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Short Communication

When moving without volition: Implied self-causation enhances binding strength between involuntary actions and effects

Myrthel Dogge [a], Marloes Schaap [a], Ruud Custers [a], Daniel M. Wegner [b], Henk Aarts [a,*]

[a] Department of Psychology, Utrecht University, PO Box 80 140, 3508 TC Utrecht, The Netherlands
[b] Department of Psychology, Harvard University, 33 Kirkland St., Cambridge, MA 02138, USA

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ABSTRACT

The conscious awareness of voluntary action is associated with systematic changes in time perception: The interval between actions and outcomes is experienced as compressed in time. Although this temporal binding is thought to result from voluntary movement and provides a window to the sense of agency, recent studies challenge this idea by demonstrating binding in involuntary movement. We offer a potential account for these findings by proposing that binding between involuntary actions and effects can occur when self-causation is implied. Participants made temporal judgements concerning a key press and a tone, while they learned to consider themselves as the cause of the effect or not. Results showed that implied self-causation (vs. no implied self-causation) increased temporal binding. Since intrinsic motor cues of movement were absent, these results suggest that sensory evidence about the key press caused binding in retrospect and in line with the participant's sense of being an agent.

1. Introduction

Humans engage in voluntary actions, which enable them to manipulate and control their environment, instead of being enslaved by it. Voluntary action is usually accompanied by a sense of agency that is central to social belief systems regarding whether one can influence the external world (Aarts & van den Bos, 2011; Haggard & Tsakiris, 2009; Wegner, 2002). A key mechanism underlying sense of agency is the association between one's actions and action-consequences that is produced by a general associative mechanism involving internal prediction models of sensorimotor control (Frith, Blakemore, & Wolpert, 2000). This linkage causes systematic distortions in the temporal experience of voluntary movements (Haggard & Tsakiris, 2009). Specifically, people perceive their voluntary actions and resulting consequences as if they are temporally bound together in conscious awareness; a phenomenon that is referred to as intentional binding (Haggard, Clark, & Kalogeras, 2002).

In the last decade intentional binding has become one of the most widely used implicit measures to study consciousness of action (Haggard & Tsakiris, 2009). Especially the notion that perceptual attraction between actions and effects results from voluntary movement (i.e. when movement is self-initiated and motor cues can predict the sensory effects), but not from involuntary movement (i.e. when movement is triggered externally and motor cues cannot predict the sensory effects) is taken as good evidence for considering the intentional binding effect as a marker of agency. While this finding has been often replicated (Haggard & Clark, 2003; Haggard et al., 2002; Tsakiris & Haggard, 2003), recent studies have reported binding in the absence of voluntary action (Moore, Wegner, & Haggard, 2009; Strother, House, & Obhi, 2010). These findings challenge

* Corresponding author.
E-mail address: h.aarts@uu.nl (H. Aarts).

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the idea that temporal binding only results from voluntary action, and hence represents an implicit measure of the sense of agency.

The present study examines temporal binding between action (a key press) and effect (the occurrence of a tone) in involuntary movement and offers a general account for how binding can arise in the absence of volitional control of action. Specifically, based on the role of inferential influences in binding action to effect (Moore & Haggard, 2008) and the pivotal role of cognition in biasing the process involved in experiences of agency and self-causation (Aarts & Van Den Bos, 2011; Van Der Weiden, Aarts, & Ruys, 2010; Wegner, 2002), we investigate whether implied self-causation can cause participants to bind action and effect together in time even though the action is involuntarily triggered. In other words, we explore whether temporal binding can occur for involuntary actions in individuals who are encouraged to consider their action to cause effects while lacking actual causation.

