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The wandering self: Tracking distracting self-generated thought in a cognitively demanding context

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ABSTRACT

We investigated how self-referential processing (SRP) affected self-generated thought in a complex working memory task (CWM) to test the predictions of a computational cognitive model. This model described self-generated thought as resulting from competition between task- and distracting processes, and predicted that self-generated thought interferes with rehearsal, reducing memory performance. SRP was hypothesized to influence this goal competition process by encouraging distracting self-generated thinking. We used a spatial CWM task to examine if SRP instigated such thoughts, and employed eye-tracking to examine rehearsal interference in eye-movement and self-generated thinking in pupil size. The results showed that SRP was associated with lower performance and higher rates of self-generated thought. Self-generated thought was associated with less rehearsal and we observed a smaller pupil size for mind wandering. We conclude that SRP can instigate self-generated thought and that goal competition provides a likely explanation for how self-generated thoughts arises in a demanding task.

1. Introduction

When we try to characterize our conscious experience, we can say that is guided in roughly two ways (see Dixon, Fox, & Christoff, 2014). On one hand, our thoughts are shaped by what we perceive in our external environment. For instance, when we are reading a book, our thoughts are likely on what we read. On the other hand, our conscious experience is not always tied to our environment. Analogously, we might find ourselves thinking about future plans while reading this article. Or: we might contemplate about the answer to a question we just received. In these situations, constructive and associative processes in memory shape our thoughts internally without the need of perceptual guidance.

This internally directed thought, or *self-generated thought*, has been extensively studied in past recent years with examples including: thinking about the self or others, mental simulations, imagination, past and future thinking, and planning (for a review see Andrews-Hanna, Smallwood, & Spreng, 2014). Self-generated thought can occur both in the absence and the presence of external stimuli. In addition, it can be triggered both by internal and external influences, but it always involves a disengagement from the external environment (Schooler et al., 2011). In this article, we will focus on self-generated thought that occurs in the context of a main external task but is not relevant to performance on this task. In other words, we want to explore self-generated thought that becomes a distraction from the main task.

One popular example of self-generated thought, oftentimes regarded as a distraction from main activities, is *mind wandering*. Mind wandering refers to a self-generated thought process that proceeds independently of an external task (Smallwood & Schooler, 2015). Since mind wandering is covert in nature, it can only be observed indirectly with self-report questions that sample thought content

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(see Csikszentmihalyi & Larson, 1987; Larson & Csikszentmihalyi, 1983). These self-report questions, or *thought-probes*, are embedded in the task to determine how mind wandering is related to performance on the task. Studies using thought-probes have identified that mind wandering is associated with higher and more variable response times (e.g., Bastian & Sackur, 2013; van Vugt & Broers, 2016) and to decrements in task performance (e.g., working memory; Rummel & Boywitt, 2014). Although mind wandering has clear adverse consequences for our current activities, this does not need to be true for tasks still in the future. The content of mind wandering has been found adaptive in many instances, with thoughts that are highly self-focused, goal-directed, and future oriented (see Baird, Smallwood, & Schooler, 2011).

Until recently, most studies have examined mind wandering in tasks imposing low cognitive demand, allowing cognitive resources for mind wandering to occur. However, one might argue that it is more interesting to investigate mind wandering (and also other self-generated thoughts) in contexts where one is busily engaged in a task, situations where performance on main activities is at stake. Research has shown that the adverse consequences of mind wandering are greater in tasks with higher cognitive demand (such as in n-back and general intelligence measures; see McVay & Kane, 2012a, 2012b; Mrazek et al., 2012; Rummel & Boywitt, 2014; Smallwood & Andrews-Hanna, 2013). Commonly, it is observed that mind wandering is less frequent in higher demand contexts (see e.g., Smallwood, Brown et al., 2011; Smallwood, Schooler et al., 2011; Thomson, Besner, & Smilek, 2013), but proportions are still substantial. Recent work by Seli, Risko, and Smilek (2016) even found equal rates of mind wandering across task demand, with relatively more reports of unintentional mind wandering in a challenging task and more intentional mind wandering in an easier task. Similar to what has been found for lower demand contexts, the content of mind wandering is predominantly self-related and focused on personal goals and future plans (Smallwood, Schooler et al., 2011). Consequently, these results suggest that mind wandering, and potentially self-generated thought in general, has similar characteristics in contexts of low and high cognitive demand.

