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Consciousness and Cognition

journal homepage: www.elsevier.com/locate/concog

Short Communication

Inferring sense of agency from the quantitative aspect of action outcome



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ARTICLE INFO

Article history:

Received 29 October 2012

Keywords:

Sense of agency
Inference
Action outcome
Action efficiency

ABSTRACT

The sense of agency refers to an experience in which one's own action causes a change in environment. It is strongly modulated by both the contingency between action and its outcome and the consistency between predicted and actual action outcomes. Recent studies have suggested that the action outcome can retrospectively modulate action awareness. We suspect that the sense of agency can also be retrospectively modulated. This study examined whether the quantity of action outcome could influence the sense of agency. The participants' task was to trigger dot motion in a display and rate the extent to which they could control the initiation of dot motion. Independently of both the temporal contiguity between action and its outcome and the consistency between predicted and actual action outcomes, the speed of dot motion as an action's outcome strongly influenced the sense of agency rating. The present study suggests that the sense of agency stems partly from the inference of action efficiency based on the quantitative aspect of action outcome.

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1. Introduction

We often have the experience that our own actions trigger changes in the external world. This experience is called the sense of agency (Haggard & Chambon, 2012). A two-stage model of the sense of agency has been proposed (Synofzik, Vosgerau, & Newen, 2008). At the first stage, a non-conceptual “feeling of agency” occurs on the basis of feed-forward cues, proprioception, and sensory feedback. Previous studies have examined how temporal congruency between an action and its effect contributes to the feeling of agency. For example, a temporally proximate action and its outcome can reduce the strength of neural signals of the outcome (i.e., sensory attenuation: Bays, Wolpert, & Flanagan, 2005; Blakemore, Frith, & Wolpert, 1999; Blakemore, Wolpert, & Frith, 1998; Kühn et al., 2011). This is because when predicted and actual sensory signals are highly contiguous, they cancel each other out (Wolpert, Ghahramani, & Jordan, 1995). The reduction in neural signals for outcome is interpreted as a causal relation between an action and its outcome, triggering a strong sense of agency (Blakemore et al., 1999). Meanwhile, some studies argue that the mere prediction of the outcome may be sufficient to cause the sensory attenuation (Waszak, Cardoso-Leite, & Hughes, 2012). In addition to the sensory attenuation, subjective compression of a temporal interval between an action and effect occurs when the action and effect are temporally contiguous with each other, which is called intentional binding (Haggard, Clark, & Kalogeras, 2002). Intentional binding is also considered as a sign of the feeling of agency (Desantis, Rousset, & Waszak, 2011). It is strong when temporal contiguity between an action and effect is high (Berberian, Sarrazin, Le Blaye, & Haggard, 2012; Ebert & Wegner, 2010; Haggard et al., 2002). In this way, temporal contiguity between an action and effect plays a significant role in determining the feeling of agency.

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At the second stage of the model proposed by Synofzik et al. (2008), the judgment of agency arises on the basis of intentions, prior thoughts, social cues, and contextual cues. The judgment of agency is related to propositional representation of agency. The judgment of agency can be assessed, for example, in a rating task in which participants rate the extent to which they are able to cause a change in the environment. Temporal contiguity between an action and effect affects the judgment of agency (Ebert & Wegner, 2010) or causality rating between action and effect (Shanks, Pearson, & Dickson, 1989). In addition to temporal contiguity, the consistency between predicted and actual action outcomes (Sato & Yasuda, 2005) and the consistency between prior thoughts about action and actual action outcome (Desantis, Weiss, Schütz-Bosbach, & Waszak, 2012; Wegner, 2004; Wegner, Sparrow, & Winerman, 2004; Wegner & Wheatley, 1999) are also contributing factors to the judgment of agency.

