

Essay Quality of Adolescents with Learning Disabilities:
Does the Medium Improve the Message?

by

Rachel Jalbert
B.A., University of Ottawa, 2009

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Supervisory Committee

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Dr. Gina Harrison, Supervisor
(Department of Educational Psychology and Leadership Studies)

Dr. Sarah Macoun, Departmental Member
(Department of Educational Psychology and Leadership Studies)

Abstract

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Dr. Sarah Macoun, Departmental Member
(Department of Educational Psychology and Leadership Studies)

Differences between handwritten and typed essays were examined in high school adolescents with a learning disability (LD) who have writing difficulties. Despite being experienced at writing on the computer and possessing fluent typing skills, there were no differences found between the quality of handwritten and typed essays. Essays were scored against quality indices for lower-level transcription (i.e., mechanics), higher-level text generation (i.e., organization, theme development, vocabulary), spelling accuracy, word count, and grammar. No differences were found across any of these dimensions between conditions. Correlations were also examined to determine any similarities, or differences in relationship among the measures, between the handwritten and typed conditions. Similar associations were found across both conditions for total essay score, lower-level transcription, and handwriting/typing fluency. However, higher-level text generation for typed essays correlated with the measures of working memory, lexical access, and spelling, whereas none of these measures correlated with the higher-level text generation for handwritten essays.

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INTRODUCTION

One of the purposes of technology is to make lives easier. For example, computers are commonly used as an accommodation for struggling writers in classrooms (Berninger, 2006) and in Canadian provincial educational testing (e.g., Alberta Education, 2011; BC Ministry of Education, 2013). However, despite the increasing and broad use of computers, there is little research that examines the effectiveness of using a keyboard as a writing accommodation for high school students with learning disabilities (LD), a population that commonly receives accommodations for writing difficulties (MacArthur, 2009). Furthermore, previous studies that included students with LD rarely examined use of the keyboard alone (without other word processing tools), making it difficult to know whether the findings from these studies are influenced by use of a keyboard, the writing intervention, or other tools of the word processor (e.g., spelling and grammar checkers). Finally, there is a lack of recent research in this area. The majority of studies that have examined how the keyboard affects writing were conducted before 1995 (Morphy & Graham, 2012), although it was within the last decade that computers became widely used in classrooms and at home. As a result, more recent studies that have looked at use of a keyboard for writing have greater effect sizes than in earlier studies (Graham & Perin, 2007). Therefore, there is a need for current research that only examines the effectiveness of a keyboard as a writing accommodation in adolescents with LD.

The purpose of the proposed study is to examine the effects of using the keyboard on essay quality for high school students with LD. The goal is to investigate solely the effects of keyboard use, so there will be no inclusion of a writing intervention or any additional tools offered in a word processor. Due to the lack of research involving students with LD, many studies reviewed in the upcoming sections involve struggling writers without LD. In the next

section, writing will be defined using the Simple View of Writing model (Berninger et al., 2002) that serves as the theoretical foundation for the proposed study. The model explains the importance of keyboarding in relation to writing. Next, the methods used to measure essay quality will be examined. Finally, there will be a critical evaluation of the few studies that have examined keyboard use as a writing accommodation.

How Keyboarding and Handwriting Impact Writing

Writing is a complex task that involves the coordination of multiple cognitive processes. Berninger and her colleagues (2002) proposed the Simple View of Writing model which captures the most relevant components related to the writing skills of students at-risk for writing difficulties. The model describes writing as a triangle that encompasses the components of transcription and executive functions as the foundational base for text generation, within a working memory environment (see Figure 1). Text generation involves transforming ideas into language, whereas transcription involves transforming internal language into external written symbols to express ideas in text. The text generation and transcription components include a large number of processes that are activated simultaneously during composition, emphasising the importance of the executive functions which are used to self-regulate mental functions (Altemeier, Abbott, & Berninger, 2008). Working memory is the immediate consciousness that devotes the limited cognitive resources to processing tasks (McCutchen, 2000). Automaticity, the act of efficiently executing a cognitive task without the need for attention, is important to writing since transcription, executive functions and text generation draw on the same limited cognitive resources of working memory (Berninger & Amtmann, 2003). Automaticity of the lower-level transcription skills are important for writing; otherwise, the transcription processes will demand more cognitive resources away from the higher-level text generation and the executive functions

(Bourdin & Fayol, 1994; Hayes & Chenoweth, 2006; Olive, Favart, Beauvais, & Beauvais, 2009). Therefore, a writer requires transcription, executive functions and text generation to work fluently in order to compose a comprehensive essay that flows.

Of all the components in the Simple View of Writing model, transcription is the first to develop and provides the foundation for writing (Berninger, 1999). More importantly, transcription has been shown to affect essay quality in both children (Bourdin & Fayol, 1994) and adults (Hayes & Chenoweth, 2006). The processes of transcription include spelling, handwriting, and keyboarding (Berninger & Amtmann, 2003). Spelling is the production of words, whereas handwriting and keyboarding are the production of letters (Berninger, Abbott, Augsburger, & Garcia, 2009). Students with LD typically experience difficulties in transcription (Berninger, 1994), which in turn negatively impacts their essay quality.

Role of spelling. Students with LD in reading or writing typically experience a spelling deficit (Berninger & Amtmann, 2003). A study by Berninger, Nielsen, Abbott, Wijsman, and Raskind (2008) resulted in spelling being the unique predictor of essay writing in 122 children with LD. Furthermore, the same study also examined 200 adults with learning disabilities and found that spelling is a persistent deficit that continues to uniquely predict essay writing. A study by Graham, Berninger, Abbott, Abbott, and Whitaker (1997) examined the contribution of transcription skills to the essay quality of 600 students in Grades 1 to 6 who are typically developed. Their results indicated that spelling contributed indirectly to essay writing through its correlation with handwriting.

Role of handwriting fluency. Research has shown the importance of handwriting fluency and that it consistently has had a significant contribution to essay quality and length in typically developing first to sixth grade students (Graham et al., 1997). In addition, slow

handwriting has been shown to negatively affect the quality of essays produced by adolescents and adults with and without LD (Connelly, Campbell, MacLean, & Barnes, 2006; Connelly, Dockrell, & Barnett, 2005), suggesting that handwriting fluency is related to the generation of well-composed essays.

Role of orthographic knowledge. Handwriting requires the integration of orthographic knowledge for representing language structures and the fine motor skills required to produce those orthographic symbols (Christensen, 2004). There are many types of orthographic knowledge, but it is generally defined as the process that converts spoken language into written language (Abbott & Berninger, 1993). Similarly, orthographic coding also refers to the ability to hold a word in memory and then analyze letter patterns (single letter or letter clusters) within the word. Orthographic coding has been shown to have a significant relationship to handwriting. Abbott and Berninger (1993) conducted a study examining handwriting fluency in relation to orthographic coding and fine motor skills. Their participants included 600 typically developing students from Grades 1 to 6. Results indicated that, in all grades, it was the orthographic coding, not fine motor skills, which had a statistically significant pathway to handwriting fluency.

An important cognitive process in developing handwriting fluency is rapid access to orthographic knowledge. Wolf, Bowers, and Biddle (2000) suggest that Rapid Automatized Naming (RAN) accesses a multitude of processes, including attention, perceptual, memory and lexical processes. Despite being commonly associated with reading, RAN has been shown to directly contribute to the speed of orthographic pattern recognition (Wolf et al., 2000).

Role of memory and executive functions. Handwriting is also associated with the cognitive processes of memory and the executive functions. A study by Swanson and Berninger (1996) determined that both short-term memory, which is the ability to hold small amounts of

information that is readily available for a short period of time, and working memory. which is the immediate consciousness that devotes the limited cognitive resources to processing tasks, predicted handwriting fluency in 300 typically developing students in Grades 4, 5, and 6. Their results indicated that short-term memory contributed considerably more than working memory in predicting handwriting fluency. These results do not suggest that working memory is unimportant to handwriting, but that handwriting automaticity may free up working memory to be allocated to other writing processes. Executive functions governs the ability to plan, organize, and manage details, and are also known to self-regulate handwriting automaticity (Altemeier et al., 2008). Executive control aids in the management of the multiple processes of handwriting, including orthographic knowledge, motor planning, orthographic-motor integration and processing speed (Altemeier et al., 2008). In sum, handwriting is not a simple individual process, but is integrated and influenced by the components of memory and executive functions.

