Missing the Joke: Reduced Re-reading of Garden-path Jokes during Mind-wandering

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Abstract

Mind-wandering, or thoughts irrelevant to the current task, occurs frequently during reading. The current study examined whether mind-wandering was associated with reduced re-reading when the reader read the so-called "garden-path jokes." In a garden-path joke, the reader's initial interpretation is violated by the final punchline, and the violation creates a semantic incongruity that needs to be resolved (e.g., "My girlfriend has read so many negative things about smoking. Therefore, she decided to quit reading."). Re-reading text prior to the punchline can help resolve the incongruity. In a main study and a pre-registered replication, participants read jokes and non-funny controls embedded in filler texts and responded to thought probes that assessed intentional and unintentional mind-wandering. Results were consistent across the two studies: Eye-tracking results show that, when the reader was not mind-wandering, jokes elicited more re-reading (from the punchline) than the non-funny controls did, and had a recall advantage over the non-funny controls. During mind-wandering, however, the additional eye movement processing and the recall advantage of jokes were generally reduced. These results show that mind-wandering is associated with reduced re-reading, which is important for resolving higher-level comprehension difficulties.

Keywords: Mind-wandering; eye movements; humor; reading

Word count: 7805

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Reading comprehension is susceptible to mind-wandering, a mental state in which attention shifts from the external task to self-generated, task-irrelevant thoughts (Smallwood & Schooler, 2015). How does mind-wandering change the way people read? Can these changes reveal impairments of the cognitive processes underlying reading? During the past few years, an increasing number of studies have used eye-tracking to study these questions (Faber, Bixler, & D'Mello, 2018; Foulsham, Farley, & Kingstone, 2013; Reichle, Reineberg, & Schooler, 2010; Schad, Nuthmann, & Engbert, 2012; Uzzaman & Joordens, 2011). One benefit of using eye-tracking is its direct examination of the "eye-mind" link – the extent to which cognition actively controls what people are looking at. But, due to reduced top-down control of comprehension, this link may break down during mind-wandering.

The normal reading process can be generally described as going through a hierarchy of stages, from extracting lexical meanings from printed words (Pollatsek, Reichle, & Rayner, 2006), to integrating words into propositions (Frazier, 1998), and finally to establishing a coherent understanding of the entire passage (Zwaan & Radvansky, 1998). A number of eye-tracking studies have shown that during mind-wandering, the normal association between fixation duration and lexical properties of the word (e.g., longer looking times for low-frequency words) was reduced (Foulsham et al., 2013; Reichle et al., 2010; Schad et al., 2012), suggesting deficits during lexical processing.

Smallwood (2011) reasoned that impairments in early stages of reading can have implications for later processes, so mind-wandering should have profound impacts on higher-level processes. Extant studies examining higher-level processes have typically used self-paced reading (for an exception, see Schad et al., 2012). One study asked participants to read "gibberish" texts that changed the order of nouns or pronouns (as described in Smallwood, 2011). Not being able to detect gibberish texts quickly, according to the authors, would indicate impairment in the creation of propositions. Results showed that when readers were mind-wandering, they were likely to keep reading without noticing that the text had become gibberish. Another study (Smallwood, McSpadden, & Schooler, 2008) asked participants to read a Sherlock Holmes story word-by-word and found that, if participants were mind-wandering when critical clues about the villain were offered, they were less likely to correctly infer the identity of the villain. The authors argued that mind-wandering at critical points interfered with the integration of important events necessary to identity the villain.

In the self-paced reading paradigm, participants can see only one word at a time and are not permitted to look back at previous portions of the text. However, during free reading, about 10% to 15% of saccades move backwards to previous text (Rayner, 1998). One important reason for making such regressions is to resolve difficulties during higher-level stages of comprehension (for a review, see Bicknell & Levy, 2011). Therefore, studying how re-reading behavior is affected during mind-wandering can advance our understanding of the mental state's effect on reading. Interestingly, previous studies did not find consistent evidence that re-reading was affected during mind-wandering (for a review, see Steindorf & Rummel, 2019), possibly because participants were not processing texts in which re-reading is critical for comprehension.

In what situation do people tend to re-read? One example is when they read the so-called "garden-path" jokes (Dynel, 2009). Garden-path jokes elicit humor by violating the reader's original interpretation of the text at the final punchline. To "get" the joke, the reader must resolve the semantic incongruity, or in other words, find a new interpretation of the text (Suls, 1972, 1983). Here is an example:

For more than forty years I have only loved one woman. I hope my wife will never *know.*[1]

In a garden-path joke, the set-up is designed to be compatible with at least two interpretations. However, to the reader one interpretation is highly salient, as determined by the reader's general world knowledge. Thus, the reader is "tricked" to adopt the salient interpretation before encountering the punchline. In the previous example, readers may wrongly assume that the set-up describes a loyal husband. However, this interpretation is violated at the punchline, causing a semantic incongruity. Thus, the reader must backtrack the set-up to search for the covert interpretation to resolve the difficulty. For example, the reader may adopt a new interpretation that the husband has been cheating on his wife for forty years. The successful resolution of semantic incongruity allows for a sense of amusement (Dynel, 2009). Note that a non-funny but coherent version of the joke can be constructed by simply replacing "know" to "forget." Doing so will reduce the text's semantic incongruity and humor potential. The incongruity-resolution theory (Suls, 1972, 1983) and its variations (Coulson & Kutas, 1998; Mayerhofer & Schacht, 2015; Ritchie, 2004) constitute a well-established framework that describes the cognitive processes of humor processing (Dynel, 2009; Mayerhofer & Schacht, 2015).

The incongruity-resolution process of garden-path jokes can be indexed by behavioral and physiological measures. In a self-paced reading task, joke endings received longer reading time than the ending of non-funny control sentences did (Mayerhofer & Schacht, 2015, experiment 1). Electroencephalography data showed that joke endings elicited a larger N400 component compared to coherent endings, indicating semantic integration difficulties (Mayerhofer & Schacht, 2015, experiment 2 and 3). Importantly, Coulson, Urbach, and Kutas (2006) used a free reading paradigm and showed that garden-path jokes, compared to non-funny controls, produced more re-reading eye movements from the ending. This finding, according to the authors, shows a processing cost due to the construction of an alternative

[1] Source: Mayerhofer and Schacht (2015).

cognitive model of the text (Coulson et al., 2006).

Some important features distinguish garden-path jokes from traditional garden-path sentences (e.g., *The horse raced past the barn fell*; Frazier & Rayner, 1982) and gibberish texts. The incongruity and its resolution of garden-path jokes are localized at the semantic level rather than the syntactic level. In other words, the reader is prompted to discover an alternative meaning rather than an alternative parsing. Other researchers have described this process as a frame-shifting (Coulson & Kutas, 1998), a forced re-interpretation (Ritchie, 2004), or a belief revision (Mayerhofer & Schacht, 2015), all of which point to a re-analysis at the semantic level. During this process, the reader must consult their general world knowledge or previous experience to re-interpret the linguistic input. Thus, the resolution of comprehension difficulties occurs at an advanced level of understanding and requires a close coupling between attention and the linguistic input. This may make its processing highly susceptible to mind-wandering (Schad et al., 2012). Moreover, compared to gibberish texts, garden-path jokes are intelligible, which might render them more ecologically valid. In sum, we believe that garden-path jokes provide a promising opportunity to study how mind-wandering affects higher-level processes of reading.

