Use of Spellcheck in Text Production by College Students with Dyslexia

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Abstract: It is widely assumed that by identifying spelling errors and suggesting replacement words, spellcheck allows writers to revise spelling errors even if they do not have the necessary spelling knowledge. However, there have been no studies evaluating the efficacy of modern spellcheck tools for students with spelling difficulties, such as dyslexia. In fact, the very limited and dated research into use of spellcheck by writers with dyslexia indicated that, even when using spellcheck to revise spelling errors, this group left many misspellings in their texts. The current study is the first to investigate whether a modern spellcheck program allows college students with dyslexia to produce texts that are as free from misspellings as texts by their peers, and whether this affects the quality of the text in other ways.

College students with dyslexia (n=18) and a control group of peers (n=18) wrote two short essays using Microsoft Word, one with spellcheck active and one without spellcheck active. Spelling accuracy and overall quality of the texts were measured. Without spellcheck, texts by students with dyslexia contained more misspellings than texts by the control group, however, when writing with spellcheck active, students from both groups left almost zero misspelled words in their texts. Text quality was not affected. Results demonstrate that spellcheck helps college students with dyslexia to overcome the limitations that poor spelling knowledge imposes. Importantly, results indicate that spellcheck does not lead to improvements in text beyond spelling accuracy or lead to poorer quality texts, indicating that it is suitable for use in exam conditions.

Keywords: spellcheck, dyslexia, spelling, writing

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1. Background

Spellchecking programs (spellcheck) are ubiquitous and widely used technological writing tools. Spellcheck is offered as an addition to many digital writing platforms, including the popular word processing program Microsoft Word (MS Word). Spellcheck offers three key affordances to the writer: an automatic red underline draws attention to words identified as misspelled, a choice of correctly spelled alternative words allows writers to identify the correct spelling, and spellcheck allows writers to replace the misspelling with one of these words using a single click. Using spellcheck should help writers to increase the spelling accuracy of their texts. However, despite its popularity, how well writers use spellcheck has been little measured.

More crucially, the efficacy of modern spellcheck to assist those writers with specific spelling difficulties, such as dyslexia, has not been established. Thus, while there is a strong assumption that spellcheck can assist those with spelling difficulties, this has not yet been demonstrated, and we do not yet know if how spellcheck is being used is to the best advantage by this group of struggling writers, many of whom leave it active in the default program settings (O'Rourke, 2019). When spellcheck offers a choice of words to replace misspelled words, those word choices have to be read and correctly selected, a skill that those with dyslexia may struggle with. Finally, an automatic red underline may in itself provide a distraction as writers with dyslexia focus overly on spelling accuracy, often to the detriment of other writing processes (O'Rourke, 2019, Ronneberg, Johansson, Mossige, Torrance & Uppstad, 2018). This study will be the first to test the assumption that spellcheck effectively assists college students with dyslexia using a modern and widely used spellchecking program.

Furthermore, while it has been established that spelling knowledge is necessary for spelling error revision (Hacker, Plumb, Butterfield, Quathamer, & Heineken, 1994; Hayes, 2004), spellcheck enables writers to revise their spelling errors without having to rely exclusively on their own spelling knowledge. This may have implications for theoretical models of writing because, by changing the level of knowledge that is actually necessary for revising spelling errors, the routine use of spellcheck may challenge our understanding of how writers today might revise spelling errors in certain situations. While we may wish to focus on new technological tools and their developing affordances, which much of the research in this special issue has done, we also need to evaluate the impact of a technological tool when it becomes very widespread in everyday use and how this may change our understanding of the writing process.

