Smartphone tapping vs. handwriting: A comparison of writing medium

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Abstract

Mobile-learning (m-learning), or mobile-assisted language learning (MALL), has been the object of a great deal of research over the last twenty years. However, empirical work in this area has largely failed to produce generalizable conclusions due to variation in methodology, target feature, and task-type (Burston, 2014, 2015). As schools in Japan begin to join the growing number of classrooms worldwide using mobile-based assignments, this study examined how Japanese EFL students' writing task production differed depending on writing medium (i.e., handwritten on paper vs. tapped on a smartphone). Writing samples were collected from N = 1,449 participants, divided into smartphone- or paper-based groups, across a spectrum of English proficiencies. Handwritten submissions were found to be significantly longer than those composed on a smartphone (p < .001, d = .54), with differences being more pronounced for learners of higher proficiency than lower ones. Significance and effect sizes steadily dropped from p < .001, d = .66 for advanced learners to p = .168, d = .38 for beginners. These results indicate that care must be taken in designing m-learning activities, and that students must be given adequate training in smartphone-input skills (i.e., tapping) and time to acclimate before using such tasks for high-stakes assessments.

Keywords: m-learning, Mobile-Assisted Language Learning, tapping, handwriting, writing task.

1. Introduction

Technology is such an integral part of writing that it is often forgotten that writing is simply not possible without technology. "Whether it is the stylus of the ancients, the pen and ink of the medieval scribe, a toddler's fat crayons, or a new Powerbook, technology makes writing possible" (Haas, 1996, p. 9). Therefore, it is peculiar how little attention writing research has focused on the technologies used, instead largely choosing to focus on cognitive or semiotic aspects, or the development of writing skills (Mangen & Velay, 2010). As national policies and educational institutions worldwide shift away from teaching skills such as cursive handwriting and calligraphy in favor of word processing (Petrescu, 2014), this study seeks to investigate whether students' compositions on smartphones differ from those on paper.

Physical differences between handwriting and using digital tools for entry are obvious. Writing is unimanual, with writers' focusing their visual attention largely on the tip of the pen as their fingers guide it across the page. Compare this to fluent blind typists, who use both hands on the keyboard (i.e., the motor space) while their eyes focus on the screen (i.e., the visual space). It is therefore said that while handwriting is a unified activity, typewriting is divided into two distinct and spatiotemporally separated spaces. Smartphones most likely land somewhere in between, as not only are the motor and visual spaces much closer together than typing, but also "blind tappers" who can compose a text without looking at their fingers are exceptionally rare. In fact, users are not unified in their tapping techniques, with styles ranging from single thumb, to double thumb, to single finger, with exceptionally proficient smartphone users utilizing "swipe-to-type", a method of text input where the user slides their finger across the touchscreen to the desired letters in succession, without releasing contact.

Graphomotorically, writing is easily more complex than both typing and tapping. Writing involves the manual creation of the individual shapes of each letter, and while each letter has a standard shape, each writer has the freedom to incorporate stylistic qualities that make their written production uniquely their own. Typing/tapping production is the same for all letters (e.g., pressing a button); the difference between letters is only their spatial location on the keyboard. As such, writing has been thought of as being a complex process involving cognition, neurosensory feedback, and fine motor skills while typing/tapping is more of an exercise in simple memory.

The different haptics (tactile perceptions associated with active movements) (Mangen & Velay, 2010) of various writing media are well known, with some authors indicating that the *feeling* of writing elicits a different emotional state than typing does. Despite these purported emotive differences, few instances of previous research have heretofore empirically examined the effects of medium on writing task performance. While there have been some studies which compared computer-based typing to handwriting (e.g., see Longcamp, Boucard, Gilhodes, & Velay, 2006 for effects on character recognition; Mogey, Paterson, Burk, & Purcell, 2010 for composition length; Mueller & Oppenheimer, 2014 for cognitive processing), it has yet to be determined whether smartphone-based tapping will mirror the results of typing or will produce unique findings. In addition to the physical differences of typing and tapping elucidated earlier, the automatic spellcheck and predictive functions of smartphones (which allow for whole words to be entered with a single tap) create for a distinct text-entry style that should be researched independently from typing. Unfortunately, despite hundreds of MALL studies having been published over the last 25 years, there have been almost no studies investigating writing (neither quality nor volume) as the target learning outcome (Burston, 2014).