The Current Study

The current study sought to investigate whether mind-wandering affected the resolution of semantic incongruity, a higher-level cognitive process required for understanding garden-path jokes. Previous research has suggested that a critical index of this process is re-reading from the punchline. Therefore, we recorded participants' eye movements while they read garden-path jokes and non-funny controls embedded in filler texts. Participants responded to thought probes after each joke and control text to report mind-wandering. Our hypothesis was straightforward: the incongruity-resolution process was present when attention was on the task but was impaired during mind-wandering.

Mind-wandering encompasses a wide range of mental experiences that vary in numerous dimensions (Seli et al., 2018). Recent evidence suggests that mind-wandering can emerge with or without intention (Seli, Risko, Smilek, & Schacter, 2016). Unintentional mind-wandering reflects a spontaneous shift from task-related to task-unrelated thoughts, despite the individual's willingness to stay on task. However, it is estimated that more than one-third of mind-wandering thoughts emerge with intention, a controlled and deliberate disengagement (Seli, Cheyne, Xu, Purdon, & Smilek, 2015; Seli, Wammes, Risko, & Smilek, 2016). Previous research has shown that intentional and unintentional mind-wandering are sometimes dissociable. For example, increasing task difficulty reduces the rate of intentional mind-wandering but increases the rate of unintentional mind-wandering (Seli, Risko, & Smilek, 2016); task motivation correlates more strongly with intentional mind-wandering than with unintentional mind-wandering (Seli et al., 2015). That said, both types of mind-wandering were found to impair task performance in a sustained-attention task (Seli et al., 2015) and a video lecture task (Seli et al., 2016). Their similar effects are not surprising, since both types of mind-wandering involve a decoupling of attention from the task at hand. In sum, it is important to treat mind-wandering not as a unitary concept, even if we predict that intentional and unintentional mind-wandering have similar effects on the incongruity-resolution process.

Main Study

Methods

Participants. Forty-seven undergraduate students from the University of Michigan (mean age = 18.96, SD = .95, 25 females) participated in the study for course credit. All participants were native English speakers with normal eyesight. Due to technical failures, three participants completed only half of the experiment. However, their data were included in data analyses.

Apparatus and Stimuli. We obtained forty-six garden-path jokes and their corresponding non-funny control texts. Each joke-control pair shared the same texts up until the ending. The jokes' endings were designed to elicit humor by violating the previous set-up. The non-funny controls' endings were designed to be coherent and neutral. Thirty-nine joke-control pairs differed only in the final word, and the other seven pairs differed in the last two words. In addition, 480 neutral fillers were constructed to mimic the linguistic style (e.g., length, topic, difficulty, etc.) of the target sentences. Some examples are shown below. See the online supplemental material for full stimuli.

1. *Joke* : For more than forty years I have only loved one woman. I hope my wife will never know.
2. *Control* : For more than forty years I have only loved one woman. I hope my wife will never forget.
3. *Filler* : I walked into the grocery store. I was going there to buy my favorite energy drink.

As a manipulation check, we recruited sixty Mturk workers to rate the jokes and the non-funny controls on three scales: comprehensibility, funniness, and predictability of the ending. Each scale included three items. All items used a Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). These rating scales were developed by Mayerhofer and Schacht (2015) and were used to evaluate the garden-path jokes used in their study. Every worker rated twenty-three jokes and twenty-three controls. One joke-control pair had very low comprehensibility (2.58, the rest: Mean = 3.96, $SD = 1.03$). We included this pair in the experiment for the convenience of constructing stimuli presentation orders (as described later in this section), but data from this pair was discarded from all subsequent data analyses.

We used linear mixed models (*lme4*, Bates, Mächler, Bolker, & Walker, 2015) to examine differences between the jokes and the non-funny controls with maximum random effects. We used the *lmerTest* package (Kuznetsova, Brockhoff, & Christensen, 2017) to obtain approximation of p-values. Results show that, compared to controls, jokes were rated as funnier (b = 1.05, SE = 0.12, t = 9.10, p < .001) and had less predictable endings (b = -0.76, SE = 0.10, t = -7.80, p < .001). However, jokes were not significantly less comprehensible than controls (b = 0.12, SE = 0.07, t = 1.71, p = 0.09). Figure 1 shows the mean ratings of jokes and controls on the three scales. In sum, the Mturkers' ratings confirmed the validity of our stimuli.

Based on the forty-six joke-control pairs, we constructed sixteen pseudo-random stimuli presentation orders. In every order, (1) twenty-three of the texts appeared as jokes and the other twenty-three appeared as non-funny controls, and (2) each joke and non-funny control was preceded by 5 to 15 fillers. We spaced out target texts with fillers to increase the distance between probes (the thought probe occurred after every joke and control), as frequently probing the participant can reduce mind-wandering reports (Seli, Carriere, Levene, & Smilek, 2013). The average distance between two targets was ten fillers. This resulted in each participant reading 526 texts throughout the experiment: 46 target texts (23 jokes and 23 controls) embedded in 480 filler trials. We divided the whole experiment into two blocks of the same size: Both blocks have 23 target trials (11 jokes and 12 controls, or *vice versa*) embedded in 240 filler trials. Further, we ensured that, across all the sixteen orders, each text appeared (1) equally often as joke and control and (2) equally often in the first and the second block.

Stimuli were presented on a 20.1-inch computer screen at approximately 70 centimeters to the participant. Text font was *Times New Roman* and text size was 37.5. Each letter subtended horizontally about 0.65 degree of visual angle. Monocular eye movements were recorded by the Eyelink Remote System at a sampling rate of 500 Hz. To ensure comfort, no chin rest was used and head movement was adjusted by tracking a sticker on participants' forehead. The experiment was implemented using the *OpenSesame* software (Mathôt, Schreij, & Theeuwes, 2012) with functions from the *PyGaze* package (Dalmaijer, Mathôt, & Stigchel, 2014).

Procedure. The experiment began with a survey asking all participants to make a to-do list for the next five days, as future-planning has been shown to increase mind-wandering rate during a subsequent task (Kopp, D'Mello, & Mills, 2015).

Then, we introduced the reading task to the participants. Participants were asked to read sentences for comprehension. Participants at this point did not know the existence of jokes or the nature of the test afterwards. This was done to ensure that re-reading did not result from participants' purposefully memorizing the jokes.

Next, participants were told that, during reading, a thought probe would occur occasionally, which required them to report whether they were "on-task" or "off-task"[2] during the previous text. The experimenter introduced the definitions of "on-task" and "off-task": *Being on-task means that, just before the screen appeared, you were focused on completing the task and were not thinking about anything unrelated to the task.* Off-task means that *just before the screen appeared, you were thinking about something completely unrelated to the task* (Seli et al., 2015). Because the framing of thought probe can affect reported mind-wandering rate (Weinstein, 2018), we used a neutral question (*Just now where was your attention?*). Participants were asked to answer "*on-task*" or "*off-task*" by pressing the corresponding key. We also randomly switched the order of "*on-task*" and "*off-task*" options across participants to reduce any confounds due to ordering. If "*off-task*" was chosen, participants were asked to indicate whether mind-wandering was intentional of unintentional. Intentional mind-wandering was defined as "*you intentionally decided to think about things that are unrelated to the task*," and unintentional mind-wandering was defined as "*your thoughts drifted away despite your best intentions to focus on the task*" (Seli et al., 2015).