Recently, a study reported that information presented as an action's outcome altered the action awareness. Wilke, Synofzik, and Linder (2012) demonstrated that the perceived direction of a pointing action was distorted by presenting pictures with emotional valence: Positive and negative pictures, respectively, attracted and repulsed the subjective pointing direction. These results indicate that the perception of an agent's own action is retrospectively modulated by the action's outcome. Action awareness is intimately related to the sense of agency, as shown in studies on intentional binding (Haggard et al., 2002). Thus, we anticipated that an action's outcome might be able to alter the sense of agency.

The present study examined whether the quantitative aspect of an action's outcome could alter the sense of agency rating. Imagine a baseball situation. You are a batter. When hitting a home run, you will feel a strong efficiency of your action on the ball. On the other hand, when hitting a pop-up, the feeling of efficiency will be low. We wanted to know whether the sense of agency is modulated by the action efficiency implied by the quantitative aspect of action outcome and if so,

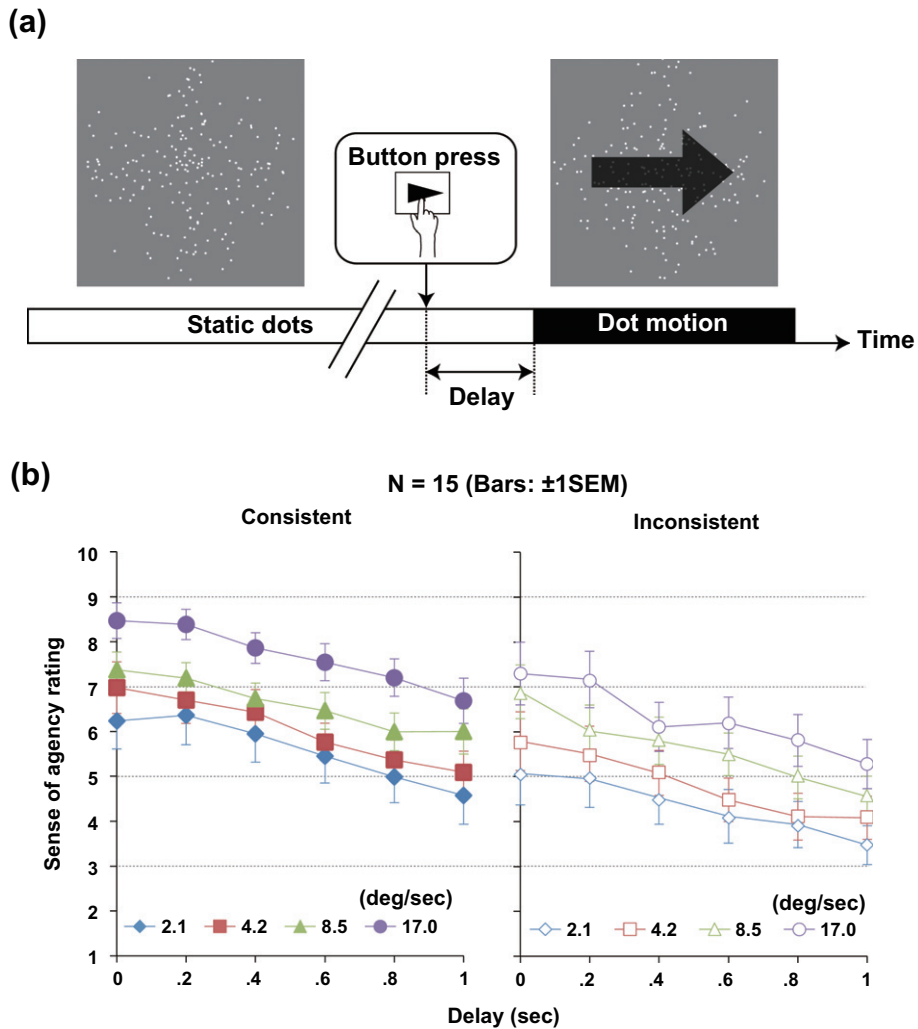


Fig. 1. (a) A schematic diagram for a task sequence. In each trial, static dots were presented, and after an participant's key press, the dots moved in a direction consistent or inconsistent with the key press. (b) Results. Error bar denotes standard error of mean ($N = 15$).

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