Previous studies in this field have also overwhelmingly looked at differences in typing and writing in participants' first language (L1). The current study examined Japanese tertiary-level students of EFL, writing in their second language (L2). This is of key concern to the massive EFL industry with over 1.5 billion learners of English worldwide (Beare, 2018), as it is yet unknown if the results found for L1 speakers can be generalized to apply to L2 learners as well. This study will therefore contribute quantitative empirical data to address this current gap in the literature by asking the following:

- Research Question 1 (RQ1): How does the use of a smartphone affect the length of compositions produced by Japanese tertiary EFL students?
- Research Question 2 (RQ2): To what degree does English proficiency affect the outcome of the experiment?

While this study only focuses on the volume of written production (i.e., number of words) as opposed to other measures such as complexity, accuracy, or lexical variation, it is important to remember that the population being investigated is that of L2 learners, not fluent L1 speakers. Traditionally, writing assignments (in both the L1 and L2) have minimum word- or page-count requirements to force students to produce at least a certain amount of prose. Acknowledging that *more* does not necessarily equate to *better*, greater quantity is nevertheless, highly desirable in the second language acquisition context. A greater volume of production means that students must be engaged in the task longer, extending their *private speech* time (i.e., planning time to think, organize, rehearse, or record one's own speech). Lantolf (2000) asserts that, "private speech as language play could be a key factor in the appropriation of the features of a second language" (p. 93), meaning that the longer the student is engaged in the task, the greater the opportunity for the acquisition of features. In addition, usage of lexical items or grammatical structures in a practical, communicative way also enhances (or reinforces) the development of form-function mapping.

Increased production also creates more opportunities for corrective feedback and engages the reader to a greater degree. This is beneficial to language learners, as feedback (both positive and negative) is another form of mediation that has been thought to enhance both oral and written linguistic accuracy (Ellis, 2009). Positive feedback provides the learner with affirmation that their language or response was correct and stimulates motivation to continue learning. Negative feedback draws a learner's attention to an inaccurate or deviant linguistic item, allowing them to notice the gap between their interlanguage and the target language. This step is considered by

many (e.g., Gass & Selinker, 1994; Long, 1996; Ellis, 1997; Schmidt, 1990) as being a necessary condition for language acquisition. For these reasons, it is important to understand how writing medium influences the length of prose produced by language learners.

2. Literature Review

Although the current study is a unique investigation into the differences between two types of writing media, philosophers have debated for centuries over the potential drawbacks of incorporating new technologies into education, even as far back as the Ancient Greeks' suspicion surrounding the invention of the written word. Education and culture in the age of Plato was based in oral transmission, which required exceptional memory and oratory skills. For those ancient philosophers, written language represented a fundamental shift away from the value placed on storytellers and created the fear that writing would not only "create forgetfulness in the learners' souls" but also remove the watchful gaze of the instructor who was ostensibly the possessor of knowledge. Once ideas had been written, they could be "tumbled about anywhere among those who may or may not understand them" (Plato, circa 370 B.C., 274e–275b).

While some cultures still based on oral transmission survive to this day, it is plain to see that most have given in to incorporating, and even prizing, literary skills of reading and writing. What Plato himself could probably not have predicted, was that in modern times there are now several different *methods* of writing, each with their own advantages and drawbacks. Even the distinction between writing in indelible versus erasable ink carries inherent differences in terms of cognitive function, as the ability to quickly erase and correct one's writing has been thought to increase flippancy and reduce planning time before putting pen to paper (Baron, 2009). The same could be said regarding typing on a typewriter versus a computer; although the body mechanics are the same for both actions, the tangible nature of one versus the digital nature of the other results in fundamentally different cognitive effects. How these effects impact learners have not been adequately researched to date, with few studies investigating typing versus handwriting, and with no studies yet investigating tapping versus either.