[2] "Off-task" was used as a synonym for "mind-wandering" in the experiment.

The order of this question's options was also randomized across participants.

We assigned participants to one of the sixteen stimuli orders based on their participant numbers. After calibrating the eye tracker, participants completed five practice trials. Each trial started with a fixation dot located at the position of the first letter of the upcoming text. The text appeared once a stable gaze signal at the dot was detected. Together with the text, there was a small fixation dot at the bottom-right corner of the screen. Participants were asked to move their focus to this dot once they have finished this trial. The trial ended once a stable gaze signal was detected at this dot. After re-calibrating the eye tracker, the experimental trials started. The task proceeded in an automated fashion. The thought probe occurred after every target sentence (i.e., jokes/non-funny controls). A research assistant quietly sat outside the participant's field of vision and monitored the gaze-overlaid stimuli on a second monitor. Re-calibration was conducted if tracking quality deteriorated.

After reading, participants were asked to complete a recall test to fill out the ending of each target trial (i.e., the part that was different between jokes and controls) with the previous text given. There was no time limit for this test. The entire experiment took about 120 minutes.

Data analysis. Fixations greater than 1500 msec or shorter than 80 msec were discarded (3.92% of data). We chose a relatively high upper bound because mind-wandering was known to produce longer fixation duration compared to normal reading (Faber et al., 2018; Reichle et al., 2010). Because the incongruity-resolution process strictly speaks to what happens after the reader encounters the punchline, the analysis region was set to where the jokes and controls differ. In the previous example, the analysis region would be the word "know" for jokes and "forget" for controls. For the seven joke-control pairs that differed in the last two words, the analysis region included both words.

We examined the following measures:

1. Recall: a binary variable indicating whether the answer matches the original text.
2. Regressions-out: a count variable indicating the number of regressions from the analysis region to previous words.
3. Regression-path duration: the sum of all fixations from entering the analysis region to the last fixation on the entire text.
4. Gaze duration: the sum of all fixations from entering the analysis region for the first time until leaving the region.
5. Total looking time: the sum of all fixations on the analysis region.
6. Skipping: a binary variable indicating whether the analysis region was not fixated on throughout the trial.

We used recall performance as an offline measure of the incongruity-resolution process. If jokes received additional visual processing (compared to controls), we expected that this should translate to better memory of the endings (Strick, Holland, Baaren, & Van Knippenberg, 2009). Thus, we expected a significant recall advantage for jokes (compared to controls) only when participants indicated on-task. Regressions-out and regression-path duration are critical measures for this study, because they can indicate the degree to which participants re-analyzed the text from the ending. We expected more such re-reading for jokes than for controls, but only when the reader was on-task. We used gaze duration, total looking time, and skipping as supplemental measures. They do not directly speak to the re-reading process but nevertheless offer important details of how the ending was processed. Gaze duration, in relation to total looking time, measures early stages of language processing because it only includes first-pass reading. Coulson et al. (2006) found that gaze duration was not statistically different between jokes and controls, but they found a trend for longer total looking time for joke endings. We included these two measures to compare our results to previous research. Finally, not skipping the ending is likely a prerequisite for the incongruity-resolution process. A joke's ending might be less likely to be skipped than a non-funny control's ending, but this effect, if true, should only occur when the participant was on-task.

We conducted a set of *a priori* contrasts to analyze the measures (Ruxton & Beauchamp, 2008; Schad, Hohenstein, Vasishth, & Kliegl, 2018). We created four orthogonal contrasts: one contrast for the effect of text type (*Joke/Control*) for each type of attention (*On-task/Intentional mind-wandering/Unintentional mind-wandering*), and an additional contrast for the difference between mind-wandering and non-mind-wandering conditions. The fourth contrast was exploratory and tested how sentence endings, aggregating over jokes and controls, were processed during mind-wandering and non-mind-wandering. A weight matrix of the contrasts can be found in the online supplemental material. A regression model was built for each of the six dependent measures. Duration measures were log-transformed to fit to linear mixed models (LMM). Binary and count measures were modeled by generalized linear mixed models (GLMM). Specifically, recall and skipping were modeled by binomial GLMMs with a logit link. Regressions-out were modeled by a Poisson GLMM with a log link (the default option). For convenience and clarity, in all models we collapsed text type and attention into a single variable of six groups called *condition*. We applied our custom contrasts to *condition*. Because word length and word frequency were known to influence eye movements (Kliegl, Grabner, Rolfs, & Engbert, 2004; Rayner, 1998), and because the jokes and controls were not equated on these measures, we included word length and the logarithm of word frequency as covariates in all models of eye movement measures[3]. Random effects included (1) variations across participants, (2) variations across text frames, (3) variations for each (observed) combination of participant and *condition*, and (4) variations for each (observed) combination of text frames and *condition*. The *R* package *lme4* (Bates et al., 2015) was used for all model-fitting. Approximations of *p*-values came from the *lmerTest* package (Kuznetsova et al., 2017).

[3] For the seven pairs that differed in the last two words, we used their total length and frequency of the phrase (source: Corpus of Contemporary American English, Davies, 2008). Results were similar without these covariates.

Results

Overall, we obtained 1195 "on-task" trials (58.35%), 546 unintentional mind-wandering trials (26.66%), and 307 intentional mind-wandering trials (14.99%). Additional details about the number of trials in each condition for each measure can be found in the online supplemental material.

Recall Performance. The probability of correct answers in each condition was shown in panel *a* of Figure 2. When participants indicated they were on-task, joke endings were more likely correctly recalled than neutral endings were, b = 0.59, SE = 0.22, z = 2.74, p = 0.01. However, this recall advantage was reduced during unintentional mind-wandering, b = 0.55, SE = 0.29, z = 1.91, p = 0.06, and was eliminated during intentional mind-wandering, b = -0.04, SE = 0.39, z = -0.11, p = 0.91. For the fourth contrast, recall was better when participants were on-task compared to when they were mind-wandering, b = 1.16, SE = 0.17, z = 7.00, $p < .001$.

Eye Movement Measures. Two critical indices of incongruity resolution were regressions-out and regression-path duration. Their marginal means were shown in panel *b* and *c* of Figure 2, respectively. When participants were on-task, jokes, compared to non-funny controls, elicited more regressions-out, b = 0.28, SE = 0.11, z = 2.56, p = 0.01. However, this difference was not significant during either unintentional mind-wandering, b = -0.15, SE = 0.19, z = -0.80, p = 0.42, or intentional mind-wandering, b = 0.11, SE = 0.26, z = 0.43, p = 0.67. For the last contrast, participants produced more regressions-out in general when they were on-task than when they were mind-wandering, b = 0.38, SE = 0.10, z = 3.77, $p < .001$.

Similarly, regression-path duration was longer for jokes than for controls when participants were on-task, b = 0.09, SE = 0.03, t = 2.74, p = 0.01. But this difference was not significant during either unintentional mind-wandering, b = -0.02, SE = 0.05, t = -0.36,

p = 0.72, or intentional mind-wandering, b = 0.08, SE = 0.07, t = 1.18, p = 0.24. Finally, an overall difference was observed between on-task and mind-wandering, b = 0.08, SE = 0.03, t = 2.84, p = .005.

