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No evidence for common processes of cognitive control and self-control

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ABSTRACT

Cognitive control and self-control are often used as interchangeable terms. Both terms refer to the ability to pursue long-term goals, but the types of controlled behavior that are typically associated with these terms differ, at least superficially. Cognitive control is observed in the control of attention and the overcoming of habitual responses, while self-control is observed in resistance to short-term impulses and temptations. Evidence from clinical studies and neuroimaging studies suggests that below these superficial differences, common control process (e.g., inhibition) might guide both types of controlled behavior. Here, we study this hypothesis in a behavioral experiment, which interlaced trials of a Simon task with trials of an intertemporal decision task. If cognitive control and self-control depend on a common control process, we expected conflict adaptation from Simon task trials to lead to increased self-control in the intertemporal decision trials. However, despite successful manipulations of conflict and conflict adaptation, we found no evidence for this hypothesis. We investigate a number of alternative explanations of this result and conclude that the differences between cognitive control and self-control are not superficial, but rather reflect differences at the process level.

1. Introduction

The ability to pursue long-term goals and to resist short-term impulses is a defining human ability. In cognitive psychology, this ability is often referred to as *controlled behavior* and it has been addressed in two major fields of research: On the one hand, research on *cognitive control* has investigated how humans shield attention and task-sets from irrelevant, distracting information in order to suppress overlearned, habitual behavior and respond in a goal-driven manner instead (Miller & Cohen, 2001). On the other hand, research on *self-control* has investigated how humans resist temptations and delay immediate gratification in order to obtain superordinate goals in the future (Kim & Lee, 2011). In the light of this conceptual overlap of cognitive control and self-control with respect to the ability to suppress or ignore short-term behavioral impulses in order to achieve long-term goals, it is an open question whether the behavioral manifestations of cognitive control and self-control reflect the workings of a common underlying process or if they result from independent underlying processes.

The common process interpretation of cognitive control and self-control seems to be self-evident in the literature, where the terms are often used interchangeably (e.g. Inzlicht, Schmeichel, & Macrae, 2014). But beside this practical interchangeability, evidence for a common process interpretation stems from clinical studies indicating that cognitive and self-control tend to co-vary. Individuals with low cognitive control, e.g. substance addicts or pathological gamblers (e.g. Alessi & Petry, 2003; Garavan & Hester, 2007; Kräplin et al., 2014; Petry, 2001) also show reduced self-control (e.g. Billieux et al., 2012; Kirby, Petry, & Bickel, 1999; Kräplin et al., 2014; Lawrence, Luty, Bogdan, Sahakian, & Clark, 2009). Conversely, high cognitive control (Hall, Fong, Epp, & Elias, 2008) and high self-control (Mischel, Shoda, & Rodriguez, 1989) confer similar improvements in positive life outcomes. Furthermore, imaging studies suggest an overlap of brain regions involved in cognitive control and those involved in self-control, especially the dorso-lateral prefrontal cortex (Hare, Camerer, & Rangel, 2009; Peters & Büchel, 2011; Shamosh et al., 2008). Such an overlap indicates that both types of controlled behavior may recruit the same neural processes or, at least, depend on a large set of shared processes.

Here, we will pursue a behavioral experimental approach to investigate whether the two types of controlled behavior are based on the same or different cognitive processes. To this end, we combine two prototypical paradigms that have been used extensively in the past to assess the effects of cognitive control and self-control on behavior.

Conflict tasks, e.g. the Stroop task (Stroop, 1935), the Flanker task (Eriksen & Eriksen, 1974), or the Simon task (Simon, 1969), are used to study cognitive control in the lab. The Simon task is a prototypical example of these experimental paradigms. In a typical Simon task

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(Scherbaum, Dshemuchadse, Fischer, & Goschke, 2010), participants attend and respond to the direction of an arrow (i.e., whether it points to the left vs. right) while ignoring its location on the screen (i.e., whether it appears on the left or right side of the display). In this paradigm, two effects are observed. Conflict trials (i.e., trials where the response indicated an arrow's direction and location do not match) take longer and are less accurate than non-conflict trials. In addition, successfully completing conflict trials is believed to trigger the recruitment of cognitive control processes that, in turn, increase the impact of task-relevant (i.e. direction) as compared to task-irrelevant (i.e. location) information on future information processing and response selection (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Botvinick, Cohen, & Carter, 2004). Empirically, this dynamic recruitment of cognitive control is reflected in conflict adaptation effects from trial to trial. That is, experience of response conflict in one trial of the Simon task leads to improved performance in a subsequent conflict trial of the Simon task (compare Gratton, Coles, & Donchin, 1992).

In contrast to the studies of cognitive control, which rely on conflict tasks, studies on self-control often employ value-based choice tasks, e.g. intertemporal decision tasks (Frederick, Loewenstein, & O'Donoghue, 2002). In such intertemporal decision tasks, participants choose between a smaller reward that is delivered relatively soon (e.g. receiving 3€ in 2 days) and a larger reward delivered relatively late (e.g. receiving 12€ in 7 days). By presenting participants with different combinations of values and delays, researchers are able to assess their level of self-control in terms of the ability to withstand the temptation of an immediate small reward and to choose a delayed but large one instead (Ainslie, 1991; McClure, Laibson, Loewenstein, & Cohen, 2004).

