

DO INTERRUPTIONS AFFECT WRITING AND READING?

by

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DEDICATION

This dissertation is dedicated to my mother for her unwavering support and love.

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ABSTRACT

DO INTERRUPTIONS AFFECT WRITING AND READING?

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This thesis showcases a series of studies that investigated whether interruptions disrupt writing and reading. Although time- and error-based metrics have often been used to determine how interruptions disrupt performance, it is likely that they do not capture all aspects of disruption. Writing and reading are two such domains that may be better suited to the use of other metrics of quality. Here I show that interruptions reduce the quality of written work, reduce the number of words written while writing, disrupt reading comprehension, and disrupt recognition following reading for low working memory capacity individuals. This thesis demonstrates that metrics beyond time and errors can be used to understand the impact of interruptions on human performance.

SUMMARY

The effects that interruptions have on task performance have long been of interest to psychologists (e.g., Zeigarnik, 1927; see Werner, Cades, & Boehm-Davis, 2015 for a recent review). Researchers traditionally use procedural tasks with a fixed sequence of correct steps to make robust predictions about expected outcomes (e.g., Foroughi, Werner, McKendrick, Cades, & Boehm-Davis, 2015), with time and/or errors as the two primary outcome metrics.

Although time- and error-based metrics have often been used to determine how interruptions disrupt performance, they are not likely to capture all aspects of disruption. For example, pretend that you sit down to write a paper for a class assignment and are interrupted five times for a total of 30 minutes. The loss of time is useful information that shows a clear disruption. However, what is likely more important is the quality of the written work. If the quality of the work suffered, resulting in you receiving a B instead of an A, the interruptions had a far greater impact than a loss of time. Thus, it is important to find ways to measure disruptions in quality with metrics that are not time- and error-based. This logic underlies the following four manuscripts that assess interrupted task performance with metrics that are not time- or error-based.

Do Interruptions Affect Quality of Work?

The goal for this study was to identify a metric that would be appropriate for measuring how interruptions disrupt the quality of written work report. As noted above, a time- or error-based measure is not likely to capture all aspects of disruption. Instead, we looked towards validated measures of writing performance. The Scholastic Aptitude Test (SAT) essay section has been used to measure writing quality for millions of potential college students. By using the SAT essay scoring guide to assess writing quality, we felt we could determine whether interruptions affected the quality of written work, instead of just measuring how much time is lost as a result of being interrupted.

Experiment 1

To determine whether interruptions affect the quality of written work, we had participants ($n = 27$) outline and write three essays (within-subjects design). There were three conditions: no interruptions (control), interruptions during the outlining phase, and interruptions during the writing phase. Participants had the same amount of time to outline and write in all three conditions. During the outlining phase, participants were instructed to outline their essay with any method they preferred (e.g., bullet points, web diagram). During the writing phase, participants were instructed to use their outline to write their final essay. Interruptions that occurred while outlining and writing significantly reduced final essay quality as measured by two independent graders ($K = .71$) compared to the control condition ($d = .66, p < .01$; $d = .77, p < .01$). No significant differences existed between the two interruption conditions. We also found that being

interrupted while writing led to a significantly lower word count compared to the other two groups ($d = .36, p < .01$ for control; $d = .25, p < .01$ for planning phase).

Experiment 2

Experiment 2 was nearly identical to Experiment 1. However, we provided participants with additional time at the end of the writing phase for all conditions to determine whether having additional time would reduce the negative effect from the interruptions. Specifically, participants had as much time as they wanted to finish their essays. The additional time did improve performance in any condition. The overall results mirror that of Experiment 1. Interruptions that occurred while outlining and writing significantly reduced final essay quality as measured by two independent graders ($K = .77$) compared to the control condition ($d = .40, p < .01$; $d = .51, p < .01$).

Lessons Learned from Study 1

1. The quality of written work can be assessed using the SAT essay scoring guide.
2. Interruptions disrupt the quality of written work.

