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Pauses in written composition: on the importance of where writers pause

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Abstract Much previous research has conceptualized pauses during writing as indicators of the engagement of higher-level cognitive processes. In the present study 101 university students composed narrative or argumentative essays, while their key logging was recorded. We investigated the relation between pauses within three time intervals (300–999, 1000–1999, and >2000 ms), at different text boundaries (i.e., between words, sentences, and paragraphs), genre (i.e., narrative vs. argumentative), and transcription fluency (i.e., typing speed). Moreover, we investigated the relation between pauses and various lexical characteristics of essays (e.g., word frequency, sentence length) controlling for transcription fluency and genre. In addition to replicating a number of previously reported pause effects in composition, we also show that pauses are related to various aspects of writing, regardless of transcription fluency and genre. Critically our results show that the majority of pause effects in written composition are modulated by pause location. For example, increased pause rates at word boundaries predicted word frequency, while pause rates at sentence boundaries predicted sentence length, suggesting different levels of processing at these text boundaries. Lastly, we report some inconsistencies when using various definitions of pauses. We discuss potential mechanisms underlying effects of pauses at different text boundaries on writing.

Keywords Writing · Pauses · Computational linguistics

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Introduction

Written composition can be described as a succession of bursts of written language and pause periods (e.g., Alves & Limpo, 2015; Matsuhashi, 1981; Schilperoord, AQ1 2002). As such, both transcription fluency (i.e., typing speed) and pauses are assumed to be indicative of writing efficiency. For example, both decreased transcription fluency and increased pause rates are seen as indicators of processing difficulty during writing (Fayol, 1999; Kellogg, 1996, 1999; Olive & Kellogg, 2002). In other words, since writing processes (e.g., planning) operate within the limits of working memory (McCutchen, 1996; McCutchen, Covill, Hoyne, & Mildes, 1994), less fluent processes should use up more resources, resulting in, for example, more pausing. While there exists much research on transcription fluency (i.e., writing speed) and its effects on writing quality (Alves, Castro, & Olive, 2008; Chenoweth & Hayes, 2001; Connelly, Campbell, MacLean, & Barnes, 2006; Connelly, Dockrell, & Barnett, 2005; Medimorec & Risko, 2016; Medimorec, AQ2 Young, & Risko, 2017; Olive, Alves, & Castro, 2009), far less is known about the exact nature of the cognitive processes underlying written production during pauses (e.g., Chenu, Pellegrino, Jisa, & Fayol, 2014; Olive et al., 2009; Schilperoord, 2002; Torrance & Galbraith, 2006). This is surprising given the evidence that pauses account for over half of the total composition time and are often assumed to be the loci of higher-level processes such as planning and retrieving (Alamargot, Dansac, Chesnet, & Fayol, 2007; Alves, Castro, de Sousa, & Strömqvist, 2007; Strömqvist & Ahlsén, 1999). In the current study, we investigate the relation between pauses (i.e., the rate, or frequency of pauses at different text boundaries—words, sentences, and paragraphs), and various lexical characteristics of essays such as word frequency and sentence length (while also controlling for transcription fluency and essay genre).

Pause variation among individuals, text boundaries, and genres

As noted above, pauses in writing are often conceptualized as indicators of the engagement of higher-level cognitive processes, (e.g., planning; McCutchen, 1996; McCutchen et al., 1994), despite a wide variety of pause thresholds used in previous studies (i.e., from 0 ms to more than 5 s, as discussed in the Defining Pauses in Composition section). This notion is based on several observations. For example, the number of pauses across a text varies as a function of writing fluency or speed (e.g., Alves & Limpo, 2015; Deane & Quinlan, 2010; Wengelin, 2007). For example, Alves et al. (2007) analyzed keystroke activity during narrative essay composition, with the pause threshold set at 2 s (pauses were analyzed across essays). The authors found that less fluent (i.e., slower) typists made more pauses, resulting in longer overall pause time, and conversely shorter bursts of written language, compared to more fluent typists, presumably reflecting the increased cognitive demands of transcription in less fluent writers. However, the narratives composed by the two groups (i.e., less and more fluent typists) did not differ in lexical density (i.e., the proportion of content words relative to total number of

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words), lexical diversity (assessed by the D measure; McKee, Malvern, & Richards, 2000), or word length. Similarly, essays produced by the two groups were judged to be similar in overall quality. Thus the analysis of the lexical characteristics of the essays together with subjective ratings of essays suggested that the writing was qualitatively similar between the two groups.