Previous studies have emphasized the contribution of internal motor cues to intentional binding. In particular, it has been suggested that the temporal linkage of actions and subsequent effects is generated as a consequence of a comparison between the predicted and actual consequence that follows from a motor act. When the predicted and actual information match, people experience self-agency. Recent studies have provided evidence for this idea. For instance, Engbert, Wohlschläger, and Haggard (2008) revealed that binding is similar for auditory, visual and somatic effects, and as such, the entire motor system is involved in the sense of agency. In addition, temporal attraction between movements and subsequent consequences is augmented when people are exposed to reward related information before they perform a voluntary action (Aarts et al., in press). This supports the role of motor prediction processes in binding, because dopamine activations are shown to affect the neural substrates of internal preparation and control of motor movement, such as the supplementary and pre-supplementary motor areas (Nachev, Kennard, & Husain, 2008; Sperduti, Delaveau, Fossati, & Nadel, 2011). Furthermore, disturbance of internal forward models, such as in people suffering from schizophrenia, is associated with diminished intentional binding strength resulting from motor predictive processes (Voss et al., 2010).

The idea that intentional binding depends on motor predictive processes suggests that binding should not occur when internal motor cues are absent (i.e. when prediction of action-consequences is not possible, such as in involuntary movement). Consistent with this claim, no binding is observed when an effect is preceded by a passive movement induced by transcranial magnetic stimulation (Haggard & Clark, 2003; Haggard et al., 2002), or when people observe an outcome caused by others (Engbert, Wohlschläger, Thomas, & Haggard, 2007; Engbert et al., 2008). Whereas motor prediction processes resulting from voluntary action seem important for intentional binding to occur, recent research suggests that voluntary action may not be the key to intentional binding, and hence motor predictive processes might not be a precondition for this effect. For instance, one study has revealed binding in participants who had no objective role in bringing about the outcome of an action (Moore, Lagnado, Deal, & Haggard, 2009; Moore, Wegner, et al., 2009). Participants engaged in an involuntary key press that was followed by a either a low or a high pitch tone. Prior to the movement one of these tones could be presented as a prime. The interval between the press and the tone was perceived to be smaller (i.e. binding occurred), when the prime matched the outcome. The authors explain this result by proposing that prior conscious thought (in this study induced by priming), strengthens the feeling that actions and effects are related. This influence of conscious thought is especially strong in the absence of other intrinsic (motor) cues to agency, such as when one engages in an involuntary movement.

Another study revealed that temporal judgements of actions and effects produced by others are similar to those produced by oneself in the context of shared actions (Strother et al., 2010). In this study participants performed the intentional binding task in pairs. Both participants were instructed to prepare and execute a key press during each trial, provided that the other participant had not pressed the key first. If participants were not the first to produce a press they were instructed to passively move their finger in concert with the other's press. Similar binding for self-generated and other-generated actions was observed, even when only one participant of the pair was instructed to plan and generate the action. These results are interpreted in the context of shared action representations; observing the act of another person activates the representations of these actions in the observer's brain which mediates binding.

Although the perceptual attraction between involuntary actions and effects is interpreted differently in the two abovementioned studies, they may share a common theme. That is, the observed binding might have resulted from the suggestion that participants had a causal role in producing the outcome, even though they did not have such a role in reality. This implied self-causation might have resulted from prior thoughts about the tone (Moore, Lagnado, et al., 2009; Moore, Wegner, et al., 2009) and from the goal to produce the tone together with the other participant (Strother et al., 2010). In other words, contextual cues may induce people to experience a sense of agency and allow them to consider themselves to be the cause of effects following their involuntary movement. The present study investigates this idea by examining whether implied self-causation can generate temporal binding in the absence of voluntary action.

One account that can explain how implied self-causation affects binding between involuntary actions and effects, focuses on the idea that consciousness of action arises from inferential processes. On this view, people use sensory evidence about an action to retrospectively generate the experience of a movement (Aarts, Custers, & Marien, 2009; Wegner & Wheatley, 1999). That is, when prior thoughts of an effect correspond to the actual effect that follows an (involuntary) action, this consistency is used to infer feelings of agency (Ebert & Wegner, 2010). In line with this idea, we suggest that implying self-causation might augment binding by increasing the perceived causal relationship between the thought, action and following effect.

The idea that not only predictive processes but also inferential processes play a role in intentional binding is supported by research on voluntary action (Moore & Haggard, 2008; Moore, Lagnado, et al., 2009; Moore, Wegner, et al., 2009). For instance, one study showed that both the predicted and the actual sensory consequence of an action contribute to binding,