Do Interruptions Affect Content Production?

To better understand the findings from *Do Interruptions Affect Quality of Work?* and identify possible sources of the observed decrements, we replicated Experiment 1 from that manuscript with one change. We instructed participants to complete a standardized outline during the outlining phase. In the former work, participants differed

in their method of outlining so equal comparisons could not be reliably made. That is, we could not determine whether the interruptions reduced the amount of content produced during the outlining phase as it did in the writing phase.

Similar to the previous findings, interruptions that occurred while outlining and writing significantly reduced final essay quality as measured by two independent graders ($K = .74$) compared to the control condition ($d = .48, p < .01$; $d = .53, p < .01$). Again, we also found that being interrupted while writing led to a significantly lower word count compared to the other two groups ($d = .44, p < .01$ for control; $d = .38, p < .01$ for planning phase). This new work revealed a new finding: interruptions that occurred during the outlining phase significantly reduced the number of words in the outline, the number of primary points produced, and the number secondary points produced, compared to the control condition ($d = .63, p < .01$; $d = .49, p < .01$; $d = .53, p < .01$), and when compared the interrupted while writing condition ($d = .70, p < .01$; $d = .58, p < .01$; $d = .49, p < .01$). Notably, the reduction in content as a result of being interrupted in the outlining phase did not result in a reduction of content in the subsequent writing phase, but did result in a reduction of quality.

Lessons Learned From Study 2

1. The quality of written work can be assessed using the SAT essay scoring guide.
2. Interruptions disrupt the quality of written work.
3. One source of the quality decrement is a reduction in the amount of content produced.

4. The reduction in content as a result of being interrupted in the outlining phase did not result in a reduction of content in the subsequent writing phase, but did result in a reduction of quality.

Summary of Exploring How Interruptions Affect Writing (Studies 1 & 2)

These two manuscripts showed that the SAT scoring guide can be used to successfully measure quality of written work. Further, they both show that interruptions disrupt quality of written work. Finally, as one possible source of the quality decrement, they show that interruptions reduce the amount of content produced (see #3 and #4 above). Importantly, this information would not have presented using a time- or error-based metric to assess changes in performance.

Interruptions Disrupt Reading Comprehension

Thinking about how interruptions disrupt writing led us to consider how interruptions may disrupt reading. Indeed, previous research showed that interruptions did not disrupt reading comprehension (e.g., Glanzer et al., 1984). This research was used as support for Long-Term Working Memory (LTWM; Ericsson & Kintsch, 1995) theory, which posits that individuals are expert readers, and that interruptions should not disrupt reading or subsequent text comprehension. It seemed odd that this domain appeared to be immune to the disruptive effects of interruptions. Upon further inspection of the original work, we realized that the metrics being used to assess changes in performance were likely not capturing comprehension. Instead, that research appeared to be assessing

recognition instead of comprehension, asking simple questions that could be answered from one individual sentence within the text.

Therefore, we sought to replicate these studies using a measure that would accurately capture comprehension. Similar to studies 1 and 2, we decided to use SAT reading comprehension prompts and questions to assess reading comprehension because this test had been used to successfully assess reading comprehension in millions of potential college students. By using the SAT reading comprehension prompts and questions, we felt we could determine whether interruptions affected reading comprehension.

Experiment 1

To determine whether interruptions affect reading and subsequent comprehension, we had participants ($n = 24$) read SAT prompts while interrupted or not interrupted (control) using a counter-balanced within-subjects design. Following reading, participants answered comprehension questions about the texts read. Importantly, these questions required information to be synthesized across the text (e.g., identifying themes or tones). Interruptions significantly reduced comprehension scores compared to control ($d = .85, p < .01$). These data do not support predictions made by Long-Term Working Memory (LTWM; Ericsson & Kintsch, 1995) theory, and suggest that the original measure did not assess reading comprehension.

