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Multi-scale control influences sense of agency: Investigating intentional binding using event-control approach

Devpriya Kumar [a,b], Narayanan Srinivasan [a,*]

[a] Centre of Behavioural and Cognitive Sciences, University of Allahabad, India
[b] Department of Humanities and Social Sciences, Indian Institute of Technology, Kanpur, India

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ABSTRACT

Control exercised by humans through interactions with the environment is critical for sense of agency. Here, we investigate how control at multiple levels influence implicit sense of agency measured using intentional binding. Participants are asked to hit a moving target using a joystick with noisy control followed by an intentional binding task initiated by the target hitting action. Perceptual-motor level control was manipulated through noise in the joystick controller (experiment 1) and goal-level control in terms of feedback about successful hit (experiments 2a and 2b). In the first experiment, intentional binding increased with amount of joystick control only when goal was not achieved and independent otherwise suggesting that the two levels interact hierarchically. In the second experiment, the estimated duration was dependent on when participants knew about goal completion. The results are similar to those obtained with explicit measures of sense of agency indicating that multi-scale event control influences agency.

1. Introduction

We interact with our environment in terms of meaningful chunks of discrete events, mostly distinguished from one another by means of a clear boundary. These interactions with the environment can occur in terms of action events, which cause and mark a predicted meaningful change in the environment (Kawabe, 2013). Match between the predicted change in the environment and the actual outcome determines the amount of control exercised by us over our environment (Nahab et al., 2011). This control over action-outcomes exists not just along a single dimension but can be exercised simultaneously over multiple time-scales, i.e., we can associate multiple predicted perceptual effects with a single action and exercise control over multiple perceptual effect operating at different time-scales. An experience that has been closely linked with control of actions is the sense of being the agent of our actions, or the sense of agency, which increases with increase in exercised control. However, the influence of control exercised simultaneously at multiple time scales on the sense of agency has not been investigated in great detail (Jordan, 2013; Kumar & Srinivasan, 2014). The objective of the study was to investigate how simultaneous multi-scale event control is linked with implicit sense of agency measured using intentional binding (IB) between a participant's voluntary action and its perceived consequence.

* Corresponding author at: Centre of Behavioural and Cognitive Sciences, University of Allahabad, Allahabad 211002, India.
E-mail address: nsrini@cbcs.ac.in (N. Srinivasan).

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1.1. Multi scale event control and behavior

Traditionally human brain has been considered as a "machine" that converts stimuli into reactions. This viewpoint is known as the "sandwich" view of cognition, where cognition is conceived as being sandwiched between two interfaces with the outside world, namely action and perception (Hurley, 2001). An alternate view of cognition is to understand human behavior in terms of control, which suggests that instead of manipulation of symbols to convert sensory information into motor actions, the function of the organism is to act in order to maintain stability when the external environment of the organism might suggest instability, resulting in a cycle of perception and action (Powers, 1973). A simple distinction between the traditional and the control based approach would be that while the former approach focuses on "producing the right response given a stimulus", the latter approach focuses on "producing the response that results in the right stimulus" (Cisek, 1999). While there are multiple ways in which control exercised by a system can be defined, here we define control in terms of the perceptual effect associated with an action, with organism being "in control" when the perceptual effect of its action matches with the predicted outcome (Powers, 1978).

In order to control these perceptual effects occurring in the environment, we first need to derive meaning out of the continuous influx of information that is obtained from the environment, by organizing the continuous information into meaningful events. Events are defined as a segment of time at a given location that is conceived by an observer to have a well-defined beginning and end (known as event boundaries). It has been suggested that event boundaries play a major role in event perception (Zacks & Tversky, 2001) and are shared by two adjacent events, which can result either in adjacently placed chain of events (the end of an event marks the beginning of next event) or a larger scale event can contain a smaller scale event, forming partonomic (one event inside the other) hierarchy (Zacks, Tversky, & Iyer, 2001). Participants identify event boundaries based on various cues including bottom-up physical changes in the stimulus as well as top-down conceptual changes in goals and causes (Zacks & Tversky, 2001). This boundary based segmentation takes place continuously resulting in a higher-level experience of a meaningful environment understood in terms of discrete multi-scale events.

Once the event structure has been extracted, the next step is to adjust our actions in order to match the perceived events in the environment with the predicted perceptual effect. These perceptual events can either be spatio-temporally proximal with respect to the original action or spatio-temporally distal. Also, a single action might be associated with a number of predicted effects and corresponding perceived events in the environment. Presence of these multi-scale simultaneous perceptual events results in what we call multi-scale event control, where participants adjusts their action in order to match perceived events with their predicted perceptual effect simultaneously at multiple levels. These individual control levels differ in terms of the proximity/distality of the perceptual event that is being controlled (Jordan, 2003). Take the example of chess, where a single action by the player (moving a piece from a position A to position B) can have multiple perceptual events associated with it; the movement influences the perceptual event related to location at which the piece is placed (proximal effect), position of the opponent's pieces in his/her turn (spatio-temporally distal effect), and the overall outcome of the game (an even more distal effect).

To achieve control at a single level, actions are modified in order to match the predicted effect with the perceived effect. With simultaneous multi-scale event control, an important question is how modifications in actions take place, when multiple predicted effects are to be matched with perceptual events. Jordan (2003) suggests that different levels of control interact in a hierarchical manner with control over more distal level perceptual events being higher up in the hierarchy, while control over more proximal perceptual event being lower in the hierarchy. Control over these multi-scale events form the basis of our interactions with the environment and can be used to understand human behavior (Gibson, 1979; Powers, 1973) as well as cognitive experiences such as sense of agency (Jordan, 2003).

1.2. Sense of agency and control

Our voluntary actions influence not only our environment but also the conscious mental state of being the agent of those actions, something that is central to all our conscious experiences (Gallagher, 2007). Sense of agency (SoA) is a complex, multifaceted, phenomenon (Pacherie, 2011) that can be described as the feeling of "I did it" (Engbert, Wohlschläger, & Haggard, 2008), the experience of causing a change in the environment by one's own action (Kawabe, 2013), the registration that the organism is the initiator of his/her own actions (Synofzik, Vosgerau, & Voss, 2013), and as the feeling of one's voluntary actions causing external events (Takahata et al., 2012). SoA can be understood as syntax or framework within which several different experiences may be accommodated (Engbert et al., 2008). SoA has been closely linked with control, prediction and monitoring of one's behavior, with majority of the studies suggesting that a greater control is linked with heightened SoA (Haggard & Chambon, 2012; Haggard & Tsakiris, 2009; Pacherie, 2014; Synofzik, Vosgerau, & Newen, 2007).

Barring a couple of studies, previous literature has not looked at how simultaneous multi-scale control might influence SoA. The event control approach (Jordan, 2003) provides a framework to understand the relationship between multi-scale control and SoA. According to the event control approach, multiple levels of control with varying spatio-temporal distality of the effect that they control interact with each other in dynamical fashion. SoA emerges out of the dynamic interaction between different levels of control. This approach proposes a much more fluid SoA that attaches itself with different levels of control at different point of time. In the current study we use the event control framework to understand the relationship between multi-scale control and SoA.