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Your mind wanders weakly, your mind wanders deeply: Objective measures reveal mindless reading at different levels

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ABSTRACT

When the mind wanders, attention turns away from the external environment and cognitive processing is decoupled from perceptual information. Mind wandering is usually treated as a dichotomy (dichotomy-hypothesis), and is often measured using self-reports. Here, we propose the levels of inattention hypothesis, which postulates attentional decoupling to graded degrees at different hierarchical levels of cognitive processing. To measure graded levels of attentional decoupling during reading we introduce the sustained attention to stimulus task (SAST), which is based on psychophysics of error detection. Under experimental conditions likely to induce mind wandering, we found that subjects were less likely to notice errors that required high-level processing for their detection as opposed to errors that only required low-level processing. Eye tracking revealed that before errors were overlooked influences of high- and low-level linguistic variables on eye fixations were reduced in a graded fashion, indicating episodes of mindless reading at weak and deep levels. Individual fixation durations predicted overlooking of lexical errors 5 s before they occurred. Our findings support the levels of inattention hypothesis and suggest that different levels of mindless reading can be measured behaviorally in the SAST. Using eye tracking to detect mind wandering online represents a promising approach for the development of new techniques to study mind wandering and to ameliorate its negative consequences.

1. Introduction

Most people experience mental states in which they are no longer attending to the task at hand and are instead thinking about something else (Schooler et al., 2011; Smallwood & Schooler, 2006). This ubiquitous phenomenon of mind wandering, which was long ignored in the cognitive sciences, has recently received considerable attention (Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Killingsworth & Gilbert, 2010; Levinson, Smallwood, & Davidson, 2012; McVay & Kane, 2010; Reichle, Reineberg, & Schooler, 2010) and is thought to be tightly related to the brain's default mode of operation (Buckner, Andrews-Hanna, & Schacter, 2008; Mason et al., 2007). Mind wandering and task focus are typically treated as a dichotomy (Schooler et al., 2011; Smallwood, 2010b; Smallwood et al., 2011), where people are either mind wandering or focused on a given task. To investigate dichotomous aspects of mind wandering many previous studies have relied on subjective self-reports (Giambra, 1995; Smallwood & Schooler, 2006). Our main goal with the present work is to propose the levels of inattention hypothesis, which assumes that different hierarchical levels of cognitive processing are decoupled from external input in a graded fashion, reflecting states of deep and weak attentional decoupling. To measure different levels of decoupling during reading, we introduce a new paradigm,

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the sustained attention to stimulus task (SAST), which is based on signal detection analyses of readers' sensitivity for errors in the text. Analyzes of a large dataset of eye movements during mindless reading support the levels of inattention hypothesis and show that eye tracking technology can be utilized to predict states of mindless reading online.

The phenomenon of mind wandering involves two specific alterations in cognitive processing (Schooler et al., 2011; Smallwood & Schooler, 2006). First, during mind wandering attention is directed away from the external environment (i.e., attention lapses), which reduces cognitive processing of perceptual information (Kam et al., 2011; Smallwood, Beach, Schooler, & Handy, 2008). This process of attentional (or perceptual) decoupling can lead to failures in the performance of external tasks (Christoff et al., 2009; McVay, Kane, & Kwapil, 2009; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997; Smallwood, Riby, Heim, & Davies, 2006). Second, mind wandering often involves stimulus independent thought (SIT) where attention is directed towards internal information derived from memory (Smallwood & Schooler, 2006; Stawarczyk, Majerus, Maquet, & D'Argembeau, 2011).

The cognitive sciences have described the mind as consisting of a multitude of different cognitive processes (Gazzaniga, 2009). As one important principle these processes are organized at different hierarchical levels, ranging from early low-level perceptual-motor processes towards increasingly abstract representations at higher levels (Cohen, 2000; Craik & Lockhart, 1972; Gazzaniga, 2009). For reading, various models – including models of eye-movement control (Engbert, Nuthmann, Richter, & Kliegl, 2005; Reichle, Warren, & McConnell, 2009) and theories of language processing (Graesser, Olde, & Klettke, 2002; Kintsch, 1998; Malmkjaer, 2002) – have postulated hierarchical processing at visuomotor, lexical, syntactic, semantic, and discourse levels. How (in)attention affects different lower and higher levels of stimulus processing was long discussed in the debate about early (Broadbent, 1958) versus late (Deutsch & Deutsch, 1963; Treisman, 1960) attentional selection, and there is evidence that attentional selection can attenuate processing at early or late stages (Chun, Golomb, & Turk-Browne, 2011; Lavie, 2005).

