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Cues for self-recognition in point-light displays of actions performed in synchrony with music

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ABSTRACT

Self-other discrimination was investigated with point-light displays in which actions were presented with or without additional auditory information. Participants first executed different actions (dancing, walking and clapping) in time with music. In two subsequent experiments, they watched point-light displays of their own or another participant's recorded actions, and were asked to identify the agent (self vs. other). Manipulations were applied to the visual information (actions differing in complexity, and degradation from 15 to 2 point-lights within the same clapping action) and to the auditory information (self-generated vs. externally-generated vs. none). Results indicate that self-recognition was better than chance in all conditions and was highest when observing relatively unconstrained patterns of movement. Auditory information did not increase accuracy even with the most ambiguous visual displays, suggesting that judgments of agent identity depend much more on motor cues than on auditory (action-generated) or audiovisual (synchronization) information.

1. Introduction

Most of the actions humans perform rely on multisensory information from the environment. For example, music performance and perception are activities that occur in multisensory contexts. Music making requires precise timing, coordination and motor control for planning and executing one's own movements, and for predicting the intentions and actions of others when playing in ensembles (Keller, 2008). In order to act appropriately, concurrent information from different sensory modalities must be efficiently processed simultaneously in space and time. Music listening is often accompanied by spontaneous body movements, even in young children. In everyday situations, the synchronization of body movements with music is a common activity, even for people without formal training, whether they are dancing, marching, or simply clapping in time during a concert. Does this contextual multisensory information help a person to know about his or her actions and the actions of others, or is the body movement alone sufficient? This study examines whether the dynamic relationship between an individual's movements and externally generated auditory information, as well as auditory information generated by the action itself, provide cues for self-recognition during the observation of impoverished visual displays of actions performed in synchrony with music.

It has been proposed that people understand their own and others' actions by means of action simulation, that is by mapping observed movements onto their own action system (Jeannerod, 2006; see also the related principle of common coding, Hommel, Müsseler, Aschersleben, & Prinz, 2001). Evidence from single cell recordings in macaque monkeys (Gallese, Fadiga,

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Fogassi, & Rizzolatti, 1996) and imaging studies of humans (Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995; Grèzes, Armony, Rowe, & Passingham, 2003) suggests that there is a close correspondence between neural activity while observing, imagining or executing the same action (for a review, see Rizzolatti & Craighero, 2004). Furthermore, embodied simulation and embodied cognition accounts (Gallese, 2007; Wilson, 2002) claim that social cognition and action understanding are grounded in the behavioral matching and neuronal overlap between action execution and action perception.

Behavioral evidence for a close relationship between perception and action has been obtained in a number of studies of self-recognition (for a review, see Knoblich, 2008). Self-recognition has been investigated mainly by focusing on either visual or auditory modalities. In the visual modality, designs employing observation of hand gestures (Daprati, Wriessnegger, & Lacquaniti, 2007), drawing movement trajectories (Knoblich & Prinz, 2001) and various full body movements (Loula, Prasad, Harber, & Shiffrar, 2005) have been used for investigating self-recognition. In the auditory modality, self-recognition has been examined by having individuals listen to the sounds of their own or others' clapping (Flach, Knoblich, & Prinz, 2004) and by having piano players discriminate between their own and others' musical performances (Repp & Knoblich, 2004). Studies of overt coordination with self- vs. other-generated stimuli (Flach, Knoblich, & Prinz, 2003; Keller, Knoblich, & Repp, 2007) have provided further support for the claim that the perception of agent identity is grounded in motor processes, specifically, in action simulation (Jeannerod, 2003, 2006). For example, in the music domain, Keller et al. (2007) found that pianists were not only able to recognize their own performances, but were also able to synchronize better when playing duets with their own previous recordings than with another pianist's recordings. Thus, visual and auditory cues to agent identity are provided by the idiosyncratic ways in which individuals move due to personal biomechanical constraints and past experience and training.