Experiment 2

To differentiate how interruptions affect comprehension versus recognition, we had participants ($n = 24$) read SAT prompts while interrupted or not interrupted (control), then answer comprehension or recognition questions. All participants completed all four conditions in a counter-balanced order. Interruptions significantly reduced comprehension scores compared to control ($d = .95, p < .01$), but interruptions did not significantly change recognition scores ($p > .25$). Again, these data do not support predictions made by LTWM theory, and these data suggest that the original measure did not assess reading comprehension.

Experiment 3

Although LTWM suggests that interruptions should not disrupt reading or subsequent comprehension, data from studies 1 and 2 suggest otherwise. Thus, it appears that interruptions are disrupting the processing of information (likely in working memory) as it is read and being transferred to long-term memory. To test this hypothesis, we had participants read SAT prompts while interrupted, not interrupted (control), or when interrupted following a short time-out period. If the time-out period remedied the negative effect of interruption, that would suggest that the information had been fully processed and stored in long-term memory prior to the interruption. Interruptions significantly reduced comprehension scores compared to control ($d = .70, p < .01$). Importantly, being interrupted following a time-out period did not disrupt performance ($p > .25$). These data suggest that information must be activated and processed in working memory before moving to long-term memory. Again, these data do not support

predictions made by LTWM theory, and they suggest that the original measure did not assess reading comprehension.

Lessons Learned from Study 3

1. Reading comprehension can be accurately assessed using the prompts and questions from the reading comprehension section of the SAT.
2. Interruptions disrupt reading comprehension, but not recognition, a finding that stands in contrast to previous research that used other measures to assess comprehension.

Interrupted Reading and Working Memory Capacity

To better understand the findings from *Interruptions Disrupt Reading Comprehension* and identify a possible mechanism that underlies the disruption, we replicated Experiment 2 while accounting for individual differences in working memory capacity. Because interruptions act as interference to tasks being completed (Foroughi et al., 2016), interruptions likely cause a bottleneck in working memory when reading. Thus, individual differences in working memory capacity should lead to differences in performance (i.e., comprehension) following interruptions.

We recruited individuals with high and low WMC as measured by the operation span task, and had them complete an experiment nearly identical to Study 2 from *Interruptions Disrupt Reading Comprehension*. Participants ($n = 36$) read SAT prompts while interrupted or not interrupted (control), then answered comprehension or

recognition questions. All participants completed all four conditions in a counter-balanced order.

Contrasts revealed that participants with low WMC scored significantly worse when interrupted compared to not interrupted for comprehension questions ($d = .59, p < .01$) and recognition questions ($d = .51, p < .05$). No differences existed within the high WMC participants, $p > .25$. That is, interruptions disrupted recognition and comprehension for low WMC participants, but not high WMC participants. These data suggest that individuals with high WMC can mitigate the negative effects of being interrupted, while individuals with low WMC are more vulnerable to the negative effects of being interrupted.

Lessons Learned from Studies 4

1. Reading comprehension can be accurately assessed using the prompts and questions from the SAT reading comprehension section.
2. Interruptions disrupt reading comprehension for some individuals, a finding that stands in contrast to previous research that used other measures to assess comprehension.
3. Differential performance as a function of individual differences in working memory capacity suggests that the processing bottleneck (i.e., mechanism) underlying performance decrements is at least in part, a limitation in working memory.

Summary of Exploring How Interruptions Affect Reading (Studies 3 & 4)

These two manuscripts showed that the prompts and questions from the SAT reading comprehension section can be used to successfully measure reading comprehension. Further, they both show that interruptions disrupt reading comprehension. Finally, they reveal one possible mechanism underlying the performance decrements: limits in working memory. Specifically, interruptions disrupted comprehension and recognition for the low WMC participants, but not for the high WMC participants. Importantly, this information would not have presented using a time- or error-based metric to assess changes in performance.

