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Perceiving by proxy: Effect-based action control with unperceivable effects

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ABSTRACT

Anticipations of future sensory events have the potential of priming motor actions that would typically cause these events. Such effect anticipations are generally assumed to rely on previous physical experiences of the contingency of own actions and their ensuing effects. Here we propose that merely imagined action effects may influence behaviour similarly as physically experienced action effects do. Three experiments in the response–effect compatibility paradigm show that the mere knowledge of action–effect contingencies is indeed sufficient to incorporate these effects into action control even if the effects are never experienced as causally linked to own actions. The experiments further highlight constraints for this mechanism which seems to be rather effortful and to depend on explicit intentions.

1. Introduction

1.1. Effect-based action control

How can we achieve what we want? Except in the land of milk and honey, we have to act in order to reach our goals; that is, we have to move our body. In order to understand how such movements are controlled, one needs to understand how potential goals are linked to the physical movements required for goal attainment. It would certainly be helpful if states that might become goals later on were directly linked to motor patterns reliably producing them. Perceiving or merely imagining an intended future state could then reactivate a motor pattern leading to its realization.

That is essentially what ideomotor theories of action control propose (Hommel, Müsseler, Aschersleben, & Prinz, 2001; Kunde, 2001; Shin, Proctor, & Capaldi, 2010). These theories even go one step further by assuming that motor patterns can only be controlled voluntarily through the mental recollection (anticipation) of the effects these motor patterns produce. Consequently, every motor action must be preceded by a recollection of the sensory effects of that action. Anticipated sensory consequences of own actions thus constitute a central aspect of human action control.

Evidence for this claim comes from studies using the *response–effect* (*R–E*) *compatibility paradigm* (e.g., Kunde, 2001; Pfister, Kiesel, & Melcher, 2010). In this paradigm, participants perform actions that produce contingent sensory effects; most importantly, employed actions and effects share certain features on a physical dimension (Kornblum, Hasbroucq, & Osman, 1990; Prinz, 1992, 1997). For instance, left vs. right actions might produce visual action effects to the left or right (Kunde, 2001; Pfister et al., 2010) or short vs. long key presses might trigger short vs. long effect tones (Kunde, 2003). In the R–E compatible condition, responses produce effects with corresponding features (e.g., short key press ► short effect

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tone, long key press ► long effect tone), whereas in the R–E incompatible condition, responses produce effects with non-corresponding features (e.g., short key press ► long effect tone, long key press ► short effect tone). A consistent finding across numerous studies is that responses are faster in the R–E compatible condition than in the R–E incompatible condition (see also Badets, Koch, & Toussaint, 2013; Hubbard, Gazzaley, & Morsella, 2011; Janczyk, Pfister, & Kunde, 2012; Kunde, Pfister, & Janczyk, 2012; Rieger, 2007). Because action effects only appear after action execution, R–E compatibility effects are a straightforward measure of anticipative processes as assumed by ideomotor theory.

Before being able to exploit such effect anticipations, however, the agent clearly needs to acquire action–effect associations and current theoretical accounts widely agree that the corresponding R–E associations are built by experiencing the contingent pairing of specific actions and their respective outcomes either by oneself (e.g., Elsner & Hommel, 2001, 2004; Hoffmann, Lenhard, Sebald, & Pfister, 2009; Wolfensteller & Ruge, 2011) or through observational learning (Paulus, van Dam, Hunnius, Lindemann, & Bekkering, 2011). But is physical experience of this contingency indeed a necessary precondition to build up associations between actions and their ensuing effects? Here we propose that, even though prior experience is the most common mechanism for acquiring R–E associations, action effect associations may also be forged by knowledge of action–effect contingencies alone.

This speculation rests on two theoretical building blocks: First, human agents need to be able to build up sensory representations of events they do not actually experience themselves and, second, they need to be able to implement those representations into action control. Evidence for these two preconditions comes from two rather distinct fields of research as we describe in the following sections.

1.2. Representing non-perceived events: Imagery and empathy

Introspective experience shows that active imagery allows reliving past events quite vividly. And indeed, imagery does seem to draw on rather similar functions as actual perception (see Kosslyn, 1994, for an overview on classic theories and findings). For instance, imagining and perceiving an event seem to recruit similar mental processes (Borst & Kosslyn, 2008; Tlauka & McKenna, 1998) and they elicit neural activity in largely similar cerebral regions (e.g., Ganis, Thompson, & Kosslyn, 2004; Halpern & Zatorre, 1999; Kosslyn et al., 1993). Furthermore, imagery causes stronger neuronal responses the more vivid it is (Cui, Jeter, Yang, Montague, & Eagleman, 2007). These studies clearly suggest that merely imagined events are represented much like actually perceived ones.

A related line of research that documents sensory representations of non-perceived events is research on human empathy (Decety & Jackson, 2004; Preston & de Waal, 2002): Seeing or even imagining the state of another person inevitably elicits a representation of how this state feels for the other and this representation motivates own behaviour. Accordingly, empathy is a "process which allows us to experience what it feels like for another person to experience a certain emotion or sensation (e.g., qualia)" (Singer, 2006, p. 856). This definition comprises both, affective components as in emotional contagion – corresponding to the use of empathy in folk psychology – as well as non-emotional sensory components. Moreover, empathy can be driven by merely anticipated future states (Batson, Early, & Salvarani, 1997; Royzman, Cassidy, & Baron, 2003) which can also include sensory experiences of other agents (Keysers et al., 2004; Schaefer, Xu, Flor, & Cohen, 2009).

Importantly, perception and imagination of another person's state seem to draw on the same mechanisms as actually experiencing this state oneself (Preston & de Waal, 2002). For example, perceiving disgusted faces automatically activates brain areas which would similarly respond to disgusting odours (Wicker et al., 2003). And what is true for emotional episodes also holds true for non-emotional sensory events: Observing someone else being touched seems to activate brain areas that are associated with the very feeling of being touched (Keysers et al., 2004). These findings suggest that human agents are able to spontaneously represent sensory experiences that they did not experience themselves. Such representations might also allow for effect-based action control if human agents are able to implement them into action control by mere intention.

1.3. Intentional control over automatic associations

Evidence for the power of intentions in forging automatic associations comes from recent studies on instruction-induced congruency effects (e.g., Cohen-Kdoshay & Meiran, 2007, 2009; Kunde, Kiesel, & Hoffmann, 2003; Liefooghe, Wenke, & De Houwer, 2012; Wenke, Gaschler, & Nattkemper, 2007). These studies indicated that usual interference effects such as flanker interference can arise even for stimuli that were simply mapped to a certain response by instruction without any actual experience. For instance, if participants are to classify bivalent stimuli according to one dimension (e.g., responding to the colour of coloured shapes), merely instructing an additional response mapping for the irrelevant dimension (e.g., shape) creates congruency effects even if the additional mapping has not been executed a single time (Wenke et al., 2007). Similarly, human agents seem to be able to counteract automatic processes by mere intentions to some degree by instantiating new intentions in terms of new task rules or specific plans (e.g., Adriaanse, Gollwitzer, de Ridder, de Wit, & Kroese, 2011; Waszak, Pfister, & Kiesel, 2013).

These findings suggest that intentions and knowledge alone have a considerable power to link representations of task-relevant events (in this case: stimuli) to motor responses. Similar processes might also take place for binding actions to their merely imagined effects, i.e., to forge bidirectional R–E associations without any physical experience of the action–effect contingency.