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Out of Mind, Out of Sight: Eye Blinking as Indicator and Embodiment of Mind Wandering

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Introduction

Mind wandering, in which cognitive processing of the external environment decreases in favor of internal processing (Smallwood & Schooler, 2006), has been consistently associated with errors on tasks requiring sustained attention and continuous stimulus monitoring (e.g., Cheyne, Carriere, & Smilek, 2006; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997; Smallwood et al., 2004). Consistent with this finding, recent neuroimaging studies suggest that mind wandering engages the default neural network (Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Mason et al., 2007; Smallwood, Beach, Schooler, & Handy, 2008; Weissman, Roberts, Visscher, & Woldorff, 2006) and is associated with decreased neural analysis of incoming information (Christoff et al., 2009; Smallwood, Beach et al., 2008; Weissman et al., 2006). Here we propose that mind wandering also involves overt embodied components whereby external input is blocked at the sensory endings. We demonstrate that during an extended period of reading, episodes of mind wandering, compared with on-task periods, contain more eye closures (blinks) and fewer fixations on the text?even as subjects continue to scan the text.

The present investigation is based on the idea that blink rate might serve to modulate trade-offs between attention to mind-wandering thoughts and to external task-related stimuli. Blinks reduce processing of external stimuli in two ways?by physically closing the eyelid and by generating cortical suppression of visual processing both before and after the time of actual lid closure (Bristow, Frith, & Rees, 2005; Bristow, Haynes, Sylvester, Frith, & Rees, 2005; Ridder & Tomlinson, 1997; Volkmann, 1986). Increasing the rate of such visual interruptions may facilitate a shift in the balance of processing from external stimuli to internal thoughts. Consistent with these considerations, evidence suggests that an increase in eye blinks is associated with errors in vigilance to external stimuli (Papadelis et al., 2007; Poulton & Gregory, 1952; Van Orden, Jung, & Makeig, 2000) and with conflict between internal and external workload (Recarte, Perez, Conchillo, & Nunes, 2008).

To assess the relation between eye blinks and mind wandering, we compared blink rates during probe-caught episodes of mind wandering and on-task periods of reading.

Mind-wandering episodes during reading are relatively frequent; everyone has experienced interfering thoughts that compromise reading (Reichle, Reineberg, & Schooler, in press; Schooler, Reichle, & Halpern, 2004; Smallwood, McSpadden, & Schooler, 2008), and it is possible to even find oneself at the end of a page with no recollection of having processed the material just "read." Such *zone-outs* (Smallwood & Schooler, 2006) can be effectively sampled by random probes that prompt people to report their immediate thoughts (Giambra & Grodsky, 1989; Sayette, Reichle, & Schooler, 2009; Schooler et al., 2004; see also Smallwood & Schooler, 2006). We expected blink rates to be higher in the 5-s periods preceding probe-caught episodes of mind wandering than in the 5-s periods preceding probe-caught on-task episodes.

Method

Fifteen graduate students at the University of Waterloo read two passages from *A Short History of Nearly Everything* by Bill Bryson. The passages were presented on a computer screen, and subjects used a game pad to navigate between pages (see Fig. 1a). As subjects read, pupils and corneal reflections were monitored using an EyeLink 1000 desk-mounted system developed by SR Research Ltd., based in Ottawa, Ontario, Canada. A blink was defined as a period in which a pupil was not detected for three or more consecutive samples (at 1000 Hz). Subjects were given 15 min to read each passage.

Ten probes (auditory tones) were randomly presented during each 15-min reading period (see Smallwood & Schooler, 2006), and after each probe, the subjects reported whether they were mind wandering or on task. Subjects were instructed that mind wandering included thoughts about earlier sections of the text and thoughts relevant to the text (task-related mind wandering), as well as thoughts completely unrelated to the text, such as thoughts about an upcoming meal (task-unrelated mind wandering).

Results

Twelve (7 males, 5 females) of the 15 subjects tested were included in the analyses. (Three subjects who reported mind wandering fewer than four times were excluded.) Subjects reported equal proportions of time mind wandering for the two passages (Passage 1: $M = 32.5\%$ of probes, Passage 2: $M = 37.5\%$ of probes).

Critically, analysis of the eye-blink rate in the 5-s intervals preceding the probes revealed a striking difference between mind-wandering and on-task periods. Subjects blinked more when mind wandering than when on task, one-tailed $t\ (11) = 4.25$, $p = .001$. This pattern was observed in all but 1 of the subjects (see Fig. 1b).

We also analyzed fixation frequency and fixation duration as a function of mind wandering. Analysis of the rate of eye fixations revealed that the eyes fixated less often during mind wandering ($M = 4.13$) than when subjects were on task ($M = 4.24$), one-tailed $t\ (11) = 2.90$, $p = .007$, a pattern consistent with recent findings reported by Reichle, Reineberg, and Schooler (in press). This was the case even though we calculated fixation rate based only on the times the eyes were actually open, ensuring that the reduced fixation rate was not simply the result of increased eye blinks during episodes of mind wandering. Analyses of average fixation durations failed to detect any significant differences between episodes of mind wandering and on-task periods, $t\ (11) = 1.14$, $p = .36$.