We then looked at gaze duration (Figure 2, panel d) and total looking time (Figure 2, panel e) on the analysis region. For gaze duration, we did not find a significant difference between jokes and controls even when participants indicated being on-task, b = 0.02, SE = 0.02, t = 1.26, p = 0.21. The difference was also not significant during unintentional mind-wandering, b = .002, SE = 0.02, t = 0.36, p = 0.72, or intentional mind-wandering, b = 0.04, SE = 0.03, t = 1.26, p = 0.21. There was also no significant difference in gaze duration between on-task and mind-wandering in general, b = -.002, SE = 0.01, t = 0.01, p = 0.99.

On the other hand, jokes produced significantly longer total looking time than controls did, when participants were on-task, b = 0.04, SE = 0.02, t = 2.25, p = 0.02. However, there was no significant difference during unintentional mind-wandering, b = 0.00, SE = 0.03, t = -0.13, p = 0.90, or intentional mind-wandering, b = 0.07, SE = 0.04, t = 1.79, p = 0.07. Total looking time did not significantly differ between on-task and mind-wandering in general, b = 0.01, SE = 0.01, t = 0.98, p = 0.33.

Finally, we looked at the probability of skipping the analysis region (Figure 2, panel e). When participants were on-task, joke endings were no less likely to be skipped than control endings were, b = -0.19, SE = 0.15, z = -1.24, p = 0.21. Moreover, the difference between jokes and controls was not significant during unintentional mind-wandering, b = -0.08, SE = 0.21, z = -0.36, p = 0.72, or intentional mind-wandering, b = 0.37, SE = 0.28, z = 1.32, p = 0.19. However, there was less skipping overall when participants were on-task than when they were mind-wandering, b = -0.33, SE = 0.12, z = -2.67, p = .008.

Discussion

We examined how mind-wandering affected the semantic incongruity-resolution process of garden-path jokes. We hypothesized that the incongruity-resolution process would be impaired during both intentional and unintentional mind-wandering, but not when participants were on-task. The most important measures of this process were regressions-out and regression-path duration from the punchline. Our results show that, when participants were on-task, joke endings elicited more regressions-out and longer regression-path duration than non-funny controls did. These results provide a benchmark for how jokes (compared to controls) were processed without mind-wandering, which replicated Coulson et al. (2006)'s findings. However, the additional re-reading of jokes was reduced during both intentional and unintentional mind-wandering, indicating impairments in the incongruity-resolution process.

We also examined several supplemental measures, including gaze duration, total looking time, and skipping. Similar to results in Coulson et al. (2006), only total looking time had a significant difference between jokes and controls when participants were on-task. Therefore, in addition of re-reading previous texts, participants examined the punchline more than once, suggesting efforts of integrating the punchline and the set-up. This difference in total looking time was not observed during unintentional mind-wandering. Interestingly, for both gaze duration and total looking time, the intentional mind-wandering condition seemed to have a larger effect than the on-task condition did (although the differences were not significant in both cases). Perhaps during intentional mind-wandering, participants could sometimes notice the incongruity, leading to longer looking time at the ending. However, they did not put enough effort in re-reading, presumably because of a lack of motivation.

For skipping, we did not find a significant difference in either the on-task, the intentional mind-wandering, or the unintentional mind-wandering condition. This finding is similar to that for gaze duration, as both speak to relatively early stages of reading. These findings suggest that the resolution of incongruity occurred at a relatively late stage, and it might not have been salient enough to affect early measures. Moreover, sentence endings naturally define processing units, and they might be important to look at for the control sentences as well.

Finally, we used recall performance as an offline measure of the incongruity-resolution process. If joke endings attracted additional attention, this would be reflected by how well participants remembered the endings (Strick et al., 2009). Our results show that the recall advantage observed when participants were on-task were reduced during mind-wandering, which was consistent with the eye-tracking results. Importantly, this measure does not directly speak to whether participants really "got" the joke, a point we shall return to in the General Discussion.

Overall, our results show a clear pattern of how mind-wandering affected re-reading and recall of garden-path jokes, signaling impairments in the incongruity-resolution process. Following the main study, we conducted a pre-registered replication, to see if our major findings can be replicated.

A Pre-registered Replication

We made some minor changes in the stimuli and procedure of the main study, as specified in the sections below. All changes were pre-registered. The pre-registration protocol is available at https://osf.io/jg27v/.

Method

Unless stated otherwise, the methodology remained the same as that in the main study.

Participants. We recruited forty-six undergraduate students from the University of Michigan to participate in the study for course credit. According to the pre-registered data exclusion criteria, we discarded data from three participants for technical failures, and three participants for not completing the entire experiment. The final sample size was forty (mean age = 18.85, SD = .89, 23 females), which was specified in the pre-registration. All participants were native English speakers with normal eyesight.

Stimuli. In the main study, one joke-control pair was rated to have low comprehensibility and seven joke-control pairs differed in the last two words. In the replication, we replaced them with eight new joke-control pairs that differed in only the last word. We recruited another 120 online workers to rate the new texts on the same scales used in the main study. Together with the items that remained the same, jokes did not statistically differ from the controls in comprehensibility (b = 0.14, SE = 0.07, t = 1.85, p = 0.07), but jokes were still rated as funnier (b = 1.07, SE = 0.09, t = 11.46, $p < .001$), and had less predictable endings (b = -0.66, SE = 0.08, t = -7.83, $p < .001$) than the controls did. These changes to the material were pre-registered.

Procedure. Due to constraints in time and personnel, we reduced the number of filler trials from 480 to 336 (randomly dropped). As a result, two consecutive target trials were separated by 5 to 9 fillers, with an average distance of 7 (previously 10). All other aspects of the procedure remained the same as in the main study. The entire experiment now took about 90 minutes. These changes to the procedure were also pre-registered.

Data Analysis. Unless otherwise stated, there was no deviation from what was specified in the pre-registration or from what was used in the main study.

Results

We obtained 1103 “on-task” trials (59.95%), 468 unintentional mind-wandering trials (25.43%), and 269 intentional mind-wandering trials (14.62%). mind-wandering frequency was comparable to that in the main study.

Recall Performance. Similar to the main study, when on-task, participants significantly more likely recalled a joke’s ending than a non-funny control’s ending, $b = 0.71$, $SE = 0.19$, $z = 3.71$, $p < .001$. This recall advantage was again reduced during unintentional mind-wandering, $b = 0.47$, $SE = 0.26$, $z = 1.79$, $p = 0.07$, and intentional mind-wandering, $b = 0.28$, $SE = 0.33$, $z = 0.86$, $p = 0.39$. For the fourth contrast, the overall difference between on-task and mind-wandering was significant, $b = 1.14$, $SE = 0.15$, $z = 7.53$, $p < .001$ (refer to the supplemental material for the marginal means).