Spelling is a vital component of writing. The selection of the correct sequence of letters for the appropriate word is a key aspect of getting the message on the page. In fact, writers are often judged harshly for spelling errors in their writing. A

consistent finding in numerous studies over the years shows that poor spelling leads to poorer assessment of a piece of writing across much more than spelling errors alone (Chase, 1986; Marshall & Powers, 1969; Rezaei & Lovorn, 2010) even compared to the exact same essays presented without spelling errors (Graham, Harris & Hebert, 2011). Assessors also rate the authors of essays that contain spelling errors as less intellectually capable than the authors of identical essays without spelling errors (Kreiner, Schnakenberg, Green, Costello & McClin, 2002). Assessors of writing are more alert to the "low level" errors of spelling and grammar than other "higher level" text errors and more skilled readers who assess essays (such as College Professors) have been shown to score texts containing spelling errors more harshly than less skilled readers (Johnson, Wilson, Roscoe, 2017). Furthermore, work, now over a decade old, has shown that assessors assume that word-processed text has been written using spellcheck, and so question the intellectual abilities of authors whose texts contain spelling errors (Figueredo & Varnhagen, 2005). Accurate, error-free spelling in word processed text is a real expectation today and spellcheck is a technological tool that can support writers to achieve this ideal.

Despite this expectation for texts to be free from spelling errors, there have been remarkably few studies of how effectively writers reduce spelling errors in text with the use of spellcheck (see Figueredo & Varnhagen, 2005; O'Rourke, 2019 for reviews of the very brief literature). This is especially so for those who struggle with spelling, such as individuals with dyslexia where there are no studies available. Developmental dyslexia is characterized by impaired performance in both reading and writing tasks (Lyon, Shaywitz, & Shaywitz, 2003; Tops, Callens, Lammertyn, van Hees, & Brysbaert, 2012). Writers with dyslexia make more spelling errors than writers without dyslexia (Connelly, Campbell, MacLean, & Barnes, 2006; Elliot & Grigorenko, 2014; Riddick, Sterling, Farmer, & Morgan, 1999; Snowling, 2012; Sumner, Connelly, & Barnett, 2013; Tops, Callens, van Cauwenberghe, Adriaens, & Brysbaert, 2013; Torrance, Rønneberg, Johansson, & Uppstad, 2016; Warmington, Stothard, & Snowling, 2012; Wengelin, 2002, 2007) and show difficulties revising spelling errors when writing without spellcheck (MacArthur, Graham, Haynes, & De La Paz, 1996; Morken & Helland, 2013; Torrance et al., 2016; Wengelin, 2007). Their writing difficulties persist into adulthood. For example, it has been reported that adults with dyslexia (not in education) wrote texts containing an average of 8% misspelled words (Wengelin, 2007), and college students with dyslexia wrote texts containing an average of between 4% (Sumner & Connelly 2020) and 6% (Warmington et al., 2012) misspelled words when spellcheck was not available to them. While spellcheck is unlikely to help with the initial production of words (Berninger, Nielsen, Abbott, Wijsman, & Raskind, 2008), it could provide a way for these writers to successfully revise their spelling errors. Providing that they can make effective use of spellcheck as a writing tool, writers with dyslexia may be able

to reduce the number of misspelled words to the same level as their peers without spelling difficulties, thus also reducing the negative impact of poor spelling on the assessors' judgement of the quality of the content.

It is important to note that poor spelling also has a wider impact on writing processes than merely producing inaccurately spelled words during writing. The essays of children and adults with dyslexia are rated as poorer in quality than the essays produced by their peers even after misspellings have been corrected by researchers (Sumner & Connelly, 2020). Writers with dyslexia may produce poorer quality texts at least in part because the excessive demands imposed by spelling restrict the amount of resources that can be devoted to developing the content. It has been reported that when children with dyslexia dictate their texts (and so spelling processes are not required) then the essays produced are of no poorer quality than their peers (Sumner et al., 2014). A tool such as spellcheck has the potential to free up cognitive resource for writing that may prove beneficial across more general writing processes. However, to date, no evaluation of this potential has taken place.

In addition, adults with dyslexia have been shown to focus many of their revisions during writing on spelling, drawing attention away from "higher order" revisions. Wengelin (2007) observed thousands of revisions made by 21 adults with and without dyslexia who wrote five texts each without spellcheck. Both groups made a similar number of revisions, but many more revisions by writers with dyslexia were related to spelling (28%) compared to the control group (less than 2%). Yet, even with more spelling related editing, writers with dyslexia still left more spelling errors in texts, averaging 8% errors across texts per person, compared to almost zero errors in the control group. If spellcheck makes spelling revision quicker and easier, then it may allow writers to focus on other, higher order revisions, potentially improving the text quality.