Moreover, pause rates and durations in written composition are not random. When Wengelin et al. (2009) analyzed pauses (longer than 2 s) during essay typewriting they found that pauses were more likely to occur at paragraph and sentence boundaries than word boundaries. This pause pattern in composition has been interpreted to indicate more general planning and reading back within a text at sentence and paragraph boundaries compared to the lexical and syntactic processing that likely predominates composition at word boundaries (Foulin, 1998; Immonen, 2011; Wengelin et al., 2009). In other words, the assumption is that lexical and syntactic processing should be less demanding compared to more general planning.

In addition, pauses also vary as a function of text genre (e.g., Alves & Limpo, 2015; Beauvais, Olive, & Passerault, 2011; Matsuhashi, 1981). For example, previous research has reported longer overall pausing in argumentative essays compared to narratives (e.g., van Hell, Verhoeven & van Beijsterveldt, 2008; a handwriting study, including all pauses). This is argued to reflect the fact that argumentative essays are more cognitively demanding (e.g., more constrained, require more planning) compared to narratives (Alves & Limpo, 2015; Beauvais, et al., 2011; Kellogg, 2001; Matsuhashi, 1981; van Hell et al., 2008). Indeed, there is evidence that argumentative essays are more linguistically complex compared to narratives (e.g., Medimorec & Risko, 2016). For example, argumentative essays contain more sophisticated vocabulary (i.e., less frequent, less familiar, more diverse words) and more complex sentence structure compared to narratives, presumably indicating increased cognitive effort during argumentative composition (Beauvais et al., 2011; Kellogg, 2001; Matsuhashi, 1981; van Hell et al., 2008).

These observed pause characteristics in composition have led researchers to infer that pauses signal engagement in higher level writing processes (e.g., Alamargot et al., 2007; Alves et al., 2007). For example, since different writing processes place competing demands on our limited working memory resources (Baddeley, 1986; Hayes & Flower, 1980; Kellogg, 2001; McCutchen, 1996), pauses could indicate that processing demands exceed available resources (e.g., Olive, & Cislaru, 2015; Schilperoord, 2002). In this case, transcription would have to be halted, enabling a writer to engage in writing processes that could not be carried out during bursts of written language (i.e., during typing). Relatedly, pauses could reflect the fact that a given process has not completed thus preventing transcription from occurring (e.g., until a writer has constructed the sentence or selected the word). According to this general framework, pauses signal the engagement of processes that cannot (or at least do not, given the current context) occur in parallel with the next burst of written language. Thus, our conceptualization of pauses in the current study assumes that they could be caused by both higher level components of the writing process (e.g., planning), but also lower level components, such as lexical access and spelling processing.

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It is important to note that the design in the current research involves a relatively unconstrained text production. As such, making a causal inference about the role of pauses in composition is relatively difficult. For example, it is likely that at least some pauses during text production are related to factors such as fatigue or mind wandering rather than cognitive activity associated with writing processes (Chenu et al., 2014; Schilperoord, 2002; Wengelin et al., 2009). Thus, it is important to keep in mind the associated caveats of the correlational approach with regard to causation between pauses and the underlying psycholinguistic processes.

Defining pauses in composition

One difficulty in investigating pauses in composition is in clearly operationalizing the construct. What should be considered a pause in writing? While pauses usually refer to inactivity (or non-scribal periods) during writing, there does not exist an objectively defined pause threshold in the literature (Chenu, et al., 2014; Wengelin, 2002, 2007). The most commonly used pause thresholds in adult writing (both handwriting and typing) are 1 and 2 s (e.g., Alves et al., 2008; Levy & Ransdell, 1995; Schilperoord, 2002; Severinson-Eklundh & Kollberg, 1996; Strömqvist, Holmqvist, Johansson, Karlsson, & Wengelin, 2006). On the other hand, some researchers have proposed using much lower pause thresholds (e.g., 250 ms in the handwriting study by Olive & Kellogg, 2002), 300 ms (Lacruz, Denkowski, & Lavie, 2014; typing), or 500 ms (Chukharev-Hudilainen, 2014; typing), while some researchers did not use any thresholds (e.g., Maggio, Lété, Chenu, Jisa, & Fayol, 2012; handwriting). In the current study, we investigate pauses defined by discrete time intervals (i.e., 300–999, 1000–1999, and >2000 ms) as this could provide additional information about the functions of pauses. The use of such an operationalization of a pause (i.e., different time intervals) marks an important contribution to the investigation of pauses in composition which has been limited by the fact that different research groups use different (single) threshold definitions and typically restrict analyzes to that definition.

As is clear from the brief overview of pause investigations presented above, researchers define pauses in composition differently. Such inconsistency potentially limits the extent to which the results of different studies can be compared. For example, adopting a minimum pause threshold implies that pauses below that threshold are not relevant for writing processes. While in the current study we consider pauses over 300 ms, this choice was not completely arbitrary. For example, recent exploratory work on developing pause criteria has suggested that pauses below certain thresholds might reflect the simple mechanics of typing (Baaijen, Galbraith, & de Glopper, 2012; Brizan et al., 2015; Wengelin, 2006). As such, pauses could be conceptualized as non-scribal periods that exceed the time needed for the execution of these simple mechanics of typing (approximated by the interword keystroke interval). In the present investigation, the mean interword key interval was ~180 ms (SD ~ 50). Thus, our lowest threshold (i.e., 300 ms) for defining a pause is approximately two and a half standard deviations above the average time an individual takes typing within words.