Struggling writers with LD typically have poor handwriting fluency due to impairment in one or more of the cognitive processes associated with handwriting (Berninger, 1994). Within the English language, orthographic coding is typically impaired in writers with LD (Berninger, Abbott, Thomson, & Raskind, 2001). Furthermore, possibly due to the impairment in orthographic coding, rapid naming has been consistently impaired in students with LD (Bowers & Wolf, 1993; Wolf et al., 2002). Finally, students with LD are typically impaired in executive functions, including inhibition, switching sets, and working memory (Berninger et al., 2006). Indeed, since students with LD in writing often have impairments in one or more of the processes associated with handwriting (orthographic coding, rapid naming, executive functions, and memory) this disability often results in poor handwriting fluency.

There is more research on handwriting than keyboarding due to its longer history and the more recent advent of modern keyboard use. Consequently, there is a lack of research that examines the similarities, or differences, of the processes in relation to handwriting and typing fluency. A moderate correlation between handwriting and keyboarding ($r = .51$; Christensen, 2004) suggests that both transcription processes are somewhat related. Despite the correlation between handwriting and keyboarding, more research is needed to investigate the relation of keyboard use to orthographic knowledge, rapid naming, executive functions and memory.

According to the Simple View of Writing model, transcription is the foundational component in developing writing skills (Berninger, 2009). Any difficulties in the lower-level transcription skills will negatively affect the quality of an essay because it will take away the cognitive resources from the other components important to writing (Bourdin & Fayol, 1994; Hayes & Chenoweth, 2006; Olive et al., 2009). Keyboarding and handwriting are transcription skills and both require the integration of orthographic coding and motor skills (Christensen, 2004). It may be that keyboarding provides a better alternative to handwriting for students with LD because they typically have poor penmanship and impaired orthographic coding.

Methods to Evaluate Essay Quality

There are two methods for analyzing the quality of an essay; holistic and analytical analysis. The Wechsler Individual Achievement Test, 2nd edition (WIAT-II; The Psychological Corporation, 2002), includes both of these methods of analysis. Holistic analysis evaluates quality by examining the essay as a whole. For example, the holistic scoring of the WIAT-II uses a rubric that describes the writing traits to be evaluated. Some of the elements required to achieve 6 points, the highest holistic score, necessitate that an essay be “well-organized, fluent, vivid, and interesting” (The Psychological Corporation, 2002, p. 95). Despite the use of a rubric,

holistic analysis has been shown to be unreliable over time and across examiners due to the subjectivity of the evaluation (Graham, 1986). In contrast, analytical analysis evaluates the quality of an essay by separately examining the individual aspects of writing. For example, the analytical analysis component of the WIAT-II determines the essay quality by using the total of four categories: mechanics, organization, theme development, and vocabulary, each with detailed rubrics for scoring within the categories. More information is derived from this method because some individuals may be more skilled on one aspect of writing (e.g., organization) and less skilled in another aspect (e.g., mechanics). For example, a study by Connelly and colleagues (2006) found that college students with LD have more mechanical errors (i.e., spelling and punctuation errors) than their peers who are typically developed, yet the organization of their essays is similar. Analytical analysis is preferred because it is a more sensitive measure capturing a broad range of writing quality components.

Researchers must also be cautious when comparing two different essay formats (e.g., handwritten and typed), because the physical appearance of an essay can influence evaluation. A review of handwriting research by Graham and Weintraub (1996) revealed that the quality of penmanship can impact the evaluation of an essay. In general, neatly written essays were assigned higher marks than essays with poor penmanship. However, despite the fact that word processors offer a consistent and neat font, the concept that evaluations can be influenced by neatness does not appear to apply when comparing across the different formats of handwritten and typed essays. MacCann, Eastment, and Pickering (2002) examined 109 essays composed by typically developing Grade 9 students; 57 essays were written using a keyboard and 52 essays were written by hand. All essays were later transcribed verbatim to the other format; that is, essays by keyboard were transcribed to the handwritten format, and essays by hand were

transcribed to the typed format. Raters evaluated essays in both their original and transcribed formats. The handwritten format received higher scores than the typed format, regardless of whether the original writing was produced by keyboard or by hand. Gregg, Coleman, Davis, and Chalk (2007) found different results. They examined the handwritten essays composed by 130 university students with and without LD, in three conditions: the original handwritten essay, the typed format of the original essay, and the typed-edited version of the original essay, which was corrected for mechanical errors. For students with LD, there were no significant differences found in essays quality across the three conditions. For students without LD, higher scores were assigned to their typed-edited version of the essays; however, there was no significant differences in essay quality between handwritten and typed essays. Therefore, the results of comparing handwritten and typed essays can result in either no differences (Gregg et al., 2007) or higher scores being assigned to the handwritten format (MacCann et al., 2002). In order to avoid this possible bias, all essays in the current study have been evaluated in the same format – that is, all essays were transcribed to a typed format for scoring.

Keyboard as an Accommodation for Writing

According to parental reports, computers are the most common accommodation offered to students with writing difficulties (Berninger, 2006). There are several potential advantages keyboarding offers over handwriting. First, the motor demands of keyboarding are simpler. Keyboarding involves pressing keys, whereas handwriting involves forming letters by hand. Students with LD are easily fatigued by the motor demands of handwriting (Berninger, 1994). As a result, essays written by hand are often significantly shorter than essays written by keyboard (Bangert-Drowns, 1993; Morphy & Graham, 2012). Second, keyboarding reduces the amount of recopying needed for editing. Whereas, essays composed on the computer can be easily edited

using the same document, handwriting requires the tedious task of recopying multiple drafts that can result in more errors if copied incorrectly (MacArthur, 2009). Third, students with LD often prefer, and are more motivated, to type than to handwrite their writing assignments, which influences their writing quality (MacArthur & Graham, 1987). Finally, writing on a computer offers legible fonts. Students with writing difficulties often have poor penmanship, which makes it difficult to read the produced text (Hetzroni & Shrieber, 2004). As a writing accommodation, keyboarding provides several advantages over the difficulties experienced in handwriting.

In order for the keyboard to be an appropriate writing accommodation, students are required to have fluent typing skills. Similar to handwriting, typing fluency can impact the quality of an essay (Berninger & Amtmann, 2003). A study by Connelly, Gee, and Walsh (2007) revealed how typing fluency impacted the essays of 48 typically developing fifth and sixth grade students. The majority of their participants were more fluent in handwriting than typing, which the authors attributed to the lack of explicit keyboard instruction offered in the schools within the United Kingdom. As a result of their low typing fluency, their handwritten essays were superior to their typed essays in every aspect of writing, including mechanics, theme development, organization, vocabulary, and grammar. Furthermore, developing typing fluency can also improve essay quality. Christensen (2004) conducted a typing intervention with 35 eighth grade students who had low typing fluency. The intervention included daily, 20-minute group sessions for 8 weeks. Each session focused only on improving typing skills, so there was no instruction in spelling, organization, grammar, or components related to essay quality. Before the intervention, higher scores were assigned to essays that students wrote by hand rather than by keyboard. After the typing intervention, their essays written by keyboard that achieved higher scores than their handwritten essays. Consistent with the Simple View of Writing model, fluency appears to

constrain essay quality regardless of the medium. As a result, students with LD must have fluent typing skills in order for them to capitalize on the keyboard as a writing medium.

Developing typing fluency also allows the student to gain more experience using a computer to write. A study by Wolfe, Bolton, Feltovich, and Niday (1996) examined how prior experience with writing on a computer impacted the essay quality of 60 typically developing tenth grade students. All participants answered a student questionnaire that examined their prior writing experience. Adolescents who rarely wrote on the computer received significantly lower scores on their essays written by keyboard compared to their essays written by hand, whereas adolescents who occasionally or frequently wrote on the computer received similar scores for both their essays by keyboard and by hand. In another study, Sandene and his colleagues (2005) examined how computer skills affected the scores of the math, science, and writing sections of an American national test that was administered by paper-and-pencil and by computer. The test was administered to 2,510 eighth grade students in the U.S., including those with and without disabilities. Their study used two different methods to establish the computer skills of their participants: a questionnaire to determine their prior experiences of writing on a computer, and an online computer task to evaluate their hands-on skills using a word processor. Hands-on computer skills significantly contributed to writing performance. For example, students who had extensive hands-on computer skills achieved similar scores for both their essays by hand and by keyboard; whereas, students who were low on this factor achieved superior scores on essays written by hand. In contrast to the results of Wolfe and his colleagues' (1996), prior experience with writing on the computer did not significantly contribute to writing performance. The authors suggested that although students may have years of experience using computer programs, they

may lack the skills to use a keyboard for writing. As such, hands-on computer skills are a better predictor of essay quality than prior experience with writing on the computer.

