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Belief in free will indirectly contributes to the strategic transition through sympathetic arousal

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ABSTRACT

Belief in free will is considered to be vital for human self-control, but most findings were obtained under externally constrained tasks. We investigated whether and how belief in free will contributes to self-control in a self-generating manner. Participants completed the Free Will and Determinism Scale in Japanese, and then performed a reversal learning task. During the task, participants' sympathetic activity was measured by finger plethysmography. We analyzed the relationships among belief in free will, sympathetic activity, and response variability indexed by entropy. The results revealed that belief in free will was positively related to sympathetic arousal when the contingencies of options and reward probabilities changed. In addition, this sympathetic arousal was positively related to increase in response variability. These results indicate that belief in free will contributes to the monitoring subprocess of self-control. We discuss the function of belief in free will and the mechanism of self-control.

1. Introduction

Free will is defined as a set of capacities for choice and action control that are essential for an agent to be responsible for his/her actions (Nahmias, 2012). Interest in the function of lay belief in free will has increased recently (e.g., Leotti, Iyengar, & Ochsner, 2010). Some researchers suggest that belief in free will is vital for human self-control. Previous research revealed that belief in free will is related to cheating (Vohs & Schooler, 2008), job success (Stillman et al., 2010), aggressive behavior (Baumeister, Masicampo, & Dewall, 2009), and intended inhibition (Rigoni, Kühn, Gaudino, Sartori, & Brass, 2012).

However, it is unclear how belief in free will is related to self-control. This uncertainty is probably due to ambiguity of the definition and methodologies of self-control. This study addressed these issues using a psychophysiological approach. Specifically, we conducted experimental research assessing participants' physiological responses to clarify how belief in free will can contribute to self-control in humans.

The idea of self-control is represented differently among researchers. For instance, self-control is represented as choosing distal reward over proximal reward (Mischel, Shoda, & Rodriguez, 1989), advancing abstract goals over concrete goals (Fujita, 2011), or overriding unwanted impulses or urges (Baumeister & Heatherton, 1996; Hofmann, Friese, & Strack, 2009). Due to such an ambiguous definition, self-control is assessed in various ways. For instance, a meta-analytical review of ego depletion, which is the temporary dysfunction of self-control caused by consecutive self-control exertion, proposed that experimental tasks can be classified into various categories (Hagger, Wood, Stiff, & Chatzisarantis, 2010). Such a variety of tasks is beneficial for generalizing experimental results to various situations. However, we cannot uncover the mechanism through which self-control is facilitated except by using well defined experimental tasks.

A way to address the mechanism of self-control is by focusing on cognitive control. Cognitive control is the process of inhibiting prepotent responses in order to exert a goal- or task-defined response (Miller & Cohen, 2001). Cognitive control is considered to be a central component of self-control (Hofmann, Schmeichel, & Baddeley, 2012; Krug & Carter, 2010). Cognitive control can be divided into two sub processes: monitoring and controlling (Krug & Carter, 2010). Controlling refers to inhibiting a prepotent response and exerting a goal-defined response. On the other hand, monitoring refers to comparing the actual responses and goal-defined responses to detect situations that require the controlling process. Previous studies using this approach revealed that a disbelief in free will reduces error detection (Rigoni, Pourtois, & Brass, 2015; Rigoni, Wilquin, Brass, & Burle, 2013). As error

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detection relies on the monitoring subprocess, these results demonstrated that belief in free will is related to the monitoring subprocess.

However, focusing on cognitive control neglects the agency aspect of self-control. One definition of self-control regarding agency is the process of engaging in a less likely response in a very familiar situation without any perceived external constraints (Thoresen & Mahoney, 1974). Typical tasks assessing cognitive control give instructions about task goals, such as "not responding to color names" (Stroop, 1935) or "inhibiting motor responses when stop signals appeared" (Aron, 2007). As participants' responses are externally constrained in these tasks, other experimental paradigms that focus on the agency aspect of self-control are needed (cf. Rigoni et al., 2012).

In this study, we focused on the transition of the strategy in decision making—from exploitation to exploration (Sutton & Barto, 1998). Exploitation is the strategy of choosing an option that is associated with the highest probability of a reward. By contrast, exploration is a strategy of seeking new and previously unexplored options. When people change their strategies from exploitation to exploration, they need to inhibit the prepotent responses derived by learned contingencies between options and rewards. Persistence in exploitation is beneficial in stable situations. However, as the natural environment is unstable and uncertain, people need to have a balance between exploitation and exploration for survival.

The transition from exploitation to exploration can occur without external constraints. Recent research suggested that the reversal learning task can induce this strategic transition (e.g., Stocco, 2012). In the reversal learning task, participants learn that one option leads to gain while the other option leads to loss. Then, contingencies between options and rewards switch implicitly. Previous research revealed that participants' responses become more variable after contingencies changed compared to just before this change (Ohira et al., 2013). As the balance between exploitation and exploration is represented by response variability, researchers assumed that such a situational change induced the transition from exploitation to exploration.

