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# Unconscious modulation of the conscious experience of voluntary control ☆

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**Abstract**

How does the brain generate our experience of being in control over our actions and their effects? Here, we argue that the perception of events as self-caused emerges from a comparison between anticipated and actual action-effects: if the representation of an event that follows an action is activated before the action, the event is experienced as caused by one's own action, whereas in the case of a mismatch it will be attributed to an external cause rather than to the self. In a subliminal priming paradigm we show that participants overestimated how much control they had over objectively uncontrollable stimuli, which appeared after free- or forced-choice actions, when a masked prime activated a representation of the stimuli immediately before each action. This prime-induced control-illusion was independent from whether primes were consciously perceived. Results indicate that the conscious experience of control is modulated by unconscious anticipations of action-effects.


*Keywords:* Experienced control; Priming; Subliminal; Action effects; Effect-anticipation; Agency; Illusion of control

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## 1. Introduction

The conscious experience of free will is a central feature of human self-perception. We usually feel that our conscious intentions cause our actions, which in turn produce desired effects in the world. Although the subjective feeling of control is an essential aspect of our self-conceptualisation as intentional agents, the mechanisms underlying this experience are not well understood (e.g., Haggard, Clark, & Kalogeras, 2002; Jeannerod, 2003; Lau, Rogers, Haggard, & Passingham, 2004; Sebanz & Prinz, 2006; Sirigu et al., 2004). Here, we argue that the conscious feeling of voluntary control is closely tied to our ability to represent future effects of our actions. William James was among the first to note that voluntary action is based on "…anticipation of the movements' sensible effects, resident or remote…" (James, 1890, p. 521; cf. Lotze, 1852). In a similar vein, Michotte identified "…our ability to foresee the result before it actually takes place…" as the main source of the experience of agency (Michotte, 1954/1963, p.10). More recently, Elsner and Hommel (2001) reported evidence suggesting that effect anticipations are based on bidirectional action-effect associations acquired in a two-stage learning process: first, behavioral acts are associated with the perceivable effects they bring about; later these associations form the basis for intentionally selecting actions that produce desired effects (cf. Goschke, 2003, 2004; Prinz, 1998, 2000).

Further evidence for the importance of sensory action effects in voluntary action control stems from experiments showing that subjects have poor awareness of specific parameters of voluntary movements and the proprioceptive feedback associated with movements, but rely primarily on sensory feedback about the intended effects in adjusting motor parameters to achieve a goal. For instance, subjects who were deprived from accurate visual feedback and instead received distorted feedback about the trajectory of a movement compensated for the deviation in order to produce the desired effect yet were not aware of this compensation (Fourneret & Jeannerod, 1998; Knoblich & Kirchner, 2004). This indicates that feedback about intended sensory effects plays a critical role in action control.

Our present investigation was motivated by the hypothesis that effect anticipations also play an important role in generating the conscious feeling of control. More specifically, we assume that if a sensory action effect is accurately anticipated before the action, individuals tend to experience the effect as self-caused, whereas in the case of a mismatch between anticipated and actual effect, the effect will be attributed to an external cause rather than to the self. Variants of this general idea can be found in a number of recent theories of willed action (e.g., Frith, 2005; see Haggard, 2005, for a review). For instance, Blakemore, Wolpert, and Frith (2002) postulated that during the execution of a voluntary movement a *forward model* computes predictions of the sensory consequences of one's movement. If the predicted consequences and the actual sensory feedback coincide, the representation of the sensory effect is attenuated and the effect is experienced as self-generated (Blakemore, Wolpert, & Frith, 1998, 2000).

Direct evidence that the experience of agency, that is, of being the originator of a sensory event, depends on the congruence between anticipated and actual