Grabowski (2008) noted that keyboarding is more complex than simply selecting the correct key; keyboarding also includes keyboard shortcuts that allow for quick access to options on the word processor. In his study, the keyboarding behaviors of 32 typically developing female university students were examined. Despite having a task that required the participants to generate text, essay quality was not examined – only the participants' facility in using the computer as a writing tool was analyzed. Students who were experienced with writing on a computer used keyboard shortcuts, which allowed them to quickly access options on the word processor program without using a mouse. By having their hands remain on the keyboard, they could quickly and efficiently switch between composition and editing. Keyboard shortcuts on the Windows platform include simultaneously pressing the keys <CTRL> and to bold words or the arrow keys to move the cursor within the document. Since keyboarding is more than pressing the correct keys, it is important to use a word processor where keyboard shortcuts are available.

Experience using the keyboard is important when researching its efficacy as a writing tool. Fortunately, due to the high-usage of computers in current society, adolescents today may be at an advantage when it comes to using the keyboard. According to Prensky (2005), adolescents of the 21st century are what he considers Digital Natives – individuals who are born and raised in a technological society. In 2009, a Canada-wide survey indicated that 98% of 15-year-old adolescents used a computer at least once, while 96% of adolescents owned a computer at home and accessed the Internet for school work (OECD, 2011). In school, there is an increasing expectation for students to submit typed assignments, especially in high school and

post-secondary education (Grabowski, 2008). Therefore, adolescents are likely to be experienced using the keyboard due to their frequent use of computers at home and at school.

A meta-analysis by Morphy and Graham (2012) examined how keyboarding impacted the essays of struggling writers and readers in Grades 1 to 12. The authors analyzed studies from as early as 1983, when the first study was conducted which examined the relationship between keyboarding and writing, through to the year of 2010. Of the studies included in the meta-analysis, only 49% included students at-risk for LD. All studies were analyzed together – there was no discrimination between students at-risk for LD, struggling writers, struggling readers, or students who struggled with both reading and writing. Additionally, the authors noted that they did not know how many studies used the additional tools of the word processors because a basic word processor comes with an integrated spelling and grammar checker. Therefore, it is unknown whether their results were due to the use of a keyboard or the tools of a word processor. Nevertheless, the average effect sizes were positive and significantly different from zero for essays written by keyboard in quality ($d = .52$), length ($d = .48$), development and organization ($d = .66$), and mechanical correctness ($d = .57$). Interestingly, the effect sizes for vocabulary ($d = .17$) and grammar ($d = .36$) were not significantly different from zero. These results are similar to previous meta-analyses focusing primarily on average writers (Bangert-Drowns, 1993; Graham & Perin, 2007), suggesting that the keyboard may be beneficial to all students regardless of their writing ability.

Despite the lack of research involving adolescents with LD, there are few studies which examined how the keyboard influences the essay writing of students with LD. MacArthur and Graham (1987) examined the narratives of 11 fifth and sixth grade students with LD under three conditions: handwriting, keyboarding, and dictation to a scribe. Of all conditions, the narratives

composed by dictation were assigned the highest score in all writing aspects, such as quality, length, vocabulary, structure, and mechanical correctness. There were no differences found between the narratives composed by keyboard or by hand, most likely because, at the time of the study, the students were not familiar with using a keyboard (MacArthur, 2009). Thus, the students were focused more on selecting the correct keys and less on their composition quality.

More recently, a study by Berninger and her colleagues (2009) compared the essays of 8 fourth and sixth grade students with LD to 12 peers without LD. They examined the length and time to complete an essay under two conditions: handwriting and keyboarding. All students were faster and composed longer essays when they were handwriting. These results suggest that, at this age group, handwriting is more automatic than keyboarding for both students with and without LD. The authors identified two possible reasons for their results. First, handwriting is taught earlier in education than keyboarding. This, in turn, gives handwriting more practice to become fluent. Second, handwriting is used more than keyboarding for written assignments, particularly in the early grades. This is evident in the meta-analysis by Goldberg, Russell, and Cook (2003) that examined studies between 1992 and 2002 involving students with and without LD. They found that the use of a keyboard had greater positive effects for older students than younger. Hence, the keyboard as a writing accommodation may be more beneficial for adolescents than children.

Similarly, Berger and Lewandowski (2013) compared the handwritten and typed essays of 30 university students with LD and 68 without LD. Using a holistic measure, both students with and without LD had achieved higher scores on their typed essays than their handwritten essays. Furthermore, the length of the typed essays were significantly more than the handwritten essays for both groups. Their results indicated that typing fluency correlated significantly with

the quality of typed essays. However, since they did not measure handwriting fluency, it is unknown if it would show a similar result with the quality of handwritten essays. Interestingly, there were no differences in the essay quality between groups; that is, students with and without LD achieved similar essay quality scores between both handwritten and typed conditions. These results may be a consequence of the selected population, as university students tend to be more academically successful than the general population.

Accordingly, in order for the keyboard to be an appropriate writing accommodation, students are required to have adequate experience using both the computer and keyboard to write (Christensen, 2004; Connelly et al., 2007; Sandene et al., 2005; Wolfe et al., 1996). The keyboard primarily bypasses many of the handwriting difficulties experienced by students with LD, including fatigue from the complex motor demands of handwriting (Berninger, 1994), the tedious task of recopying handwritten drafts (MacArthur, 2009), and the illegibility of handwriting which renders the text unreadable (Hetzroni & Shrieber, 2004). Results of the few studies that have examined the use of a keyboard as a writing accommodation for students with LD have been variable, resulting in the typed essays being poorer (Berninger et al., 2009), equal to (MacArthur & Graham, 1987), or superior to (Berger & Lewandowski, 2013) their handwritten essays. On one hand, for the studies in which the typed essays were equal or poorer than their handwritten essays, the authors recognized that their participants were not familiar with using the keyboard (Berninger et al., 2009; MacArthur, 2009). On the other hand, the study in which the typed essays achieved higher quality scores than their handwritten essays, the participants had adequate keyboarding skills. As the Simple View of Writing model suggests, typing fluency is important to the generation of well-composed essays (Berninger & Amtmann, 2003; Christensen, 2004; Connelly et al., 2007; Sandene et al., 2005; Wolfe et al., 1996).

Therefore, students with LD must possess adequate typing fluency in order for the keyboard to be an appropriate accommodation for their writing difficulties.

To summarize, transcription plays an important role in writing (Berninger et al., 2002). Difficulties with lower-level transcription will affect composition by drawing more limited cognitive resources away from the other components important to writing, such as the higher-level text generation and the executive functions (Bourdin & Fayol, 1994; Hayes & Chenoweth, 2006; Olive et al., 2009). All three components are required to work in synchrony in order to produce a well-written text (Berninger & Amtmann, 2003). There are several methods for analyzing the quality of an essay. Analytical analysis is preferred because it separately examines the individual writing aspects, whereas holistic scoring evaluates the essay as a whole. The keyboard may bypass any handwriting motor difficulties that are typically experienced in students with LD (MacArthur, 2009). The few studies that examined students with LD showed a variety of results - the typed essays were either equal (MacArthur & Graham, 1987), poorer (Berninger et al., 2009) or superior (Berger & Lewandowski, 2013) than the handwritten essays. For the studies in which the typed essays were either poorer or equal to their handwritten essays, the authors suspected that their participants lacked the necessary typing fluency (Berninger et al., 2009; MacArthur, 2009). Fortunately, due to the frequent use of computers in the 21st century, many adolescents with LD may have the appropriate skills necessary for the keyboard to be an effective writing accommodation.