What little research that has been published on the typing/handwriting dichotomy, largely focused on perceptive or retention differences. Several studies have found that learning a new writing system by typing results in poorer development of letter recognition compared with learning by writing. This result has been replicated in both pre-literate children in their L1 (Longcamp, Zerbato-Poudou, & Velay, 2005; James & Engelhardt, 2012; Kiefer et al., 2015), and adult learners of an L2 (Longcamp et al., 2006). Further evidence of the link between reading and writing has been provided by neural imaging studies which revealed that motor-control regions of the brain are activated while reading handwritten text (James & Gauthier, 2006); essentially the brain recalls and simulates the act of writing by hand when reading. In the case of learning letters via typing/tapping, the only action required to produce a letter is pressing a button, resulting in a dearth of stimulation as there is no variation in graphomotor skills recruited. In the case of learners of L2 English, who already have limited exposure to the target language, the lower stimulation afforded by typing may pose a serious detriment to their language acquisition efforts.

Writing letters in meaningful context (as opposed to drawing them as objects or tracing) was further shown to lead to increased stimulation in both left and right anterior fusiform gyrus regions of the brain, with researchers proposing that the greater variation produced by free-form writing was what led to the greater activation. As everyone has a unique handwriting style, "only free-form printing leads to a non-stereotypical, noisy form of a specific letter" (James & Engelhardt, 2012, p. 41), which allows for a wider range of variable exemplars from which to categorize and therefore identify letters. Unfortunately, especially for learners from non-alphabetic-based languages, the only opportunity for writing the alphabet in a meaningful context is likely the EFL classroom.

As the current study investigates tertiary students who have already mastered the English alphabet (although their L1 uses a logographic writing system), the question becomes whether the above findings, which focused only on *letter* recognition, can be expanded to include *word* recognition as well. The limited research in this area has not yet produced any quantitative data to support this theory, although interviews with EFL students have indicated that

this may be the case. When Japanese EFL students (*N* = 225) were asked if they would prefer to complete writing assignments on their smartphones, 76.44% of respondents expressed little to no interest in doing so, citing reasons such as, "I feel I remember more when I write something out by hand" and "I don't think it's possible to memorize words unless you physically write them out" (Lee, 2019a, p. 221). This could possibly be reflective of the students' long exposure to the traditional Japanese method of teaching kanji (logographic writing) which utilizes finger movements when reading new characters, which has been shown to lighten neural loads (Matsuo et al., 2003). It also illustrates an important distinction between L1 and L2 research in that EFL learners approach writing tasks as not only opportunities for personal expression, but also for learning. EFL writers must go through the additional process of looking up new words and expressions; essentially both *what* to say and *how* to say it, placing further strain on their cognitive resources.

It has yet to be determined how smartphones' enhanced texting features (e.g., spellcheck, next-word prediction) affects the speed/accuracy of writers, though potential benefits to EFL learners certainly exist. As next-word prediction only offers correctly spelled and grammatically correct suggestions, EFL students who are worried about their grammatical accuracy may increase their tapping speed and confidence while using this feature. This advantage is particularly salient as keyboarding fluency has been identified as a major contributing factor which influences the quality of typed prose. Correlations have been found between slower typing speed and lower quality of writing due to the increased demand on higher-order processes such as planning and reviewing (Connelly, Gee, & Walsh, 2007). However, Mogey et al. (2010) found that students writing responses to exam questions generally wrote more words than their handwriting counterparts. These findings should not be conflated with Mueller and Oppenheimer's influential study (2014) which found that while factual recall was comparable between typed and handwritten notetakers, typists performed poorer on conceptual understanding questions. The researchers hypothesized that since typed notes were faster, this allowed for a tendency to take notes largely verbatim. The slower speed of taking notes by hand forced students to paraphrase, i.e., synthesize the content, resulting in a greater degree of comprehension.

