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Brief article

Driven to distraction: A lack of change gives rise to mind wandering

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ABSTRACT

How does the dynamic structure of the external world direct attention? We examined the relationship between event structure and attention to test the hypothesis that narrative shifts (both theoretical and perceived) negatively predict attentional lapses. Self-caught instances of mind wandering were collected while 108 participants watched a 32.5 min film called *The Red Balloon*. We used theoretical codings of situational change and human perceptions of event boundaries to predict mind wandering in 5-s intervals. Our findings suggest a temporal alignment between the structural dynamics of the film and mind wandering reports. Specifically, the number of situational changes and likelihood of perceiving event boundaries in the prior 0–15 s interval negatively predicted mind wandering net of low-level audiovisual features. Thus, mind wandering is less likely to occur when there is more event change, suggesting that narrative shifts keep attention from drifting inwards.

1. Introduction

We frequently find ourselves thinking about things other than what we were trying to focus on. Our minds spontaneously self-generate thoughts that are decoupled from the external environment. For instance, we think about our internal state (e.g., feeling hungry), current and future concerns (e.g., having to do something later), and our past (e.g., ruminating) (Smallwood & Schooler, 2015). The general trait to engage in self-generated thoughts has been associated with creativity and other positive outcomes (Mooneyham & Schooler, 2013). However, experiencing one type of self-generated thought (i.e., mind wandering) while completing tasks that require cognitive engagement has been consistently linked with lower task performance (see meta-analysis by Randall, Oswald, & Beier, 2014). One reason for this negative relationship is that mind wandering engenders a form of perceptual decoupling (Mills, Graesser, Risko, & D'Mello, 2017; Smallwood, Beach, Schooler, & Handy, 2008), manifested by a breakdown between the external environment and internal thoughts. But how does the dynamic unfolding of the external environment constrain or facilitate mind wandering? We addressed this question by exploring the relationship between the unfolding of a dynamic stimulus (a film) and the occurrence of mind wandering using indices of stimulus structure: the amount of *situational change* and the likelihood of perceiving *event boundaries*. By doing so we take initial steps towards integrating two disparate literatures—event cognition and self-generated thought.

Our work is grounded in theoretical perspective that we segment the world into discrete events, which guide our perception and encoding of ongoing activity (Radvansky & Zacks, 2014; Zacks & Tversky, 2001; Zacks et al., 2001). The perception of boundaries between events (i.e. one event ending and another beginning) is related to changes in space, time, and causality as well as changes in characters, their interactions, and their goals (Radvansky & Zacks, 2014; Zacks, Speer, & Reynolds, 2009; Zwaan & Radvansky, 1998). We hypothesize that change in event structure is related to less mind wandering as such shifts might direct attention to stimulus processing (Swallow, Zacks, & Abrams, 2009) and mental model updating (Magliano, Zwaan, & Graesser, 1999). We tested this hypothesis by investigating whether event structure predicted mind wandering in a narrative film comprehension task. In doing so, this study is the first to shed light on whether and how the structural dynamics of ongoing events direct attentional focus to external stimuli and away from self-generated thoughts—as measured by mind wandering—over time.

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2. Data analysis

2.1. Mind wandering data

2.1.1. Participants

We obtained mind wandering data from 108 college students who participated in a study investigating the occurrence of mind wandering while watching a narrative film (see Kopp, Mills, & D'Mello, 2015). Students attended either a private Midwestern university ($n = 65$) or a public university in the southern United States ($n = 43$), and participated for partial course credit (66% female; average age = 20.1 years). All 108 participants were included in the analyses.

2.1.2. Film

Participants viewed the narrative film *The Red Balloon* (Lamorisse, 1956). This short (32.5 min) French film (with English subtitles) is about a young boy in Paris who finds a red balloon that follows him wherever he goes. This film has been widely used in event perception research because it has many situational changes and little dialogue (Zacks, Speer, Swallow, & Maley, 2010; Zacks et al., 2009). Furthermore, because it is an older film, the likelihood that college-age participants would be familiar with it is low.

