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Feeling of control of an action after supra and subliminal haptic distortions

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ABSTRACT

Here we question the mechanisms underlying the emergence of the feeling of control that can be modulated even when the feeling of being the author of one's own action is intact. With a haptic robot, participants made series of vertical pointing actions on a virtual surface, which was sometimes postponed by a small temporal delay (15 or 65 ms). Subjects then evaluated their subjective feeling of control. Results showed that after temporal distortions, the hand-trajectories were adapted effectively but that the feeling of control decreased significantly. This was observed even in the case of subliminal distortions for which subjects did not consciously detect the presence of a distortion. Our findings suggest that both supraliminal and subliminal temporal distortions that occur within a healthy perceptual–motor system impact the conscious experience of the feeling of control of self-initiated motor actions.

1. Introduction

The feeling of control is a phenomenon that is present throughout our everyday actions. It is present when one performs an effortful movement (e.g., lift a heavy box) and provides a sense of achievement; it is associated with multiple factors, like the fact that the action went as planned, that we managed to avoid possible difficulties, or that we adapted successfully to an unexpected event. The feeling of control has been reported to be involved in well-being (Larson, 1989), and is expected to bring about a sense of satisfaction. However, the concept of "feeling of control" can be used in many different contexts. In our work, we were interested in the feeling of control emerging in case of simple motor actions. We do not consider actions causing changes in the environment (e.g. switching a light on), and thus explore the feeling of control independent of causal relationships (Dewey, Pacherie, & Knoblich, 2014). The feeling of control can be considered as a subcomponent of the feeling of agency, i.e. the feeling of being author of one's own action (Synofzik, Vosgerau, & Newen, 2008). Although feeling of control

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and sense of agency are sometimes used indistinctly (Menzer et al., 2010), here we make a clear distinction between them. Whereas the feeling of agency is an all-or-none phenomenon in case of a simple action (but see Dewey et al., 2014 for more complex ones), the feeling of control is a qualitative feeling that may vary continuously between an optimal feeling and a complete loss of control. Moreover, the feeling of control can vary even when there is no ambiguity about the fact that we are the author of the action. Even though the determinants of the feeling of control have been conceptualized (Pacherie, 2008), it has scarcely been explored experimentally (see Chambon & Haggard, 2012). One of the difficulties is that the feeling of control is a subjective feeling that emerges following actions based on mechanisms that are largely subconscious. In addition, the sense of agency has been explored mainly by manipulating the visual consequences of the action (Franck et al., 2001; Knöblich, Stottmeister, & Kircher, 2004). We suspect that haptic feedback (i.e. tactile and kinesthetic sensory information) may have an even larger role in the feeling of control, because it can be used to check for both the consequences of the action and the ongoing progression of the action itself, like e.g. the kinetic properties of a movement trajectory. Here we explore to which extent the feeling of control varies as a function of distortions in sensory haptic feedback, and as a function of the motor planning adaptations that follow these sensory distortions. To check for unconscious influences on the feeling of control, we distinguish between subliminal (unconscious) and supraliminal (conscious) sensory distortions.

1.1. The feeling of control and motor control models

The feeling of control is tightly related to our ability to adapt motor responses. As a matter of fact, our motor system allows us to efficiently and automatically adapt to unexpected changes in the environment. When climbing stairs, we might be surprised by a change in one step height, but we will adapt quickly and this will not prevent us from racing up the stairs two by two. This can work even if the change is not consciously perceived. In fact, motor adaptation does not systematically require awareness of the discrepancy in order to be efficient (Fourneret & Jeannerod, 1998). The well-accepted model of Wolpert and collaborators (Wolpert, 1997) provides an explanatory framework for the mechanisms subtending motor adaptation. According to this model, a voluntary action is first planned by means of the inverse model, which has the role to determine the motor plan in function of action goal and of the environmental constraints in which the action is to be performed. Once determined, a copy of the motor command, i.e., the efference copy, is used in a second internal model, the forward model, to generate predictions regarding the sensory feedback resulting from the action if it were to be performed. These predictions are compared with the real sensory feedback in order to adapt the action if necessary, even before its execution. Yet, some complex motor sequences may need support from conscious feelings to be optimized, as the feeling of control. Following our example of stair climbing, when the climbing is fluent, we have a positive feeling of control. But, if we feel ourselves stumbling, our feeling of control decreases. This usually incites us to take care, to slow down, and to focus attention in a voluntary endogenous way toward our action. Even though the consequence of this attention focus is largely beyond the reach of consciousness, it can be expected to increase again our sense of control, especially if it is successful. The sense of control may thus help to better adapt to unexpected changes in the environment.

Consistent with these examples, the feeling of control has been suggested to depend on two main mechanisms (Pacherie, 2008). It can increase if the action is voluntarily controlled, and involves effort, whether mental or muscular. On the other hand, in the case of over-practiced and skilled behavior, the feeling of control can be quite high without involving effort. In that case, it may decrease if the action does not lead to its expected outcomes. Here, the sensory information resulting from the action plays an important role. Chambon and Haggard (2012) have reported that a prime shown before the action can increase the sense of control if it is compatible with the outcome of the action. This effect is independent of the motor performance itself, but suggests that both the planning and the verification of the action outcome may affect the feeling of control. However, in both cases it is still difficult to understand how the conscious feeling of control emerges from the subconscious mechanisms involved in motor planning.

It is mainly the sense of agency that has been studied i.e. the feeling of being the author of one's own action. In pathology, experiments have been conducted to understand delusions of control (Franck et al., 2001; Knöblich et al., 2004), arising when patients with schizophrenia attribute their actions or thoughts to an external force. It has often been suggested that the correspondence between predicted sensory outcome and actual sensory outcome reinforce our sense of agency (Frith, Blakemore, & Wolpert, 2000; Sato & Yasuda, 2005). For example, studies such as those conducted by Fourneret and Jeannerod (1998) and Knöblich and Kircher (2004) were based on elegant manipulations of the visual information during manual actions. Subjects did not have direct visual access to their hands or to their actions, and visual information was sent back to them through a computer screen. This installation allowed the experimenter to introduce visual distortions within the sensory feedback. These studies revealed that subjects adapted their action in order to reach a pre-defined goal (drawing a straight line or a circle), with both subliminal and supraliminal distortions. Results showed that a disruption in the sense of agency occurred only in rare cases, e.g., in those cases with the largest discrepancies. Unfortunately, the feeling of control was not explored. As already emphasized, subjects may have a modulating feeling of control while maintaining the knowledge of being the authors of their acts. Since the feeling of control can vary more frequently than the feeling of agency, it might be more sensitive than the feeling of agency to small distortions in the sensory feedback, when the action is obviously attributed to oneself (Synofzik et al., 2008). In the present study, we question whether the arising of the feeling of control could be related to the existence of small and undetected distortions in the sensory feedback. Moreover, instead of focusing on visual sensory feedback, we used in the present case, distortions of the haptic feedback. The haptic feedback plays indeed