3. Study design

3.1. Participants

Participants were undergraduate students at a small private university in rural Japan, which specializes in industrial sciences. All students are required to take compulsory English courses to graduate; there is no English major at present, and all the participants attended this school to study other disciplines. The overall English proficiency of the participants could be classified as 'elementary', reflected by their average TOEIC score of 346, which is well behind the national average of 425 for university students of similar fields (Nyugaku et. al, 2017).

Upon matriculation, each first-year student is given a TOEIC Bridge test, the scores of which are used to determine class groupings within each course major. The number of class divisions per department varies, as the university endeavors to keep class sizes down to generally 25 students or less, and each academic department has a different number of students enrolled. However, in order of descending proficiency, the naming system follows the pattern: A1, A2, B1, B2, and B3. (Note that TOEIC Bridge does not test writing ability; proficiency assessments should therefore be taken to refer to listening and reading abilities only.) In total, *N* = 1,449 participants were recruited for this study consisting of first-year (*n* = 509), second-year (*n* = 465), and third-year students (*n* = 475) from all proficiency levels, across all academic departments. All participants were L1 Japanese speakers.

3.2. Materials and methods

The writing task for this study consisted of a simple prompt, written in the L1 of the participants, asking students to describe in English how they spent their summer holidays (Wolfe and Manalo (2004) employed a similar study design to assess writing performance, though their writing prompt was taken from a TOEFL test and provided in English). No guidance was given to the students

as to how much they were expected to write, nor was there a time limit, as the study hoped to investigate how much prose the participants would produce naturally, in an unstructured context.

The number of words (i.e., tokens) produced was chosen to be the assessment metric, as it is possible to measure objectively. Previous research comparing typed and handwritten text has shown differences in this area (see Mogey et al., 2010), creating a reference point which makes cross-study comparison possible. Further, studies have shown that raters of text 'quality' are unreliable due to bias based on appearance (e.g., poor penmanship) and expectations of higher quality for word-processed text (Gentile, Riazantseva, & Cline, 2001). An analysis of complexity, accuracy, and frequency (CAF) was also not considered appropriate as handwritten text has been found to generally employ shorter sentence length (Collier & Werier, 1995), contain fewer mechanical errors (Gentile et al., 2001), and be written in a different (weaker) voice than typed text (Wolfe, Bolton, Feltovich, & Bangert, 1996), which would potentially bias the results.

Participants were divided into smartphone-based (n = 725) and paper-based (n = 724) groups, with smartphone users directed to a Google Form with the writing prompt. The response field was deliberately expanded to show 15 blank lines (the default is to initially show only a single blank line, which expands as needed). The default setting was shown to be a source of confusion during piloting, as some trial users incorrectly assumed that they could only enter a single line of text. This Google Form was printed out in A4-size for the paper-based respondents in order to visually match the aesthetics of the tasks for both groups in terms of color, font, illustrations, spacing, etc.

The total number of tokens was manually calculated (i.e., automatic word count features were not employed). The following conventions were established to ensure consistency:

- Contractions (e.g., I'm or don't) were counted as two tokens.
- Non-words, alphabetic in nature (e.g., lol or ha ha) were counted as a single token.
- Non-words, graphic in nature (e.g., :-P or (^_^)) were not counted.
- All text was counted, even that which did not directly relate to the question prompt (e.g., greetings, closings, other pleasantries, etc.).
- Text written in Japanese (though rare) was *not* counted.
- Grammar mistakes were counted at face value without correction (e.g., I was go = three tokens).

IBM's Statistical Package for the Social Sciences (SPSS) v.23 was used to determine descriptive statistics and perform t-tests; Cohen's *d* calculations were done using the langtest.jp online tool.

4. Results

Descriptive statistics for the two groups are presented below in Table 1.

