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

5 **Srdan Medimorec¹** · **Evan F. Risko¹**

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

26
27 **Keywords** Writing · Pauses · Computational linguistics

A1 **Electronic supplementary material** The online version of this article (doi:[10.1007/s11145-017-9723-7](https://doi.org/10.1007/s11145-017-9723-7))
A2 contains supplementary material, which is available to authorized users.

A3 Srdan Medimorec
A4 smedimor@uwaterloo.ca

A5 ¹ Department of Psychology, University of Waterloo, 200 University Avenue West, Waterloo,
A6 ON N2L 3G1, Canada

31 Introduction

32 Written composition can be described as a succession of bursts of written language
 33 and pause periods (e.g., Alves & Limpo, 2015; Matsuhashi, 1981; Schilperoord,
 34 ^{AAQ1}2002). As such, both transcription fluency (i.e., typing speed) and pauses are
 35 assumed to be indicative of writing efficiency. For example, both decreased
 36 transcription fluency and increased pause rates are seen as indicators of processing
 37 difficulty during writing (Fayol, 1999; Kellogg, 1996, 1999; Olive & Kellogg,
 38 2002). In other words, since writing processes (e.g., planning) operate within the
 39 limits of working memory (McCutchen, 1996; McCutchen, Covill, Hoyne, &
 40 Mildes, 1994), less fluent processes should use up more resources, resulting in, for
 41 example, more pausing. While there exists much research on transcription fluency
 42 (i.e., writing speed) and its effects on writing quality (Alves, Castro, & Olive, 2008;
 43 Chenoweth & Hayes, 2001; Connelly, Campbell, MacLean, & Barnes, 2006;
 44 Connelly, Dockrell, & Barnett, 2005; Medimorec & Risko, 2016; Medimorec,
 45 ^{AAQ2}Young, & Risko, 2017; Olive, Alves, & Castro, 2009), far less is known about the
 46 exact nature of the cognitive processes underlying written production during pauses
 47 (e.g., Chenu, Pellegrino, Jisa, & Fayol, 2014; Olive et al., 2009; Schilperoord, 2002;
 48 Torrance & Galbraith, 2006). This is surprising given the evidence that pauses
 49 account for over half of the total composition time and are often assumed to be the
 50 loci of higher-level processes such as planning and retrieving (Alamargot, Dansac,
 51 Chesnet, & Fayol, 2007; Alves, Castro, de Sousa, & Strömquist, 2007; Strömquist &
 52 Ahlsén, 1999). In the current study, we investigate the relation between pauses (i.e.,
 53 the rate, or frequency of pauses at different text boundaries—words, sentences, and
 54 paragraphs), and various lexical characteristics of essays such as word frequency
 55 and sentence length (while also controlling for transcription fluency and essay
 56 genre).

57 Pause variation among individuals, text boundaries, and genres

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

73 words), lexical diversity (assessed by the D measure; McKee, Malvern, & Richards,
 74 2000), or word length. Similarly, essays produced by the two groups were judged to
 75 be similar in overall quality. Thus the analysis of the lexical characteristics of the
 76 essays together with subjective ratings of essays suggested that the writing was
 77 qualitatively similar between the two groups.

78 Moreover, pause rates and durations in written composition are not random.
 79 When Wengelin et al. (2009) analyzed pauses (longer than 2 s) during essay
 80 typewriting they found that pauses were more likely to occur at paragraph and
 81 sentence boundaries than word boundaries. This pause pattern in composition has
 82 been interpreted to indicate more general planning and reading back within a text at
 83 sentence and paragraph boundaries compared to the lexical and syntactic processing
 84 that likely predominates composition at word boundaries (Foulin, 1998; Immonen,
 85 2011; Wengelin et al., 2009). In other words, the assumption is that lexical and
 86 syntactic processing should be less demanding compared to more general planning.