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Present investigation

In the current study we analyze pauses in composition using a large set of approximately 500-word narrative and argumentative typewritten essays collected as a part of an independent research project (Medimorec & Risko, 2016). In the current study we use a pause rate measure, calculated as an average number of pauses per text boundary (i.e., pause rate per word, sentence, and paragraph). Using our corpus, we expand on three previously reported findings by investigating pauses across three text boundaries (i.e., word, sentence, and paragraph) and at three discrete time intervals (300–999, 1000–1999, and >2000 ms). Specifically, we examine (a) whether pause rate varies as a function of text boundary (i.e., less likely at word boundaries, than sentences and paragraph boundaries; Wengelin et al., 2009; typing with pause threshold at 2 s), (b) whether pause rate is greater in the argumentative genre than narrative genre, and (c) whether pause rate is related to transcription fluency, (i.e., as transcription fluency decreases pause rate increases; Alves et al., 2007). Determining the extent to which these effects replicate, change form as a function of how pauses are defined, and are modulated by text boundary (with respect to the latter two questions) represent important extensions of existing investigations of pausing in written composition.

In addition to further examining these phenomena, we also assessed the extent to which pauses across different text boundaries and pause definitions correlate with various lexical indices of essays independently of genre (i.e., narrative vs. argumentative) and transcription fluency. The lexical indices reported in the current study are measures of lexical sophistication (i.e., word frequency, lexical diversity) and sentence length. Importantly, previous research has showed a relation between these indices and writing quality (e.g., Crossley & McNamara, 2011, 2012). As noted above, pauses and fluency should be correlated and as such in order to gain a deeper understanding of the relation between pause rates and writing the potential influence of fluency (which is known to be related to writing quality; Alves, Castro, & Olive, 2008; Chenoweth & Hayes, 2001; Connelly et al., 2005, 2006; Olive, Alves, & Castro, 2009) needs to be controlled. In addition, since pauses and genre are also related (e.g., Beauvais et al., 2011; Matsuhashi, 1981; van Hell et al., 2008) we control for genre in our analyses. To our knowledge this critical test has not been provided previously thus leaving the relation between pause rates and lexical characteristics of writing ambiguous. Alves et al.'s (2007) suggestion that low transcription fluency writers can use pauses to increase the "quality" of their writing (to the level of high transcription fluency writers) suggests that there should be a positive relation between pause rate and the lexical characteristics of writing associated with writing quality when fluency is held constant. On the other hand, given the association between pauses and compositional difficulties, we might expect a negative relation.

As noted above, in the current study pauses are conceptualized as signaling the engagement of writing processes (both higher and lower) that cannot go in parallel with the next burst of written language. For example, increased demands of sentence planning (e.g., formulating longer sentences) might cause a writer to pause more at

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sentence boundaries (e.g., transcription could resume once the planning is done). This theoretical framework can be expanded to derive a number of predictions in the present context. In particular, given argumentative essays are expected to contain less frequent words and more complex sentences, thus presumably requiring deeper lexical search compared to narratives (Beauvais et al., 2011; Kellogg, 2001; Matsuhashi, 1981; van Hell et al., 2008), we should expect a higher overall rate of pauses (at least at word and sentence boundaries) when individuals are writing an argumentative essay compared to a narrative essay. Moreover, since decreased transcription fluency is related to increased pause frequencies across a text (Alves et al., 2007), there is reason to expect similar relations between transcription fluency and pause frequencies at different text boundaries. Finally, lexical characteristics of essays, such as word frequency and sentence length should be related to word level pauses and sentence level pauses, since those pauses are arguably related to lexical and syntactic processing.

Thus, in the current study we investigate several questions. We start by investigating how pause rates change as a function of text boundary (i.e., word, sentence, and paragraph), and how genre (i.e., narrative vs. argumentative) affects pause rates. We then investigate the relation between transcription fluency and pauses, and potential relations between pauses and lexical characteristics of essays. Pauses are investigated within three time intervals (300–999, 1000–1999, and >2000 ms). Thus the present investigation will allow us to determine the extent to which any of these effects vary as a function of how a pause is defined (e.g., what pause interval is used).

Methods

Participants

Participants were 101 undergraduate university students (female = 68) from different subject areas. Participants were fluent English speakers. All participants were compensated with course credit.