2.1.3. Procedure

Participants were randomly assigned to a prior knowledge or control condition. These conditions were part of a larger research project aimed at establishing whether prior knowledge suppresses mind wandering (Kopp et al., 2015). Before participants were informed that they would watch *The Red Balloon*, they either read a text version of *The Red Balloon* (Lamorisse, 1956) (prior knowledge, $n = 56$) or an unrelated story (*Bernie the Early Bloomer*, Smith, 1999) (control, $n = 52$).

We used self-caught mind wandering reports rather than periodical thought probing. The latter can inadvertently miss instances of mind wandering, that do not correspond to a probe. Self-caught reporting on the other hand captures each instance that the participant is aware of. Importantly, it preserves the temporal relationship between stimulus unfolding and mind wandering, which is critical for our analyses. Participants received the following instructions:

> "Your primary task is to watch the movie to understand the plot. At some points during the movie, you may realize that you have no idea what you just saw. Not only were you not thinking about the movie, you were thinking about something else altogether. This is called "zoning out". If you catch yourself zoning out at any time during the movie, please indicate what you are thinking about at that moment during the movie. For example, when zoning out, if you are thinking about the task itself (e.g., how long is the movie, this movie is very interesting) or how the task is making you feel (e.g., curious, annoyed) but not the actual content of the movie, please press the key that is labeled TASK. Or, if you are thinking about anything else besides the movie (e.g., what you ate for dinner last night, what you will be doing this weekend) please press the key that is labeled OTHER".

As illustrated by these instructions, participants reported zoning out whenever they found themselves focusing on content-unrelated thoughts, and had no idea of what just happened in the film. "Task" and "Other" responses were therefore conceptually similar in that both reflect self-caught instances of zoning out. They also displayed similar negative relationships with event measures (defined below; see Supplemental Table 1), so we combined them into one mind wandering measure to increase reliability.

As expected, there were more mind wandering reports in the prior knowledge condition (number of mind wandering reports: $M = 9.77$, $SD = 13.3$, range = 0–70) compared to the control condition ($M = 13.8$, $SD = 14.9$, range = 0–54). Given this difference, we included condition as an interaction term to test whether the relationship between mind wandering and event change is moderated by prior knowledge.

Data for each participant were aggregated into 5 s time windows (as commonly done in event segmentation research; see e.g., Kurby, Asiala, & Mills, 2013; Zacks et al., 2009). This resulted in 390 windows per participant, each containing whether the participant reported mind wandering during that 5 s interval. Data can be found in the Supplementary materials.

2.2. Event change data

We computed measures of event change using theoretical coding and human event segmentation data. Our first measure consisted of situational change coding (from Zacks et al., 2009), which reports (for each video frame) whether there was a change in causal structure, character, goal, object, space or time. The second measure used event segmentation data from 41 college students (Zacks et al., 2009) who reported any perceived boundaries in the film at a coarse and a fine grained level. Perceived boundaries were defined as instances where "one meaningful unit of activity had ended and another had begun" (Zacks et al., 2009, p. 316; cf. Newtson, 1973). For coarse-grained segmentation, participants were instructed to "identify the largest units they found meaningful"; for fine-grained segmentation, they were asked to "identify the smallest units that were meaningful to them" (Zacks et al., 2009, p. 316).

We counted the number of reports of situational change, fine grained, and coarse grained boundaries for each 5 s time window. For the situational change measure, we added all changes in the window (cf. Magliano, Miller, & Zwaan, 2001) and then z-scored the measure. For the human segmentation measure, we first z-scored the coarse and fine grained segmentation measures, and then averaged them. This was done to capitalize on the convergence between coarse and fine grained segmentation ($r = 0.575$) and is justified due to an overlap in the neural processes that underlie both grain sizes of segmentation (Zacks et al., 2001). We also computed the amount of visual (the average frame-level RGB change) and auditory (the average frame-level volume change) change per 5-s time window to control for these low level perceptual features.

3. Results

We assessed the relationship between mind wandering and event change by fitting mixed effects logistic regression models to predict the binary occurrence of mind wandering in each 5 s window from the event change measures. The measures of low level visual and auditory change were added as control variables. Condition (prior knowledge or not) was added as an interaction term with event change. Participant identity was added as a random intercept.