Eye Movement Measures. Participants had more regressions-out from punchlines than from the controls’ endings when they were on-task, $b = 0.36$, $SE = 0.11$, $z = 3.28$, $p = .001$. This difference was reduced during both unintentional mind-wandering, $b = 0.32$, $SE = 0.16$, $z = 1.98$, $p = 0.05$, and intentional mind-wandering, $b = 0.15$, $SE = 0.22$, $z = 0.69$, $p = 0.49$. Different from the main study, the overall difference between on-task and mind-wandering was not significant, $b = 0.09$, $SE = 0.09$, $z = 0.99$, $p = 0.32$.

Participants made longer regression-path duration from punchlines than from neutral endings when they were on-task, $b = 0.13$, $SE = 0.04$, $t = 3.06$, $p = .003$. This difference was reduced during unintentional mind-wandering, $b = 0.11$, $SE = 0.06$, $t = 2.00$, $p = 0.05$. Interestingly, we found a somewhat larger estimate of the difference during intentional mind-wandering, $b = 0.16$, $SE = 0.08$, although it was only marginally significant, $t = 2.00$, $p = 0.05$. Finally, no significant difference was found between on-task and mind-wandering, $b < .001$, $SE = 0.03$, $t = 0.02$, $p = 0.99$, different from the main study.

Similar to the main study, we did not find any significant difference in gaze duration, ps > .10. Different from the main study, however, the difference in total looking time between jokes and non-funny controls in the on-task condition was *not* significant, $b = 0.02$, $SE = 0.02$, $t = 0.81$, $p = 0.42$. The difference was also not significant during either unintentional mind-wandering or intentional mind-wandering, ps > .05.

Finally, we did not find any significant difference in skipping, ps > .10. In particular, the overall difference between on-task and mind-wandering was not significant, b = -0.09, SE = 0.13, z = -0.70, $p = 0.48$.

Discussion

Despite some changes in stimuli and procedure, we observed significantly more re-reading and better recall for joke endings compared to neutral endings when participants were on-task. These differences were generally reduced during both unintentional and intentional mind-wandering. Quite interestingly, there seemed to be a larger effect in regression-path duration between jokes and controls during intentional mind-wandering, compared to that when participants were on-task. Unlike regressions-out, duration measures treated skipping as a missing value instead of a zero. Thus, this difference only referred to cases in which the last word was fixated on. Nevertheless, these results raised the possibility that, during intentional mind-wandering, the incongruity-resolution process was not always affected.

Different from the main study, we did not observe a significant difference in total looking time when participants were on-task. In self-paced reading, where re-reading is not permitted, reading time for punchlines is usually longer than that for neutral endings (Coulson & Kutas, 1998; Mayerhofer & Schacht, 2015). However, in free reading, the reader might not need to examine the punchline multiple times, as long as they had re-read previous texts. The difference in total looking time was only marginally significant in another eye-tracking study that used a free reading paradigm (Coulson et al., 2006).

Results from the fourth contrast (non-mind-wandering vs. mind-wandering across all sentence types) differ from those in the main study. We did not observe any significant difference in eye movement measures between mind-wandering and non-mind-wandering, aggregating over jokes and controls. Therefore, sentence endings in general received about the same amount of visual attention during mind-wandering and non-mind-wandering. Despite these inconsistencies, we again observed reduced re-reading and recall advantage for jokes during mind-wandering.

Additional Analysis: Mind-wandering and Lexical Processing

Existing theories offer different accounts for why deficits at higher-level linguistic processes occur during mind-wandering. The *cascade model of inattention* posits that deficits at higher-level processes are rooted in deficits at lower-level processes (Smallwood, 2011), whereas the *levels of inattention hypothesis* posits that higher-level deficits can still occur even when lower-level processes are intact (Schad et al., 2012). To adjudicate between the two accounts, we explored whether lexical processing at the punchline was also affected during mind-wandering. Specifically, we examined if the word frequency effect, as measured by the two early measures (gaze duration and skipping), was modulated by attention. If lexical processing at the ending was indeed impaired during mind-wandering, we should observe a smaller word frequency effect, compared to when participants were on-task. We combined data from the main study and the replication to improve statistical power. This analysis was not pre-registered.

The fixed effects of our analysis are shown in Figure 3. In general, the word frequency effect during mind-wandering did not significantly differ from that when participants were on-task, except for a smaller word frequency effect during intentional mind-wandering on word skipping. Thus, we did not find consistent evidence suggesting deficits at the lexical level during mind-wandering.

General Discussion

Garden-path jokes work by disrupting a narrative understanding built from the initial set-up. The higher-level processes of resolving the semantic incongruity are cognitively demanding, and this makes such jokes a promising venue for studying how we manage our attention in the face of distractions. The two studies described in the current paper suggest that the resolution of semantic incongruity depends on the reader's moment-to-moment attentional state.

The Incongruity-resolution Process

Our results obtained from the on-task condition support the incongruity-resolution theory of garden-path joke processing (Suls, 1972, 1983). In both studies, jokes read without mind-wandering elicited more re-reading from the punchline than from the non-funny controls, as if participants were re-examining previous part of the text to find clues for an alternative explanation. Moreover, similar to Coulson et al. (2006), we did not observe any difference between joke and controls in the early measures of reading (i.e., gaze duration and skipping), but observed a significant difference in total looking time (only in the main study). These findings suggest that the processing cost was related to a higher-level stage of language processing.

Additional re-reading triggered by the punchline also fits with a recently-updated computational model of eye movement control during reading (E-Z Reader 10; Reichle, Warren, & McConnell, 2009). In the E-Z reader model, the majority of regressions are due to difficulties in the post-lexical processing stage. Specifically, regressive eye movements can be initiated when the reader detects a failure in the integration of the current word into the overall meaning of the sentence (i.e., rapid integration failure). On the other hand, these results do not seem to fit well with the SWIFT model (Engbert, Nuthmann, Richter, & Kliegl, 2005), which assumes that the majority of regressions are due to unfinished lexical processing. Because garden-path jokes in theory do not entail additional processing at the lexical level, lexical difficulties do not seem to be the main reason that triggered re-reading from punchlines. However, garden-path jokes can be a special case and our findings may have no bearing on the overall utility of the SWIFT model.

Joke Processing During Mind-wandering

The current research contributes to a growing body of literature on how mind-wandering disrupts higher-level cognitive processes of reading. While some previous studies have used self-paced reading to answer this question (Smallwood, 2011; Smallwood et al., 2008), we reasoned that the re-reading pattern in a free reading setting can convey important information about the reader's attentional state. Our two studies show that the additional re-reading from the punchline observed in the on-task condition was generally reduced during mind-wandering. Mind-wandering also affected how well participants remembered the punchline during a subsequent cued-recall task. These results indicate that the incongruity-resolution process was impaired during mind-wandering, making the processing of a joke less distinguishable from the processing of a neutral sentence.

Mind-wandering during reading has been theorized as "attentional decoupling," such that attention shifts away from the linguistic input to internal thoughts and exerts less control on eye movements. Previous studies have shown that attentional decoupling can be measured at the lexical level, using variables such as word frequency (Foulsham et al., 2013; Reichle et al., 2010). The current study shows that attentional decoupling can also be measured at an advanced level of text processing. Moreover, our preliminary analysis did not find consistent evidence of deficits at the lexical level during mind-wandering. Thus, deficits at the higher-level stage during mind-wandering in our study cannot be solely attributed to deficits at the lexical level. This finding complicates assumptions that attentional decoupling during reading follows an "all-or-none" manner (Smallwood, 2011), but instead points to an alternative claim that attentional decoupling is graded in nature (Schad et al., 2012). Word recognition for skilled readers is largely automated, which may make it less susceptible to mind-wandering's effects. However, higher-level processes are usually more effortful and may go astray during even weak levels of inattention.