Furthermore, the poor speller is often a slow and hesitant writer. A number of recent studies examining the time course of writing in children with spelling and/or literacy difficulties have illustrated that those with spelling difficulties take longer to produce text than their peers (Afonso, Suarez-Coalla & Cuetos, in press; Kandel, Lassus-Sangosse, Grosjacques, & Perret, 2017; Sumner, Connelly & Barnett, 2012, 2014). This difference was not due to slower handwriting (there were no reported differences in handwriting speed) but because they paused more than their similarly aged peers when writing and this was the crucial factor in producing fewer words per minute. This extra time spent pausing when composing text was predicted by spelling ability and linked to pauses within words. This pattern continues into adulthood and includes long pauses in words that are actually correctly spelled, suggesting hesitation at the word level (Afonso, Suarez-Coalla & Cuetos., 2015) and is also reflected in typing speeds (Torrance, et al., 2016; Wengelin, 2007).

Therefore, while it is hoped that spellcheck will support spelling error revision and so reduce the number of spelling errors in texts, it could have other positive impacts, especially for those writers who devote a lot of time and effort to spelling. The automatic identification of misspelled words and the easy replacement of words afforded by spellcheck could reduce hesitation at the word level and allow writers to concentrate on other areas of their writing. Thus, with spellcheck, writers with dyslexia might improve the quality of their texts beyond simply correcting spelling errors.

In one of the few studies investigating the efficacy of spellcheck, Pedler (2001) assessed the performance of four different spellchecking programs, including spellcheck in MS word 97 (Microsoft, 1997), on the identification of misspelled words, and whether spellcheck offers the correct word in the replacement candidate list. Pedler (2001) determined that spellcheck in MS Word 97, could support revision of 55% of 577 misspellings. A further 20% of misspellings were not flagged, these were real-word errors. Real-word errors are words that are used incorrectly within the context of the surrounding text. The words themselves do not contain spelling errors. Spellcheck cannot identify real-word errors only inaccurate spellings. The remaining misspellings were flagged but the target word did not appear in the replacement candidate list. Roughly 18% of these flagged words contained multiple errors (*vrnegest,* instead of *varnished*), and approximately 8% were boundary infractions, causing run-on errors (*icoud,* instead of *I could*) and split words (*rey mebber,* instead of *remember*).

This study indicates that spellcheck could potentially help writers who struggle with spelling to identify and correct only half of their misspelled words. However, only one of the participants in this study was considered to have dyslexia, the other misspellings were from office documents written by one adult, and texts written by UK secondary-school students described as having low academic ability in the 1960s, so three decades earlier. Moreover, this study was a textual analysis of scripts produced without spellcheck thus gives no indication of how well the individuals who wrote these texts would actually use spellcheck to revise their spelling errors.

One of the few studies investigating the use of spellcheck by poor spellers is by MacArthur et al., (1996). Children with learning disabilities in the United States (*N*=27, aged 11 to 14- years-old), wrote and then revised their own essays using MS Word 4.0 (Microsoft, 1989). Writers' misspelled words made up 13.4% of total words. Writers revised their texts with spellcheck or using a hard copy of a dictionary. Using a dictionary, they corrected only 9% of their spelling errors. With spellcheck, they corrected 37%. Thus, spellcheck certainly increased spelling accuracy but, surprisingly, the majority of spelling errors remained uncorrected. There are perhaps reasons for this low success in spelling error revision. First, real-word errors were included in the count of spelling errors and made up 37% of total spelling errors. Second, in 18% of cases, it was found that the poor spellers did not

successfully identify the target word from the list of candidate words offered by spellcheck. Thus, even when the real-word errors were excluded, these young writers still only corrected approximately 58% of spelling errors despite 100% being identified as spelling errors by spellcheck.

It is worth noting however that the children in this study used spellcheck on documents that they had written a week before, and this break may have interfered with their ability to identify errors or select the target word from the list. While MacArthur et al.'s (1996) findings do suggest that children with learning disabilities (a much wider definition than dyslexia) have particular difficulties using spellcheck to successfully revise spelling errors there was no comparison group in the study and so it was not known if these poor spellers would be worse at using spellcheck than other same-aged peers. MacArthur et al.'s (1996) study has been described multiple times in their subsequent reviews of spellcheck (MacArthur 2006; 2009) but no more recent studies where writers use spellcheck in their own writing have been carried out.