To explore temporal relationships, we repeated the analysis after lagging or leading the mind wandering time series. This resulted in seven additional analyses, representing the amount of event change in the 25 s before and 10 s after each 5 s time window (divided in seven 5 s time windows, so 25–30 s before and 10–15 s after a time point in each window). Previous work has shown that people experience shifts in thought content every 5–30 s (Klinger, 1978), so we did not expect event change beyond 30 s in the past to be predictive of current thoughts. We did not expect to find a strong predictive relationship between event change in future time windows and mind wandering. Therefore, to avoid spurious relationships, we did not model time points beyond 10–15 s into the future. Bonferroni correction was used to correct for multiple comparisons, resulting in an alpha of 0.00625 (eight time windows per event change variable).

The results, shown in Fig. 1, demonstrated that event structure negatively predicted the occurrence of mind wandering. More event change in the current (i.e., t = 0) time window and two preceding (t − 5 and t − 10) time windows was related to a lower probability of

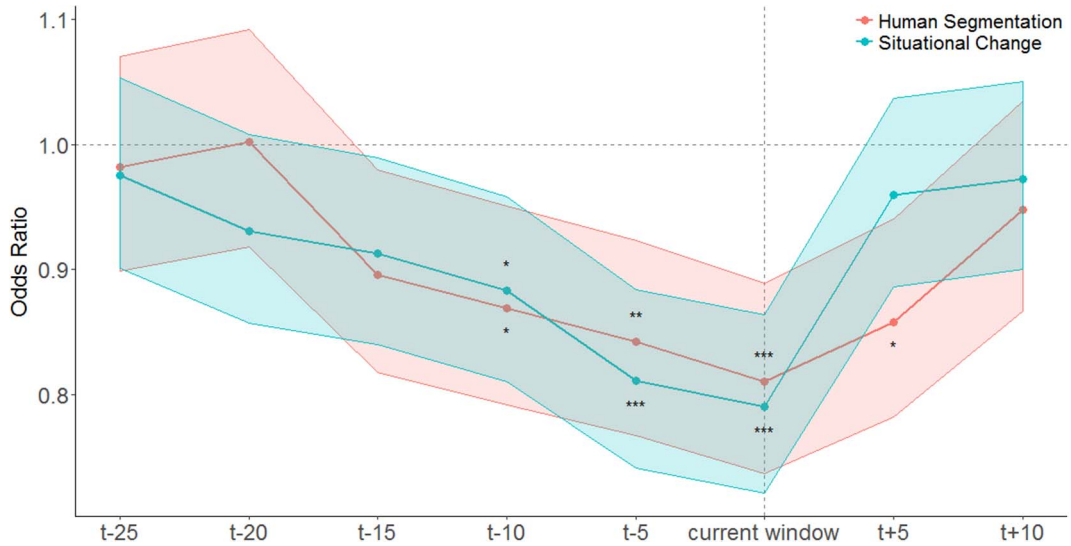

Fig. 1. The relationship between mind wandering and event structure over time shown as the odds ratio of the occurrence of mind wandering given the amount of event change for the current time window and in periods preceding and succeeding it (times in seconds). Bands are 95% confidence intervals of the odds ratio. An odds ratio of 1 reflects even odds (no effect). *** indicates $p \leq .001$; ** indicates $p < .01$; * indicates $p < .05$ after Bonferroni correction. *p*-values are based on the Wald statistic.

Table 1
Odds ratios and 95% confidence intervals for predicting mind wandering as a function of event change.

	Situational change		Human segmentation	
Time window (sec)	Odds ratio [95% CI]	*p*-value	Odds ratio [95% CI]	*p*-value
−25	0.975 [0.901–1.053]	.523	0.982 [0.899–1.070]	.676
−20	0.931 [0.857–1.008]	.078	1.002 [0.918–1.092]	.956
−15	0.913 [0.840–0.989]	.026	0.896 [0.818–0.980]	.015
−10	0.883 [0.810–0.958]	.003[a]	0.869 [0.792–0.951]	.002[a]
−5	0.811 [0.741–0.884]	< .001[a]	0.842 [0.767–0.923]	< .001[a]
0	0.790 [0.721–0.864]	< .001[a]	0.810 [0.737–0.889]	< .001[a]
+5	0.960 [0.886–1.037]	.307	0.858 [0.782–0.940]	.001[a]
+10	0.972 [0.900–1.050]	.463	0.948 [0.867–1.035]	.232

[a] Indicates significance at Bonferroni-corrected $\alpha = 0.006$.

mind wandering. As expected, the relationship broke down for time windows in the more distant past and future. The results were mostly consistent for both the situational change and human segmentation measures (see Table 1).