The Current Study

The purpose of this study is to determine whether the keyboard is an appropriate writing accommodation for adolescents with LD. The goal of the current study is to examine only the effects of keyboard use without an associated writing intervention or additional word processing

features (e.g., spelling and grammar checkers). Four research questions guide the study: (a) Are evaluations of essay quality based on analytical methods higher for essays written by the keyboard than the handwritten conditions? (b) If essay quality is higher for the keyboard condition, which aspects of quality (i.e., lower-level transcription, higher-level text generation) improve between conditions? (c) Are the associations between handwritten and typed conditions similar or different across cognitive, linguistic, and writing measures? and (d) Do the students' computer skills affect the quality of their typed essays? Previous research suggests that computer skills are important in order to fluently write on the computer. Due to the frequent use of computers at school and at home, it is hypothesized that students will be skilled at using the computer to write, which will be tested in the current study.

METHOD

Participants

Participants were recruited from three high schools in an urban school district in a medium-high SES location in British Columbia, Canada (Statistics Canada, 2012). Eligibility for the study required the students to have (a) any type of learning disability that is recognized by the school district, and (b) difficulties in writing as indicated by achieving a score at the 16th percentile or lower (≤ 1 SD) on the written language composite of their latest psychoeducational assessment which was conducted within the last five years. Students with other neurodevelopmental or neurocognitive disorders (with the exception of ADHD), sensory-motor impairments, or students for whom English was not their first language were excluded from the study. All students were selected by special education teachers of each participating school who reviewed their psychoeducational assessment and confirmed the potential participants met the inclusion criteria.

Overall, 15 high school students (13 males, 2 females) between the ages of 15 to 17 ($M = 16$ years, 7 months) volunteered to participate in the study. This ratio is representative of the typical distribution of students with LD who have writing difficulties (Berninger, Nielson, Abbott, Wijsman, & Raskind, 2008). All students were Caucasian native-English speakers. There were six students in grade 10, eight students in grade 11, and only one student was from grade 12. Due to the high comorbidity with LD, nearly half of the students self-reported as also having Attention Deficit/Hyperactivity Disorder (ADHD; 47%; $N = 7$). The author did not have access to their IEPs or psychoeducational assessments and, thus, was unable to confirm the diagnosis of ADHD. Nevertheless, the co-occurrence of ADHD is common among adolescents with LD (Barkley, 2002). All students were reported to have an Individual Education Plan (IEP) and,

during the time of the study, had a block in their current semester in which they received learning assistance support. The support received during this block included assistance with homework completion, help with completing classroom assignments, and writing tests in a separate setting with or without additional accommodations. Writing accommodations used by the students included using a word processor (53%; $N = 8$), scribe (40%; $N = 6$), spelling checker (7%; $N = 1$), and three students (20%) claimed that they do not use any accommodations for writing. The majority of the students were right-handed (73%; $N = 11$) and used 1-finger typing (67%; $N = 10$). Only two students (15%) used touching typing on the keyboard, and three students (20%) used 2-finger typing (e.g., using their index and middle fingers).

Materials

An HP Pavilion laptop with the installation of Microsoft Windows 7 was used for computer-related measures. The screen size was 15 inches by 8.5 inches, and had a standard American keyboard with a number pad. The essays were typed on Microsoft Word 2007TM with basic installation, but the spelling and grammar checkers were disabled. Both the laptop and word processor were comparable to the computers used in the students' schools.

Measures

Prior writing experience. An orally-administered questionnaire was used to determine the students' prior writing experience using a keyboard and handwriting. The questionnaire, developed by Wolfe and his colleague's (1996), was adapted for the purpose of the current study and was used to gather information that would be useful in accurately interpreting the results of the study (see appendix A for an example of the questionnaire).

Verbal span. The Digit Span Forward subtest of the Wechsler Intelligence Scale for Children, 4th Edition (WISC-IV; Wechsler, 2003) was administered to assess students' short-term verbal memory span. Digit Span Forward requires the student to repeat increasingly longer number sequences verbatim. This task was administered according to the instructions in the WISC-IV manual. The manual reports strong internal consistency for this task based on the split-half method: $r = .83$ for age 15, and $r = .86$ for age 16. Raw scores were converted to the standard scores based on age-norms.

Verbal working memory. The Digit Span Backward subtest of the WISC-IV (Wechsler, 2003) was administered to assess students' verbal working memory. The task required the student to listen to increasingly longer number sequences and repeat them to the examiner in the backward order. This task was administered according to the instructions in the WISC-IV manual. The manual reports strong internal consistency for this task based on the split-half method: $r = .82$ for age 15, and $r = .86$ for age 16. Raw scores were converted to standard scores based on age-norms.

Lexical access. The Rapid Automatized Naming (RAN) Letters subtest from the RAN/RAS test kit (Wolf & Denckla, 2005) was administered according to the instructions in the manual to assess students' ability to perceive and name letters as accurately and rapidly as possible. The raw score is based on the amount of time required to name all items on a test. The Letters subtest has good test-retest reliability of $r = .98$ for high school students. Raw scores were converted to standard scores based on age-norms.

Executive Control. The Rapid Alternating Stimulus (RAS) 2-Set Letters and Numbers subtest from the RAN/RAS test kit (Wolf & Denckla, 2005) was administered according to the instructions in the manual to assess students' executive control. The task requires the student to

perceive and name alternating letters and numbers as accurately and rapidly as possible. The raw score is based on the amount of time required to name all items on a test. The 2-Set Letters and Numbers subtest has good test-retest reliability of $r = .95$ for high school students. Raw scores were converted to standard scores based on age-norms.

Hands-on computer skills. On the computer, students were presented with a Microsoft Word document containing the lyrics of *O, Canada*. They were asked to alter the document using the software options of *select, cut, copy, paste, undo, and save as*. One point was awarded for every correct action for a total of six points. The students had the choice of using a mouse, touchpad, and/or keyboard in order to access the software options. This task is similar to the Technology-based Assessment Tutorials used by the National Center for Education Statistics' (2005). The purpose of this task is to evaluate the students' knowledge of computer software options. Students' total raw scores were recorded.

Handwriting fluency. Using a pencil, students were told to continuously write the alphabet in lowercase, manuscript letters for 60 seconds. The score was the number of legible letters in alphabetical order; illegible letters, omissions or substitutions were scored as errors. Previous studies have shown that this task has a high inter-rater reliability ($r = .97$; Berninger et al., 1997).

Typing fluency. Similar to the handwriting fluency task, students were required to continuously type the alphabet in lowercase letters for 60 seconds on a word document using a keyboard. The document was saved on the laptop and scored in the same method as the handwriting fluency; the final score was the number of letters in alphabetical order, and omissions and substitutions were scored as errors. This task was used by Christensen (2004) and a high inter-rater reliability ($r = .99$) was reported.

Spelling. Students completed the spelling (blue) subtest from the Wide Range Achievement Test, 3rd Edition (WRAT-3; Wilkinson, 1993), which assesses the students' ability to spell words in isolation. This task was administered according to the instructions in the manual. Using a pencil, students were required to spell increasingly difficult words. The manual reports strong internal consistency for this task based on the coefficient alphas by age: $r = .93$, $r = .91$, and $r = .92$ for ages 15, 16, and 17 to 19, respectively. Raw scores were converted to standard scores based on age-norms.

Essay writing. The two essay prompts used for the essay writing task were taken from the WIAT-II. For the first prompt, students wrote an opinion on the requirement of physical education or gym classes in school, and for the second prompt, students expressed their opinion about wearing uniforms to school. The topics were alternated between the typing and handwriting conditions. The handwriting condition required the students to write their essay on standard line paper using a pencil without an eraser. In order to minimize the presentation effect, the handwritten essays were carefully transcribed verbatim on the word processor, including all errors, indentations, and paragraphs. The typing condition required the students to type their essay on a Microsoft Word document on the laptop. The typed essays were later formatted to be similar to the transcribed handwritten essays; that is, all essays were formatted to be double-spaced using 12-size Times New Roman font. Consistent with WIAT-II administration procedures, students were allocated a maximum time of 15 minutes to complete the essay. The examiner recorded the time the student finished writing their essay if they completed before the 15-minute time limit.

