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Short Communication

Power to the will: How exerting physical effort boosts the sense of agency

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ABSTRACT

The sense of agency refers to the experience of being in control of one's actions and their consequences. The 19th century French philosopher Maine de Biran proposed that the *sensation of effort* might provide an internal cue for distinguishing self-caused from other changes in the environment. The present study is the first to empirically test the philosophical idea that effort promotes self-agency. We used intentional binding, which refers to the subjective temporal attraction between an action and its sensory consequences, as an implicit measure of the sense of agency. Effort was manipulated independent of the primary task by requiring participants to pull stretch bands of varying resistance levels. We found that intentional binding was enhanced under conditions of increased effort. This suggests not only that the experience of effort directly contributes to the sense of agency, but also that the integration of effort as an agency cue is non-specific to the effort requirement of the action itself.

1. Introduction

A unifying human experience is the intrinsic sense that one maintains voluntary control over their actions, thereby shaping the environment in a goal-directed manner. This subjective experience of self-causation is commonly referred to as the *sense of agency* (SoA). The SoA is considered to be a crucial component of human volition (Haggard, 2008) and can also be seen as an important motivator of goal-directed behavior, as it nurtures the belief that we as individuals are capable of attaining the goals we wish to pursue (Bandura, 1997; Bandura, 2001).

A less addressed component of voluntary action is the *sensation of effort*. Although it has been considered to be an essential phenomenological aspect of action control (Pacherie, 2008), its precise contribution to agentic experiences remains unclear. More than two centuries ago, the French philosopher Maine de Biran (1805) argued that subjective sensations of effort may constitute a central internal cue for inferring the self in interaction with the environment (see Lafargue & Franck, 2009 for a contemporary account). This concept of effort as a precondition for the rise of coherent experiences of self-agency has also proven useful in explaining abnormal agency attributions (i.e., passivity symptoms) in patients with Schizophrenia (Daprati et al., 1997; Frith, 1992; Frith, Blakemore, & Wolpert, 2000; Lafargue, Franck, & Sirigu, 2006). Nevertheless, a direct link between effort and the SoA has yet to be established.

The aim of the current study is to determine whether sensations of physical effort are used to infer one's agency over the outcomes of an action. If this assumption holds true, then it should be possible to bias the SoA by means of an experimental effort manipulation. Moreover, it has been argued that the sense of effort is rather abstract in

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nature, and integrates signals from various channels (Baumeister, Bratslavsky, Muraven, & Tice, 1998; Baumeister, Muraven, & Tice, 2000; Preston & Wegner, 2009). Hence, exerting effort may prime self-agency even under conditions in which the primary task is not directly related to the effort source. We explored this question using the intentional binding (IB) paradigm as an implicit measure of the SoA (Haggard, Aschersleben, Gehrke, & Prinz, 2002; Haggard, Clark, & Kalogeras, 2002). IB refers to the temporal attraction of a voluntary action and its sensory consequences within the actor's perception (see Moore & Obhi, 2012 for a review). This phenomenon has been linked to the SoA, as it is more pronounced for intentional actions than for less controlled actions such as passive movements, or for observed actions performed by other agents (Engbert, Wohlschlager, & Haggard, 2008; Engbert, Wohlschlager, Thomas, & Haggard, 2007; Haggard, Aschersleben, et al., 2002; Moore, Wegner, & Haggard, 2009). More evidence for the relation between IB and the SoA was provided by recent studies that found IB to be sensitive to both dispositional and experimentally induced beliefs about self-causation of action outcomes (Aarts & van den Bos, 2011; Desantis, Roussel, & Waszak, 2011; Haering & Kiesel, 2012). This corroborates the notion that IB reflects '*the extent to which goal-directed behavior is perceived as intentional and self-caused*' (Aarts & van den Bos, 2011 pp. 535).

The present study was designed to test whether inducing different levels of task-unrelated physical effort could modulate IB. To this end, participants were asked to hold stretch bands of either low or high resistance while performing an IB task. Hypothesizing that effort sensations promote the experience of self-agency, we expected IB to be enhanced in conditions with high physical effort.

2. Method

2.1. Participants

Thirty-six undergraduate students (eight male) from Ghent University participated in the study, receiving either course credit or a monetary compensation in return.

2.2. Effort manipulation

Effort was manipulated with latex resistance bands (Thera-Band®) that are typically used for physical exercise. Participants were asked to hold a band in their left hand for the full duration of a block. The band was held with the left arm bent in an 'arm-wrestling' pose (see Fig. 1 for a graphical illustration of the setup). To vary the degree of required effort, each participant utilized two different stretch bands in the course of the experiment. One of these bands had a low resistance level (*low effort condition*), whereas the other band required a much stronger force to be held in the required position (*high effort condition*). It is important to note that the same arm position was maintained across conditions. To induce relatively similar levels of effort in all participants, we decided to use bands of different resistance for male and female participants. For female participants, the amount of force needed to hold the band in the correct position was approximately 28 N in the low effort condition and 49 N in the high effort condition. For male participants the respective resistance values were 37 N and 67 N. An instruction screen that was displayed in advance of each experimental block indicated which band participants had to hold for the duration of the next block (approximately 150 s).

Fig. 1. Experimental setup: 'arm-wresting' pose adopted for the effort manipulation.

2.3. Procedure

IB was assessed using a modified version of the method introduced by Haggard, Aschersleben, et al. (2002), Haggard, Clark, et al. (2002). Participants attended to the image of a centrally presented circular clock face (diameter = 8 cm) consisting of 60 dots (diameter = 2 mm). In each trial a circular clock hand (diameter = 4 mm) rotated clockwise along the dots at a rate of 3 s per rotation, starting from an unpredictable clock hand position. Four different block types were employed, differing with respect to the event to be judged (action vs. tone) and whether or not there was an instrumental relation between actions and tones (agency vs. baseline). In the agency conditions, participants were instructed to press a response key (keyboard space bar) with their right hand at a moment of their choosing. Their responses were followed by a brief sine wave tone (frequency = 600 Hz, duration = 75 ms) presented via headphones at a delay of 250 ms, while the clock hand continued rotating for an unpredictable interval (varied between 1000 and 2000 ms in steps of 250 ms) and then disappeared. Upon disappearance of the clock hand, participants were prompted to indicate the perceived time of either their button press (*agency action*) or the tone onset (*agency tone*) by manually selecting (mouse clicks) the corresponding clock hand position. In the two baseline conditions, temporal judgments were made about actions (*baseline action*) or about tones (*baseline tone*) when these events occurred in isolation. Altogether, participants performed two runs of each of the four block types, once under low effort conditions and once under high effort