One exception was that there was a significant negative relationship between mind wandering and the likelihood of humans perceiving an event boundary 5 s into the future. This suggests that not only the occurrence but also the anticipation of a salient future boundary (as evidenced by its likelihood) might suppress mind wandering. An alternative explanation is that the timing of the human segmentation reports might be slightly delayed compared to the situational change coding, as reports are likely to occur after perceiving the boundary (i.e. not instantaneously).

With respect to the other factors in the model, we did not find a significant interaction between prior knowledge and change. This indicates that event structure affects the occurrence of mind wandering regardless of whether a person knows how the story will unfold. Furthermore, we found that event change significantly predicted the occurrence of mind wandering over and above low-level perceptual features, which did not explain a significant amount of variance at any time window (see supplemental Table S2 for results).

We also tested whether the relationship between mind wandering and event change might be curvilinear by repeating our analyses with an added quadratic term. This did not significantly improve model fit (i.e., no significant reduction of the residual sum of squares) for either variable (situational change or human segmentation) at any time window, suggesting that a linear model is appropriate (Osborne, 2014; see supplemental Table S3 for results).

Furthermore, we split the data into task-related inferences and task-unrelated thoughts and repeated our analyses to establish whether these types of mind wandering have different relationships with event change. In each analysis, we excluded participants who never reported the mind wandering content type of interest to avoid convergence issues of our generalized linear mixed effects models. We found a consistent negative relationship between the occurrence of each type of mind wandering and the amount of situational change at the time windows of interest (0, −5, and −10). The probability of perceiving an event boundary (human segmentation) predicted both task-related and –unrelated mind wandering at time window 0. At the other windows of interest, the pattern of results was the same for both types of thoughts, but the effect only reached significance for task-unrelated thoughts (with a smaller sample than the main analyses, and after Bonferroni correction for multiple comparisons). Note however that the odds ratios for each mind wandering type overlap with the confidence intervals for the other type (with the exception of −15 s, which we did not observe in our main analyses), suggesting that the difference between the effects is likely to not be significant (see supplemental Table S1 for results).

To ensure that we are not merely capitalizing on base rate effects, we repeated the analyses with shuffled event change time series. These control analyses yielded no significant results, suggesting that the observed effects arise from the hypothesized temporal relationship between mind wandering and event change.

4. Discussion

Our aim was to study how environmental dynamics constrain self-generated thought. We did this by investigating how unfolding stimulus characteristics influence one type of self-generated thought, namely mid wandering, during a narrative film comprehension task. We found that the amount of situational change (based on theoretical coding) and the likelihood of people perceiving an event boundary (based on human event segmentation) negatively predicted the occurrence of mind wandering after covarying features capturing low-level audiovisual change. Specifically, mind wandering was less likely when there were more situational changes and discernible boundaries in the past 15 s (i.e. the time window of the report, and/or the two windows preceding it), demonstrating that the occurrence of mind wandering is related to how events unfold over time.

We attribute this effect to the idea that event change directs attention to stimulus processing. Findings from neuroimaging studies suggest that anticipating an event boundary gives rise to a cascade of increased neural activity (Zacks et al., 2010), which is associated with better memory for what occurred at that boundary (Swallow et al., 2011; Zacks et al., 2001). Attention is thought to be modulated by this automatic anticipatory process (Swallow et al., 2009), ostensibly reducing the likelihood of mind wandering when event changes occur or are imminent. Furthermore, when a boundary is encountered, the new state of events is discontinuous with the previous state. This mismatch triggers immediate updating of a person's mental model (Kurby & Zacks, 2008), which directs attention to the stimulus, thereby reducing the likelihood of mind wandering.

