writing with a writing pad. While they wrote, their hand was screened from view and they did not receive visual feedback about the emerging trajectory. In addition, they needed to follow a certain stroke sequence and stroke direction for each letter. For instance, in order to produce the letter "P" they needed to start with a down-stroke, lift the pen, and produce the bended stroke from top to bottom.

In the second session, participants were asked to identify their own past writing. They observed two kinematic displays of the production of the same symbol, one of them self-produced and one of them produced by another participant, in random order. Each kinematic display consisted of a moving dot that re-produced the movement of the pen tip on the writing pad without leaving a static trace on the monitor (just like the movement of a laser pointer leaves no trace on the wall). The task was to decide whether the first or second display was self-produced. The participants received no feedback about the accuracy of their judgments.

The result of a first experiment demonstrated that participants could recognize their own handwriting based on the sparse information provided in the kinematic displays. The same results were obtained when the self- and other-produced displays presented in each trial were scaled to have the same size and overall duration. However, if the differential velocity information was removed from the displays, that is, when the dot moved with constant velocity, participants could not identify their own handwriting anymore. The crucial role of velocity information was further supported by the finding that self-identification was more accurate for kinematic displays of symbols the production of which was associated with larger velocity changes (e.g., at corners). Interestingly, the accuracy of self–other-judgments was not higher for writing samples reproducing familiar symbols.

Taken together, these results provide first evidence for the claim that past actions can be identified, even if only a minimal amount of information about their consequences is provided. Importantly, velocity changes seemed to be crucial for self-identification, whereas the familiarity of the symbols did not affect self-recognition. This supports the claim that self-recognition is informed by the action system, because velocity changes are clearly an action-related parameter. Thus, it seems that participants were able to identify their own handwriting by its "rhythm," that is, its invariant relative timing.

3.2. Clapping

In order to generalize the evidence for self-recognition to a different modality and to further explore the role of timing, we conducted another series of studies that explored whether and how one is able to recognize one's own clapping. In contrast to trajectories of handwriting, it is possible to remove all spatial information from the sounds of clapping. What remains, is the temporal and the acoustic information, like tempo, relative timing, etc. Repp (1987) found in an earlier study that participants were able to identify their own clapping. He suggested that participants derived information about their individual hand configurations from the acoustical pattern in the recordings. However, he did not systematically control the temporal information. Our experiments aimed at replicating the phenomenon and at determining how action-related timing information informs self-recognition (Flach, Knoblich, & Prinz, submitted).

Again, there were two sessions that were at least 1 week apart. In the first session, participants were asked to clap rhythmic patterns of varying complexity. Their clapping was recorded. In the second session, they heard one sample of clapping in each trial and were asked to indicate on a continuous scale the likelihood that this sample reproduced their own clapping. In this study, we created pairs of two participants. Both participants provided judgments for exactly the same samples, half of them produced by themselves and half of them produced by the other participant in the pair. Thus, the same clapping sample that needed to be judged as self-generated by one participant, needed to be judged as other-generated by the other participant. This design completely removes any stimulus differences that might provide an alternative explanation for the self-recognition hypothesis.

The result of a first experiment provided clear evidence that participants recognized original recordings of their own clapping. The accuracy of self-recognition was not affected by the rhythmic complexity of the clapping pattern. In a further experiment, we assessed whether self-identification was still possible when participants listened to a sequence of simple tones (beeps) reproducing the times of the clapping sounds' maximum altitudes. Such a beep sequence retains the general tempo and the relative timing of the original recording, but it removes all other acoustic differences, including the ones that might be used to derive information about the hand configuration during clapping. Surprisingly, participants were as accurate in identifying their own clapping from such beep sequences as from the original recordings. Apparently, the general tempo and the rhythmic information provided sufficient information for self-identification.