We used cued-recall performance as an offline measure of joke processing. The results in the on-task condition replicated the humor effect, such that people have better memory for information perceived as humorous (Schmidt, 1994, 2002). Importantly, our results suggest that one contributing factor is the elaborated visual processing triggered by semantic incongruity. However, this recall advantage disappeared during mind-wandering. While recall and comprehension are usually related, the current study did not directly measure whether the reader "got" the joke. Instead, we measured a cognitive process that is necessary but not sufficient for getting a joke (Dynel, 2009). In other words, the reader might not have understood the joke after extensive processing. If so, the reader might still be able to report the ending but not the intended meaning of the text. In this sense, not getting a joke does not always mean that the reader was mind-wandering.

A potential future research direction is to look at whether re-reading patterns, at least in some situations, can help detect mind-wandering. Research on mind-wandering has relied critically on asking participants to diagnose their mental states. While self-categorized mind-wandering seems valid (Smallwood & Schooler, 2015), the field is in need of more objective measurements to resolve important theoretical debates (Smallwood, 2013). Moreover, the ability to identify when people are mind-wandering without interrupting them would open the possibility of systems that could respond to wandering attention in order to promote better task performance. There has been important progress in this line of research (e.g., Bixler & D'Mello, 2016; Faber et al., 2018). However, the best performing models appear to favor global features (text-irrelevant features) over local features. We note that local features may boost prediction performance in a more clearly-defined setting, such as reading texts that contain occasional inconsistencies. When certain words trigger re-reading, failing to do so can indicate a breakdown of attention.

We believe that mind-wandering research can benefit from connecting theories about attention to theories about language processing. To illustrate their interactions, eye-tracking will be an important methodology. We hope the current research will promote this integration, so that we can better understand how people manage their attention in different contexts with different distractions that surround them.

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References

Aust, F. (2019). Papaja (Preparing APA Journal Articles) is an R package that provides document formats and helper functions to produce complete APA manscripts from RMarkdown-files (PDF and Word documents).: Crsh/.. Retrieved from https://github.com/crsh/papaja

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*. doi:10.18637/jss.v067.i01

Bicknell, K., & Levy, R. (2011). Why readers regress to previous words: A statistical analysis. In *Proceedings of the Annual Meeting of the Cognitive Science Society* (p. 7).

Bixler, R., & D'Mello, S. (2016). Automatic gaze-based user-independent detection of mind wandering during computerized reading. *User Modeling and User-Adapted Interaction*, *26*(1), 33–68. doi:10.1007/s11257-015-9167-1

Coulson, S., & Kutas, M. (1998). Frame-shifting and sentential integration. *Cognitive Science Technical Report*, *98*(02).

Coulson, S., Urbach, T. P., & Kutas, M. (2006). Looking back: Joke comprehension and the space structuring model. *Humor*. doi:10.1515/HUMOR.2006.013

Dalmaijer, E. S., Mathôt, S., & Stigchel, S. der. (2014). PyGaze: An open-source, cross-platform toolbox for minimal-effort programming of eyetracking experiments. *Behavior Research Methods*, *46*(4), 913–921.

Davies, M. (2008). *The corpus of contemporary American English*. BYE, Brigham Young University.

Dynel, M. (2009). *Humorous garden-paths: A pragmatic-cognitive study*. Cambridge Scholars

Publishing.

Engbert, R., Nuthmann, A., Richter, E. M., & Kliegl, R. (2005). SWIFT: A Dynamical Model of Saccade Generation During Reading. *Psychological Review*, *112*(4), 777–813. doi:10.1037/0033-295X.112.4.777

Faber, M., Bixler, R., & D'Mello, S. K. (2018). An automated behavioral measure of mind wandering during computerized reading. *Behavior Research Methods*, *50*(1), 134–150. doi:10.3758/s13428-017-0857-y

Foulsham, T., Farley, J., & Kingstone, A. (2013). Mind wandering in sentence reading: Decoupling the link between mind and eye. *Canadian Journal of Experimental Psychology*. doi:10.1037/a0030217

Frazier, L. (1998). Getting There (Slowly). *Journal of Psycholinguistic Research*, *27*(2), 123–146. doi:10.1023/A:1023241830722

Frazier, L., & Rayner, K. (1982). Making and correcting errors during sentence comprehension: Eye movements in the analysis of structurally ambiguous sentences. *Cognitive Psychology*, *14*(2), 178–210. doi:10.1016/0010-0285(82)90008-1

Kliegl, R., Grabner, E., Rolfs, M., & Engbert, R. (2004). Length, frequency, and predictability effects of words on eye movements in reading. *European Journal of Cognitive Psychology*, *16*(1-2), 262–284. doi:10.1080/09541440340000213

Kopp, K., D'Mello, S., & Mills, C. (2015). Influencing the occurrence of mind wandering while reading. *Consciousness and Cognition*. doi:10.1016/j.concog.2015.03.003

Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2017). lmerTest Package: Tests in Linear Mixed Effects Models. *Journal of Statistical Software*, *82*(13).

doi:10.18637/jss.v082.i13

Mathôt, S., Schreij, D., & Theeuwes, J. (2012). OpenSesame: An open-source, graphical experiment builder for the social sciences. *Behavior Research Methods*, *44*(2), 314–324.

Mayerhofer, B., & Schacht, A. (2015). From incoherence to mirth: Neuro-cognitive processing of garden-path jokes. *Frontiers in Psychology*, *6*(MAY). doi:10.3389/fpsyg.2015.00550

Pollatsek, A., Reichle, E. D., & Rayner, K. (2006). Tests of the E-Z Reader model: Exploring the interface between cognition and eye-movement control. *Cognitive Psychology*, *52*(1), 1–56. doi:10.1016/j.cogpsych.2005.06.001

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin*, *124*(3), 372–422. doi:10.1037/0033-2909.124.3.372

Reichle, E. D., Reineberg, A. E., & Schooler, J. W. (2010). Eye Movements During Mindless Reading. *Psychological Science*, *21*(9), 1300–1310. Retrieved from http://www.jstor.org/stable/41062370

Reichle, E. D., Warren, T., & McConnell, K. (2009). Using E-Z Reader to model the effects of higher level language processing on eye movements during reading. *Psychonomic Bulletin & Review*, *16*(1), 1–21. doi:10.3758/PBR.16.1.1

Ritchie, G. (2004). *The Linguistic Analysis of Jokes*. Routledge. doi:10.4324/9780203406953

Ruxton, G. D., & Beauchamp, G. (2008). Time for some a priori thinking about post hoc testing. *Behavioral Ecology*, *19*(3), 690–693. doi:10.1093/beheco/arn020

Schad, D. J., Hohenstein, S., Vasishth, S., & Kliegl, R. (2018, July). *How to capitalize on a priori contrasts in linear (mixed) models: A tutorial*. Retrieved from https://arxiv.org/abs/1807.10451v2