Design

We used a 2 (narrative ($N = 51$) vs. argumentative essay) between subject design.

Stimuli and apparatus

Participants typewrote essays in MS Word (versions 2010 or 2013; Calibri 11pt font), using a standard QWERTY keyboard, and a 24-in. PC monitor. Spelling and grammar check options were disabled. Participants' keystroke activity was recorded using the Inputlog key logger (Leijten & Van Waes, 2013).

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Procedure

Each participant wrote a timed (50 min; participants could finish earlier) narrative essay (about a memorable day) or argumentative essay (about cellphone use in schools; see supplementary materials for the essay prompts). Participants were asked to write a 500-word essay and informed that their essays would be graded.

Measures

Pauses

We investigate pauses within three time intervals (300–999, 1000–1999, and >2000 ms). We analyzed pauses between words, sentences, and paragraphs, recorded by the Inputlog key logging software (Leijten & Van Waes, 2013). Inputlog uses an algorithm to identify pause locations and classify them at different text levels (e.g., before and after words, sentences, and paragraphs; for more details, see Leijten & Van Waes, 2013). Generally, pauses after words are latencies between the last letter of the previous word and the spacebar, while the pauses before words are latencies between the spacebar and the first letter of the current word. Similarly, pauses after sentences are latencies between the last letter of the previous word and the full stop, while pauses before sentences are latencies between the full stop and the spacebar. Finally, pauses after paragraphs are latencies between the ending of the previous paragraph (i.e., full stop) and the enter/return keypress, while pauses before paragraphs are latencies between return and r-shift/tab. It is important to note that, since Inputlog captures (and thus classifies) all key presses and mouse clicks, there can be more than two pauses between consecutive words, sentences, or paragraphs. In the current study all classified (before and after) pauses were used. In our analyses we use the rate of pauses at different text boundaries (i.e., before + after words, sentences, and paragraphs). The reported pause rates are frequencies per lexical unit (i.e., word, sentence, and paragraph; e.g., the rate between words is calculated as pause count at word boundaries/number of words). Finally, it is important to note several caveats related to the current approach in investigating pauses in composition. The pause criterion that we have chosen combines detected pauses before and after text boundaries (i.e., words, sentences, and paragraphs) into a single "between" pause measure (i.e., between words, sentences, or paragraphs). Thus a potential limitation of this approach is that it implies functional similarity between "after" and "before" pauses. Future analysis investigating roles of before and after pauses in text production separately will provide more information about potential functional differences between the two measures. In addition, Inputlog also classifies revisions (or editing) as a separate category from pausing. Revision measures were not considered in the current study. Since the pause count used here is based on the number of boundaries created during production, it is possible that some of the sentence structure (i.e., the number of words in a sentence) was changed during editing. Using our approach would not be sensitive to those changes.

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Transcription fluency

Transcription fluency was calculated as the mean keystroke interval within a word (onset of the current letter keypress—onset of the previous letter keypress in ms; e.g., Medimorec & Risko, 2016; but also see Strömqvist, 1999). The keystrokes equal to or exceeding 2.5 SD within each participant individually were excluded, resulting in the removal of 1.5% of keystrokes (mean values of transcription fluency across genres are presented in Table 1). It is important to note that this measure is only one of the potential indicators of fluency in composition. Other fluency indicators include measures such as the mean number of strokes per minute, and the total number of strokes (e.g., Van Waes & Leijten, 2015). Note that our transcription fluency measure correlated strongly with the average strokes per minute such that increased fluency was related to more strokes per minute, $r(99) = -.62$, $p < .001$, while there was only a weak correlation (in the same direction) with the total number of strokes, $r(99) = -.32$, $p = .001$.

Measuring linguistic features of essays

Essays were analyzed by using Coh-Metrix, an automated text analyzer (Graesser, McNamara, Louwerse, & Cai, 2004; Graesser, McNamara, & Kulikowich, 2011; McNamara, Graesser, McCarthy, & Cai, 2014). We include three indices representing lexical sophistication and sentence complexity (i.e., log frequency-all words, the measure of textual lexical diversity (MTLD; McCarthy & Jarvis, 2010), and number of words per sentence), which have been showed to reliably predict human assessed essay quality (e.g., Crossley & McNamara, 2011, 2012; Crossley, Weston, McLain Sullivan, & McNamara, 2011; Guo, Crossley, & McNamara, 2013; McNamara et al., 2014). More detail about individual text features are provided below.