Summary of How Interruptions Affect Writing and Reading (Studies 1-4)

These four manuscripts reveal that measures other than time- and error-based metrics can be used to measure how interruptions disrupt performance, specifically, quality. By using two validated tests from the SAT, we were able to show that interruptions disrupt quality of written work and reading comprehension. Further, we showed that a reduction in the amount of content produced may underlie the decrement in writing quality when interrupted, and limits in working memory may underlie the disruption in reading comprehension when interrupted.

DO INTERRUPTIONS AFFECT QUALITY OF WORK?

Abstract

Objective: To determine if interruptions affect the quality of work.

Background: Interruptions are commonplace at home and in the office. Previous research in this area has traditionally used time and errors as the primary measures of disruption. Little is known about the effect interruptions have on quality of work.

Method: Fifty-four students outlined and wrote three essays using a within-subjects design. During condition one, interruptions occurred while outlining. During condition two, interruptions occurred while writing. No interruptions occurred in condition three.

Results: Quality of work was significantly reduced in both interruption conditions when compared to the non-interruption condition. The number of words produced was significantly reduced when interrupted while writing the essay, but not when outlining the essay.

Conclusion: This research represents a crucial first step in understanding the effect interruptions have on quality of work. Our research suggests that interruptions negatively impact quality of work during a complex, creative writing task. Since interruptions are such a prevalent part of daily life, more research needs to be conducted to determine what other tasks are negatively impacted. Moreover, the underlying mechanism(s) causing these decrements needs to be identified. Finally, strategies and

systems need to be designed and put in place to help counteract the decline in quality of work caused by interruptions.

Full Citation

Foroughi, C. K., Werner, N. E., Nelson, E. T., & Boehm-Davis, D. A. (2014). Do interruptions affect quality of work? *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 56(7), 1262-1271.

DOI: 10.1177/0018720814531786

DO INTERRUPTIONS AFFECT CONTENT PRODUCTION?

Abstract

Interruptions have become a persistent annoyance in our lives; they reduce performance in many domains. Traditional interruption research uses time and errors as measures of disruption. However, in creative tasks, time and errors may not be suitable measures of disruption. This study investigates how interruptions affect content production in a creative task as the amount of content created can be a better indicator of the effect of interruptions. Interruptions were found to reliably reduce the production of content while outlining and writing essays. Moreover, interruptions in both conditions (outlining and writing) reliably reduced the final quality of essays. A carry-over effect from impoverished outlines appeared to have reduced quality of the final essays.

Full Citation

Foroughi, C. K., Werner, N. E., Hatcher, M. C., Lopez, A. J., Zafar, T. W., & Boehm-

Davis, D. A. (2014, September). Do Interruptions Affect Content Production? In

Proceedings of the Human Factors and Ergonomics Society Annual Meeting

(Vol. 58, No. 1, pp. 255-259). SAGE Publications.

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INTERRUPTIONS DISRUPT READING COMPREHENSION

Abstract

Previous research suggests that being interrupted while reading a text does not disrupt the later recognition or recall of information from that text. This research is used as support for Ericsson and Kintsch's (1995) long-term working memory (LT-WM) theory, which posits that disruptions while reading (e.g., interruptions) do not impair subsequent text comprehension. However, to fully comprehend a text, individuals may need to do more than recognize or recall information that has been presented in the text at a later time. Reading comprehension often requires individuals to connect and synthesize information across a text (e.g., successfully identifying complex topics such as themes and tones) and not just make a familiarity-based decision (i.e., recognition). The goal for this study was to determine whether interruptions while reading disrupt reading comprehension when the questions assessing comprehension require participants to connect and synthesize information across the passage. In Experiment 1, interruptions disrupted reading comprehension. In Experiment 2, interruptions disrupted reading comprehension, but not recognition of information from the text. In Experiment 3, the addition of a 15 second time-out prior to the interruption successfully removed these negative effects. These data suggest that the time it takes to process the information needed to successfully comprehend text when reading is greater than that required for recognition. Any interference (e.g., an interruption) that occurs during the comprehension process may

disrupt reading comprehension. This evidence supports the need for transient activation of information in working memory for successful text comprehension and does not support LT-WM theory.