Schad, D. J., Nuthmann, A., & Engbert, R. (2012). Your mind wanders weakly, your mind wanders deeply: Objective measures reveal mindless reading at different levels. *Cognition*, *125*(2), 179–194. doi:10.1016/j.cognition.2012.07.004

Schmidt, S. R. (1994). Effects of Humor on Sentence Memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. doi:10.1037/0278-7393.20.4.953

Schmidt, S. R. (2002). The humour effect: Differential processing and privileged retrieval. *Memory*. doi:10.1080/09658210143000263

Seli, P., Carriere, J. S. A., Levene, M., & Smilek, D. (2013). How few and far between? Examining the effects of probe rate on self-reported mind wandering. *Frontiers in Psychology*, *4*. doi:10.3389/fpsyg.2013.00430

Seli, P., Cheyne, J. A., Xu, M., Purdon, C., & Smilek, D. (2015). Motivation, intentionality, and mind wandering: Implications for assessments of task-unrelated thought. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *41*(5), 1417–1425. doi:10.1037/xlm0000116

Seli, P., Kane, M. J., Smallwood, J., Schacter, D. L., Maillet, D., Schooler, J. W., & Smilek, D. (2018). Mind-Wandering as a Natural Kind: A Family-Resemblances View. *Trends in Cognitive Sciences*, *22*(6), 479–490. doi:10.1016/j.tics.2018.03.010

Seli, P., Risko, E. F., & Smilek, D. (2016). On the Necessity of Distinguishing Between Unintentional and Intentional Mind Wandering. *Psychological Science*, *27*(5), 685–691. doi:10.1177/0956797616634068

Seli, P., Risko, E. F., Smilek, D., & Schacter, D. L. (2016). Mind-Wandering With and Without Intention. *Trends in Cognitive Sciences*, *20*(8), 605–617.

doi:10.1016/j.tics.2016.05.010

Seli, P., Wammes, J. D., Risko, E. F., & Smilek, D. (2016). On the relation between motivation and retention in educational contexts: The role of intentional and unintentional mind wandering. *Psychonomic Bulletin & Review*, *23*(4), 1280–1287. doi:10.3758/s13423-015-0979-0

Smallwood, J. (2011). Mind-wandering While Reading: Attentional Decoupling, Mindless Reading and the Cascade Model of Inattention: Mind-wandering While Reading. *Language and Linguistics Compass*, *5*(2), 63–77. doi:10.1111/j.1749-818X.2010.00263.x

Smallwood, J. (2013). Distinguishing how from why the mind wanders: A process–occurrence framework for self-generated mental activity. *Psychological Bulletin*, *139*(3), 519–535. doi:10.1037/a0030010

Smallwood, J., & Schooler, J. W. (2015). The Science of Mind Wandering: Empirically Navigating the Stream of Consciousness. *Annual Review of Psychology*, *66*(1), 487–518. doi:10.1146/annurev-psych-010814-015331

Smallwood, J., McSpadden, M., & Schooler, J. W. (2008). When attention matters: The curious incident of the wandering mind. *Memory and Cognition*. doi:10.3758/MC.36.6.1144

Steindorf, L., & Rummel, J. (2019). Do your eyes give you away? A validation study of eye-movement measures used as indicators for mindless reading. *Behavior Research Methods*. doi:10.3758/s13428-019-01214-4

Strick, M., Holland, R. W., Baaren, R. van, & Van Knippenberg, A. (2009). Humor in the Eye Tracker: Attention Capture and Distraction from Context Cues. *The Journal of*

General Psychology, *137*(1), 37–48. doi:10.1080/00221300903293055

Suls, J. (1972). A two-stage model for the appreciation of jokes and cartoons: An information-processing analysis. In J. H. Goldstein (Ed.), *The psychology of humor: Theoretical perspectives and empirical issues* (1st ed., pp. 81–100).

Suls, J. (1983). Cognitive Processes in Humor Appreciation. In P. E. McGhee & J. H. Goldstein (Eds.), *Handbook of Humor Research: Volume 1: Basic Issues* (pp. 39–57). New York, NY: Springer New York. doi:10.1007/978-1-4612-5572-7_3

Uzzaman, S., & Joordens, S. (2011). The eyes know what you are thinking: Eye movements as an objective measure of mind wandering. *Consciousness and Cognition*, *20*(4), 1882–1886. doi:10.1016/j.concog.2011.09.010

Weinstein, Y. (2018). Mind-wandering, how do I measure thee with probes? Let me count the ways. *Behavior Research Methods*, *50*(2), 642–661. doi:10.3758/s13428-017-0891-9

Zwaan, R. A., & Radvansky, G. A. (1998). Situation models in language comprehension and memory. *Psychological Bulletin*, *123*(2), 162–185. doi:10.1037/0033-2909.123.2.162

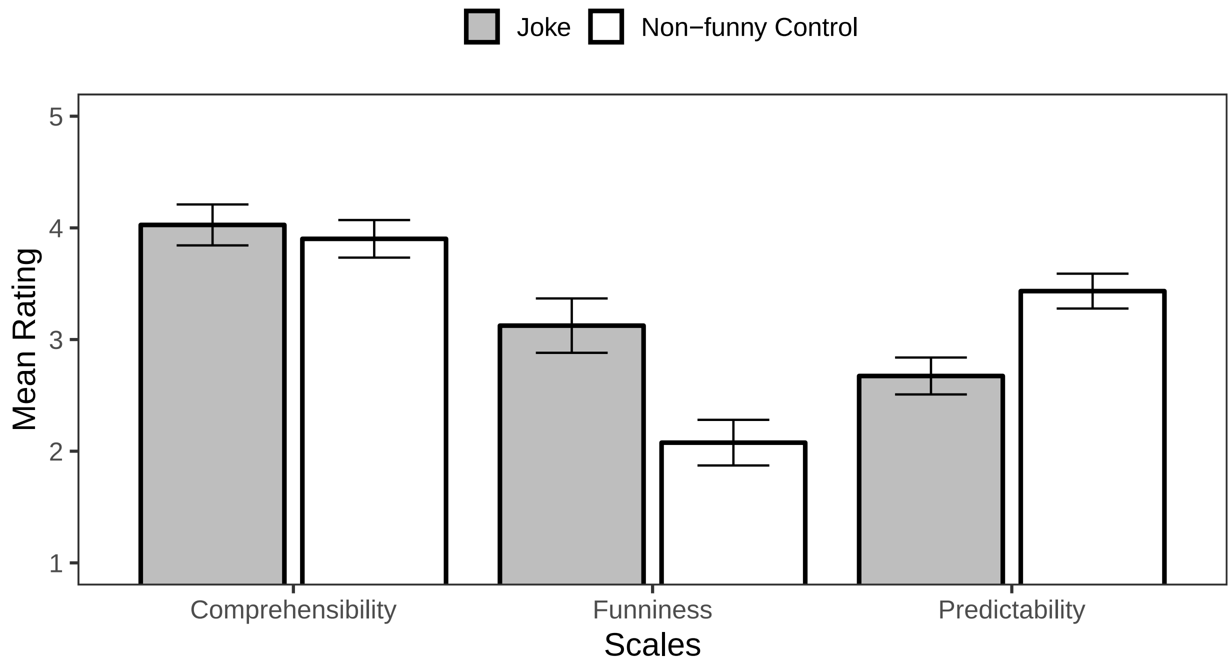

Figure 1. Mean ratings of jokes and non-funny control sentences by Mturk workers. Error bars show 95% confidence intervals.