Neurophysiological and neuroimaging evidence suggests that the perception–action links are implemented on a neuronal level (Blakemore & Decety, 2001; Decety & Grèzes, 1999; Jeannerod, 2001; Rizzolatti & Craighero, 2004). In the domains of music (Bangert & Altenmüller, 2003) and dance (Calvo-Merino, Glaser, Grezes, Passingham, & Haggard, 2005; Cross, Hamilton, & Grafton, 2006; Cross, Kraemer, Hamilton, Kelley, & Grafton, 2009), it has been shown that perception–action links become more robust as a function of training and expertise, leading to stronger activation of brain areas that are related to action planning and motor performance in experts relative to novices (Haslinger et al., 2005; Haueisen & Knösche, 2001). Additional evidence for shared auditory and motor processing networks in musical activities comes from studies by Lahav, Saltzman, and Schlaug (2007), Lindenberger, Li, Gruber, and Muller (2009), Mutschler et al. (2007) and Zatorre, Chen, and Penhune (2007).

Self-recognition studies employ various methods, paradigms and designs, including online (concurrent) vs. offline (delayed) tasks, full body movements vs. fine movements of body effectors and goal-directed vs. nongoal-directed actions. Furthermore, self-recognition has been studied by using point-light displays (Loula et al., 2005), the rubber hand illusion paradigm (Botvinick & Cohen, 1998), neuroimaging (for reviews see Legrand & Ruby, 2009; Lenggenhager, Smith, & Blanke, 2006) and more recently, virtual reality paradigms (Lenggenhager, Tadi, Metzinger, & Blanke, 2007). The main methodological technique in self-recognition experiments is to observe and compare self- vs. other-generated action signals. The crucial question is how signals that stem from oneself or another person are monitored and used in order to disambiguate the identity of the bodies and the origin of the actions.

The interplay between efferent and afferent signals is considered a key factor in the sense of agency – the experience that oneself is the cause of an ongoing action (Gallagher, 2000, 2005). Recent evidence suggests that the sense of agency may depend especially on efferent (motor) signals from one's own actions (Engbert, Wohlschläger, & Haggard, 2008; Tsakiris & Haggard, 2005; Tsakiris, Haggard, Franck, Mainy, & Sirigu, 2005). Although efferent information can modulate awareness of an action's timing, the sensory processing of self-generated events and action attribution (Tsakiris & Haggard, 2005), the role of afferent signals in the conscious phenomenal experience of agency remains unclear (Tsakiris, 2008). The meaning of afferent signals for perception is ambiguous because afferent signals may be either self- or externally-generated (i.e., re-afferent or ex-afferent; see also Knoblich & Repp, 2009; Repp & Knoblich, 2007). However, if the pattern of afferent information is such that it seems familiar or evokes resonance in the observer's motor system, it may be sufficient for self-recognition.

Most of the studies that aimed at investigating the role of motor cues in on-line judgments of agency (e.g., Daprati et al., 1997; Sirigu, Daprati, Pradat-Diehl, Franck, & Jeannerod, 1999; Van den Bos & Jeannerod, 2002) have used simple actions of specific body effectors (e.g., finger flexion, hand tapping). By contrast, studies of off-line self-recognition often have used more complex, whole-body actions. Even when human action is depicted by just a few point-lights (Johansson, 1973; for a review, see Blake & Shiffrar, 2007), observers can identify themselves, their friends or strangers from these point-light movement trajectories (Beardsworth & Buckner, 1981; Cutting & Kozlowski, 1977; Jokisch, Daum, & Troje, 2006; Loula et al., 2005; Prasad & Shiffrar, 2009). When walking movements were used, participants were able to recognize themselves and their friends equally well (Cutting & Kozlowski, 1977) and there was only a small advantage for self vs. friend recognition in a study by Beardsworth and Buckner (1981). In both studies, however, recognition rates were barely above chance. In the Loula et al. (2005) study, where a number of different actions were displayed, self-recognition was better than recognition of a friend's movements, although agent recognition was still not above chance for some actions such as walking. Recognition accuracy was action dependent, with the rich kinematic information contained in actions such as dancing affording a higher degree of recognition. In the Jokisch et al. (2006) study, distinction of self and other in walking patterns was achieved, although recognition for other's actions deteriorated when the actions were seen in profile rather than in a frontal viewpoint. By applying viewpoint manipulations, Prasad and Shiffrar (2009) obtained results that led them to conclude that