Lexical diversity

Lexical diversity is an indicator of vocabulary diversity in a text. The Coh-Metrix measures of lexical diversity include type–token ratio (TTR; Templin, 1957), the measure of textual lexical diversity (MTLD, McCarthy & Jarvis, 2010), and vocd-D

Table 1 Lexical indices and transcription fluency across genres, mean values, 95% confidence intervals, and Cohen's d's

Measure	Genre		d
	Narrative M [95% CI]	Argumentative M [95% CI]	
Log frequency-all words	3.15 [3.13, 3.16]	3.01 [2.98, 3.04]	1.65
Measure of textual lexical diversity	78.38 [75.23, 81.53]	81.37 [76.51, 86.24]	.21
Words per sentence	21.61 [20.60, 22.62]	22.96 [21.73, 24.19]	.34
Transcription fluency	171 [159, 183]	189 [174, 204]	.37

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(Malvern, et al., 2004). Texts with increased lexical diversity scores are considered more lexically sophisticated (McNamara et al., 2014).

Word frequency

Word frequency measures how often words occur in the English language. Coh-Metrix calculates several measures of word frequency (i.e., content words and all words) by using CELEX database (Baayen, Piepenbrock, & Guilkers, 1995). Texts with decreased word frequency are considered more lexically sophisticated (Crossley & McNamara, 2012).

Sentence complexity

Sentence complexity can be assessed by using various indices such as number of words before main verb or noun phrase (Perfetti, Landi, & Oakhill, 2005), and sentence length (i.e., words per sentence; e.g., Medimorec, Pavlik, Olney, Graesser, & Risko, 2015). Text quality increases with increased sentence complexity (Crossley & McNamara, 2011, 2012).

It is also worth noting that various lexical indices indicating psychological word ratings (e.g., word concreteness, word meaningfulness; Coltheart, 1981; Gilhooly & Logie, 1980; Paivio, 1965; Toglia & Battig; 1978) and text cohesion (e.g., logical connectives, content word overlap) are also correlated with text quality (Crossley & McNamara, 2011). In our essay corpus most of these indices correlated highly with the indices used in the current study. Correlations among indices used in the current study were weak, all $rs < .23$ (mean values of lexical indices used in the current study are presented in Table 1).

Results

To address positively skewed pause data, all statistical analyses in this section and throughout were carried out on log10 transformed pause data. The results were qualitatively similar when raw data were used. In the following sections, we report only statistically significant results in text, and present all relevant values in Tables. Mean values of lexical indices and transcription fluency across genres (narrative and argumentative) are presented in Table 1.

Pause rates at different text boundaries

In our first set of analyses we examine whether pause rates varied across different text boundaries (i.e., increased pause rates from word, sentence, and paragraph; e.g., Wengelin et al., 2009). We performed a series of repeated measure ANOVAs with pause location (i.e., between words, sentences, and paragraphs) as the factor. A Greenhouse-Geisser correction was applied to address violations of sphericity where appropriate. Partial eta squared is reported as a measure of effect size.

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There was a significant effect of pause position on pause rates at all intervals (i.e., 300–999, 1000–1999, and >2000 ms), such that pause rates increased from the smallest text unit (i.e., words) to the largest (i.e., paragraphs), all $Fs > 20.69$, $ps < .001$, $\eta_p^2 s > .19$ (for means and standard deviations see Table 2; correlations among pause rates at different text boundaries across three pause intervals are presented in Table 3). Pause rates differed significantly among all text boundaries at all intervals, $ts > 3.06$, $ps < .004$, $ds > .34$.

As predicted, pause rate was the highest at paragraph boundaries, followed by sentence and word boundaries.

Genre effect on pause rates

Our next set of analyses investigated whether pause rates differed across narrative and argumentative essays. We performed a series of one-way ANOVAs with genre (narrative vs. argumentative) as the sole between-subject factor and pause rates at different text boundaries (i.e., words, sentences, and paragraphs) as the dependent variables. In the current section Cohen's d are provided as measures of effect size.

There was a significant effect of genre on pause rates at word boundaries at each interval such that pause rate was higher in argumentative essays compared to narratives, all $Fs > 4.30$, $ps < .041$, $ds > .40$. Moreover, there was a marginally significant effect at sentence boundaries at the 300–999 ms interval, $F(1, 99) = 3.33$, $MSE = .05$, $p = .071$, $d = .36$, such that pause rates were higher in argumentative than narrative essays. There were no effects of genre on pause rates at sentence boundaries at the remaining intervals (i.e., 1000–1999, and >2000 ms), nor significant effects at paragraph boundaries at any interval (see Table 4).

In summary pause rates were higher at word boundaries in argumentative essays across all intervals. The same was true for pauses at sentence (marginally) at 300–999 ms interval, while there were no statistically significant differences in pause rates at paragraph boundaries. Finally, it is worth noting that given possible inter-writer variability across different writing tasks (e.g., writing narrative vs. argumentative essays; Olinghouse, Santangelo, & Wilson, 2012) future investigation of pauses in composition implementing a within-subject design could provide more insight into the relation between pausing and writing across different genres.