We can confidently assume that most writers today are more accustomed to writing with spellcheck in comparison to the writers in MacArthur et al.'s (1996) study. Furthermore, the user experience of spellcheck in MS Word has changed since the 1990s, as outlined in the following section 'details of the spellcheck used in this study', and so an evaluation of the use of spellcheck by poor spellers is long overdue. Until now, no study has allowed college students with dyslexia to produce and revise their own texts using spellcheck as they write, as they would in everyday use of spellcheck.

It is thought that today's writers use spellcheck by default and that they have generally not received any support or guidance on how to best make use of this writing tool, even those with spelling difficulties. Spellcheck can be used in a number of different ways. An understanding of the general effectiveness of spellcheck and knowledge of how to best use the spellcheck tool for those who struggle with spelling could make a positive difference for many writers. For instance, the ability to choose the accurate word from a list of alternative words could still prove a disadvantage for students with dyslexia who will often have reading as well as spelling difficulties. In later reviews of his 1996 study, MacArthur (MacArthur 2006; 2009) suggests that using word processors (and spellcheck) is an added burden to the writing process and emphasizes that the writer must learn to use it effectively to reduce the burden it adds to writing.

However, among many educators, there is an assumption that spellcheck does assist with spelling accuracy and so will advantage those who use it in their writing. For example, many universities in the UK do not allow any individuals, including those with dyslexia, to use spellcheck during examinations for this reason (Connelly & Birchenough, in prep). Instead, the essays of these individuals are marked with labels requiring assessors to ignore spelling errors in the text, despite the clear

evidence of the potential for bias of having spelling errors in a text. It is not yet known how prevalent this ban on spellcheck in examinations is in other nations but a cursory search of university sites in the US does reveal similar restriction in some places (Boston University, 2019; Harvard Law School, 2018: University of Washington, 2019; University of Florida, 2019; Yale University, 2019). Thus, it is important to evaluate how effectively college students use spellcheck and what impact this has on their texts in order to provide evidence to support or deny these institutional assumptions.

Theoretical models of the writing process do include the environment of the writer, in terms of the physical and social surroundings that impact writing (for example, Hayes & Berninger, 2014). This includes acknowledgement that using a keyboard affords a physically different method of transcription to pen and paper, however, these models do not appear to account for how word processing programs, or the tools included in them, impact the writing process. The research base on revision and its place in wider models of the writing process depends largely on the writer evaluating text and detecting, diagnosing and correcting errors, including spelling mistakes (Bereiter & Scardamalia, 1987; Flower, Hayes, Carey, Schriver & Stratan, 1986; Hayes, Flower, Schriver, Stratman & Carey, 1987). While there is evidence that spelling errors can also be quasi-automatically detected by writers as they write without purposeful evaluation of a text (Hayes et al., 1987; Piolat, Roussey, Olive & Amada, 2004), current models of the writing revision process do not account for technological tools that automatically detect misspellings and can intercede to impact on the writing process by motivating the writer to correct errors. Furthermore, spellcheck could potentially change the writing process of revision by providing spelling information that the writer may not have.

Details of the spellcheck used in this study

The spellcheck program used in this study is part of MS Word 2013 (Microsoft, 2013). This version was selected because, at the time of data collection, this was used at the university where participants were recruited and therefore it was the version they were assumed to be most familiar with.

Since MS Word version 4, which was used in previously described research (MacArthur et al., 1996) Microsoft has made many modifications to its spellcheck program, such as improving algorithms used to identify target words from misspelled words, and presenting fewer options to replace the misspelled word; with the aim of making it easier for writers to identify words from the list provided by spellcheck. The most noticeable development in terms of user experience, is that spellcheck is now active during text production by default.