In order to assess the contribution of each of these sources we conducted an experiment in which participants listened to beep sequences that retained the original relative timing, but were replayed in the tempo produced by the other participant. In this experiment, participants could not identify their own clapping anymore. This means that general tempo and relative timing information was used for self-recognition. If participants had only used general tempo information they should have mistaken the other participant's clapping for their own clapping, and if they had only used relative timing information they should have been as accurate as for beep sequences retaining their general tempo.

Taken together, the results extend the evidence for action identity. As in the earlier handwriting study, it is likely that self-recognition was informed by action knowledge that was made accessible on a level of common event codes. Other explanations seem implausible. There were no anatomical cues involved. The recognition session took place 1 or 2 weeks after the recording session. Thus, it is unlikely that self-identification was based on episodic memories of the production. Also, if episodic memory had been crucial the original recordings of clapping should have been easier to identify than the beep sequences. A recently conducted study on self-recognition in piano experts further extended the evidence for action identity in the acoustical domain (Repp & Knoblich, submitted).

4. Prediction

The results described in the previous section clearly demonstrate that phenomena of action identity can be demonstrated in a variety of domains. The studies reviewed in this section address the question of whether action identity is restricted to determining whether some action one currently perceives is self-generated or whether one is also able to generate more accurate predictions of the future consequences of a currently observed action that one has performed in the past. Such a result would support current theories assuming that observing an action can trigger action simulations that use mechanisms in the motor system to predict the future consequences of the observed actions.

4.1. Handwriting

The first series of prediction studies addressed the hypothesis that one can generate more accurate predictions when observing one's own past actions in the handwriting domain (Knoblich et al., 2002). In the first experiment, participants were asked to write different versions of the digit "2" on a writing pad. In addition, they also produced the first stroke in isolation (two strokes are needed to produce the digit "2"; a bended one that ends at the lower left corner and a consecutive straight one; the criterion for separating strokes is that a clear velocity minimum is reached between them). The participants' writing hand was screened from view and they did not receive visual feedback about the emerging trace. One week later they returned for a second session. In this session they observed kinematic displays of bended strokes that were either produced in isolation or as part of the production of the complete digit "2." A moving dot reproduced the movement of the pen tip and did not leave a static form trace on the monitor. Half of the strokes were self-produced and half of them were produced by another participant. The task was to decide whether the observed stroke had been produced in isolation or as a part of the digit "2." No feedback about the judgments was given. Note that judging whether a stroke was produced in isolation required the participants to predict whether another stroke would follow the first stroke that was displayed.

The results were clear-cut. When watching strokes that had been produced by somebody else participants' predictions were at chance. However, when they observed their own past strokes, their predictions were significantly above chance level. Thus, they were able to generate accurate predictions for their own handwriting but not for somebody else's handwriting. A second experiment introduced a variation in the production session. Participants needed to fit their writing within two horizontal auxiliary lines while they produced the samples. The pattern of results did not change. Accurate predictions could only be generated for self-produced strokes but not for other-produced strokes. However, this pattern changed, when writing was constrained by horizontal and vertical auxiliary lines. The reasoning behind this manipulation was that it should not leave any room for inter-individual differences in production. Moreover, this was the only experiment in which accurate predictions could be made for other-generated strokes. Indeed, these predictions were as accurate as the ones for self-generated strokes.

The results exactly correspond to the pattern one would expect if action observation resulted in an activation of common event codes that in turn triggered an action simulation in the motor system to predict future events. When production was unconstrained, there was a large variability between different persons' actions and their consequences. Therefore, the simulations were only accurate for self-generated actions. When the production was highly constrained, all persons needed to perform in highly similar ways, and therefore produce similar consequences that reflect general invariants of human performance (Kandel, Orliaguet, & Viviani, 2000). Accordingly, others' actions and their consequences provided perceptual input that was as informative as one's own actions and their consequences. Therefore, the predictions for others were as accurate as for self. It seems very difficult to explain the pattern of results obtained in this study without assuming an action simulation mechanism.

