Cognition 132 (2014) 383–397

Contents lists available at ScienceDirect

Cognition

journal homepage: www.elsevier.com/locate/COGNIT

The phenomenology of controlling a moving object with another person

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ARTICLE INFO

Article history:
Received 8 October 2013
Revised 19 March 2014
Accepted 6 May 2014

Keywords:
Agency
Control
Joint action
Phenomenology

ABSTRACT

The phenomenology of controlling what one perceives is influenced by a combination of sensory predictions and inferential processes. While it is known that external perturbations can reduce the sense of control over action effects, there have been few studies investigating the impact of intentional co-actors on the sense of control. In three experiments, we investigated how individuals' judgments of control (JoC) over a moving object were influenced by sharing control with a second person. Participants used joysticks to keep a cursor centered on a moving target either alone or with a co-actor. When both participants' actions had similar perceptual consequences, JoC ratings were highest when self-generated movements were the only influence on the cursor, while the appearance of sharing control with a second person decreased JoC ratings. By contrast, when participants performed complementary actions with perceptually distinctive consequences, JoC ratings were highest when both participants were able to influence the cursor. The phenomenology of control during joint action is influenced by low-level visuomotor correlations, the presence of competing causal influences, and group-level performance.

1. Introduction

To control something is to act in order to bring it to a pre-specified condition, possibly in the face of external forces or changes in the environment that tend to alter it (Powers, 1978). This broad definition encompasses most purposeful human behavior, as voluntary actions are usually performed with the intent of producing a particular change in the environment that can be perceived as a sensory outcome of performance (henceforth "action effects").

The question of what processes contribute to the phenomenology of controlling what one perceives has motivated much research. The emerging consensus is that the sense of control is not a unitary phenomenon, but rather depends on a combination of efferent motor signals, sensory predictions and higher level cognitive processes (Haggard & Tsakiris, 2009; Pacherie, 2008; Synofzik, Vosgerau, & Newen, 2008). The sense of control over body movements is thought to depend on a system of sensorimotor comparators which detects discrepancies between sensory predictions triggered by efferent motor signals, and actually executed movements (Blakemore, Wolpert, & Frith, 1998; Frith, 2012; Tsakiris, Haggard, Franck, Mainy, & Sirigu, 2005). Sensory predictions also influence the sense of control over distal events outside the body. For example, auditory stimuli triggered by keystrokes are more likely to be attributed to external sources when the timing or frequency is different from what was expected (Knoblich & Repp, 2009; Sato & Yasuda, 2005).

The sense of control can also be influenced by inferential processes. For example, priming unintended action effects has been shown to increase feelings of authorship,

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http://dx.doi.org/10.1016/j.cognition.2014.05.002
0010-0277/

which suggests one's own causal role may be inferred post hoc from the match between a prior mental state and a subsequent action effect (Aarts, Custers, & Wegner, 2005; Moore, Wegner, & Haggard, 2009; Sato, 2009; Wegner & Wheatley, 1999). The sense of control may be further modulated by the fluency of action selection (Haggard & Chambon, 2012), and by the magnitude and valence of action effects (Aarts, Wegner, & Dijksterhuis, 2006; Kawabe, 2013).

Although there has been progress in understanding the mechanisms which contribute to a sense of control, the types of task environments that have been studied are limited in scope. Many investigators have focused on the phenomenology of causal initiation, i.e. the sense of agency. In these experiments, participants are typically asked to rate their agreement that a brief event such as a tone (e.g. Engbert, Wohlschlõger, & Haggard, 2008; Sato & Yasuda, 2005), the sudden appearance of a visual stimulus (e.g. Linser & Goschke, 2007; Sato, 2009), or the sudden stopping of a previously moving stimulus (e.g. Aarts et al., 2005; Jones, de-Wit, Fernyhough, & Meins, 2007; Wegner & Wheatley, 1999) was caused by their own prior action. Although interesting in its own right, causal initiation does not guarantee that an entire action will be experienced as controlled (Pacherie, 2007). One may initiate an event, but lose control as it unfolds over time, as for example when one loses control of an automobile while driving. Yet there have been relatively few studies investigating the sense of control for events lasting longer than a few milliseconds (but see Dewey, Seiffert, & Carr, 2010; Metcalfe & Greene, 2007).