The aim of this study is to test whether or not cognitive control and self-control rely on the same set of control processes. If this was the case, one would expect that experimental manipulations that cause control adjustments in one task should also increase controlled behavior in the other task. Accordingly, we investigated if changes in cognitive control in a Simon task resulted in the mobilization of self-control in an intertemporal decision task. To this end, we interlaced trials of an intertemporal decision task with trials of a Simon task such that each intertemporal decision was preceded and followed by Simon trials that either did or did not contain conflict. Based on the assumption that cognitive control and self-control rely on a common set of control processes, we expected that an increase in cognitive control should also result in an increase in self-control. Empirically, this should result in participants being more likely to choose the late but large option in an intertemporal decision when they had just completed a conflict trial in the Simon task compared to intertemporal decisions that directly followed a non-conflict Simon trial. Importantly, for this prediction to be viable, two prerequisites must be met: First, because the experience of response conflict is believed to trigger an increase in cognitive control (Botvinick et al., 2001), the Simon task must reliably induce such response conflict. Behaviorally, this should be reflected in a Simon effect, that is, slower response times in conflict than non-conflict trials. Second, the increase in cognitive control triggered by the experience of conflict must persist during the completion of the intertemporal decision. Behaviorally, this would be indicated by a conflict adaptation effect from Simon trial to Simon trial. That is, there should be a reduced effect of conflict in a Simon trial following an intertemporal decision, if the Simon trial preceding that intertemporal decision was a conflict Simon trial.

Taken together, we expect (I) an increased number of LL choices in the intertemporal decisions following conflict trials in the Simon task compared to intertemporal decisions following non-conflict trials. As measures of successful manipulation, we expect (II) a reliable Simon effect and (III) a reliable conflict adaptation effect from Simon trial to Simon trial.

2. Method

2.1. Ethics statement

The study was performed in accordance with the guidelines of the Declaration of Helsinki and of the German Psychological Society. An ethical approval was not required since the study did not involve any risk or discomfort for the participants. All participants were informed about the purpose and the procedure of the study and gave written informed consent prior to the experiment. All data were analyzed anonymously.

2.2. Participants

Forty-eight students of the Technische Universität Dresden, Dresden, Germany (39 female, mean age = 22.4 years), participated in the experiment. All participants had normal or corrected-to-normal vision. They received class credit or 5€ payment.

Sample size was calculated using G*Power (http://www.gpower.hhu.de/). We based our estimation of expected effect size on a previous study of self-control in intertemporal decisions (Scherbaum, Dshemuchadse, & Goschke, 2012) that showed an effect size for the established date-delay manipulation of $d = 0.37$. To reach a power of 0.8 (Cohen, 1988), a minimum of 47 participants was determined (Faul, Erdfelder, Lang, & Buchner, 2007). To compensate for experimental loss, our total sample comprised 50 participants. As two participants could not participate due to technical problems, 48 data sets were included in our final analyses.

2.3. Apparatus and stimuli

We used Psychophysics Toolbox 3 (Brainard, 1997; Pelli, 1997) in Matlab 2006b (Mathworks Inc.) as presentation software, running on a Windows XP SP2 personal computer. Participants performed their responses with a standard German QWERTZ computer keyboard. Stimuli were presented on a 17 in. screen running at a resolution of 1280 × 1024 pixels (75 Hz refresh frequency).

In Simon trials, the target stimuli (left- and right-pointing arrows) had a width of 300 pixels and an eccentricity (center of stimulus to center of screen) of 440 pixels.

In intertemporal decision trials, the two options – soon small (SS) and late large (LL) option – were presented on the left (e.g. SS option) and the right (e.g. LL option) of the screen. This position of the SS and LL options was balanced across participants. Values and delays were presented in Arial font, 32 pt., and had an eccentricity (center of stimulus to center of screen) of 256 pixels.

2.4. Procedure

The experiment consisted of 576 trial pairs. In each trial pair, participants were first asked to respond to an arrow of the Simon task and consecutively to choose between a soon but small (SS) and a late but large (LL) option (see Fig. 1) of the intertemporal decision task.

Each trial pair started with a randomly chosen inter-trial-interval of 0.9, 1, or 1.1 s during which a fixation cross was presented at the center of the screen. The ITI was followed by the Simon trial. The arrow was presented for 0.3 s and then followed by a black screen. Participants had to indicate the direction (left or right) of the arrow by pressing the 'y' key with the left index finger or the 'm' key with the right index finger within a response deadline of 2 s. Immediately after responding to the arrow, the intertemporal decision trial started. Participants were asked to decide which of two options they preferred, the SS or the LL option. Participants were instructed to respond to the hypothetical choices as if they were real choices and they had to make their decision within a response deadline of 10 s. If participants missed any of the two deadlines or responded erroneously in the Simon trial, a feedback was