4.2. Dart throwing

In order to determine whether the results for prediction generalize to situations in which the production and observation perspective are different, we conducted a further series of experiments (Knoblich & Flach, 2001). In these experiments, we asked participants to throw darts at the upper, middle, and lower third of a target board. We recorded 10 samples in which they hit the upper, middle, and lower third, respectively (see Fig. 1). After a week, participants returned for the prediction session. In this session, they watched video clips of themselves or somebody else throwing darts at a target board. Two participants formed a pair and watched exactly the same stimuli. Each clip started with a person (self or other) picking up the dart and ended in the moment in which the dart left the person's hand. The task was to predict whether the dart would land in the upper, middle, or lower third of the target board. Again, the participants were not told whether a judgment was accurate or not.

Generally, participants could predict the landing position of the dart quite well. In initial trials, the predictions were as accurate for other-generated throws as for self-generated throws. In later trials the predictions became significantly more accurate for self-generated throws than for other-generated throws. In other words, whereas the accuracy of the predictions increased when observing oneself, it did not increase when observing somebody else. Two further experiments varied the amount of information provided about the person throwing. In one experiment upper body and throwing arm were visible (the head was hidden behind a cover, see Fig. 1), in the other only the throwing arm was visible. Although the overall accuracy of the predictions decreased, the less information was provided, the pattern of results for the self–other manipulation remained the same. The predictions were equally accurate during the initial trials and the accuracy selectively increased for self-generated throws in later trials.

A possible reason for the initial lack of a self–other difference is that a certain time is needed to adjust action simulations to the new perspective. Alternatively, one might need to couple different event representation with the help of intentional schema. Such schemata have been assumed to provide flexible couplings between self- and other-related information (Barresi & Moore, 1996). A further interesting question is whether action simulations are automatically triggered when a corresponding action is observed or whether they are strategically employed, whenever a task requires action knowledge. Regardless of these specifics, it is clear that the intra-individual aspects of performance that allowed our participants to make better predictions for their own throws were invariant across the different perspectives. Thus it is possible that action timing was again a major factor, because it is one invariant that might have differed across different individuals and remained stable across different perspectives.

Fig. 1. Illustration of the dart prediction task. The participants watched video clips showing themselves or other persons throwing a dart at a target board. The clip stopped exactly after the first frame at which the dart left the person's hand. The task was to predict whether the dart would hit the upper, middle, or lower third of the target board displayed on the right.

5. Online coordination

The prediction results suggest that action identity could indeed be based on action simulation mechanisms. This raises the question of whether such simulations provide information that is available sufficiently quickly to also ameliorate the performance of new actions that are directed towards the earlier performed ones. An instructive analogue for the question at hand is whether one would be one's best dance partner.

5.1. Turning points in visual trajectories

In one series of experiments we addressed the question of whether one can coordinate new actions more accurately with the products of self-generated actions in the following way (Flach, Knoblich, & Prinz, in press): in a first session, participants were asked to draw zigzag and sinusoidal line patterns with constant or alternating amplitudes on a writing pad (see Fig. 2). In a second session, participants observed a moving point-light-display reproducing their own or somebody else's drawings. In addition, they were instructed to press a button at the exact moment in time at which the dot turned from moving upwards to moving downwards. In order to accurately perform this task one needs to time one's own action based on a temporal prediction of the next turning point in the trajectory.