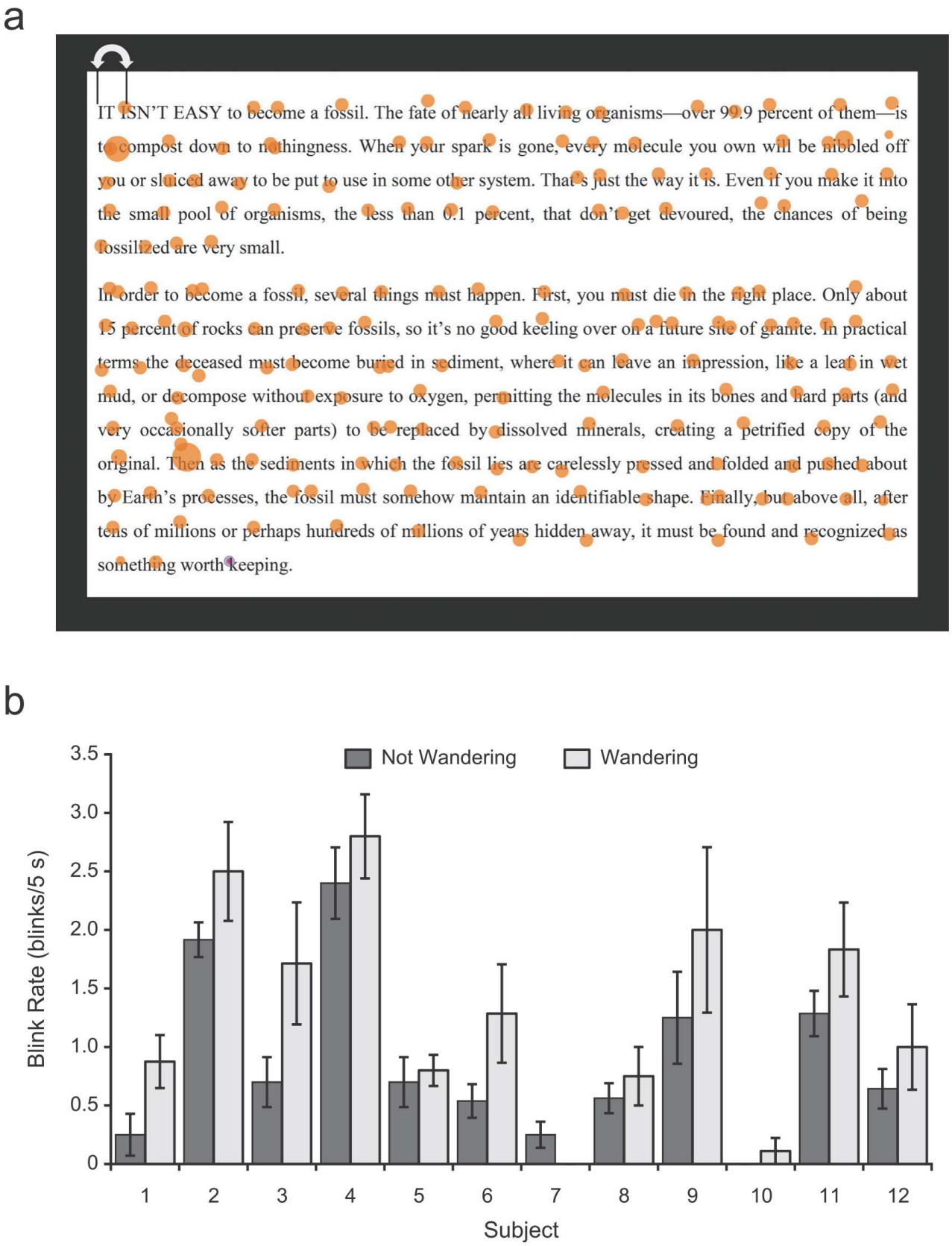

Fig. 1. Example of the reading passages and experimental results. In the example of a passage (a), the filled circles represent the eye fixations from a representative subject. The sizes of the circles indicate the duration of the fixations. The space subtended by 1° of visual angle is shown at the top left. The graph (b) shows the blink rates for each subject (number of blinks per 5-s interval) prior to probe-caught moments when the mind was wandering and not wandering. Error bars indicate 1 *SEM* for each subject.

Discussion

This study provides an initial demonstration that during bouts of mind wandering, the body physically blocks sensory stimulation by reducing exposure of the sensory transducers to external energy sources. At present, the causal relation between eye blinks and mind wandering remains unclear. However, we suggest that changing rates of eye blinks serve to modulate shifts between attending to internal thoughts (i.e., mind wandering) and attending to ongoing task-relevant stimuli. It is important to note that in addition to, and independently of, occlusion of the retina, eye blinks trigger cortical deactivation of areas responsible for processing the external visual world (Bristow, Frith, & Rees, 2005; Bristow, Haynes, et al., 2005), substantially extending the impact of blinking on reduced processing of visual information (Poulton & Gregory, 1952). These considerations lead us to propose that future analysis of neural correlates of mind wandering should include assessments of bodily reactions, such as blinking, that may interact with default network activity reported to be associated with mind wandering (Christoff et al., 2009; Mason et al., 2007). Finally, the present results are consistent with the finding that people avert their gaze when they engage in internal problem solving (Bakan, 1971; Kinsbourne, 1972); averting gaze may serve to turn the visual receptors away from interfering physical and social sources of information, thus facilitating internal thought.

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