87 In addition, pauses also vary as a function of text genre (e.g., Alves & Limpo,
 88 2015; Beauvais, Olive, & Passerault, 2011; Matsuhashi, 1981). For example,
 89 previous research has reported longer overall pausing in argumentative essays
 90 compared to narratives (e.g., van Hell, Verhoeven & van Beijsterveldt, 2008; a
 91 handwriting study, including all pauses). This is argued to reflect the fact that
 92 argumentative essays are more cognitively demanding (e.g., more constrained,
 93 require more planning) compared to narratives (Alves & Limpo, 2015; Beauvais,
 94 et al., 2011; Kellogg, 2001; Matsuhashi, 1981; van Hell et al., 2008). Indeed, there is
 95 evidence that argumentative essays are more linguistically complex compared to
 96 narratives (e.g., Medimorec & Risko, 2016). For example, argumentative essays
 97 contain more sophisticated vocabulary (i.e., less frequent, less familiar, more
 98 diverse words) and more complex sentence structure compared to narratives,
 99 presumably indicating increased cognitive effort during argumentative composition
 100 (Beauvais et al., 2011; Kellogg, 2001; Matsuhashi, 1981; van Hell et al., 2008).

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

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

126 Defining pauses in composition

127 One difficulty in investigating pauses in composition is in clearly operationalizing
 128 the construct. What should be considered a pause in writing? While pauses usually
 129 refer to inactivity (or non-scribal periods) during writing, there does not exist an
 130 objectively defined pause threshold in the literature (Chenu, et al., 2014; Wengelin,
 131 2002, 2007). The most commonly used pause thresholds in adult writing (both
 132 handwriting and typing) are 1 and 2 s (e.g., Alves et al., 2008; Levy & Ransdell,
 133 1995; Schilperoord, 2002; Severinson-Eklundh & Kollberg, 1996; Strömqvist,
 134 Holmqvist, Johansson, Karlsson, & Wengelin, 2006). On the other hand, some
 135 researchers have proposed using much lower pause thresholds (e.g., 250 ms in the
 136 handwriting study by Olive & Kellogg, 2002), 300 ms (Lacruz, Denkowski, &
 137 Lavie, 2014; typing), or 500 ms (Chukharev-Hudilainen, 2014; typing), while some
 138 researchers did not use any thresholds (e.g., Maggio, Lété, Chenu, Jisa, & Fayol,
 139 2012; handwriting). In the current study, we investigate pauses defined by discrete
 140 time intervals (i.e., 300–999, 1000–1999, and >2000 ms) as this could provide
 141 additional information about the functions of pauses. The use of such an
 142 operationalization of a pause (i.e., different time intervals) marks an important
 143 contribution to the investigation of pauses in composition which has been limited by
 144 the fact that different research groups use different (single) threshold definitions and
 145 typically restrict analyzes to that definition.

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

161 **Present investigation**

162 In the current study we analyze pauses in composition using a large set of
 163 approximately 500-word narrative and argumentative typewritten essays collected
 164 as a part of an independent research project (Medimorec & Risko, 2016). In the
 165 current study we use a pause rate measure, calculated as an average number of
 166 pauses per text boundary (i.e., pause rate per word, sentence, and paragraph). Using
 167 our corpus, we expand on three previously reported findings by investigating pauses
 168 across three text boundaries (i.e., word, sentence, and paragraph) and at three
 169 discrete time intervals (300–999, 1000–1999, and >2000 ms). Specifically, we
 170 examine (a) whether pause rate varies as a function of text boundary (i.e., less likely
 171 at word boundaries, than sentences and paragraph boundaries; Wengelin et al.,
 172 2009; typing with pause threshold at 2 s), (b) whether pause rate is greater in the
 173 argumentative genre than narrative genre, and (c) whether pause rate is related to
 174 transcription fluency, (i.e., as transcription fluency decreases pause rate increases;
 175 Alves et al., 2007). Determining the extent to which these effects replicate, change
 176 form as a function of how pauses are defined, and are modulated by text boundary
 177 (with respect to the latter two questions) represent important extensions of existing
 178 investigations of pausing in written composition.