In the 1990s versions of spellcheck, writers needed to choose when to activate spellcheck, and once active, misspellings and options to revise them were

presented in a separate dialogue box which obscured the page of text. However, in more recent versions of MS word, or at least since MS Word 2003, in its default settings, spellcheck is active during text production and so writers today are alerted to their misspellings straight away. A red underline is displayed as an error is detected on the text being produced. Thus, writers can see the error within the context of the whole text and can revise spelling errors while the target word is still fresh in their mind. A right click on the underlined word will activate a quick menu, a small unobtrusive list of candidate replacement words. It has been recently reported that most writers leave spellcheck on the default setting (O'Rourke, 2019). However, the writer can choose to deactivate spellcheck until they wish to activate it.

Unlike some other spelling support tools, such as autocorrect or autocomplete, spellcheck does not automatically make any changes to the text other than adding the automatic underline, it still requires the writer to address the spelling errors and allows the writer to do this in their own time.

Details about how MS Word's spellcheck is exactly configured are not publicly available. However, online discussion forums on the details of the MS Word spellcheck and reviews of other spellchecks indicate that most spellchecking programs work in a very similar manner (Hanov 2011; Lawley, 2016; Norvig, 2016). Spellcheck identifies misspelled words by comparing words written to words stored in a specific dictionary. If a word does not match any entry in that dictionary, then it will be identified as a misspelling. Words that are not in the spellcheck dictionary but that are spelled correctly, and thus are misidentified as a misspelling, can be added to that dictionary.

In order to suggest the most likely candidate word to replace the misspelling, a combination of rules is used, with some rules carrying more weight than others (Damerau, 2002; Norvig, 2016). Examples of these rules are outlined here. Candidate words tend to be words from the dictionary that are similar to the misspelled word. To find the most similar words, the misspelling is compared with all words in the dictionary and the words with the smallest distance from the misspelling are put forward as the most likely candidates (Damerau, 2002; Norvig, 2016). A popular measure of the distance between words is Levenshtein distance, also called 'edit distance' (Levenshtein, 1966). Edit distance is the number of deletions, transpositions, replacements, or additions between two words. Another method for measuring distance is to code the misspelling and words in the dictionary phonetically and then compare them. The most phonetically similar words to the misspelling can be candidate words, even though they may not be the smallest edit distance from the error (for example, SoundEx algorithm, Jacobs, 1982).

Word frequency can also be used to identify the most likely candidate. For example, a more frequent word will be more likely to be selected as a candidate word than a less frequent word. Some spellcheck programs cache (store) previously

computed spelling problems and through reuse become more likely to suggest the most frequently used replacement for any given misspelling. Spellcheck programs can also contain rules about which parts of the misspelled word are likely to be correct or incorrect. For example, vowels are more likely to be incorrect than consonants in English (if using something like the SoundEx algorithm) and the beginning of a word is less likely to be incorrect than the remainder of the word. In addition, the probability that the misspelling would be caused by typing errors can be included in the decision to propose and rank candidates (Norvig, 2016).

2. The present study

Spellcheck is widely used and there is a strong assumption that its use will help those with spelling difficulties, even advantage them in some cases. Yet, there has been no recent evaluation and the very few evaluations cited here raised issues regarding the efficacy of spellcheck for poor spellers. The first aim was to evaluate the effectiveness of spellcheck in MS Word 2013 when used by college students with dyslexia, compared to college students without dyslexia of a similar age, and compared to writing without spellcheck. Specifically, what amount of spelling errors, if any, remain in texts written with spellcheck active compared to without spellcheck? Do students with and without dyslexia produce text free of spelling errors when writing with spellcheck? How many real-word spelling errors remain in the text and does this differ for those with and without dyslexia?

It was expected that when written without spellcheck, the texts by college students with dyslexia would contain more misspellings than texts written by college students without dyslexia, as demonstrated by the body of work described above. However, with spellcheck active, no significant difference between the two groups was expected. As cited above, MacArthur et al. (1996) reported that real-word errors were problematic for their sample of poor spellers and spellcheck does not recognize real-word errors as misspelled words. Therefore texts by writers with dyslexia were expected to contain more real-word errors than texts by writers without dyslexia, whether written with or without spellcheck active.