Essay scoring. The total essay quality was evaluated by the Essay Analytical Analysis as described in the WIAT-II's manual. This analysis evaluates the student's essay quality in four

areas: mechanics (i.e., the number of spelling and punctuation errors in the text; max. score 9), organization (i.e., sentence structure, sequencing, and whether an introductory sentence of paragraph is evident; max. score 17), theme development (i.e., whether there are supporting evidence for their position; max. score 8), and vocabulary (i.e., lexical diversity; max. score 7) (The Psychological Corporation, 2002). With the exception of the score on mechanics, which was converted to quartile scores based on the WIAT-II standardization sample, raw scores across the other domains were recorded. In addition to the total essay quality, scores were also examined across lower-level transcription skills (max. score 9), based on the composite of the WIAT-II mechanics subsection, and the higher-level text generations skills (max. score 32) based on the composite of the WIAT-II subsections, including organization, theme development, and vocabulary. Spelling accuracy encompassed the percentage of correctly spelled words in the essay, and the word count provided an index of essay length. Finally, grammar was evaluated using the Correct Incorrect Word Sequence (CIWS) from the WIAT-III (The Psychological Corporation, 2009). Only Section 4 of the CIWS was used as this section evaluates only grammatical errors; whereas, the other sections evaluate spelling, capitalization, punctuation, and semantic errors which are already captured in the WIAT-II scoring criteria. Two trained graduate students, who were blind to the conditions, rated the transcribed essays and inter-rater reliability coefficient was high, $r = .90$. Disagreements were resolved by the author. This method of scoring was previously used in studies examining writing quality (Harrison, 2009; Harrison & Beres, 2007).

Procedures

Only students with parental consent and who themselves consented to participate in the study were included. Data collection took place during early spring near the end of the school

year. Students completed all of the tasks individually during one 50-60 minute session. The author tested all participants in a quiet room in their school during school hours. Writing condition (by hand or by keyboard) and the writing prompts (A and B) were counterbalanced across participants.

RESULTS

In a sample of adolescents with learning disabilities and writing difficulties, the present study aimed to: (a) Investigate whether there are differences in students' essay quality between typed and handwritten essays, and (b) Examine if there any differences in lower-level transcription and higher-level text generation components between students' typed and handwritten essays. A summary of the descriptive statistics will be presented first, followed by the students' background knowledge and skills using the computer, then the correlational analysis. Finally, the results of the analyses of differences in the quality of students' writing between handwritten and typed conditions will be presented.

Descriptive Statistics

Descriptive statistics across all measures are presented in Tables 1, 2, and 3. There was no skewness or kurtosis present in the distribution of scores on the measures. Students' verbal memory span and verbal working memory as assessed by the Digit Span task, and their spelling skills in isolation were below average for their age, unsurprising given their LD status. However, students achieved average scores on both the RAN and RAS tasks, an unexpected finding given their LD status. Results indicated that the sample was quite familiar with the use of the keyboard, as demonstrated by their typing fluency. A paired *t*-test showed that the differences between typing and handwriting fluency was statistically significant ($t = 6.560$, $df = 14$, $p = .001$), indicating that students typically type more alphabetical letters per minute than they do producing handwritten letters. However, there was no significant difference between typing and handwriting word count ($t = 1.564$, $df = 14$, $p = .140$), suggesting that their writing fluency is comparable across typed or handwritten conditions.

Table 1: Descriptive statistics for cognitive and spelling measures

Measure	M ^a	SD
WISC-IV – Digit Span Forward	6.5	2.4
WISC-IV – Digit Span Backward	7.3	2.1
RAN/RAS – RAN Letters	103.1	9.4
RAN/RAS – RAS 2-Set Letters and Numbers	102.7	9.8
WRAT-3 – Spelling	80.7	10.8

Note. WISC-IV = Wechsler Intelligence Scale for Children - 4th Edition; RAN/RAS = Rapid Automatized Naming and Rapid Alternating Stimulus; WRAT-3 = Wide Range Achievement Test - 3rd Edition

Table 2: Descriptive statistics for writing measures for handwritten and typed conditions

Measure	Handwritten		Typed	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Fluency – Alphabet (Letters per minute)	63.2	15.4	92.1	18.1
Spelling Accuracy (%)	90	8	89	12
Word Count	93.5	50.5	116.9	89.0
WIAT-III – Grammar (%)	94.9	3.5	95.5	4.5
Essay – WIAT-II Total Score (max. 41)	13.3	4.1	13.4	5.2
Essay – Lower-level Transcription (max. 9)	3.1	2.9	2.7	2.6
Essay – Higher-level Text Generation (max. 32)	10.3	4.4	10.7	4.7

Note. WIAT-III = Wechsler Individual Achievement Test - 3rd Edition ; WIAT-II = Wechsler Individual Achievement Test - 2nd Edition

Table 3: Descriptive statistics for WIAT-II essay measures for handwritten and typed conditions

Measure	Handwritten		Typed	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Mechanics (max. 9)	3.1	2.9	2.7	2.6
Organization (max. 17)	5.8	3.2	6.6	2.8
Theme Development (max. 8)	3.2	1.1	2.9	1.3
Vocabulary (max. 7)	1.3	0.8	1.3	1.0

Computer Skills

Prior writing experience. Students responses to the Prior Writing Experience questionnaire were examined and the results are presented in Table 4. Half of the students have been using the computer to write at school (53%; $n = 8$) and at home (53%; $n = 8$) for over 5 years, and the majority of the students have used the computer to write at least once a week at school (87%; $n = 13$) and at home (60%; $n = 9$). Seven students (47%) reported they had taken keyboard lessons at school before, usually during late elementary school. Nine students (60%) rated their keyboarding skills as being good/very good. All students (100%) had reported to have prior experience using Microsoft Word, which is unsurprising considering it is the word processing program used in their schools. In general, the reports by students suggest that this population is familiar with writing on the computer.

Table 4: Prior writing experience responses from students (n = 15)

QUESTION	n	%
Years using the computer to write in school:		
1 year	1	7 %
2 years	2	13 %
3 years	4	27 %
4 years	0	0 %
5 years or more	8	53 %
Years using the computer to write at home:		
1 year	3	20 %
2 years	1	7 %
3 years	1	7 %
4 years	2	13 %
5 years or more	8	53 %
Frequency of using the computer to write at school:		
Everyday	5	33 %
2-3 times a week	2	13 %
Once a week	6	40 %
Once every few weeks	1	7 %
Never or hardly ever	1	7 %
Frequency of using the computer to write at home:		
Everyday	4	27 %
2-3 times a week	2	13 %
Once a week	3	20 %
Once every few weeks	3	20 %
Never or hardly ever	3	20 %
Previous Keyboarding lessons:		
Yes	7	47 %
No	8	53 %
Self-reported keyboard skills:		
Excellent	0	0 %
Very good	2	13 %
Good	7	47 %
Fair	4	27 %
Terrible	2	13 %
Previously used word processor programs:		
Microsoft Word	15	100 %
Google Docs	1	7 %
Corel WordPerfect	0	0 %
Microsoft Works	0	0 %
Word Pad	0	0 %
Other	0	0 %

Writing tool preference across writing activities. A series of chi-squares were conducted in order to determine whether students preferred to use the computer or pen and paper

for a number of writing activities. The test was significant for informative writing (e.g., school work), $\chi^2(1, n = 15) = 5.40, p = .02$; when their writing will be graded, $\chi^2(1, n = 15) = 11.27, p = .001$; and when their writing will be shared with friends, $\chi^2(1, n = 15) = 5.40, p = .02$. These results suggest that students prefer to use the computer more than pen and paper for the activities in which their writing will be viewed, and perhaps evaluated, by others. However, there was no significant preference between computer and pen and paper for the activities that are more personalized, such as personal writing (e.g., journals, letters), $\chi^2(1, n = 15) = 0.07, p = .80$; narrative writing (e.g., stories, poems), $\chi^2(1, n = 15) = 1.67, p = .20$; and when students need to write something quickly, $\chi^2(1, n = 15) = .60, p = .44$.

Writing tool preference across activities as a function of self-reported keyboarding skills. A series of chi-squares were conducted in order to determine whether the students' responses varied as a function of their self-reported keyboard skills. There were no significant differences in response frequencies found for students who self-reported as having very good/good keyboarding skills (60%; $n = 9$) and students who self-reported as having fair/terrible keyboarding skills (40%; $n = 6$) for questions pertaining to the various writing activities as already described. Specifically, no differences in response frequencies were found for personal writing, $\chi^2(1, n = 15) = 1.607, p = .21$; narrative writing, $\chi^2(1, n = 15) = 0.00, p = 1.00$; informative writing, $\chi^2(1, n = 15) = 0.69, p = .79$; when they need to write something quickly, $\chi^2(1, n = 15) = .185, p = .67$; when their writing will be shared with friends, $\chi^2(1, n = 15) = 2.50, p = .11$.

