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Sense of agency for movements

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ABSTRACT

In this paper, we argue that the comparator model is not a satisfactory model of sense of agency (SoA). We present a theoretical argument and experimental studies. We show (1) most studies of SoA neglect a distinction between SoA associated with movements (narrow SoA) and SoA associated with environmental events (broad SoA); (2) the comparator model emerges from experimental studies of sensory consequences narrowly associated with movements; (3) narrow SoA can be explained by a comparator model, but a motor signal model is simpler and explain narrow SoA equally well; and (4) standard experimental paradigms study only broad SoA. Finally, we present results from two experiments, where we have failed to induce illusory narrow SoA in healthy participants. We believe our experimental approaches should have led to illusory SoA, if the comparator model of SoA was correct. The results challenge proponents of the comparator model of narrow SoA.

1. Introduction

Many cognitive scientists accept that agents experience a sense of agency (SoA) when they perform voluntary actions. SoA has often been claimed to play important roles in motor control and motor cognition (Haggard, 2017; Jeannerod, 2006; Longo & Haggard 2009; Moore, Ruge, Wenke, Rothwell, & Haggard, 2010). For many years, the dominant model to explain these experiences and functional roles has been the so-called comparator model (Frith, 1987, 2015). In this paper, we argue that the comparator model is highly problematic as a model of SoA. Our argument is partly theoretical and partly experimental.

Theoretically, we show that researchers in their characterisations of the SoA often shift from describing SoA as associated with bodily movements to describing it as associated with the planned consequences of the movements (e.g. auditory or visual events) (Sections 2). Researchers often shift between understanding SoA in terms of control of bodily movements and in terms of control of external events. This shift is problematic for two reasons. First, the comparator model is a model of motor control. At its core, it comprises a mechanism or module that uses motor signals to compute likely proprioceptive feedback and feedback related to eye movements. It is problematic to cast this module in the role of a mechanism for predicting all kinds of likely sensory consequences (Section 3). Second, even insisting that the comparator model for SoA is primarily a model for the SoA associated with movements (and not their consequences) turns out to be problematic. Reviewing the experimental literature shows that all standard SoA-paradigms are paradigms for studying the feeling of control over external events (Section 4).

Experimentally, we test the claim that SoA for movements is produced by a comparator mechanism (Section 5). Given the

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comparator model of SoA, we can predict situations in which agents should experience illusory SoA. That is, there should be situations in which agents are passively moved but it feels to them as if they moved voluntarily. Using a new paradigm, we test this prediction. The experiments show no illusion effects. To be sure, null results do not demonstrate anything; but the results nevertheless pose a serious challenge to proponents of the comparator model of explaining why inducing illusory SoA for movements is so difficult.

Taken together, the theoretical and experimental arguments show that the comparator model of SoA is highly problematic (Section 6). The near absence of paradigms to study the SoA for movements has made it difficult to test the comparator model and develop alternative proposals. One proposal that would explain the results of the experiments presented in this paper would be a model according to which SoA for movements can be driven primarily by motor signals.

2. SoA for movements

A persistent form of confusion creates problems for neuro-cognitive research on SoA. In this section, we illustrate a prominent version of this confusion. In a recent review, Haggard characterises SoA in the following way:

> *The sense of agency is the feeling of making something happen. It is the experience of controlling one's own motor acts and, through them, the course of external events. […] the experience that occurs before, during and after actual muscular movement, rather than on beliefs or facts about potential actions. Thus, I use the term sense of agency to refer to an experience that accompanies the performance of a specific motor act.* (Haggard, 2017, p. 197)

Two different ideas are manifest in Haggard's definition of SoA. First, SoA is tied to specific motor acts. Here the idea is that a specific kind of feeling of activity is accompanying my voluntary movements but not the involuntary ones. Second, SoA is characterised as a broader phenomenon that refers to an experience that covers the complete temporal stretch of the action: preparation, motor performance, and environmental consequences. So, not only is SoA a strictly movement-related phenomenon, it is also the feeling an agent might have that she is the one controlling the occurrence of some environmental event (say, making a doorbell ring or turning on a light by pressing a button).

A confusion is created when these two ideas in the characterisation of SoA are coupled with one common, simple explanatory mechanism. The comparator model of motor control offered a simple way to explain the movement-related SoA. Often without noticing, this model of motor control has been extended also to the explanation of the feeling of control over external events. In the next section, we will look more closely at the way in which the comparator model, originally developed to explain a set of motor related phenomena, has been used to explain also the feeling of control over external events. For now, we will focus on the two ideas manifest in Haggard's characterisation of SoA.

In what follows, we will call the SoA narrowly associated with voluntary movements *the narrow SoA* and the broader notion of a feeling of control over environmental events *the broad SoA*. Narrow SoA is only related to the bodily movements, whereas broad SoA includes additional events in the environment that accompany the bodily movement (see Christensen & Grünbaum, 2017, for a further description of this distinction). The distinction between the two becomes evident when the same bodily movement, for instance, the movement of one's finger, can lead to several different events in the environment, such as a light that turns on or a doorbell that rings.

The confusion consists in using the same motor control mechanism to explain both the narrow SoA and the broad SoA. This enlargement of scope often goes unnoticed for the reason that researchers often have been inattentive to the distinction between narrow and broad SoA. Some researchers define SoA in relation to movements (for instance, Lynn, Muhle-Karbe, Aarts, & Brass, 2014, p. 1: "[…] sense of agency, i.e., the intrinsic sensation of being in control of one's own actions." See also Gallagher, 2000, p. 15, Synofzik, Vosgerau, & Voss, 2013, p. 1). Some researchers emphasize the control of external events (for instance, Wen, Yamashita, & Asama, 2016, p. 1: "The ubiquitous experience of a subjective feeling of control over the outcome of events through one's behaviour refers to sense of agency."). Finally, some researchers include both movements and external effects in their definition of SoA (for instance, Caspar, Christensen, Cleeremans, & Haggard, 2016, p. 585: "Sense of agency refers to the subjective experience of controlling one's actions, and, through them, external events". See also Dewey & Knoblich, 2014, p. e110118, Moore, Middleton, Haggard, & Fletcher, 2012, p. 1748, Spaniel et al., 2015, p. 916). The important point here is not so much the differences in stressing movements or external events in the definitions of SoA but the fact that the distinction between narrow and broad SoA has gone unnoticed and that both aspects of SoA are coupled with the same explanatory mechanism (i.e., the comparator mechanism), as will become apparent in the next section.

As is common, Haggard (2017) distinguishes between, on the one hand, SoA understood as an experience or low-level phenomenal feeling and, on the other hand, beliefs or judgements about one's action and its environmental consequences (see Synofzik, Vosgerau, & Newen, 2008). The above-mentioned confusion is not a neglect of this distinction between sense of agency (SoA) and judgements of agency (JoA). The confusion concerns only the definition and explanation of SoA. It is with respect to the standard characterisation of SoA that researchers have neglected to acknowledge the distinction between narrow and broad SoA.

Our focus in the present paper is the narrow SoA, i.e. the SoA associated with the performance of specific motor acts (rather than distal consequences of movements). There are reasons for thinking that the performance of voluntary movements is associated with a distinctive kind of experience. When I place my hand on the table in front of me and lift my index finger, I have an experience of moving my finger upwards. Such simple examples make it intuitively appealing that there is a sense of activity directly related to one's bodily movement. The extent to which this experience is clear may depend on the amount of attention paid to the movements. These intuitions are corroborated by experimental evidence suggesting that there is a distinct type of experience associated with motor performance. These studies have either used direct electrical cortical stimulation during surgery (Desmurget et al., 2009; Fried