The strategic transition in reversal learning task requires both the monitoring and controlling subprocesses in a self-generated manner. Monitoring is essential for detecting erroneous responses while controlling is essential for inhibiting erroneous and prepotent responses. Some neuropsychological studies of reversal learning tasks revealed that inhibiting a previously rewarded response was accompanied by the activation of the ventrolateral prefrontal cortex (e.g., Cools, Clark, Owen, & Robbins, 2002), which is a common neural region recruited for control. As no instructions about rule-switching were given, the strategic transition is considered to be a more complex form of cognitive control than controlling responses under external instruction (Cohen & Lieberman, 2010). These two processes should be generated by participants' own awareness. Thus, the strategic transition is consistent with the idea of self-control that includes the agency aspect.

This study aims to investigate how belief in free will contributes to self-control by focusing on strategic transition in a reversal learning task. In order to dissociate between monitoring and controlling, we assessed participants' sympathetic activity. Analytical frameworks of this study mainly follow the line of Damasio (1994)'s somatic marker hypothesis. When one detects emotional (i.e., unpredictable, aversive) contents, sensory information is delivered to the amygdala, a region of the limbic system, via the thalamus and sensory cortex. The amygdala evokes some bodily change, such as sympathetic arousal. These bodily changes are then relayed to the somatosensory cortices, such as the insular or cingulate cortex. Then, the prefrontal cortex calibrates the optional value and controls the participant's choice.

Recent research has revealed that strategic transition was associated with high sympathetic arousal (Ohira et al., 2013). In their research, sympathetic arousal was assumed to be a bodily signal that informs the necessity of behavioral change. They assessed participants' sympathetic arousal through changes of epinephrine in their blood flow. Results revealed that increased epinephrine when contingencies between options and rewards changed correlated with the activity of the right insula. Then, right insular activity positively predicted the strategic transitions. As a body-brain-behavior connection is consistent with the somatic marker hypothesis, we can assume that the increase in sympathetic arousal is an index of the monitoring process of self-control.

In this study, we investigate whether belief in free will contributes to monitoring or controlling processes of self-control, by focusing on individual differences of sympathetic arousal and relationships between sympathetic arousal and strategic transition. Following the somatic marker hypothesis and Ohira et al. (2013), we made two predictions. First, if belief in free will contributes to the monitoring process, then it should be positively correlated with sympathetic activity (indirect prediction). Second, if belief in free will contributes to the controlling process, then it should modulate the relationship between sympathetic activity and strategic transition (moderation prediction). We conducted exploratory analysis to investigate which prediction (or whether both predictions) is supported.

2. Method

2.1. Participants

Sixty undergraduates and graduate students participated (male:female = 46:14; mean age = 21.5, *SD* = 3.1). This study was approved by the Ethics Committee in Graduate School of Education, Kyoto Universoty (approval number: CPE-37). All the participants gave their written informed consent before participating in this study.

2.2. Questionnaire

Before arriving at the laboratory, participants completed the Free Will and Determinism Scale in Japanese (FAD-J; Goto, Ishibashi, Kajimura, Oka, & Kusumi, 2015) via the Qualtrics web site. The FAD-J is the Japanese version of the Free Will and Determinism Scale (Paulhus & Carey, 2011), which is a useful assessment tool about belief in free will. The FAD-J consists of 27 items in a 5-point Likert format. The four subscales are free will, scientific determinism, fatalistic determinism, and unpredictability. As we focused on individual differences in beliefs in free will, we included only the score of free will (seven items; e.g., "People have complete control over their decisions they make.") in further analysis ($M = 3.52$, $SD = 0.47$, min = 2.29, max = 4.86).

2.3. Experimental task

On another day, participants arrived at the laboratory and performed four blocks containing 40 trials each (two initial learning blocks and two reverse learning blocks) of the decision making task, which is a modified version of the task used in Ohira et al. (2013). On each trial, after the fixation cross was presented at the center of the computer screen for 500 ms, two differently colored cards were presented on the left and right sides. Participants were required to choose one by pressing the left or right key within 1000 ms. At 1500 ms after the cards were presented, both cards were turned over, and participants were given feedback on whether their choice yielded a reward of 10 Japanese yen (JPY; 10 JPY is approximately 9 US cents) or loss of 10 JPY. If participants did not choose a card within 1000 ms, then they lost 10 JPY on that trial. The inter trial interval varied between 3500 and 5000 ms.[1]

In the initial learning block (i.e., Block 1 and 2), one card was associated with reward at a probability of 70% and loss at a probability of 30% (advantageous card), while the other card was associated with reward at a probability of 30% and with loss at a probability of 70%

[1] We inserted a jittered inter-trial-interval in this task so that we could use this task with neuroimaging methods (e.g., fMRI) in future research.