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Supplemental Information

The Active Sensing of Control Difference

Wen Wen, Hiroshi Shibata, Ryu Ohata, Atsushi Yamashita, Hajime Asama, and Hiroshi Imamizu

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Transparent Methods

Participants

Sixteen healthy participants took part in the experiment (14 males and 2 females, mean age = 22.1 years, *SD* = 1.0 years). All participants were right-handed except for two. The two left-handed participants self-reported the daily use of their right hand for manipulating a computer mouse and touchpad. All participants used their right hand to operate a touchpad in the task, and they all had corrected-to-normal visual acuity. The sample size was chosen based on a power calculation using G*Power 3 (Faul et al., 2007, 2009) and an effect size estimated based on pilot data from a similar control exploration task to produce a power larger than 0.95 (alpha = .05, Cohen's d = 1.12 compared to chance level when people identified an object over which they had 50% control among four objects). The experiment was conducted according to the principles of the Helsinki Declaration and was approved by the Ethics Committee of the Department of Psychology at the University of Tokyo. All participants provided written informed consent prior to participation.

Tasks and Procedures

Participants conducted two tasks: a control difference detection task followed by a control judgment task. Figure 2 illustrates the timeline of a trial in the control difference detection task. In the control difference detection task, people had different levels of control over three visually identical stimuli on the screen (details given below). Participants freely explored their control over the three objects and then selected one target over which they felt the control was different from the other two in each trial. Two objects among the three were under the same level of control (30, 50, 70, or 90%). The control over these two dots was called *control context*. The level of control over the target was 10, 20, or 30% more or less than this context.

The task was programed and conducted using Matlab (R2012b, MathWorks) and Psychtoolbox-3. During each trial, three 40-px (11.28-mm) white dots were presented in the center area of a 22-inch LED monitor (P2217c, DELL, 1680×1050 px, 0.282mm/px, refresh rate = 59 Hz). The observation distance was about 50 cm. The positions of the dots were randomly generated by the program, under the restriction of a maximum distance of 400 px from the center of the screen and a minimum distance of 200 px between dots. The dots remained static on the screen until participants started to move their index finger on a touchpad. The velocity, onset, and offset of the dots' movements were normalized to match the participants' finger movements, while the directions of the dots were mixed based on participants' movements and randomly selected sections from 10,000 pre-recorded motions. The magnitude of mouse movement was reduced to 4/10 to prevent excessive movement of the stimuli. The algorithm of motion blending was identical to that in Wen, Brann, Di Costa, and Haggard (2018). Specifically, a section of pre-recorded movements was randomly selected for each dot in each trial. At each refreshed frame, if participants moved their finger on the touchpad from the last frame, a pre-recorded movement was taken out, and its direction was mixed with the direction of the participant's finger movement at a certain ratio depending on the level of control. For example, if a dot was under 30% control, the direction of the pre-recorded motion was mixed with the direction of the participant's motion at a 70/30 ratio. Finally, the mixed motion was normalized to match the magnitude of the participant's finger movement, and thereafter it was used to re-draw the dot on the screen. In addition, because different sections of pre-recorded motion were selected for different dots, the three dots moved in different directions even when the control over them was at the same level (if the control was less than 100%). Participants were told to freely explore their control over the three dots by continuously moving their fingers on a touchpad for 5 s and then to select, by pressing a number key, the one dot they felt was under a different level of control from the other two dots when the three dots stopped with numbers shown beside them. Thereafter, participants answered whether their control over the dot they selected was under less or more control than the other two dots by pressing one of two buttons labelled 'LESS' and 'MORE.'

There were two within-participant independent variables. The first was control context, which was set at 30, 50, 70, or 90% in each trial. The control contexts were selected to cover the range from the sense of not-in-control to the sense of in-good-control according to our pilot results (also see results in Figure 7). The second variable was the control difference between the target and the context, which was set at -30, -20, -10, 0, +10, +20, or +30%. Note that the two variables were not fully factorially designed, since the +20 and +30% conditions were not applicable to the control context of 90%. There were 26 possible combinations of the two independent variables, each repeated 10 times, resulting in a total of 260 trials. The trial order was randomized. There were 26 extra trials (1 repeat for each condition) conducted for practice before the actual task. The actual task took 45 min on average.

After the main task (i.e., control difference detection task), participants then performed a short control judgment task, in which they explored their control over one dot for 3 s and then answered whether they felt that the dot was under their control by pressing one of two keys labeled ‘Yes’ and ‘No.’ There were 11 levels of actual control within the range of 0–100% at 10% steps. Each level was repeated 10 times, resulting in 110 trials. The trial order was randomized. This task was designed to measure the point of subjective equality (PSE) in control in order to compare it with the control context in the main task. There was no practice for this task, since the participants had familiarized themselves with the dot motion experimental setup in the main task. The control judgment task took 5 mins on average. The experiment took approximately one hour for each participant, including instructions, practice, and actual tasks.

Data and Code Availability

Original data have been deposited to Mendeley Data: [DOI: 10.17632/8r4y4zmdvn.1].
Wen, Wen; Shibata, Hiroshi; Ohata, Ryu; Yamashita, Atsushi; Asama, Hajime; Imamizu, Hiroshi (2020), “The dataset of the study on active sensing of control difference”, Mendeley Data, v1
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