Table 1. Descriptive statistics of written production (token count)

Writing medium	*N*	*M*	*SD*	*SE*
Paper	724	22.97	16.59	.62
Smartphone	725	15.01	12.91	.48

As can been seen in Table 1, the participants using paper produced a greater amount of prose (M = 22.97, SD = 16.59) compared to their smartphone-using classmates (M = 15.01, SD = 12.91). An independent-samples t-test was subsequently run, which confirmed that the difference between the means of the two groups was statistically significant; $t(1447) = 10.19$, $p < .001$ (see

Table 2, below). A Cohen's *d* of .54 was obtained, which is considered small-to-medium as per current benchmark standards in L2 research (Plonsky & Oswald, 2014).

Table 2. Output of t-tests (comparing token counts of paper- vs. smartphone-based groups)

	T	*df*	*p*	*d*	95% *CI*
Paper- vs. Smartphone-based	10.19**	1447	< .001	.54	6.42, 9.49

** denotes significance at the $p < .001$ level

The results in Table 2 serve as the basis to answer RQ1. EFL learners using a smartphone for English composition produced significantly less tokens than their classmates writing on paper. A secondary objective of this study was to investigate the relationship between English proficiency and writing task production under the two conditions. As previously described, first- and second-year English courses at the university are divided into classes based on proficiency. However, English classes for third-year students and above are elective classes with free enrollment. As a result, data collected from the third-year participants ($n = 475$) was not able to be considered for proficiency-related calculations and are not included in the following analyses. Table 3 shows the remaining 70 classes worth of data ($n = 974$) tabulated by proficiency level.

Table 3. Descriptive statistics of written production (token count)

Proficiency Level	*N*	*M*	*SD*	*SE*
A1 (paper)	105	33.17	23.60	2.30
A1 (smartphone)	100	19.70	16.32	1.63
A2 (paper)	125	25.02	15.18	1.36
A2 (smartphone)	123	16.89	15.23	1.37
B1 (paper)	127	19.40	15.32	1.36
B1 (smartphone)	125	14.26	11.31	1.01
B2 (paper)	94	16.77	10.15	1.06
B2 (smartphone)	97	11.27	12.45	1.26
B3 (paper)	27	13.41	9.03	1.74
B3 (smartphone)	27	10.41	6.53	1.26

There is a clear trend that the mean production of English prose was higher for paper-based participants over smartphone users throughout the entire spectrum of proficiency levels, even as mean production drops steadily overall. This is a key finding which also lends support to strengthen the conclusions found in the previous analysis of RQ1. However, to specifically

address RQ2, a series of t-tests was again run to determine the t-values, statistical significance, and effect sizes of the differences in mean at each proficiency level (see Table 4).

Table 4. Output of t-tests (comparing token counts of paper- vs. smartphone-based groups)

Proficiency Level	*T*	*df*	*p*	*d*	95% *CI*
A1	4.73**	203	< .001	.66	7.86, 19.08
A2	4.21**	246	< .001	.53	4.33, 11.93
B1	3.03*	250	.003	.38	1.80, 8.49
B2	3.33*	189	.001	.48	2.24, 8.76
B3	1.40	52	.168	.38	-1.30, 7.30

* denotes significance at the $p < .05$ level

** denotes significance at the $p < .001$ level

Significant differences in production between paper and smartphone media were found at proficiency levels A1 through B2. Additionally, the t-values for the A1 and A2 participants were both larger than those for the B1 and B2 groups ($t = 4.73$ and 4.21, respectively, compared with $t = 3.03$ and 3.33) and more statistically significant ($p < .001$ for both A groups, compared with $p = .003$ and .001, respectively). Cohen's *d* effect sizes were also larger for the A groups than the B groups ($d = .66$ and .53, respectively, compared with $d = .38$ and .48). The B3-level proficiency group was the only group in the study which did not see significant differences in English production between the two media, although mean production followed the global trend, favoring paper-based composition. However, it should be noted that this group had the least number of participants by far, at only $n = 27$ for both experimental groups, which limits the ability to draw direct comparisons to the other groups which are more statistically robust. Nonetheless, this result reinforces the conclusion that the differences in production between paper-based and smartphone-based EFL learners becomes more pronounced as English proficiency level increases.