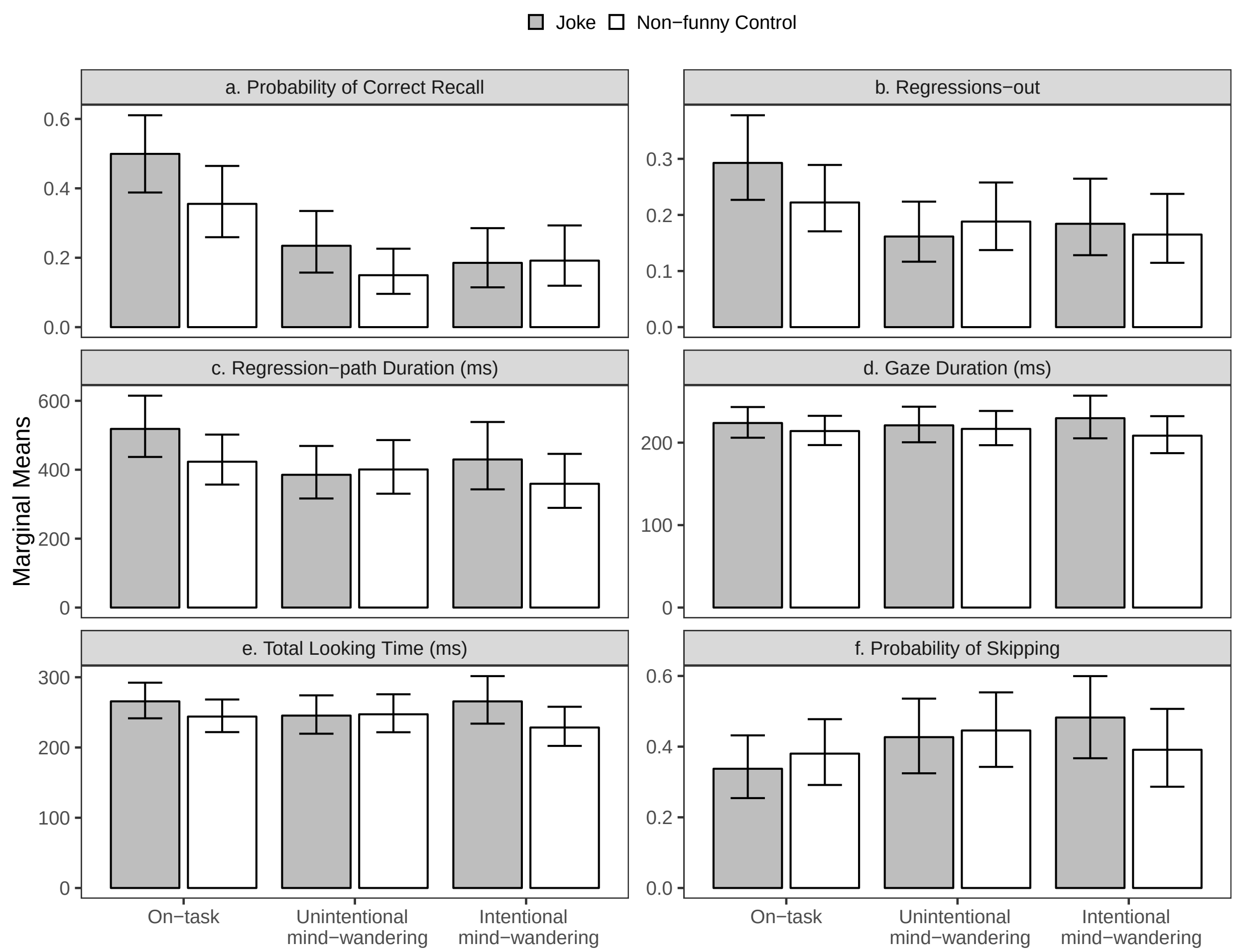

Figure 2. Recall performance (panel *a*) and eye movement measures (panel *b* to *f*), by attention (On-task, Unintentional mind-wandering, intentional mind-wandering) and text type (Joke, Control). Error bars show 95% confidence intervals. All measures were back-transformed to the original scale. Eye movement measures were adjusted for word length and log word frequency.

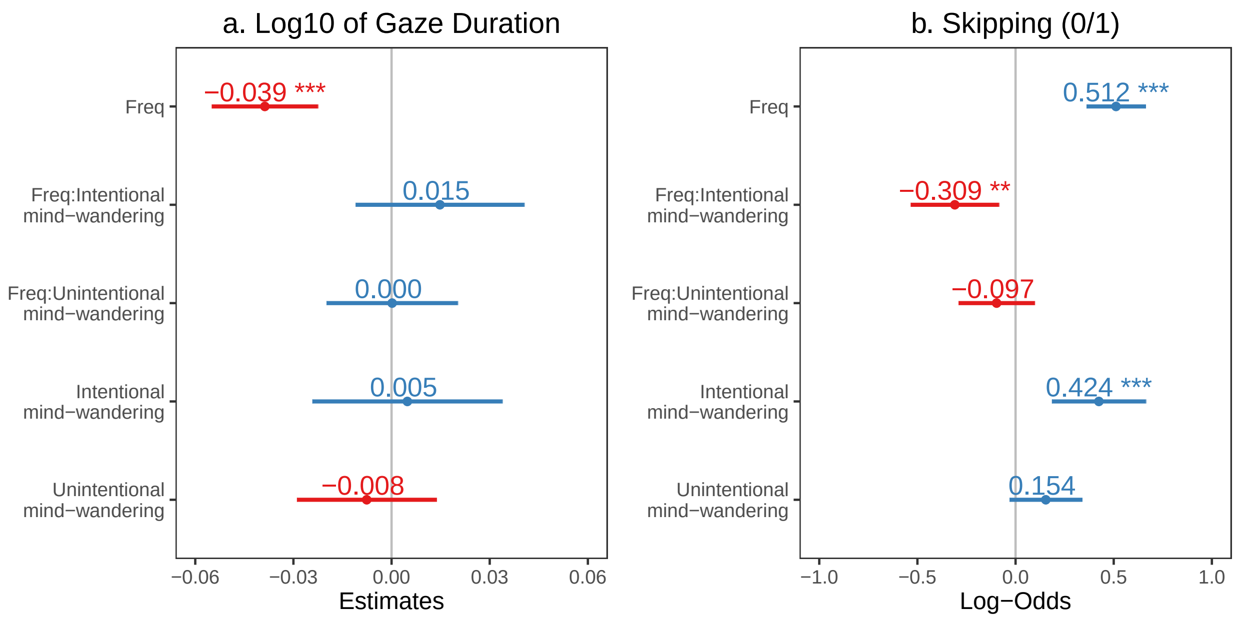

Figure 3. Fixed effects of regression analysis on the interaction between attention and word frequency. Attention (On-task, Intentional mind-wandering, Unintentional mind-wandering) was dummy-coded, with "on-task" as reference level. Freq: Log10 of Word Frequency. *** $p < .001$, ** $p < .01$, * $p < .05$. Error bars show 95% confidence intervals.