Transcription fluency and pauses

In our next set of analyses, we examined the relation between transcription fluency and pause rates at different pause intervals. We performed a set of bivariate

Table 2 Pause rates per text interval, means and (SD), raw data

Text Boundary	Pause interval (ms)		
	300–999	1000–1999	>2000
Word	.44 (.20)	.10 (.06)	.10 (.06)
Sentence	.61 (.27)	.15 (.13)	.14 (.16)
Paragraph	.89 (.61)	.39 (.41)	.27 (.30)

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Table 3 Correlations among pause rates at different text boundaries across three pause intervals, log transformed data

Pause Interval (ms) and Text Boundary	1	2	3	4	5	6	7	8	9
1. 300–999, Word	–	.79***	.64***	.54***	.47***	.27**	.09	.09	.08
2. 1000–1999, Word		–	.79***	.42***	.54***	.41***	−.07	.01	.10
3. >2000, Word			–	.30**	.56***	.57***	.05	.06	.24**
4. 300–999, Sentence				–	.42***	.24**	.02	−.12	.001
5. 1000–999, Sentence					–	.71***	−.01	.19**	.25**
6. >2000, Sentence						–	−.02	.28**	.45***
7. 300–999, Paragraph							–	.12	−.14
8. 1000–1999, Paragraph								–	.28**
9. >2000, Paragraph									–

* $p < .10$, ** $p < .05$, *** $p < .001$

Table 4 Pause rates per text boundary across genres at three pause intervals, raw data (means and SD). effect sizes are Cohen's d's

Text boundary	Pause interval (ms)	Genre		d
		Narrative M (SD)	Argumentative M (SD)	
Word	300–999	.40 (.20)	.48 (.21)	.36
	1000–1999	.09 (.04)	.11 (.07)	.46
	>2000	.08 (.04)	.11 (.08)	.50
Sentence	300–999	.56 (.26)	.66 (.28)	.38
	1000–1999	.14 (.14)	.16 (.12)	.15
	>2000	.13 (.14)	.15 (.18)	.15
Paragraph	300–999	.82 (.54)	.95 (.67)	.20
	1000–1999	.37 (.33)	.40 (.46)	.06
	>2000	.27 (.27)	.27 (.32)	.01

correlations between transcription fluency and pause rates at different text boundaries (i.e., word, sentence, and paragraph).

Correlations between pause rates and transcription fluency were significant at word and sentence boundaries at all intervals, such that decreased fluency was

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related to higher pause rates, $rs > .39$, $ps < .001$, while the correlations at paragraph boundaries were not statistically significant (see Table 5).

Relations between pauses and lexical indices

Next, we performed a series of regression analyses to investigate relations between pause rates at different text boundaries and various text features controlling for transcription fluency and genre. Thus, in the first step we entered transcription fluency, and genre (0 = narrative vs. 1 = argumentative) as the IVs and the individual lexical indices (i.e., log frequency-all words, MTLD, and words per sentence (WPS)) as the DVs. In the second step we entered pause rates. In the following section, we only report standardized regression coefficients (betas) for the second model if R Square Change is significant (all standardized regression coefficients are presented in Table 6). In the current section 95% confidence intervals are provided in square brackets [lower limit, upper limit] and semipartial correlations (r_s) are provided as measures of effect size.

AQ3

Pauses at word boundaries

There was a significant effect of pause rates at word boundaries on log frequency-all words at all pause intervals, such that word frequency decreased with increased pause rates, all (absolute value), $\beta s > .24$, $ts > 2.59$, $ps < .012$, $r_s > .19$. On the other hand, there were no statistically significant effects of pauses at word boundaries on MTLD. Finally, there was a marginal effect on WPS, such that sentence length decreased with increased pause rates.

Pauses at sentence boundaries

There were no effects of pause rates at sentence boundaries on word frequency at any interval (although increased pause rates at sentence boundaries were related to decreased word frequency). There was a marginally significant effect on MTLD at 1000–1999 ms interval, $\beta = -.21$, $t(97) = -1.93$, $p = .056$, $r_s = -.19$, such that MTLD decreased with increased pause rates. There was an effect of pause rates on WPS at 1000–1999 ms interval, $\beta = .22$, $t(97) = 2.06$, $p = .042$, $r_s = .20$, such that WPS increased with increased pause rates (there was a similar trend at remaining intervals).