Mind wandering reduces external attention and can attenuate stimulus processing at all levels of the cognitive hierarchy (for review see Smallwood, 2011). This was demonstrated in studies investigating high-level episodic memory encoding (Riby, Smallwood, & Gunn, 2008; Smallwood, Baracaia, Lowe, & Obonsawin, 2003; Smallwood, McSpadden, & Schooler, 2008; Smallwood et al., 2006), intermediate task-relevant stimulus processing (Barron, Riby, Greer, & Smallwood, 2011; O'Connell et al., 2009; Smallwood et al., 2008), early low-level multimodal perceptual processing (Kam et al., 2011; Weissman, Roberts, Visscher, & Woldorff, 2006), and sensory input processes (Smilek, Carriere, & Cheyne, 2010b). The present work concerns how these diverse findings can be integrated into a coherent theoretical framework.

The cascade model of inattention (Smallwood, 2011; Smallwood, Fishman, & Schooler, 2007) proposes a mechanism to explain decoupling in a hierarchical cognitive system. According to the model, mind wandering reduces cognitive processing of incoming information at a very early perceptual level and across multiple sensory modalities. The consequences of such low-level decoupling then "cascade downward through the cognitive system" (Smallwood et al., 2007, p. 233) and cause decoupling at higher levels. Based on this mechanism, the model parsimoniously explains why decoupling impairs performance in "as wide a range of tasks as perception, encoding and reading" (Smallwood, 2011, p. 68).

Stimulus-independent thought and stimulus-dependent thought are usually treated as a dichotomy (Smallwood et al., 2011), and this view has dominated previous research (e.g., Christoff, 2012; Fox et al., 2005; Killingsworth & Gilbert, 2010; Levinson et al., 2012; McVay & Kane, 2012b; Reichle et al., 2010; Smallwood, 2010b). Here, we investigate attentional decoupling and whether it is of a dichotomous or a hierarchically graded nature. First, the dichotomy-hypothesis proposes that different levels of cognitive processing are decoupled from external input in an all-or-none fashion (see Fig. 1a): during task focus all hierarchical levels of cognitive processing are coupled to the external environment, but when the mind wanders this coupling breaks down at all levels. As a potential mechanism, attentional decoupling may always attenuate early perceptual processing stages across modalities (reflecting early attentional selection, Broadbent, 1958) and the consequences of this low-level decoupling may cascade into the system to impair analysis at higher levels (Smallwood, 2011; Smallwood et al., 2007). For the phenomenon of mindless reading, the dichotomy-hypothesis predicts that impaired visual representations of the text prevent a successful analysis at the lexical, syntactic, semantic, and the discourse level.

As an extension of the dichotomous view, we propose the levels of inattention hypothesis (Fig. 1b): We postulate that cognitive processing of external input does not always fail at an early perceptual level, but fails at different hierarchical levels, resulting in different graded degrees of weak and deep attentional decoupling. During occasional episodes of deep decoupling, cognitive processing of external input ceases at an early perceptual level (early attentional selection), and the consequences of this low-level decoupling cascade into the system to cause decoupling at higher levels (Smallwood, 2011; Smallwood et al., 2007). As a new contribution, we postulate states of weak decoupling, where high-level cognitive processing is decoupled from the external environment (i.e., late attentional selection, Deutsch & Deutsch, 1963) but low-level processing is fully intact. Lastly, during states of full attentional coupling external information is processed at all levels. Combining the levels of inattention hypothesis with the cascade model of inattention (Smallwood, 2011; Smallwood et al., 2007) predicts that decoupling at different levels is hierarchical because reduced cognitive processing at one specific level will cause decoupling at higher levels in the hierarchy.

Previous studies on attentional decoupling have typically focused on dichotomous aspects of the decoupling process: many studies investigated decoupling in the sustained attention to response task (SART) via failures to inhibit the response to rare target stimuli (Manly, Robertson, Galloway, & Hawkins, 1999; Robertson et al., 1997;