

# Self-recognition: body and action

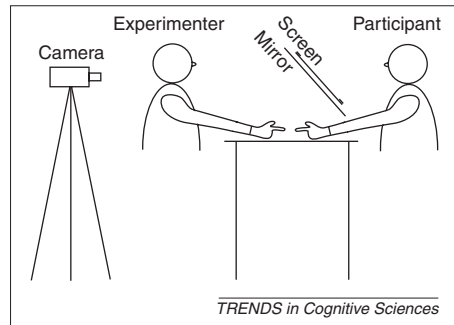
Günther Knoblich

**How do I know it was me who moved? A recent experimental study illustrates the contribution of one's body schema and awareness of one's own actions to self-recognition. The results provide evidence that bodily cues and action cues are important in self-recognition, and they demonstrate that action cues overrule bodily cues.**

How do we recognize ourselves? The first intuition is that self-recognition has something to do with recognizing our own face and other features that characterize us, as when we look in a mirror. Previous research has shown that our own face is indeed an important cue for self-recognition and that specific neural circuits are dedicated to its processing [1,2]. Mirror self-recognition has been considered a benchmark for self-recognition in general [3]. However, developmental and comparative studies suggest that this benchmark is not easily met: toddlers do not recognize themselves in the mirror before the age of 15 months [4] and, apart from humans, this ability has only been observed in great apes [5].

## Self-recognition of body and action

There is good reason to believe that mirror self-recognition is only one particular aspect of self-recognition. Observing ourselves in mirrors is not representative of the way in which we normally perceive and recognize our body and our actions. Most of the time, we have only some parts of our body in our field of view; for example, our hands, forearms, belly, legs and feet. Moreover, we also continuously receive tactile and proprioceptive information about our body that is integrated with this visual information. The correlations between these different sources of information lead to the formation, from early childhood, of an inter-modal representation of our body often referred to as 'body image' [6]. It is likely that the body image plays an important role in self-recognition because it provides information about which parts of the visual input might belong to our own



**Fig. 1.** Experimental set-up in van den Bos and Jeannerod's experiment [13]. The participant and the experimenter sit opposite each other and place their right hands on a table. The participant's hand is hidden below a screen. A video camera films the image reflected by a mirror attached to the back of the screen, and the image on the screen creates the impression for the participant of looking directly at the table.

body, given a certain tactile and proprioceptive input.

An equally important aspect of self-recognition is related to the fact that some of our body parts frequently move. If we are lucky enough not to suffer from neurological syndromes like the anarchic hand [7], these movements follow our intentions. In order to assure that they do, we need to compare our intentions with the events that follow them [8,9]. For instance, when intending to move our index finger we would be very surprised to see our thumb move. Thus, anticipation of events accompanying or resulting from intended actions can also contribute to self-recognition because one can attribute the intended events to oneself [10–12].

## Alien hands

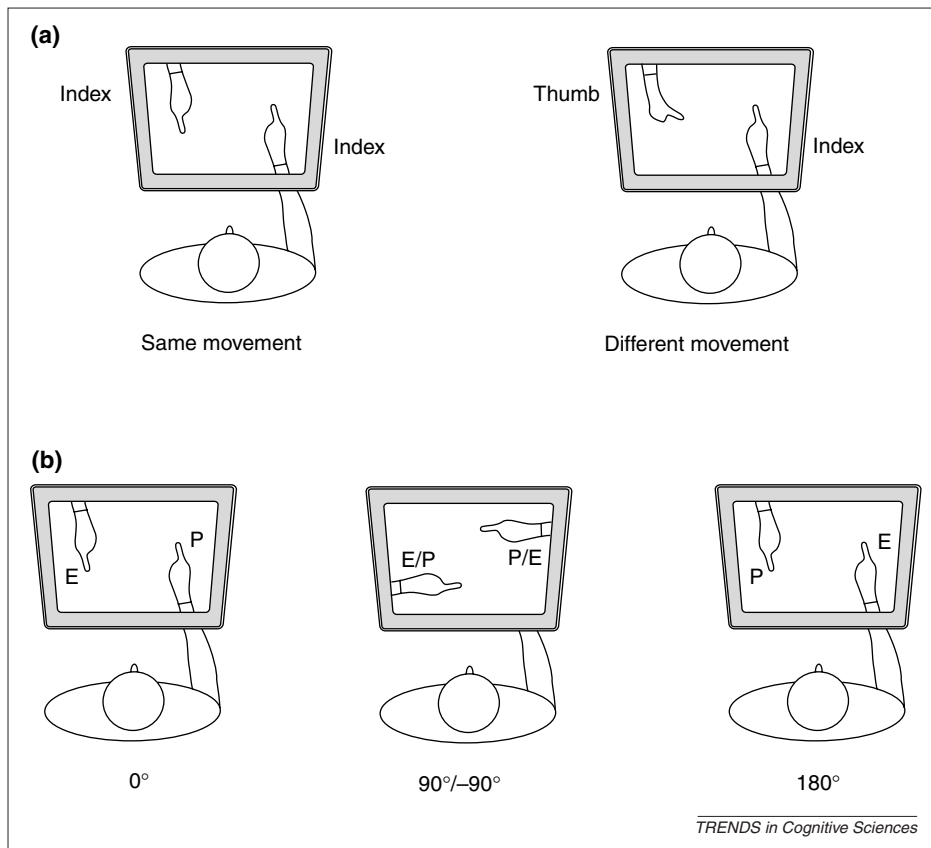
Until recently, only few empirical studies addressed self-recognition. One reason might be that it is very difficult to think of situations in which healthy adults fail to recognize themselves. However, in a recently published study, Esther van den Bos and Marc Jeannerod [13] successfully created an experimental setting that allowed them to assess the relative contributions of bodily and action cues to self-recognition. They used a modified version of the alien hand paradigm, originally developed by Elena Daprati and her colleagues [14] to investigate