Although the task was not easy for the participants, they performed reasonably well. In particular, they improved their performance in the course of the experiment, that is, the constant timing error decreased in later trials. They more substantially improved more substantially for the more difficult line patterns with alternating amplitudes (irregular patterns) than for the easier line

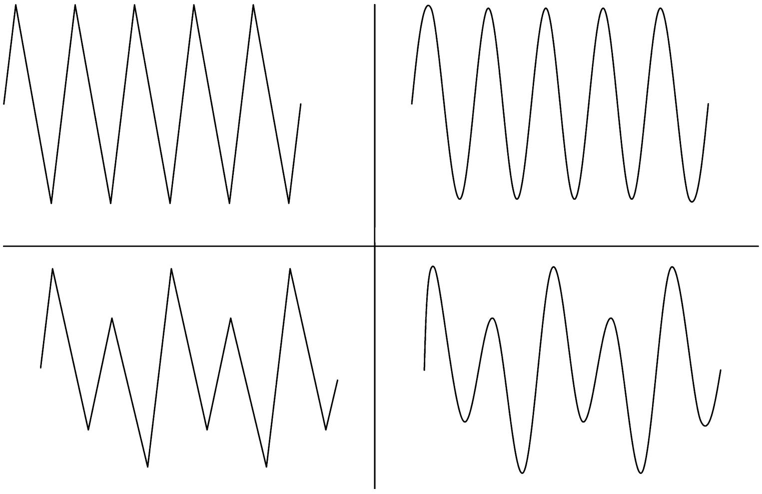

Fig. 2. Stimulus patterns used in the coordination study. The zigzag patterns are displayed on the left and the sinusoidal patterns are displayed on the right. The regular patterns are displayed at the top, the irregular pattern are displayed at the bottom. Note that participants actually saw a moving point-light-display of a self- or other-generated pattern during the crucial experimental session.

patterns with constant amplitudes (regular patterns). They reached a comparable level for regular and irregular patterns only for the trajectories that were self-generated. When coordinating with others' trajectories, the constant timing error remained higher for irregular patterns throughout the experiment. In other words, participants could better coordinate the timing of their actions with a predicted self-generated action event, when the task was sufficiently difficult and when they had sufficient practice.

In a further experiment, we replicated the finding that a self–other difference emerged for the irregular patterns and found that it remained stable across a larger number of trials. Thus, the results indicate that the emerging self–other difference in constant error was asymptotic in nature. There are at least two possible reasons for the lack of a self–other difference during the initial trials that was present in both experiments. First, it might take some time to identify the intra-individual invariants in a point-light-display of a drawing movement. Second, it could be that the invariants are identified right from start, but do not immediately affect online action control. In either case, the benefit of action identity seems to consist in allowing one to better adjust one's actions in the long run. To come back to the initial example, one might actually become one's best dance partner, but only after some training.

5.2. Clapping

Further evidence that speaks to the question of whether one is better able to time one's current actions in synchrony with the results of one's own past actions comes from the earlier reported studies of clapping (Flach et al., submitted). In some of the experiments, the participants were asked to synchronously press buttons with earlier recorded clapping patterns that were self-produced or other-produced. There was no evidence in any of these studies that participants could synchronize their button presses more accurately with their own clapping.

6. Summary and conclusion

The studies reviewed in this paper provide ample evidence that action identity is a real phenomenon that can be observed across different action domains. Individuals do not only recognize their "action style," but they can also generate more accurate predictions of future action outcomes when observing their own past actions. The results for online coordination with one's own past actions are less clear. We have obtained some evidence that one can better temporally adjust a new action with events that reflect one' own past actions. However this result could not be replicated in a clapping study. Thus, the issue of online coordination needs to be further explored. In our view, phenomena of action identity are best explained by the assumption of a close link between perception and action. Our preferred way of conceptualizing this link is to postulate a level of common event representations that are equally involved in action perception and action production. The assumption of common codes does not only provide a principled way to assess the similarity between perception and action and thereby explain how action representations are pre-activated through perception. It also allows one to better understand how current perceptual information and predictions derived from action simulations might become integrated.

Acknowledgments

We thank Gisa Aschersleben and Chris Frith for their helpful comments. Correspondence concerning this article should be addressed to Günther Knoblich, Max Planck Institute for Psychological Research, Amalienstrasse 33, Munich 80799, Germany. Electronic mail may be sent via Internet to knoblich@psy.mpg.de.

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