Students' perception of writing by keyboard versus by hand. Another series of chi-squares were used to determine whether students perceived their writing to be different between the keyboard and pencil. Overall, the students believed that there was a difference in their

writing between typing and handwriting. They believed that their typed essays were longer and better quality than their handwritten essays. Specifically, the tests were significant for their belief that they write differently, $\chi^2(1, n = 15) = 5.40, p = .02$; they write more by keyboard than by hand, $\chi^2(2, n = 15) = 14.80, p = <.001$; and that their typed essays are better than their handwritten essays, $\chi^2(1, n = 15) = 11.27, p = <.001$. The students explained that typing an essay was better than handwriting due to the use of spelling and grammar checkers (67%; $n = 10$), they do not have to worry about illegible writing (47%; $n = 7$), and the ease of editing on the computer (47%; $n = 7$).

Hands-on computer skills. The measure of hands-on computer skills examined the students' knowledge of software options commonly associated with writing on the computer, such as *undo*, *save as*, *select*, *cut*, *copy*, and *paste* text. Results indicated that all of the students were highly proficient in their hands-on computer skills. Out of a total score of 6, the mean score was 5.1 with a standard deviation of 1. While only six students (40%) were awarded full points, five students (33%) only had one error. The errors resulted from substituting *cut* (47%; $n = 7$) or *undo* (20%; $n = 3$) with *delete*. Only two students (13%) did not know how to use the *undo* or *save as* option of the word processor. Furthermore, the students had the option to use the mouse, keyboard, and touchpad. All students opted to use the mouse for the majority of the task; only nine students (60%) used the keyboard shortcut, and it was mainly to *paste*.

Relation Among the Cognitive, Linguistic, and Writing Measures across Conditions

The correlational matrix is presented in Table 5. Specifically, the pattern of associations and any differences between handwritten and typed conditions across the measures administered were examined. Out of the cognitive, linguistic, and writing measures, only working memory significantly correlated similarly for handwriting fluency ($r = .62$) and typing fluency ($r = .63$).

For both handwritten and typed conditions, handwriting and typing fluency did not show any significant associations with the essay's total score, lower-level transcription, and higher-level text generation.

As for the total essay scores, the measure of spelling correlated significantly with the handwritten ($r = .55$) and typed ($r = .53$) essays. The handwritten essay's total score correlated with the measure of verbal span (digit span forward) ($r = .62$), whereas the typed essay's total score correlated with the measure of verbal working memory (digit span backward) ($r = .55$). There were no significant correlations found for both the handwritten and typed lower-level transcription skills. Finally, there were no significant correlations with the handwritten higher-level text generation, yet the typed higher-level text generation correlated significantly with the measures of RAN ($r = .52$), RAS ($r = .55$), and spelling ($r = .55$).

Table 5: Correlational matrix of the measures

Measure	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. DSF	--													
2. DSB	.25	--												
3. RAN	.24	.33	--											
4. RAS	.09	.22	.68**	--										
5. Spelling	.13	.00	.27	.51	--									
6. Hands-On Comp.Skill	.39	.28	.06	-.08	.17	--								
7. HW Fluency	-.15	.62*	.28	.07	-.22	.10	--							
8. KB Fluency	.41	.63*	.39	.43	.06	.23	.49	--						
9. HW Essay - Total	.62*	.25	.25	.28	.55*	.49	-.23	.18	--					
10. KB Essay - Total	.17	.55*	.33	.38	.53*	-.02	.16	.17	.55*	--				
11. HW Essay - Lower	.31	-.06	-.15	-.12	.06	.31	-.19	.15	.19	-.20	--			
12. KB Essay - Lower	-.16	.09	-.29	-.12	.06	-.11	.02	-.09	.13	.41	.47	--		
13. HW Essay - Higher	.36	.16	.31	.31	.41	.25	-.12	.02	.77**	.57*	-.45	-.22	--	
14. KB Essay - Higher	.27	.55*	.52*	.48	.55*	.04	.16	.23	.53*	.87**	-.48	-.07	.70**	--

Note. DS = Digit Span; DSF = Digit Span Forward; DSB = Digit Span Backward; RAN = RAN Letters; RAS = RAS 2-set Letters and Numbers; Hands-on Comp.Skill = Hands-on Computer Skill; HW = Handwritten; KB = Keyboard ** $p < .01$. * $p < .05$.

Differences in Writing Quality Between Typed and Handwritten Essays

Preliminary analysis of students who use the keyboard as a current writing accommodation compared to students who do not use the keyboard found no significant differences across all writing measures. The next set of analyses used a paired t -test, with Bonferroni correction, to examine whether there were significant differences between the quality of handwritten and typed essays. The results indicated that there were no statistically significant difference in overall essay quality between typed or handwritten conditions ($t = -.115$, $df = 14$, $p = .910$). To further investigate in more detail whether there were differences found within the essay quality that may have been masked by the total score, the quality indices of writing were

examined at the lower-level transcription (e.g., mechanics) and higher-level text generation (e.g., organization, theme development, vocabulary). There were no statistically significant differences between the typed and handwritten essays on lower-level transcription skills ($t = .646$, $df = 14$, $p = .529$) or higher-level text generation skills ($t = -.440$, $df = 14$, $p = .667$).

A further fine-grained analysis was conducted as a means of exploratory analysis due to the small sample size. There were no statistical significant differences between handwritten and typed essays on spelling accuracy ($t = .192$, $df = 14$, $p = .851$), word count ($t = -1.564$, $df = 14$, $p = .140$), or grammar ($t = -.370$, $df = 14$, $p = .717$). Further analysis examined the individual subsections of the WIAT-II essay scoring. There were no statistical significant differences between handwritten and typed essays on mechanics ($t = .646$, $df = 14$, $p = .529$), organization ($t = -1.293$, $df = 14$, $p = .217$), theme development ($t = .863$, $df = 14$, $p = .403$), and vocabulary ($t = .323$, $df = 14$, $p = .751$).

It should be noted that the author found that several of the handwritten essays were illegible ($n = 10$; 67%), which is common for students with writing difficulties (Hetzroni & Shrieber, 2004). While the statistical scores found no difference between the typed and handwritten essays, writing on the computer may be advantageous solely for the purpose of eliminating illegible writing.

On average, the difference in total scores between typed and handwritten essays were 3 points, but there was no distinctive preference for either conditions. There were three students who achieved a quality difference of 6 or 8 points between essay conditions, favouring their typed essays. All three students were male and right-handed. Two students were in grade 11, and one student was in grade 10. Two students used the 1-finger typing, while the other student used touch-typing. When compared to the other students in the study, there was no evident pattern

found in their cognitive, linguistic, and literacy measures. The benefits of using the computer to write varied between each student. For one student, writing on the computer allowed him to carefully plan his essay and thereby achieved a significantly higher score on his higher-level text generation. For another student, using the computer to write increased his spelling accuracy, even without the use of the spelling checker. As a result, his lower-level transcription scored significantly higher on his typed essay than his handwritten essay. Another student had difficulty with his graphomotor skills, resulting in illegible writing and tired easily from the motor demands of handwriting. Using the computer to write allowed him to write more, and also increased his spelling accuracy for his typed essay than his handwritten essay.

Out of all the participating students, only one student scored significantly higher on his handwritten essay than typed essay. He is in grade 11, right-handed and used 1-finger typing. Compared to the other students in the study, his typing speed was significantly low, yet was still faster than his handwriting. This student wrote significantly less for his typed essay when compared to other students in this study. Anecdotal observations found that he repeatedly revised each sentence for several minutes for mechanical errors, whereas in the handwritten condition he was able to quickly move to the next sentence with minimal revisions. For this student, using the keyboard may have been disadvantageous due to his repetitively long periods of revision for each sentence.

DISCUSSION

Limited research has compared quality of writing achieved by adolescents with LD when they write using a computer, or by hand. The current study was conducted in order to fill this research gap. Drawing on the Simple View of Writing model (Berninger & Amtmann, 2003), a number of cognitive, linguistic, and writing measures were selected. Many of the measures chosen assessed lower-level transcription skills (e.g., spelling, handwriting and typing fluency) and processes linked with handwriting fluency (e.g., memory, orthography, executive control), since these skills are typically impaired in students with a writing LD (Berninger, 1994).