It is an open question as to whether this redirection of attention would make a person aware that they were mind wandering, thereby ending the episode. We argue that this is unlikely to be the case. Studies have shown that attention is somewhat decoupled from the external environment during mind wandering (Mills et al., 2017), so change is likely to go unnoticed (Smallwood, Beach, et al., 2008). Indeed, previous work has found that people sometimes miss critical event information when they mind wander, which is detrimental to narrative comprehension and leads to an impoverished mental representation (Feng, D'Mello, & Graesser, 2013; Randall et al., 2014; Smallwood, McSpadden, & Schooler, 2008). The event model normally exerts top-down influence on the allocation of attention by providing predictions about the unfolding of the events. An impoverished event model could therefore result in poor event segmentation, resulting in change going unnoticed. For these reasons, it seems unlikely that event change affects an ongoing mind wandering episode. Rather, we propose that the updating and anticipation associated with event change prevents the mind from wandering in the first place rather than re-engaging a wandering mind.

If the event model is impaired by mind wandering, one might wonder if people are able to recognize relevant event changes. In our study, mind wandering was reported every 2.5 min on average, with some participants providing only one or two reports. This suggests that participants were mostly attending to the film and had adequate mental representation to perceive relevant changes and boundaries when not mind wandering. An open question pertains to how mental model impairments—to the extent attributable by mind wandering—affect ongoing attention. On one hand, an impoverished mental model might lead to failures in perceiving relevant changes and therefore, more mind wandering (Kopp et al., 2015). On the other hand, participants might try to "catch up" with the film, leading to an uptick in attention. Further research could examine these possibilities in more detail.

It should be noted that event change reflects one, but not the only, type of environmental condition that might be related to mind wandering. Although we controlled for low-level audiovisual changes, other aspects of the unfolding film, such as key moments in the plot or emotional intensity, might be associated with mind wandering independent of event change. Future work should investigate how different aspects of the environmental changes—not captured by event change—affect how the mind wanders. It is likely that these aspects are related to event change, especially for ecological stimuli like encountered here. For example, a key moment is likely to be an event *followed* by a large change in characters, their goals, and the setting, emotional intensity is often established by a lack of event change (e.g., suspense is anticipated but delayed change), and emotional build-up occurs within rather than across an event. Furthermore, these features are likely related to auditory change (e.g., a crescendo accompanying a key moment), so they are probably (to some extent) already captured by our low-level audiovisual features.

Like all studies, ours has limitations. For one, subtle or very brief periods of mind wandering might be missed or not reported, as self-caught mind wandering relies on a participant's meta-awareness, judgment, and honesty (Smallwood & Schooler, 2006). More sensitive measures such as eye movements could shed light on the relationship between event structure and more subtle lapses in attention (Faber, Bixler, & D'Mello, 2017; Mills, Bixler, Wang, & D'Mello, 2016). These could also help determine the onset of the mind wandering episode, which is an open question in mind wandering research (Smallwood & Schooler, 2015). Speculative extrapolation of our findings suggest that it is likely to arise during periods with little event change, but this awaits corroboration.

Our results were also obtained in the context of a specific film. We expect the present findings to generalize across different narrative films as event change robustly predicts how people segment unfolding streams of action and discourse (see e.g. Zwaan, 2016 for an overview). Event segmentation is an automatic process that leads to an uptick in attention around boundaries, so it is likely to be similar across films, though the relative contribution of other factors might vary. For this reason, replication with alternate materials is warranted.

Furthermore, we only sampled the undergraduate student population. Some studies have found that older adults mind wander less than younger adults (e.g., Krawietz, Tamplin, & Radvansky, 2012). Although these (non-clinical) populations might differ in terms of their mind wandering rates, we think that it is unlikely that their segmentation of the film—and therefore, the relationship between mind wandering and event change—is different. Nevertheless, future research could shed light on this by including more diverse samples to alleviate more basic concerns of exclusively relying on undergraduates.

In conclusion, we have shown that event change produces environmental conditions that affect the occurrence of mind wandering: intervals with more event change are less likely to give rise to mind wandering. Our work is an important first step towards a better understanding of the allocation of attention and the modulation of self-generated thought while experiencing continuous naturalistic stimuli.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.cognition.2018.01.007.

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