Full Citation

Foroughi, C. K., Werner, N. E., Barragán, D., & Boehm-Davis, D. A. (2015).

Interruptions disrupt reading comprehension. *Journal of Experimental Psychology: General*, 144(3), 704.

DOI: <http://dx.doi.org/10.1037/xge0000074>

INTERRUPTED READING AND WORKING MEMORY CAPACITY

Abstract

Long-term working memory (LT-WM; Ericsson & Kintsch, 1995) theory claims that the “transient portion of working memory is not necessary for continued comprehension” (pp. 225-226) and that “reading can be completely disrupted for over 30s with no observable impairment of subsequent text comprehension” (p. 232). Follow-up research testing claims made by LT-WM report conflicting, indirect evidence for and against the theory. The goal for this research was to use individual differences in working memory capacity (WMC) to provide support for or against the theory that activation of information in working memory is necessary for successful comprehension of text. By extension, this tests predictions made by Ericsson and Kintsch’s (1995) LT-WM theory. Thirty six participants with either high or low WMC (18 in each group) read prompts while interrupted or not interrupted (control), then answered recognition and comprehension questions. We found that interruptions disrupted both the recognition and comprehension of text following interrupted reading for individuals with low WMC, but not for individuals with high WMC. These results support the view that the activation of information in working memory is necessary for successful recognition and comprehension of information and argue against LT-WM theory.

Full Citation

Foroughi, C. K., Barragán, D., & Boehm-Davis, D. A. (2016). Interrupted reading and working memory capacity. *Journal of Applied Research in Memory and Cognition*.

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REFERENCES

- Ericsson, K. A., & Kintsch, W. (1995). Long-term working memory. *Psychological review*, *102*(2), 211.
- Foroughi, C. K., Barragán, D., & Boehm-Davis, D. A. (2016). Interrupted reading and working memory capacity. *Journal of Applied Research in Memory and Cognition*.
- Foroughi, C. K., Werner, N. E., Barragán, D., & Boehm-Davis, D. A. (2015). Interruptions disrupt reading comprehension. *Journal of Experimental Psychology: General*, *144*(3), 704.
- Foroughi, C. K., Werner, N. E., Hatcher, M. C., Lopez, A. J., Zafar, T. W., & Boehm-Davis, D. A. (2014, September). Do Interruptions Affect Content Production? In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 58, No. 1, pp. 255-259). SAGE Publications.
- Foroughi, C. K., Werner, N. E., Nelson, E. T., & Boehm-Davis, D. A. (2014). Do interruptions affect quality of work? *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *56*(7), 1262-1271.
- Foroughi, C. K., Werner, N. E., McKendrick, R., Cades, D. M., & Boehm-Davis, D. A. (2016). Individual Differences in Working-Memory Capacity and Task

Resumption Following Interruptions. *Journal of Experimental Psychology: Learning, Memory, and Cognition*.

Glanzer, M., Fischer, B., & Dorfman, D. (1984). Short-term storage in reading. *Journal of Verbal Learning and Verbal Behavior*, 23(4), 467-486.

Werner, N. E., Cades, D. M., & Boehm-Davis, D. A. (2015). Task Performance. In L. D. Rosen, N. Cheever, & L. M. Carrier (Eds.), *The Wiley Handbook of Psychology, Technology and Society*. (pp. 436–452). Chichester, United Kingdom: Wiley-Blackwell.

Zeigarnik, Bluma 1927 "Das Behalten erledigter und unerledigter Handlungen. " *Psychologische Forschung*, 9: 1-85.

BIOGRAPHY

Cyrus Khan Foroughi graduated from Stonewall Jackson High School, Virginia, in 2003. He received his Bachelor of Science from George Mason University in 2012. He received his Master of Arts in Psychology from George Mason University in 2014.