Are Evaluations Higher for Typed Essays than Handwritten Essays?

Despite the fact that using the computer eliminates the graphomotor demands of writing, the results of the current study indicated no differences in the quality of the handwritten and typed essays. No differences were found between conditions for the lower-level transcription (e.g., mechanics), higher-level text generation (e.g., organization, theme development, vocabulary), the fine-grain details of the essay quality (e.g., spelling accuracy, grammar, word count) or any of the WIAT-II subsections (e.g., mechanics, organization, theme development, vocabulary).

The similar scores between the handwritten and typed essay qualities were comparable to MacArthur and Graham's (1987) study involving fifth and sixth grade students with LD. MacArthur (2009) attributed the similar scores between conditions due to a lack of experience of writing on the computer. However, despite the fact that students in the current study were certainly more experienced at writing on the computer, there were still no differences in the quality of handwritten and typed essays. Other studies which examined the handwritten and

typed essays of students with LD have shown different results. Berninger and her colleagues (2009) reported that elementary students in their study were lacking typing fluency, and as a result her students wrote more by hand than by keyboard. The students in the current study have sufficient typing fluency, yet achieved similar word count between the two conditions, suggesting that typing fluency does indeed influence word count. The students' experience and skills of writing on the computer was similar to Berger and Lewandowski's (2013) population, yet unlike the results of the current study, they were able to achieve a higher score on their typed essays than handwritten essays. It could be due to their population of university students with LD that caused them to have different results than the current study. University students typically achieve higher in academics than the general population and it was unclear whether all of the students had writing difficulties; whereas, the participants in the current study were high school students with documented LD and writing difficulties.

There are two possible reasons why there were no differences in the quality between handwritten and typed essays. First, the time limitation of writing the essay within 15 minutes is similar to a test rather than writing assignments. In high school, writing assignments typically do not have a such a short time limitation, allowing students to complete their writing assignments without the concern of a time constraint. Future research might investigate if there are differences between timed and untimed writing assignments under handwriting and typing conditions. Second, the current study did not use spelling or grammar checkers. The selected students demonstrated that they have spelling difficulties, which in turn will impact their writing (Berninger et al., 2008). Differences might arise between typed and handwritten essays when the spelling checker is used. Future research might want to compare handwritten essays, typed essays without a spelling checker, and typed essays with a spelling checker.

As a group, there were no significant differences in the quality of handwritten and typed essays. However, there were three students whose typed essays achieved a higher score than their handwritten essays, and only one student achieved a higher score in their handwritten essay than his typed essay. There was no evident pattern amongst the students in the cognitive, linguistic, and literacy measures to explain the significant boost, or decrease, in the quality of their typed essays. There were various reasons as to why these students benefited by writing on the computer, including increasing mechanical correctness and eliminating graphomotor difficulties and illegible writing. Only one student achieved a significantly higher score in his handwritten essay than typed essay, which could be a result of his slow typing fluency or his behaviour to spend several minutes repetitively revising sentences on the typed essays more than his handwritten essays. Nevertheless, it demonstrates that even though as a group there were no differences between handwritten and typed essays, there were some individual students who particularly benefited, or were hindered, by using the computer to write.

What are the Associations Between Handwritten and Typed Conditions Among the Cognitive, Linguistic, and Writing Measures?

This study found a moderate correlation between handwriting and typing fluency ($r = .49$), and while it was not significant (due to the limited sample size) it was comparable to Christensen's (2004) results ($r = .51$). Previous research suggested that handwriting and typing fluency have a significant association with RAN, RAS, verbal short-term memory, and verbal working memory. However, in the current study, only the measure of verbal working memory correlated significantly with both handwriting fluency and typing fluency. Previous studies involving students without LD have similarly found that both short-term and working memory correlates with handwriting fluency, but it is short-term memory rather than working memory

that correlates significantly more (Swanson & Berninger, 1996). These results imply that handwriting fluency might be more cognitively demanding in the LD population than the non-LD population, consistent with previous research (e.g., Berninger, 1994).

The Simple View of Writing model suggests that spelling, memory, handwriting/typing fluency, RAN, and RAS would be significantly associated with the quality of typed and handwritten essays. However, only spelling, verbal short-term and verbal working memory significantly correlated with the total scores for handwritten and typed essays. Given the results of previous research (e.g., Berninger et al., 2008; Graham et al., 1997), it is not surprising that spelling correlated significantly with the handwritten total essay quality ($r = .55$), yet the current study suggests that spelling also correlated significantly with the typed total essay quality ($r = .53$). It is interesting that the measure of verbal working memory only correlated significantly with the typed total essay quality score, but the measure of verbal short-term memory only correlated significantly with the handwritten total essay quality score. Further research is needed to expand on the relationship between verbal short-term and working memory and essay quality in the two writing mediums (e.g., handwriting and typing). Nevertheless, as Berninger and Amtmann (2003) suggested, the relationship of spelling and short-term and working memory may continue to be significant to the quality of essays written by students with LD, regardless of the writing medium (e.g., typing and handwriting).

Surprisingly, there were no significant correlations between any of the cognitive, linguistic, and writing measures for the lower-level transcription skills in both handwritten and typed conditions, suggesting that the lower-level transcription skills of students with LD are drawing on different processes. The difference between typed and handwritten condition become more prominent when examining the associations with the higher-level text generation. While

the handwritten condition resulted in no significant correlations, the typed condition correlated with the measures of verbal working memory, RAN, and spelling. Since RAN and verbal working memory are predictive of both spelling and handwriting fluency (Savage et al., 2005; Swanson & Berninger, 1996), it may be that transcription continues to impact the higher-level text generation of typed essays whereas it may not be as significant to the higher-level text generation of the handwritten condition.

Interestingly, none of the computer measures were associated with the total, lower-, or higher-level writing scores of the typed essays. In the current study, the students had proficient computer skills; however, students with lower computer skills may show an association to typed essays, or computer skills may not impact typed essays at all. Future research should explore the differences between students with high and low computer skills in relation to the quality of typed essays.

Do Adolescents with LD and Writing Difficulties Possess Adequate Knowledge and Experience for Writing on the Computer?

Previous studies in this area have often omitted or provided little information pertaining to participants' skills at writing on the computer. However, this study included several background questionnaires and tasks to derive information on the students' skills in using the computer to write. The students in the current study generally had several years of writing on the computer, both at home and at school, and demonstrated adequate hands-on computer skills. It was hard to determine whether the students in this study had adequate typing fluency due to the lack of norms. More often than not, the participants in previous studies were more fluent at handwriting than typing (Christensen, 2004; Connelly et al., 2007; MacArthur & Graham, 1987; Wolfe et al., 1996). Since the students in the current study can type significantly faster than they

can handwrite, it is likely that they have adequate typing fluency. However, without the availability of norms, it is unknown whether they were above, below or at the age expectancy for their handwriting fluency, especially since handwriting fluency is a documented difficulty for the LD population (Berninger, 1994).

Interestingly, nearly half of the students reported to have previously received keyboarding lessons, which usually occurred during the late elementary years. Educators might want to consider administering keyboarding lessons more in school since typing is becoming frequently used, if not more than handwriting. Keyboarding lessons may teach students the proper touch typing, which would allow the writer to monitor the screen more than 1-finger typing or other typing styles. As a result, there would be reduced pauses between sentences allowing for uninterrupted writing (Stevenson & Just, 2012). In the current study, only two students (13%) used touch typing, whereas the other students used 1-finger typing (87%; $N = 13$). Previous research had suggested that there were no differences between touch typing and 1-finger typing in relation to typing fluency (Stevenson & Just, 2012). Even though the majority of the students did not receive keyboarding lessons and used 1-finger typing they were still more fluent at typing than handwriting fluency in isolation, likely due to their experience of frequently writing on the computer.

Do the Students' Computer Skills Impact their Typed Essays?

Despite the students' perception that their typed essays would be longer and better quality than their handwritten essays, the results of the current study indicated that there were no differences between the two conditions even with proficient computer skills and with sufficient experience writing on the computer. Nevertheless, since previous studies had shown that low computer skills can actually hinder quality (Christensen, 2004; Connelly et al., 2007; Wolfe et

al., 1996), the students' computer skills likely did impact their typed essays, even if it is to improve the quality of their typed essays to be equivalent to their handwritten essays.