The second aim was to evaluate whether using spellcheck impacts text quality. As reported above, the research literature demonstrates that texts by individuals with dyslexia is often rated as generally poorer, even after spelling errors have been corrected. However, spelling difficulties may cause text to be poorer due to the large amount of cognitive effort involved in producing the words or revising misspellings (and even correctly spelled words), reducing the cognitive resources available for other writing processes. Therefore, it was anticipated that the essays of college students with dyslexia, written without spellcheck, would be generally poorer in quality, even after spelling errors had been corrected, in accordance with previous studies. However, in default settings, spellcheck will automatically identify misspellings and provide suggestions to more quickly and easily replace the

misspelled word, potentially reducing the cognitive burden of spelling error revision. Thus, the quality of texts written with spellcheck active was not expected to differ between the college students with and without dyslexia (after spelling errors were corrected).

3. Method

3.1 Participants

Two groups of college students studying undergraduate degrees in a British university (5 men, 13 women per group) all with English as their first language took part. The group with dyslexia (n =18, mean age of 20.33 years) consisted of participants who had previously been diagnosed with dyslexia; seven students were in their first year, five were in their second year, six were in their third year, and one in their fourth year, and they studied a range of subjects (seven psychology students, 11 students studied other subjects). Each person in the control group (n=18, mean age of 19.33 years) reported that they did not have dyslexia or any other difficulties with reading or writing. All writers in the control group were full-time first-year psychology students. The difference in mean ages between groups was significant, $t(34)=2.43$, $p=.021$. However, for adults, a difference of 1 year is very small and unlikely to cause developmental differences and so was not expected to impact the results.

An overall sample of 36 provides a suitable size for t-tests as well as for performing 2x2 mixed between-within analysis of variance tests (ANOVA's) (Pallant, 2013). Furthermore, this reflects the group sizes used in similar studies (for example, Warmington et al., 2013). All data met assumptions for the statistical tests performed.

Due to some reports of school-aged girls outperforming same-aged boys in writing-based tasks (such as Kim, Al Otaiba, Wanzek, & Gatlin, 2015 and Klecker, 2005), and because dyslexia is often reported as diagnosed in more boys than girls (Elliot & Grigorenko, 2014), writing performance was compared between the men and women. All measures were compared using independent t-tests. No significant differences were found, all t-values were below 2.

Participant measures

College students with dyslexia

Reading and phonemic awareness of students in the dyslexia group were assessed using the York Adult Assessment –Revised (YAA-R, Warmington, Stothard, & Snowling, 2012) to confirm their diagnosis of dyslexia. The YAA-R provides confidence interval boundaries (95%) based on the performance of 106 UK university students without dyslexia, which allows performance to be compared to

what is expected of UK university students without dyslexia. The mean scores for reading and phonemic awareness of the dyslexia group indicate that this group has poorer mean performances than is expected of 95% of a population without a history of reading or writing difficulties.

Students with dyslexia also completed a nonverbal reasoning task measured using Block Design Matrix Reasoning from the Wechsler Adult Intelligence Scale 4th edition (WAIS-IV, Wechsler, 2008) as a measure of cognitive reasoning that does not involve phonological awareness, but poor performance can indicate other difficulties not associated with dyslexia. All students with dyslexia performed within 1 SD of the mean for non-verbal reasoning. Therefore, we can be confident that the students with dyslexia have specific difficulties with literacy but are no less competent in nonverbal reasoning than expected for their age.

All participants

To estimate spelling ability and to confirm that the group with dyslexia did indeed have poorer spelling than their peers, all participants completed the dictated single-word spelling task from the Wide Range Achievement Test (WRAT 4, Robertson & Wilkinson, 2006). The WRAT 4 was chosen because it is widely used in the field of dyslexia research and is designed to fully assess adults' spelling competence with little chance of ceiling effects in groups of college students. This test was normed on a US population but this was not considered problematic as the test was for comparison purposes only since the students with dyslexia all had a current diagnosis of dyslexia based on psychometric testing (in accordance with the university policy, Oxford Brookes University, 2019) and we confirmed their difficulties with literacy using tests from the YAA-R. It was more important to have a sensitive test that could differentiate college students with dyslexia, who often perform at levels above the average of the population for their age, from their peers without dyslexia, who generally perform better. The green form of the test was used, with reported alternate form immediate retest reliability coefficients that ranged from .78 to .89 (Robertson & Wilkinson, 2006).