5. Discussion

This study was the first large-scale attempt to investigate EFL learners and the differences in their written English production using smartphones versus paper. The finding that using smartphones for English composition led to reduced production should be examined carefully by teachers and program designers, as this may limit students' abilities to fully express themselves and potentially slow their rate of language acquisition. Furthermore, the finding that learners of higher proficiency are influenced by writing medium to a larger degree agrees with the findings of the pilot study (Lee, 2019b), and raises the stakes for students who are operating at the higher end of the spectrum. Although *technology* usually invokes the concept of *progress*, this study argues that in the case of English written production, using smartphone technology may actually hinder language learners' progress.

However, while the results of this experiment indicate that smartphone users naturally tend to produce less English prose than when writing on paper, this does not mean that smartphones cannot or should not be used in the classroom, only that care must be taken when designing writing tasks. In fact, numerous studies have suggested that students are interested in m-learning

and report more confidence when writing with the aid of multimedia tools (Tsai, Kuo, Horng, & Chen, 2012), especially apps specifically for writing (Chen, Carger, & Smith, 2017). Godwin-Jones reminds us that outright banning the use of phones in the classroom is counterproductive, making the classroom "into an even more unreal environment, where language learning is an artificial enterprise" (2017, p. 10).

The data for this study was collected via an unstructured writing task with no time limit or expressed expectation of composition length. One idea for counteracting the tendency of smartphone users to write less would be for writing tasks to include a minimum required word count. This would guarantee parity in at least the volume of text produced, regardless of medium, especially for assignments which do not have a time limit. Of course, *only* accepting one type of media or the other would be an effective way to put all students on the same playing field. Another consideration is the type of writing assignment in question, as it has been suggested that writing type influences lexical sophistication, syntactic complexity, cohesion, and agency (Elgort, 2017). The results of the current study would tend to indicate that more casual writing situations (e.g., forum/blog posts, student-to-student discourse) may be more suitable for smartphone users as these compositions are usually shorter, less complex, and more conversational in nature.

6. Limitations and directions for further research

For many participants, even though they have used smartphones daily for several years, it was the first time they were using them to complete English writing assignments. In fact, most students have never used their phones for any sort of academic assignment, in either language. As this study only collected a single writing sample, it would be insightful to do a follow-up study which collected and examined changes in writings over a longer period. It is possible that a 'practice effect' may be observed, where smartphone compositions would gradually increase in length over time. If so, it would be vital to determine how much practice is needed for students to achieve parity with paper submissions *before* any high-stakes events like graded homework or tests are implemented.

This study revealed statistically significant differences in composition *length*, depending on writing medium. This is merely one metric by which to assess performance, and is by no means the only, or best, one. Future studies may seek to investigate if any differences in CAF exist; particularly, *frequency* (speed of writing) would be particularly salient if smartphones were to be used for timed tests or classwork. Clearly, much more research in this field is needed in order to make the most effective use of m-learning, in a way that does not unintentionally harm the users.

7. Conclusion

This study provides compelling evidence that changing the medium of a writing task has tangible effects on students' writing production, i.e., that students tend to write significantly less on a mobile device compared to traditional pen-and-paper. While prose *length* does not directly equate to prose *quality*, language learners specifically benefit from greater production for a number of reasons (e.g., increased engagement, longer private-speech time, enhanced form-function mapping, greater potential for corrective feedback/engagement with the reader, among others). This study also found that the disparity in volume shows some correlation with English proficiency, i.e., the higher the proficiency, the greater the observed effect sizes. This is a key finding, as course designers may determine that m-learning is more easily integrable into lower-level classes. Regardless, it is strongly recommended that students are given ample practice and time to acclimate to m-learning assignments before any high-stakes events are conducted.

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