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Understanding intentions from actions: Direct perception, inference, and the roles of mirror and mentalizing systems

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ABSTRACT

This review asks whether observers can obtain information about others' intentions from observation of their actions; and if so, whether this process is performed using direct perceptual or inferential processes (prominent examples of each being the intention understanding theory of mirror neuron function, and mentalizing accounts of intention understanding, respectively). I propose four conditions that should be fulfilled in order to support a direct perception account, and suggest that only two of these conditions are supported by the existing data. I then propose and review three further sources of evidence which have the potential to inform this debate, concluding that the data do not support the direct perception account. In particular, mirror neurons may be involved in lower-level processes of action perception, but there is no evidence to support their involvement in the type of higher-level intention understanding that is proposed by the direct perception account.

1. Introduction

The overarching question of this special issue is how humans acquire information about other people's mental states. In this review I focus on one particular type of mental state: that of having an intention, i.e. a motive to perform an action in order to produce an effect; and I discuss the processes by which humans can acquire information about others' intentions, i.e. identify *why* an action was performed, from the observation of their actions.

The link between action observation and intention understanding has garnered particular interest over the last two decades due to the discovery of 'mirror' neurons in the macaque (Di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992) and subsequently the human (Mukamel, Ekstrom, Kaplan, Iacoboni, & Fried, 2010) brain. These neurons have been found primarily in motor areas of the macaque brain (although the human data suggest that they may be considerably more widespread) including premotor, primary motor, and parietal cortex (Di Pellegrino et al., 1992; Fogassi et al., 2005; Kraskov, Dancause, Quallo, Shepherd, & Lemon, 2009). The defining characteristic of a mirror neuron is that it fires both when performing an action, and when passively perceiving the same, or a related, action performed either by a conspecific or an experimenter (the perceived action can be presented in either the auditory or visual modality: Cook, 2012; Kohler et al., 2002; but for conciseness, this review will focus on vision as the modality in which the majority of research has been performed). Thus, mirror neurons appear to match the observation of another's action with the motor program that would be required for the observer to produce that action themselves. This characteristic has led to speculation that mirror neurons underlie the ability to

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understand others' intentions by observing their actions. For example, it has been claimed that mirror neurons allow us to "... understand the actions of others by means of our own 'motor knowledge': this knowledge enables us immediately to attribute an intentional meaning to the movements of others" (Rizzolatti & Sinigaglia, 2007, p. 205). The term 'intention' has been used in the mirror neuron literature to refer both to the immediate outcome of an action, and to the higher-level motivation that produced the action. This review focuses on the latter definition because it is more clearly related to the mental state of having an intention. In addition, this definition has excited the most interest precisely because it suggests that mirror neurons provide a mechanism for identifying an actor's underlying intention. However, the evidence either for or against this claim is relatively sparse (Cook, Bird, Catmur, Press, & Heyes, 2014). It is therefore important to establish: whether we can indeed acquire information about others' intentions from observation of their actions; whether this process is performed by mirror neurons, and if not, what are the alternative candidate processes for acquiring information about intentions; and which of these processes is best supported by the existing data.

In Section 2 I review evidence for whether it is possible to acquire information about intentions from the observation of others' actions: is information about intentions indeed present in performed actions, and if so, do observers make use of this information? The third section asks how observers can acquire this information, and sets out the competing possibilities, with reference to the distinction between direct perception and inferential processes described by Michael and de Bruin (2015). I discuss what would constitute evidence for one of these processes over another, and review the current research in this area. I conclude that there is insufficient evidence to support the involvement of mirror neurons in understanding others' intentions, and that the existing data are better explained by the involvement of inferential processes.

2. Can we acquire intentions from actions?

In order to acquire information about an actor's intentions from the observation of their actions, two conditions need to be fulfilled (see Ansuini, Cavallo, Bertone, & Becchio, 2014, for a more detailed discussion of this literature). First, there need to exist reliable perceptual differences between actions performed with different intentions; and second, observers must be able to detect and utilise these differences to make judgements about the actor's intentions.

2.1. Intentions modulate action kinematics

A substantial body of evidence indicates that an actor's intentions can indeed modulate the kinematics of their subsequent action. Importantly, the kinematics of reach-to-grasp actions are modulated even when actions are performed on the same object, but with different intentions. Thus Marteniuk and colleagues (1987) demonstrated differences in the kinematic profiles of actions when the actor's intention was to place an object carefully into a small container, versus into a large box (see Ansuini, Giosa, Turella, Altoè, & Castiello, 2008; Ansuini, Santello, Massaccesi, & Castiello, 2006, for a similar result). Consistent with these results, Schuboe and colleagues (2008) showed kinematic differences between actions towards a bottle depending on whether the intention was to pour or to place the bottle; and a comprehensive set of studies from Becchio and colleagues demonstrated differences in kinematics between cooperative and competitive actions, between social and non-social actions, and between individual and communicative actions (Becchio, Sartori, Bulgheroni, & Castiello, 2008; Georgiou, Becchio, Glover, & Castiello, 2007; Sartori, Becchio, Bara, & Castiello, 2009). Most recently, Naish and colleagues (2013) demonstrated systematic differences between the kinematic profile of reach-to-grasp movements depending on whether the intention of the movement was to place an object or to bring it to the mouth. Thus it appears that actions performed with different intentions do result in reliable kinematic, and thus presumably perceptual, differences.

2.2. Do observers use action kinematics to acquire intention information?

Whether observers are able to use these kinematic differences to make judgements about an actor's intentions is less clear-cut. Work from Becchio and colleagues indicated that observers can use kinematic information to judge whether actions are performed in a competitive or cooperative context (Sartori, Becchio, & Castiello, 2011); and that observers can extract and use this kinematic information to make such judgements even from relatively degraded point-light displays (Manera, Becchio, Cavallo, Sartori, & Castiello, 2011). Similar results from Stapel and colleagues (2012) indicated that observers use kinematic information to determine whether an actor intends to continue walking or to crawl in order to reach a target object. In contrast, Naish et al. (2013) demonstrated that observers were not able to use kinematic information to decide whether an actor was performing a reaching movement in order to place an object, or in order to eat it. This inability to acquire intention information from kinematics is perhaps surprising since there were reliable differences between the kinematic profiles of these two types of action (see Section 2.1). However, Naish et al. did not test whether participants were able to *detect* a difference between the two profiles (for example, by using a delayed match to sample task). Such a task would establish whether the differences between the two kinematic profiles were not perceived by the observers, or whether these differences were perceived but instead observers were unable to label or identify the profiles as 'reach-to-place' versus 'reach-to-eat'.

In conclusion, it appears that in most cases observers are able to use kinematic information to acquire information about actors' intentions; but it will be important for future work to establish whether failures to use such information are due to an