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

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



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

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

228 **Methods**

229 **Participants**

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

233 **Design**

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

235 **Stimuli and apparatus**

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

240 **Procedure**

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

245 **Measures**246 **Pauses**

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



281 **Transcription fluency**

282 Transcription fluency was calculated as the mean keystroke interval within a word
 283 (onset of the current letter keypress—onset of the previous letter keypress in ms;
 284 e.g., Medimorec & Risko, 2016; but also see Strömquist, 1999). The keystrokes
 285 equal to or exceeding 2.5 SD within each participant individually were excluded,
 286 resulting in the removal of 1.5% of keystrokes (mean values of transcription fluency
 287 across genres are presented in Table 1). It is important to note that this measure is
 288 only one of the potential indicators of fluency in composition. Other fluency
 289 indicators include measures such as the mean number of strokes per minute, and the
 290 total number of strokes (e.g., Van Waes & Leijten, 2015). Note that our
 291 transcription fluency measure correlated strongly with the average strokes per
 292 minute such that increased fluency was related to more strokes per minute,
 293 $r(99) = -.62$, $p < .001$, while there was only a weak correlation (in the same
 294 direction) with the total number of strokes, $r(99) = -.32$, $p = .001$.

295 **Measuring linguistic features of essays**

296 Essays were analyzed by using Coh-Metrix, an automated text analyzer (Graesser,
 297 McNamara, Louwerse, & Cai, 2004; Graesser, McNamara, & Kulikowich, 2011;
 298 McNamara, Graesser, McCarthy, & Cai, 2014). We include three indices
 299 representing lexical sophistication and sentence complexity (i.e., log frequency-all
 300 words, the measure of textual lexical diversity (MTLD; McCarthy & Jarvis, 2010),
 301 and number of words per sentence), which have been showed to reliably predict
 302 human assessed essay quality (e.g., Crossley & McNamara, 2011, 2012; Cross-
 303 ley, Weston, McLain Sullivan, & McNamara, 2011; Guo, Crossley, & McNamara,
 304 2013; McNamara et al., 2014). More detail about individual text features are
 305 provided below.

306 **Lexical diversity**

307 Lexical diversity is an indicator of vocabulary diversity in a text. The Coh-Metrix
 308 measures of lexical diversity include type–token ratio (TTR; Templin, 1957), the
 309 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



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

312 **Word frequency**

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

318 **Sentence complexity**

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

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

332 **Results**

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

339 **Pause rates at different text boundaries**

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

Author Proof

346 There was a significant effect of pause position on pause rates at all intervals (i.e.,
 347 300–999, 1000–1999, and >2000 ms), such that pause rates increased from the
 348 smallest text unit (i.e., words) to the largest (i.e., paragraphs), all $F_s > 20.69$,
 349 $p_s < .001$, $\eta_p^2 > .19$ (for means and standard deviations see Table 2; correlations
 350 among pause rates at different text boundaries across three pause intervals are
 351 presented in Table 3). Pause rates differed significantly among all text boundaries at
 352 all intervals, $t_s > 3.06$, $p_s < .004$, $d_s > .34$.

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

355 Genre effect on pause rates

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

361 There was a significant effect of genre on pause rates at word boundaries at each
 362 interval such that pause rate was higher in argumentative essays compared to
 363 narratives, all $F_s > 4.30$, $p_s < .041$, $d_s > .40$. Moreover, there was a marginally
 364 significant effect at sentence boundaries at the 300–999 ms interval, $F(1,$
 365 $99) = 3.33$, $MSE = .05$, $p = .071$, $d = .36$, such that pause rates were higher in
 366 argumentative than narrative essays. There were no effects of genre on pause rates
 367 at sentence boundaries at the remaining intervals (i.e., 1000–1999, and >2000 ms),
 368 nor significant effects at paragraph boundaries at any interval (see Table 4).

369 In summary pause rates were higher at word boundaries in argumentative essays
 370 across all intervals. The same was true for pauses at sentence (marginally) at
 371 300–999 ms interval, while there were no statistically significant differences in
 372 pause rates at paragraph boundaries. Finally, it is worth noting that given possible
 373 inter-writer variability across different writing tasks (e.g., writing narrative vs.
 374 argumentative essays; Olinghouse, Santangelo, & Wilson, 2012) future investiga-
 375 tion of pauses in composition implementing a within-subject design could provide
 376 more insight into the relation between pausing and writing across different genres.