Data are at the ratio level, normally distributed with a suitable sample size for an independent t-test. Students with dyslexia scored significantly lower on the dictated spelling task than students without dyslexia. Thus, we can be confident that the students with dyslexia were indeed poorer spellers than the comparison group of students without dyslexia.

Typing speed and accuracy of all participants were also measured, not as an indication of dyslexia, but in case typing speed impacted writing performance. The two-minute copy task from the YAA-R was used. Typing speed was measured as keys pressed per minute. Typing accuracy was initially measured as the percentage of incorrect characters. However, this measure was heavily influenced by writers repeatedly missing words, so the scores were adjusted to not include repeatedly

missed whole words. Typing data are at ratio level, normally distributed with a suitable sample size for independent t-tests for all typing data except the proportion of typing errors, which was positively skewed as many texts contained no errors, thus, in this case, a Wilcoxon signed rank test has been reported instead. Writers with dyslexia typed more slowly, deleted fewer characters and made fewer typing errors than the control group. The results of all participant measures are displayed in Table 1.

3.2 Materials

Participants used MS Word 2013 to write two short essays, one with spellcheck activated and one without. In the spellcheck condition, spellcheck was left in its default settings to underline misspellings as they were made. For the no spellcheck condition, spellcheck was deactivated. Writers were told whether spellcheck would be available or not before they began each essay.

Each essay was written in response to a writing prompt taken from the analytical writing measure of the Graduate Record Examinations (GRE) of the revised general test (Educational Testing Service, 2010).

Table 1. Participant measures

Ability measured	Measure details	Group with dyslexia (n=18) Mean (SD)	Control group (n=18) Mean (SD)
Spelling score	Out of 42	26.83(3.99)	32.72 (2.11)**
Typing Speed	Characters typed per min	224.88 (68.95)	335.83 (124.00)*
Typing Accuracy	% characters kept in product	94.86 (4.71)	85.30 (7.11)**
	% errors in the product, adjusted	0.37 (0.72)	0.17 (0.16)
Reading	Total time (s)	225.50 (38.06)	-
	Rate (wpm)	134.49 (22.61)	-
	Accuracy	480.44 (4.44)	-
Phonemic awareness	Rate (s per correct trial)	6.62 (3.52)	-
	Accuracy (out of 24)	19.39 (3.20)	-
Non-verbal reasoning	Raw	18.11 (1.94)	-
	Scaled	9.50 (1.26)	-

*p<.01**p<.001

Writing prompts for the GRE are designed to reflect the kind of thinking required in graduate school and is a test taken by prospective graduate school applicants interested in pursuing a master's, or doctoral degree (Educational Testing Service, 2010). It is therefore an age and ability appropriate choice of writing activity.

Each prompt has been piloted with GRE test-takers to ensure that: regardless of their field of study or special interests, writers each understood the task and could easily respond to it; the task elicited complex thinking and persuasive writing; the responses were varied in content and in the way the writers developed their ideas (Educational Testing Service, 2010).

3.3 Procedure

The following task instructions were given verbally before each writing prompt was displayed:

> "The purpose of this task is to measure writing skills. An essay question will appear at the top of the screen, I will read this aloud and then you will have the opportunity to ask questions before you begin writing. You will then have 15 minutes to write your response to the essay question. Your response will be scored on the content, your ideas and how well you support these ideas; as well as spelling and vocabulary. Do you have any questions?"

The two writing prompts used were as follows:

1. "Educational institutions should dissuade students from pursuing fields of study in which they are unlikely to succeed.

   Write a response in which you discuss your views on the policy and explain your reasoning for the position you take. In developing and supporting your position, you should consider the possible consequences of implementing the policy and explain how these consequences shape your position."

2. "As people rely more and more on technology to solve problems, the ability of humans to think for themselves will surely deteriorate.

   Discuss the extent to which you agree or disagree with the statement and explain your reasoning for the position you take. In developing and supporting your position, you should consider ways in which the statement might or might not hold true and explain how these considerations shape your position."