Table 5 Correlations between transcription fluency and pause rates at different text boundaries at three pause intervals, log transformed data

Pause interval (ms)	Text boundary		
	Word r	Sentence	Paragraph
300–999	.61***	.59***	−.03
1000–1999	.59***	.45***	.14
>2000	.55***	.40***	.13

*** $p < .001$

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Table 6 Relations between pause rates and lexical indices—standardized regression coefficients (β values) at different pause intervals and across text boundaries, log transformed data

Text boundary	Pause interval (ms)	Log frequency all words β	Measure of textual lexical diversity	Words per sentence
Word	300–999	−.254**	−.012	−.209*
	1000–1999	−.255**	.015	−.003
	>2000	−.271**	−.044	−.050
Sentence	300–999	−.106	−.057	.144
	1000–1999	−.056	−.214*	.223**
	>2000	−.074	−.111	.175
Paragraph	300–999	.002	−.080	−.205*
	1000–1999	.099	.006	.000
	>2000	−.111	.086	.132

* $p < .10$; ** $p < .05$

Pauses at paragraph boundaries

There was a marginally significant effect of pause rates at paragraph boundaries on WPS, $\beta = -.21$, $t(80) = -1.95$, $p = .054$, $r_s = -.20$, such that WPS decreased with increased pause rates. There were no other effects of pause rates at paragraph boundaries.

In general, our regression analyses supported the notion that higher pause rates are related to decreased word frequency and to a limited extent increased sentence complexity, both features of better writing quality (e.g., Crossley and McNamara, 2011, 2012). We show that this is true for pauses at word and (to a lesser extent) sentence boundaries. The results were consistent across pause intervals (for beta values see Table 6).

Discussion

The present investigation revealed a number of important findings about pauses during writing. We replicated previous work showing that pauses (in this case at 300–999, 1000–1999, and >2000 ms intervals) occur more often at paragraph boundaries, followed by sentence, and word boundaries (controlling for the number of boundaries). In addition, we found both more pausing when composing argumentative essays than narrative essays, and a significant relation between pausing and transcription fluency. Critically, we also showed that these latter effects varied as a function of text boundary, and to an extent pause interval. In particular pause rate was higher in argumentative essays at word boundaries compared to narratives. The same was true for pauses at sentence boundaries (marginally) at 300–999 ms interval. Finally, there were no differences in pause rates at paragraph

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boundaries at any interval between genres. In addition, decreased fluency was related to increased pause rates at word and sentence boundaries at all intervals, but not at paragraph boundaries. Moreover, we showed that increased pause rates at word and sentence boundaries were related to decreased word frequency and increased sentence length respectively, even when controlling for transcription fluency and genre. Pauses at paragraph boundaries were not systematically related to any of the lexical indices tested.

Pause rates at different text boundaries

We started our investigation of pauses during composition by successfully replicating the text boundary effect (i.e., increase in pause rates from word to paragraph boundaries; Immonen, 2011; Wengelin et al., 2009). This effect was significant at all intervals. Previously this pattern has been interpreted to indicate increased cognitive demands at sentence and paragraph boundaries. Thus processes such as sentence planning (at pauses between sentences) and more global text planning (at paragraph boundaries) seem to require longer time compared to, for example, lexical access (at word boundaries). This general notion provides an important lens through which to interpret our demonstrations the relation between pausing and transcription fluency, and the relation between pausing and lexical characteristics of the essays are all modulated by text boundaries.

Genre effect on pause rates

As noted above, previous research has showed that the overall duration of pauses was longer in argumentative than narrative texts. This result has been taken to reflect, for example, deeper lexical selection during argumentative text composition (e.g., van Hell et al., 2008). Here we showed higher pause rates in argumentative essays compared to narrative essays at word boundaries across all pause intervals. On the other hand, the results regarding pause rates at sentence and paragraph boundaries were inconsistent across pause intervals (marginally significant at 300–999 ms interval at sentence boundary, and not statistically significant at the other intervals). Importantly, the argumentative essays produced in the present investigation were more complex at the word and sentence levels (i.e., they contained less frequent words and longer sentences compared to narratives; see Table 1). Taken together these results are consistent with the idea that writing that requires prolonged lower or higher level processes (e.g., deeper lexical selection; planning of complex syntax), leads to more pauses. For example, deeper lexical search associated with argumentative essays was most salient at word boundaries, while additional syntactic planning was detected at sentence boundaries. In addition, some research has showed that writers seem to use similar global writing strategies across genres (i.e., generating and organizing of ideas, reading back; Haas, 1989; Van Waes, & Schellens, 2003). Thus, the difference between argumentative and narrative texts in terms of global writing strategies across genres might be a smaller effect. Consistent with this idea, there was no effect of genre at paragraph boundaries and the effect at sentence boundaries was limited (the effect sizes were

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all "small" to "medium" and all in the predicted direction). Thus, at this juncture is seems fair to conclude that individuals pause at a higher rate when composing argumentative than narrative essays and that this effect is particularly pronounced for pauses at the word boundary reflecting the greater lexical complexity typically associated with argumentative texts.