Limitations to the Current Study

There were some limitations to the current study. First, the sample size was small reducing power in the statistical analyses. However, the sample size was comparable to other studies that examined the handwritten and typed essays in students with LD. For instance, the study by MacArthur and Graham (1987) had a sample of 11 middle school students with LD, Berninger and her colleagues' (2009) had a sample of 12 elementary students with LD, and the study by Berger and Lewandowski (2013) had a sample of 30 university students with an LD in at least one of the following areas: reading, writing, and processing speed.

Second, the study only examined the essays of students with LD. Comparing results to a non-LD population may provide more information about whether the keyboard is an appropriate accommodation for writing difficulties. Previous studies involving non-LD populations who had sufficient skills and experience writing on the computer found that students achieved a higher quality score for their essays by keyboard than by hand. Morphy and Graham (2013) noted that the improvement between handwritten and typed essays were substantially better in struggling non-LD writers than the average writer. Comparing both typed and handwritten essays of students with and without LD may prove enlightening. It may be that neither the students with and without LD show a significant difference between typed and handwritten conditions, or it may be that the typed essays of students without LD vastly improve in quality compared to their handwritten essays.

Third, the laptop used for computer-related measures could have presented some limitations to the results. The students may have been unfamiliar with the laptop impacting their

computer skills. However, Sandene and his colleagues (2005) found that there were no differences between the essays composed using a familiar or unfamiliar computer. Furthermore, the current study allowed for an adequate amount of time for students to familiarize themselves with the provided laptop by administering the typing fluency and hands-on computer tasks before the essay by keyboard task.

Fourth, no spelling or grammar checkers were used in the current study, as it was only examining how the keyboard impacted essay quality. Modern word processors have the spelling and grammar checkers integrated into the program, so it is unnatural to write on the computer without them. Furthermore, since the students experienced spelling difficulties, it was likely that they depended on the spelling checker to aid them in their typed essays. Regardless, the current study demonstrated that when students with LD write with the keyboard only, without spelling and grammar checkers, they achieved similar writing quality scores for both typed and handwritten essays.

Fifth, our measure of hands-on computer skills may not be an accurate representation of the students' computer skills. In the current student, students had the option to use the mouse, keyboard, and touchpad. All students chose to use the mouse to access most of the software options, and few students used the keyboard for the *paste* command. Previous studies have shown that more experienced computer users would often use keyboard shortcuts rather than the mouse (Grabowski, 2008). Knowledge of software options may be more pronounced when the students' are asked to use only the keyboard shortcuts. Future research might consider using only keyboard shortcuts rather than using the mouse in order to measure hands-on computer skills.

Educational Implications

The current study suggests that, under timed conditions with the spelling and grammar checkers disabled, there are no differences in the quality of handwritten and typed essays by high school adolescents with learning disabilities who have writing difficulties. Furthermore, despite the fact that the students were proficient and experienced with writing on the computer, using the computer did not notably improve the quality of the typed essays more than the handwritten essays. Nevertheless, if a student has illegible writing, using the computer to write may be a necessary accommodation just for this reason alone.

This study examined only the effects of the keyboard, and thus did not include spelling and grammar checkers. Given the importance of spelling accuracy as an aspect of transcription to writing quality, it is possible that students' use of spelling checkers may have improved the quality of typed essays, especially since spelling is an area of weakness within this population. The accommodation of using the keyboard alone to bypass graphomotor/handwriting difficulties does not appear to lead to improved quality in written essays. As suggested by the Simple View of Writing model, compensating for output difficulties alone does not improve the writing quality. Rather, interventions aimed at improving students' writing quality (e.g., learning how to plan, generate ideas, organize ideas, revise, and edit) irrespective of the writing medium are necessary.

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Appendices

Appendix A: Writing Experience Questionnaire

Writing Experience Questionnaire

How many years have you been using computers to write?

In school:

1 year	2 years	3 years	4 years	Over 5 years
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Outside of school:

1 year	2 years	3 years	4 years	Over 5 years
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When you write, how often do you use computers?

In school:

1 year	2 years	3 years	4 years	Over 5 years
--------	---------	---------	---------	--------------

Outside of school:

1 year	2 years	3 years	4 years	Over 5 years
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How good are your keyboard skills?

Excellent	Very good	Good	Fair	Terrible
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Have you taken keyboarding lessons before?

No

Yes:

Which of the following word processor programs have you used?

Microsoft
Word

Google Docs

Corel
WordPerfect

Microsoft
Works

WordPad

Other: _____

For each of the following types of writing, please indicate whether you are more likely to use a computer or a pen and paper?

	Computer	Pen
Personal writing (e.g., journals, letters)	_____	_____
Narrative Writing (e.g., stories, poems)	_____	_____
Informative Writing (e.g., school work)	_____	_____

Would you rather write at the computer or with pencil and paper under the following conditions:

	Computer	Pen
When you need to write something quickly	_____	_____
When your writing will be graded	_____	_____
When your writing will be shared with friends	_____	_____

When you write using a computer, do you do things differently than when you are using a pen and paper? You might think about what you do when you generate ideas, draft, revise, share with others in the class, and correct mistakes.

When you write using a computer, do you usually write more or less than when you use a pen and paper?

Do you think your writing is better when you use a computer or pen and paper? Why?

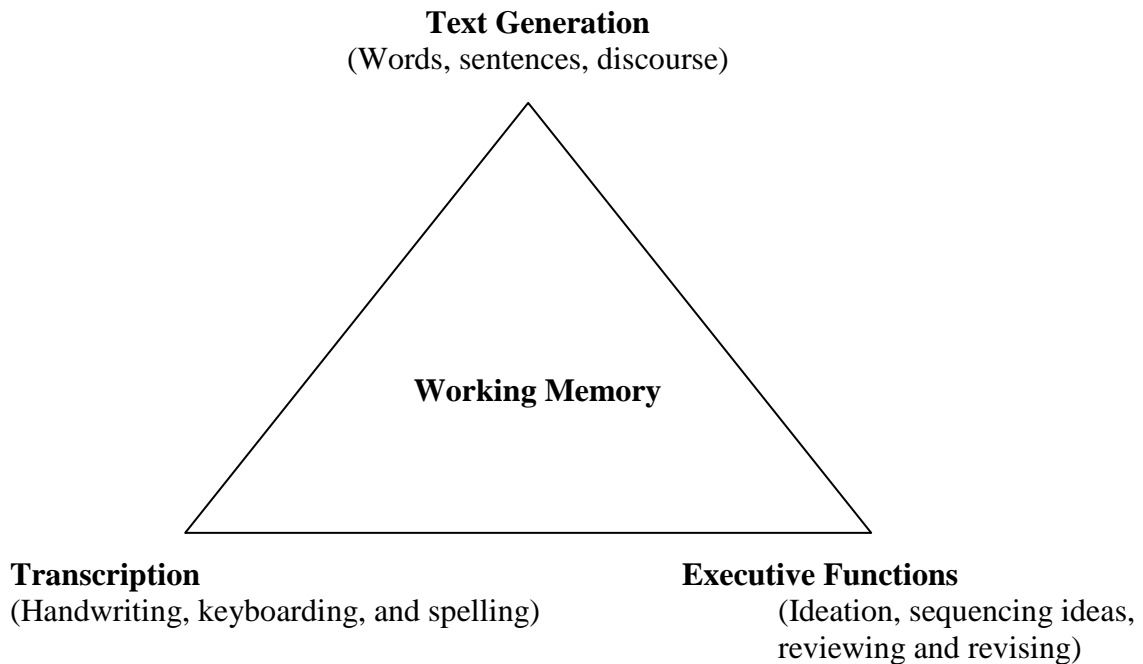


Figure 1: The Simple View of Writing model

The Simple View of Writing model demonstrates how the three components – transcription, executive functions, and text generation – work in unison within a working memory environment. Adapted from “Preventing Written Expression Disabilities through Early and Continuing Assessment and Intervention for Handwriting and/or Spelling Problems: Research into Practice” by Berninger and Amtmann, 2003, in H. L. Swanson, K. Harris, & S. Graham (Eds.), *Handbook of research on learning disabilities* (pp. 345–363). New York: Guilford Press.