Another limitation of research in this area has been the focus on individuals performing tasks in isolation. In everyday life people often act in a social context, performing joint actions with others. Joint action can be defined as a social interaction where individuals coordinate their actions to bring about a change in the environment (Sebanz, Bekkering, & Knoblich, 2006). There are some studies which have investigated the sense of agency and related processes in social contexts (e.g. Desantis, Weiss, Schütz-Bosbach, & Waszak, 2012; Dewey & Carr, 2013; Obhi & Hall, 2011a,b; Wegner & Wheatley, 1999). Typically, participants perform a task either with or without a partner, but only one agent actually controls the stimulus at any given time. By contrast, we were interested in situations in which two actors share control. For example, consider white water rafting with a group. In this scenario, the motion of the raft is jointly determined by several people working together with a more or less common purpose, plus some unpredictable perturbations caused by the water currents. In a situation like this, what are the implications for the individual's sense of control? Can people distinguish their own contributions from the contributions of their co-actors? Are the contributions of co-actors perceived as perturbations that reduce the individual's sense of control? Or do the contributions of co-actors increase the individual's sense of control by facilitating attainment of shared goals? To begin addressing these questions, in the present study we investigated the phenomenology of control during a cooperative joint action lasting several seconds.

1.1. The sense of control during joint action

A fundamental question is whether the sense of control during cooperative joint actions engages the same processes which shape the sense of control during individual action, or if it is in some sense a special case. One possibility is that the sense of control is essentially egocentric, depending on the perception of a causal relationship between one's motor inputs and the perceived action effect. In this case the contributions of a co-actor might be experienced as external perturbations if both agents tried to manipulate an object at the same time. On the other hand, if each agent's contribution was perceptually distinctive (for example, the two agents take turns manipulating an object), the egocentric hypothesis predicts that the co-actor's actions would have little impact on the sense of control.

An alternative to the egocentric hypothesis is that the contributions of a cooperative co-actor might increase the sense of control due to the agents' shared intentions. There is evidence that when individuals feel themselves to be part of a group, this can influence action-perception links, including response times (Tsai, Sebanz, & Knoblich, 2011), the perceived timing of actions and their effects (Obhi & Hall, 2011a), and the sensory attenuation of effects generated by another person (Weiss, Herwig, & Schütz-Bosbach, 2011). A catch-all term for these effects of shared intentionality is the "we-mode" (Gallotti & Frith, 2013). Cognition in the we-mode might lead individuals to evaluate control at a group level, e.g. based on the success of the joint action. We will refer to this as the joint control hypothesis. With this background, we considered three non-exclusive ways in which actions performed by agent B might influence agent A's sense of controlling the action effect during a cooperative joint action.

Action effect predictability. When individuals perform tasks alone, the sense of control is influenced by congruence between intended, predicted, and actually perceived action effects. Thus, one way agent B could influence agent A's sense of control is by altering the objective correlation between agent A's motor inputs and the action effect, whether positively or negatively (Fig. 1a). This could be characterized as an impact at the level of egocentric sensory predictions. There could also be an impact of action effect predictability at a perceptual level that does not depend on motor signals. In that case, predictable contributions from agent B might increase agent A's sense of control even if they did not correlate with agent A's motor inputs. The latter possibility would be consistent with the joint control hypothesis.

Performance cues. A second possibility is that agent B's contribution to a joint action could modulate agent A's sense of control by causing the joint action to be more or less successful (Fig. 1a). Positive outcomes can lead to illusions of control, particularly when people are led to believe the outcome is skill dependent (Langer, 1975). For example, acquisition of a goal can influence judgments of control over moving objects, even leading individuals to overlook minor discrepancies between predicted and observed action effects (Dewey et al., 2010; Metcalfe & Greene, 2007). Performance cues can also have a