377 Transcription fluency and pauses

378 In our next set of analyses, we examined the relation between transcription fluency
 379 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)

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

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

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

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

386 **Relations between pauses and lexical indices**

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

398 *Pauses at word boundaries*

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

405 *Pauses at sentence boundaries*

406 There were no effects of pause rates at sentence boundaries on word frequency at
 407 any interval (although increased pause rates at sentence boundaries were related to
 408 decreased word frequency). There was a marginally significant effect on MTLD at
 409 1000–1999 ms interval, $\beta = -.21$, $t(97) = -1.93$, $p = .056$, $r_s = -.19$, such that
 410 MTLD decreased with increased pause rates. There was an effect of pause rates on
 411 WPS at 1000–1999 ms interval, $\beta = .22$, $t(97) = 2.06$, $p = .042$, $r_s = .20$, such
 412 that WPS increased with increased pause rates (there was a similar trend at
 413 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	Sentence	Paragraph
300–999	.61***	.59***	-.03
1000–1999	.59***	.45***	.14
>2000	.55***	.40***	.13

*** $p < .001$

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

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

414 *Pauses at paragraph boundaries*

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

419 In general, our regression analyses supported the notion that higher pause rates
 420 are related to decreased word frequency and to a limited extent increased sentence
 421 complexity, both features of better writing quality (e.g., Crossley and McNamara,
 422 2011, 2012). We show that this is true for pauses at word and (to a lesser extent)
 423 sentence boundaries. The results were consistent across pause intervals (for beta
 424 values see Table 6).

425 **Discussion**

426 The present investigation revealed a number of important findings about pauses
 427 during writing. We replicated previous work showing that pauses (in this case at
 428 300–999, 1000–1999, and >2000 ms intervals) occur more often at paragraph
 429 boundaries, followed by sentence, and word boundaries (controlling for the number
 430 of boundaries). In addition, we found both more pausing when composing
 431 argumentative essays than narrative essays, and a significant relation between
 432 pausing and transcription fluency. Critically, we also showed that these latter effects
 433 varied as a function of text boundary, and to an extent pause interval. In particular
 434 pause rate was higher in argumentative essays at word boundaries compared to
 435 narratives. The same was true for pauses at sentence boundaries (marginally) at
 436 300–999 ms interval. Finally, there were no differences in pause rates at paragraph

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

444 **Pause rates at different text boundaries**

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

456 **Genre effect on pause rates**

457 As noted above, previous research has showed that the overall duration of pauses
 458 was longer in argumentative than narrative texts. This result has been taken to
 459 reflect, for example, deeper lexical selection during argumentative text composition
 460 (e.g., van Hell et al., 2008). Here we showed higher pause rates in argumentative
 461 essays compared to narrative essays at word boundaries across all pause intervals.
 462 On the other hand, the results regarding pause rates at sentence and paragraph
 463 boundaries were inconsistent across pause intervals (marginally significant at
 464 300–999 ms interval at sentence boundary, and not statistically significant at the
 465 other intervals). Importantly, the argumentative essays produced in the present
 466 investigation were more complex at the word and sentence levels (i.e., they
 467 contained less frequent words and longer sentences compared to narratives; see
 468 Table 1). Taken together these results are consistent with the idea that writing that
 469 requires prolonged lower or higher level processes (e.g., deeper lexical selection;
 470 planning of complex syntax), leads to more pauses. For example, deeper lexical
 471 search associated with argumentative essays was most salient at word boundaries,
 472 while additional syntactic planning was detected at sentence boundaries. In addition,
 473 some research has showed that writers seem to use similar global writing strategies
 474 across genres (i.e., generating and organizing of ideas, reading back; Haas, 1989;
 475 Van Waes, & Schellens, 2003). Thus, the difference between argumentative and
 476 narrative texts in terms of global writing strategies across genres might be a smaller
 477 effect. Consistent with this idea, there was no effect of genre at paragraph
 478 boundaries and the effect at sentence boundaries was limited (the effect sizes were

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

484 **Transcription fluency and pauses**

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

511 **Relations between pauses and lexical indices**

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

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

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

538 **Different pause intervals**

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

557 **Conclusion**

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

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

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AQ2	Please confirm the section headings are correctly identified.	
AQ3	Please note that the citation Table 5 has been changed to Table 6, hence it matches the citation. Since Table 5 was not provided in original manuscript, henceforth the remaining Tables renumbered and cited accordingly. Kindly check and confirm the changes made. And suggest the alternate if necessary.	