disorders of self-recognition in schizophrenic patients [15–17].

The setting in van den Bos and Jeannerod's experiment was as follows (see Fig. 1). The participant and the experimenter sat at opposite sides of a table. Both wore gloves on their right hands to remove cues to identity. Each of them placed his or her right hand on the table so that the hands faced each other. The participant's hand was hidden below a screen mounted on the table and inclined by 45°. A mirror was attached to the back side of the screen so that it reflected both hands. A video camera filmed the mirror image that was displayed on the screen. For the participant, this created the impression of looking directly at the table on which the two hands were placed.

Each trial began with the participant's and experimenter's hands held in a fist. While the screen was still switched off a signal indicated to the participant to move either the thumb or the index finger. The screen was then switched on and after another auditory signal the participant and the experimenter simultaneously initiated their movements. In a 'same-movement' condition, the experimenter moved the same finger as the participant, whereas in a 'different-movement' condition, the experimenter moved another finger (see Fig. 2a). After 1 second, the screen was switched off again and an arrow appeared pointing to the location on the screen where one of the two hands had been displayed. The participant's task was to judge whether the hand he or she had seen at this location was his or her own.

In addition, the image on the screen was either rotated by 90°, -90°, 180°, or not rotated (see Fig. 2b). Image rotation was pre-programmed and did not create noticeable temporal delays. With no rotation, the spatial orientation of the participant's own hand was of course congruent with the orientation of her or his body. When the image was rotated by 90° or -90°, the orientation of the participant's as well as the



**Fig. 2.** Experimental conditions used by van den Bos and Jeannerod. (a) The experimenter simultaneously carried out either the same or a different movement from the participant. For instance, in the same-movement condition (left), both moved their index finger; in the different-movement condition (right) the experimenter moved the thumb when the participant moved the index finger. (b) In addition, the image displayed on the screen was rotated by 0°, 90°, -90°, or 180°. In the 0° degree condition, the orientation of the participants' hand (P) was congruent with their body orientation. When the image was rotated by 90° or -90°, the orientation of both hands was incongruent. When the image was rotated by 180°, the orientation of the experimenter's hand (E) was congruent with the participant's body orientation.

experimenter's hand was incongruent with the participant's body orientation, that is, both hands were seen as 'alien'. When the image was rotated by 180°, the experimenter's hand orientation was congruent with the participant's body orientation and the participant's hand orientation was congruent with the experimenter's body orientation. In other words, the experimenter's hand was seen as if it belonged to the participant's body and the participant's own hand was seen as if it belonged to the experimenter's body.

Using this set-up, van den Bos and Jeannerod first assessed the effect of action cues on self-recognition by comparing error rates in the different-movement (DM) and the same-movement (SM) conditions (chance level is at 50%). The participants almost always recognized their own hand in the DM condition (1% error rate). However, they had much more difficulty recognizing

their own hand when the experimenter carried out the same movement (24% error rate in the SM condition). This result indicates that the participants used action cues because self-recognition became more difficult when fewer action cues were present.