Transcription fluency and pauses

Previous research has also showed that decreased transcription fluency is related to increased pause rates (Alves et al., 2007; Deane & Quinlan, 2010; Wengelin, 2007). This result has been interpreted as evidence that high demands of transcription lead to a kind of cognitive overload (i.e., writing processes such as planning cannot be executed during bursts of written language) in less fluent typists, resulting in more pausing during composition (Alves & Limpo, 2015). Consistent with this interpretation, in the current study, transcription fluency was strongly related to pause rates at word and sentence boundaries though the relation seems stronger in the former than the latter case. However, relations between transcription fluency and pause rates at paragraph boundaries were for the most part weak (see Table 3). Thus, the strength of correlations between pauses and transcription fluency decreases from word to paragraph boundaries. Moreover, as is clear from Table 3, pause rates at word boundaries are correlated with pause rates at sentence boundaries at all intervals, but only weakly at paragraph boundaries. On the other hand, pauses at sentence boundaries are related to both pauses at word and paragraph boundaries, the former being a stronger relation. Taken together, these results suggest that pauses at word and paragraph boundaries seem to be largely distinct, while pauses at sentence boundaries may overlap functionally with both pauses at word and paragraph boundaries and thus reflect more than only global text planning. Moreover, the relation between pauses at sentence and paragraph boundaries increased across time intervals (i.e., from non-significant at 300–999 ms, to significant at 1000–1999, and >2000 ms). Finally, pauses at word boundaries seem to be functionally similar, regardless of interval. The same was true for pauses at sentence boundaries, but not for pauses at paragraph boundaries. This is theoretically interesting because it suggests that, for example, lower level processes (at word) do not have to necessarily be relatively short in duration.

Relations between pauses and lexical indices

Lastly, previous research has suggested that lexical and syntactic processing are mostly related to pauses at word boundaries (e.g., Wengelin et al., 2009). Consistent with this idea, we showed that increased pause rates at word boundaries (at all intervals) predicted word frequency (decreased) even when controlling for transcription fluency and genre, suggesting that pauses at word boundaries are likely providing an index of online lexical processing (e.g., the depth of lexical search). Moreover, we showed that pause rates at sentence boundaries predicted sentence length, suggesting that these pauses indicate syntactic processing. Finally, there were no systematic effects of pauses at paragraph boundaries on lexical

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indices. This is consistent with the fact that none of the measures used index writing at the paragraph level. Overall, the foregoing suggests that pauses at different text boundaries are aligned with their respective context (i.e., word level processing with pauses at word boundaries, sentence level processing with pauses at sentence boundaries). However, our analyses also suggest that pausing at sentence boundaries could be related to some aspects of lexical processing. For example, pauses at sentence boundaries were negatively related to lexical diversity (i.e., there was a consistent trend across intervals). As such, investigating the effects of pauses at different locations separately instead of studying overall pause rates and/or durations across text seems appropriate in future investigations of pauses in written composition.

As noted in the introduction, the assumptions about relations between pauses and lexical indices in the current study are derived from correlational analysis (i.e., here a correlation between two measures is assumed to indicate a shared underlying mechanism). Thus it is important to keep in mind the limitations of such a method with regard to causation between pauses and the underlying psycholinguistic processes.

Different pause intervals

In the current study we investigated whether effects of pause rates on various aspects of writing varied as a function of different time intervals. This is important given different pause thresholds used in previous work. It is worth noting that, since the distribution of pauses is positively skewed, increasing pause interval led to a systematic loss of pause variance, at least when the pause rate measure is used. For example, while at the 300–999 ms interval we captured .95 pauses at paragraph boundaries in argumentative essays, this number dropped to .27 at the >2000 ms interval. This result is an artefact of pause operationalization in the current study. For example, we decided to include the total number of pauses between paragraphs (i.e., before paragraphs, after paragraphs) captured by Inputlog at a chosen threshold. This means that by choosing a pause interval of >2000 ms we excluded any individual before paragraph or after paragraph pause below 2 s, even though if taken together these pauses (i.e., before + after) might sum up to 2 s or more. As such higher pause thresholds might be less suitable for investigation of the more nuanced effects, such as the relation between pauses at different boundaries and various text characteristics, at least when using the pause rate measure. Nonetheless, the present investigation clearly shows that how a pause is defined is an important consideration in investigating pauses during written composition.

Conclusion

The current study has replicated and extended a number of phenomena previously reported in the literature investigating pausing during written composition. In addition, we provided a number of novel analyses of the relation between pausing and the lexical and syntactic features of written essays. Critically, most effects were

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modulated by where an individual was pausing in the text. Together with the pattern of correlations between pause rates at different boundaries these results suggest strongly that pauses at different location might perform different functions within written communication. Thus, the present investigation underlines the importance of considering *where* individuals pause in assessing how pausing might be related to written composition.

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