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Fluctuations in pre-trial attentional state and their influence on goal neglect

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ABSTRACT

Fluctuations in attentional state and their relation to goal neglect were examined in the current study. Participants performed a variant of the Stroop task in which attentional state ratings were given prior to each trial. It was found that pre-trial attentional state ratings predicted subsequent trial performance, such that when participants rated their current attentional state as highly focused on the current task, performance tended to be high compared to when participants reported their current attentional state as being unfocused on the current task. This effect was larger for incongruent than congruent trials leading to differences in the magnitude of the Stroop effect as a function of pre-trial attentional state. Furthermore, variability in attentional state was correlated with overall levels of performance, and when attentional state was covaried out, the Stroop effect was greatly reduced. These results suggest a link between fluctuations in pre-trial attentional state and goal neglect.

1. Introduction

Our ability to focus and sustain attention on important task-relevant information is a critically important skill that is needed in a host of everyday activities. Despite the importance of focusing and sustaining attention on goal-relevant information, sometimes the attention system falters leading to lapses of attention. Understanding these lapses of attention, whereby attention is disengaged from the current task and focused on other external distracting stimuli or internal thoughts (daydreaming), is important for understanding how and when attentional processes falter in both the laboratory and in real world situations (Kane et al., 2007; Reason, 1984; Reason & Mycielska, 1982; Smallwood & Schooler, 2006; Unsworth, McMillan, Brewer, & Spillers, 2012). Theoretically, cognitive control processes are needed to ensure active goal-maintenance leading to task appropriate behaviors. Prominent theories of cognitive control suggest that cognitive control is implemented by the prefrontal cortex in situations where task goals need to be actively maintained and dynamically updated (Miller & Cohen, 2001). Accordingly, top-down attention control processes are needed to maintain task goals and bias responding so that the appropriate behavior is executed. In many situations, participants will have to actively maintain a novel task goal that is in direct opposition to prepotent response tendencies (Roberts & Pennington, 1996). If there is a failure of active goal maintenance, then it is likely that prepotent response tendencies will guide behavior, leading to goal neglect and the execution of the incorrect response (Duncan, 1995). In situations when attention is tightly focused on the task goal, performance will be both fast and accurate. However, if attention is not tightly focused on the task goal, goal neglect can occur, which will

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lead to overall slower responses or to fast errors that are guided by prepotent tendencies. For example, consider the Stroop task in which participants are required to name the color in which color names are printed. When the color and the word match ("RED" presented in red ink), the task is quite easy. When the color and the word conflict ("RED" presented in blue ink), however, both reaction time and error rates increase. According to views of cognitive control, because the prepotent response conflicts with the task goal ("Say the color not the word"), a loss of goal maintenance should result in the prepotent response guiding behavior and hence the occurrence of fast word-naming errors or slower overall response times (Kane & Engle, 2003).

De Jong, Berendsen, and Cools (1999) presented evidence in support of this general argument in a study in which participants performed congruent and incongruent Stroop trials with either a long or a short response-stimulus interval (RSI). De Jong et al. reasoned that the fast pace of the short RSI would keep attention tightly focused on the task goal, thereby preventing losses of goal-maintenance. The long RSI, however, should induce more lapses of attention (and goal neglect) as participants would have ample time between trials for their minds to wander. This suggests that the Stroop effect should be much larger in the long RSI condition than the short RSI condition. This is precisely what was found. In the long RSI condition there was a significant Stroop effect, but in the short RSI condition the Stroop effect was no longer significant. Furthermore, examining the reaction time distributions in each condition, De Jong et al. found that the difference in the magnitude of the Stroop effect was localized primarily in the slowest RTs. De Jong et al. suggested that these results provide evidence for fluctuations in attention that occur on a trial-by-trial basis and lead to goal neglect (see also Kane & Engle, 2003; West, 1999).

The above work suggests the importance of maintaining goal-relevant information in an active state to ensure accurate responding and further suggest that periodic lapses in attention can lead to goal neglect problems. Indeed, it is a common assumption that attention waxes and wanes during a task in which attention is initially focused on the task, but slowly wanes as our minds wander or we become distracted, then attention once again focuses back on the task at hand (Gilden, 2001). These trial-to-trial fluctuations of attention have been found to occur in a number of prolonged tasks and research suggests that participants' self-reports of their attentional state are reliable and valid indicators of variations in attention (Smallwood & Schooler, 2006). Specifically, a number of studies have utilized thought-probe techniques in which periodically during a prolonged attention task participants are probed and are required to report whether their attention was currently focused on-task or whether they were mind-wandering. This research has consistently found that not only do participants report extensive mind-wandering during attentional tasks, but also these self-reports of mind-wandering are correlated with actual performance, such that self-reports of mind-wandering are associated with lower levels of performance (McVay & Kane, 2012; Schooler, Reichle, & Halpern, 2004).

More recently Macdonald, Mathan, and Yeung (2011) examined trial-to-trial fluctuations in attentional state in a rapid serial presentation detection task by probing participants after each trial (rather than randomly throughout the task) and found that fluctuations in subjective attentional state strongly predicted performance such that when attentional state ratings were high, performance was relatively good, and when attentional state ratings were low, performance was worse. Furthermore, Macdonald et al. found that subjective attentional state ratings were negatively related with pre-stimulus EEG alpha power suggesting that fluctuations in attention are reflected in not only subjective ratings, but also in EEG alpha power.

The goal of the present study was to examine the extent to which fluctuations in pre-trial attentional state would predict performance on the subsequent trial and the extent to which pre-trial attentional state would predict levels of goal neglect. In particular, prior work has suggested that fluctuations in attentional state are one of the main contributors to goal neglect such that when attention is sharply focused and the current goal state is actively maintained performance will be good. However, when attention is loosely focused the goal will not be maintained as well (or at all) leading to worse performance (De Jong et al., 1999). Despite these initial claims, no study has actually attempted to measure pre-trial subjective attentional state on a trial-by-trial basis to see if trial-to-trial differences in attentional state influence the amount of goal neglect observed on a task. Therefore, to directly examine the notion that pre-trial attentional state is an important predictor of subsequent performance, participants performed a version of the Stroop task that promoted goal neglect. Specifically, in this task participants were presented with both congruent and incongruent trials, but critically there were far more congruent trials than incongruent trials. Prior research has suggested that proportion congruence manipulations in the Stroop and other tasks place high demands on goal maintenance (Kane & Engle, 2003). In one condition participants performed the Stroop task under normal conditions. In the other condition, participants performed the same Stroop task, with the exception that prior to each trial participants were instructed to provide a numerical rating (1–10) on their current attentional state. Specifically, in the attentional state condition, participants rated how focused they were on the current task prior to each trial. This was done because we were primarily interested in determining if pre-trial attentional state would predict subsequent performance on a trial-by-trial basis. Prior research has primarily examined changes in attentional state by probing participants periodically after some trials, and thus it is not known how pre-trial attentional state (i.e., how focused one is) relates to performance and how this changes on a trial-by-trial basis. Furthermore, most prior research has participants indicate if they are on- or off-task and we wanted to see if a more continuous measure of attentional state would predict performance. The reason for including a condition where participants did not provide attentional state ratings was to examine possible reactivity effects whereby providing attentional state ratings could lead to changes in performance compared to more standard versions of the Stroop task. If there are no differences between the two conditions, we can assume that the attentional ratings provide a window into normally ongoing processes in the Stroop task. If pre-trial attentional state is an important determinant of performance, we should see that pre-trial attentional state not only predicts trial-to-trial variability in performance, but critically pre-trial attentional state should predict the amount of Stroop interference that is observed.