In a next step, van den Bos and Jeannerod assessed the effects of bodily cues on self-recognition by comparing error rates for different rotations. In the DM condition, bodily cues did not affect the error rates. Thus, non-ambiguous action cues completely overruled bodily cues. However, in the SM condition (when action cues were therefore ambiguous) bodily cues affected the error rates. They were lowest (15%) when participants' hand orientation was congruent with their body orientation (0° rotation), intermediate (24%) when the orientation of both hands was incongruent with body orientation (-90° and 90° rotation), and highest (35%) when the experimenter's

hand orientation was congruent with the participants' body orientation (180° rotation). The result that the error rate in the 180° condition was higher than in all other conditions clearly indicates that the body schema contributes to self-recognition, at least when non-ambiguous action cues are unavailable.

#### Future research

One question not fully answered by the experiment is which action cues allowed the participants to distinguish their own actions from those of the experimenter despite their carrying out the same movement. There are several potential differences between the two movements that might have been detected, including spatial deviations [18], differences in the temporal onset [19], or other differences in the movement kinematics [20]. Disentangling the contributions of different action cues to self-recognition would be well worth investigating in future research.

In conclusion, van den Bos and Jeannerod's study provides new evidence that helps to clarify the relative contributions of body schema and awareness of action to self-recognition. The results show that bodily cues are used when action cues are ambiguous. The technique they have developed could also be used to study distortions of self-recognition in different groups of neuropsychological and psychiatric patients. Such studies could help elucidate which specific neural systems underlie self-recognition.

Similar techniques could also be applied to address further aspects of self-recognition in healthy adults. In van den Bos and Jeannerod's study the movement itself was the action goal. In many situations, however, the action goal consists of manipulating objects, either directly or with the help of tools – for example, when hammering a nail. It is to be hoped that future studies will address the question of whether the same or different cues are used for these and other types of actions. Such studies could make an important contribution to the scientific understanding and demystification of the self.

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# The amazing adventures of robotrat

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**By using electrical brain stimulation to deliver both 'virtual' tactile cues and rewards to freely roaming rats, Talwar *et al.* have been able to instruct animals remotely to navigate through complex mazes and natural environments they have never visited before. These results provide both an elegant alternative way to train animals and a new approach to study basic neurophysiological principles of animal navigation.**

Traditionally, neuroscientists interested in investigating the physiological properties of neural circuits in behaving animals have faced tremendous challenges when using routine operant-conditioning paradigms to instruct their subjects to learn a particular task. Not only are these classical training procedures very time-consuming, but they also impose significant physical constraints that limit their implementation to very restricted and controlled laboratory conditions. These serious shortcomings, combined with a natural reticence to incorporate state-of-the-art signal-processing technologies into neurophysiological studies, have seriously limited the range of electrophysiological measurements that can be made in behaving animals.

## Remote control rats

A report by Talwar *et al.* [1] published early this year is likely to change this picture significantly in years to come. These researchers combined an ingenious and creative experimental paradigm – which significantly simplifies the operant-learning paradigm used to train their animals – with modern microelectronic tools and signal-processing techniques. Using this approach, Talwar and colleagues were able to use 'virtual tactile cues' and 'virtual rewards' to instruct rats remotely to navigate through extremely challenging mazes and environments, most of which the animals had never visited before. To accomplish this feat, the authors devised several elegant procedures. First, to instruct a rat which direction it should turn when navigating a maze, the authors designed a backpack containing a microprocessor-based, remote-controlled microstimulator. Then, using a laptop and a wireless interface to activate the backpack microstimulator, the authors took advantage of chronically implanted arrays of microwires to deliver brief trains of electrical pulses to the whisker representation area of either the left or right primary somatosensory (SI) cortex. Animals quickly learned to associate the target of these virtual 'tactile' stimuli (left or right SI cortex) with

the direction they should turn (left or right) by receiving a 'virtual' but very powerful incentive: if they moved to the correct direction after the cortical stimulus they immediately received an electrical stimulus in the medial forebrain bundle, a brain region whose stimulation is thought to mimic the pleasure experienced by the animal following a powerful positive reward. Using this training paradigm, a remote operator was able to train freely roaming rats to learn how to navigate through a variety of daunting obstacles, placed either in a laboratory or even in outside environments.

**'...a remote operator was able to train freely roaming rats to learn how to navigate through a variety of daunting obstacles...'**

Having witnessed the amazing achievements of 'robotrat' (as I referred to these animals since the first day I saw them in action), I believe that many areas of research will be influenced by the results obtained in these experiments. Of course, as pointed out by the authors, the use of intracranial electrical stimulation to mimic either a sensory cue or a reward is not a new idea. Several authors in the past have taken advantage of this method to study particular brain functions. The elegant recent studies of