In the present study, we will focus on demanding task paradigms to examine self-generated thought in a context where it becomes a distraction for a main task. Building on earlier work (viz., Daamen, Van Vugt, & Taatgen, 2016), we are interested in investigating the potential of self-referential processing to instigate such thoughts. Our approach is to test the assumptions of a computational cognitive model, which describes the cognitive processes of participants in a task and predicts how self-generated thought can occur in short spare moments of a task. We will test whether self-generated thought occurs in spare moments of the task by means of triangulating eye-tracking measures and thought-probes. However, before explaining the full details of our experiment, we will first provide a short review on correlates of self-generated thought in eye-tracking measurements. Subsequently, we will discuss the role of self-referential processing in instigating self-generated thought.

1.1. Correlates of self-generated thought in eye-tracking

The thought-probes we just introduced have the advantage to provide insight in the content of self-generated thought. However, the discrete nature of the measure makes it hard to determine when the thoughts occurred. Correlates in physiological or task performance measures (e.g., response times) can provide this knowledge and may allow us to track self-generated thought online (e.g., Franklin, Smallwood, & Schooler, 2011; Grandchamp, Braboszcz, & Delorme, 2014; Mittner et al., 2014). Here we will review studies using eye-movement and pupil size measurement, since these are the measures we will use in our current study.

With eye-tracking we continuously measure eye-movement and pupil size throughout an experiment while having the advantage of being entirely unobtrusive (unlike e.g., fMRI and EEG). Eye-movement correlates of self-generated thought have commonly been investigated in linguistics studies, in which this measure is employed to examine real-time cognitive processing during reading (e.g., Reichle, Reineberg, & Schooler, 2010; Uzzaman & Joordens, 2011). For instance, a recent study by Foulsham, Farley, and Kingstone (2013) found that participants showed longer and slightly more frequent fixations in sentence reading during mind wandering. According to the researchers, the longer fixation duration are a result of a decoupling between seeing the words and processing their meaning, which provides evidence for the idea that self-generated thought, such as mind wandering, involves a disengagement of attention from the external task (see Kam & Handy, 2013).

Similar results were found in a recent study by Benedek, Stoiser, Walcher, and Körner (2017). The researchers examined the influence of self-generated thought (called internally-directed cognition in their study) on eye-movement and pupillometric measures by manipulating the focus of attention (internal and external) with an externally demanding task (sentence generation) and an internally demanding task (anagram). The rationale was that the anagram task would require self-generated thought to solve, building on an internal representation of the problem. The sentence generation task, however, could be solved without. The researchers found that self-generated thought was associated with fewer fixations and saccades, but with increased fixation duration. Based on the results, the researchers conclude that eye-movements are more spontaneous and less directed during self-generated thought. In addition to eye-movement differences, they also identified a larger average pupil size for self-generated thought, indicating higher levels of arousal (see Gilzenrat, Nieuwenhuis, Jepma, & Cohen, 2010; Murphy, Robertson, Balsters, & O'Connell, 2011). Potentially, the higher levels of arousal reflected the decoupling of attention from the external task, which is hypothesized to occur with self-generated thought.

Research on pupil size correlates for mind wandering has not been fully consistent. Similar to the above-mentioned study of Benedek, some studies have identified larger pupil sizes prior to reports of mind wandering (Franklin, Broadway, Mrazek, Smallwood, & Schooler, 2013; Smallwood et al., 2012; Smallwood, Brown et al., 2011), whereas other studies have found smaller pupil sizes (e.g., Grandchamp et al., 2014; Konishi, Brown, Battaglini, & Smallwood, 2017; Mittner et al., 2014; Unsworth & Robison, 2016). Explanations for these mixed results are speculative. Notable about the above mentioned studies is that larger pupil sizes during mind wandering episodes were primarily found in relatively undemanding tasks (e.g., reading) whereas the smaller pupil sizes were identified in more demanding tasks (e.g., n-back). In more difficult tasks, mind wandering may result in a lower arousal state