Each prompt, presented in an MS Word document, was read aloud and remained at the top of the document as participants typed. Participants wrote for 15 minutes per prompt, then were provided with the other prompt in the other condition. A time limit was used to reflect exam conditions where writers have limited time to produce their texts. Time pressure during examinations is problematic for many undergraduates (Connelly Dockrell & Barnett, 2005). Controlling how long

participants typed also helped to make texts comparable between participants. Prompts were counterbalanced across conditions (spellcheck on and spellcheck off) and order presented for each group.

3.4 Measures

The following four aspects of each essay were measured.

Misspellings

The number of misspelled words in each of the final texts produced after 15 minutes was counted and measured as a percentage of the total number of words. This was to reduce the effects of text length. Only incorrectly spelled words were included in this count, real-word errors were not included in the the number of misspellings.

Real-word Errors

Words that were spelled correctly, but used incorrectly, were counted separately from misspelled words. The amount of real-word errors has been reported as a percentage of total words. Table 2 includes typical examples of real-word errors found in the essays.

Table 2. Typical examples of real-word errors

Participant, condition	Original text	Correct text
Dyslexia, no spellcheck	… we are more able to fully understand the problem rather *then* the idea that…	… we are more able to fully understand the problem rather *than* the idea that…
Dyslexia, spellcheck	…the majority of the time it corrects automatically but also *are* time is no longer consumed by…	…the majority of the time it corrects automatically but also *our* time is no longer consumed by…
No dyslexia, no spellcheck	…shows that humans' ability to think for themselves *with* deteriorate,…	…shows that humans' ability to think for themselves *will* deteriorate,…
No dyslexia, Spellcheck	…there is a huge shortage of women which has *lead* to a shortage of engineers…	…there is a huge shortage of women which has *led* to a shortage of engineers…

NB. The real-word errors and corrected words have been italicized for illustrative purposes.

Word Count

The number of words in each essay was counted.

Essay Quality Rating

The essays were evaluated using the GRE scoring overall quality (Educational Testing Service, 2019). Essays were scored on the ability to reason, assemble evidence to develop a position and communicate complex ideas, and the grammar and the mechanics of writing. Each essay was scored on a scale of 1-6 in increments of .5. Spelling accuracy would usually contribute to the scoring as part of mechanics; however, essays were scored after spelling errors and real-word errors, were all corrected. The quality of essays was scored by one rater using the GRE analytical writing rubric (Educational Testing Service, 2019). A second rater scored a sample of 20 essays. Raters showed a very good degree of reliability, the average measure of intraclass correlation was .910, which indicates that the two raters agreed 91% of the time, with a 95% confidence interval level boundary from .773 to .964, $F(19,19)=1.11$, $p<.001$.

4. Analysis

ANOVAs (mixed within-between) have been used to investigate main effects of group and of condition (spellcheck) and the interaction. T tests have been used occasionally to compare mean values between groups (independent t tests) or between conditions (paired samples t-test). The type and number of data is suitable for these tests and is tolerant of violations of normality (skew and kurtosis) (Pallant, 2013). The variance of data has been measured using Levene's test of equality of error variances and has been found non-significant for all ANOVAs and t-tests. Results have been reported as significant if the alpha level is below .05. Effect sizes for ANOVA tests and t-tests have been reported as partial eta squared (ηp2) and interpreted using guidelines proposed by Cohen (1988, cited in Pallant, 2013) where .01= small effect, .06=moderate effect, and .14=large effect. Some correlations have been carried out between some measures from the essay task and participant measures described earlier, normality tests indicate that Pearsons *r*, is the most suitable correlation in these cases.

5. Results

Misspellings

In the analysis conducted on the percentage of misspelled words in text, as expected main effects and the interaction between spellcheck and group were significant. Without spellcheck, students with dyslexia, who are poorer spellers, produce texts that contain a significantly higher percentage of misspelled words (4.35%) than the texts produced by students without dyslexia (0.82%), $t(34)6.18$, $p<.001$, large effect size of ηp2=.57. When spellcheck is active, texts written by students both with and without dyslexia contain almost no errors (0.03% by

students with dyslexia, and 0.17% by students without dyslexia $t(34)=2.34$, $p=.025$, moderate effects size ηp2=.06). Thus, spellcheck improves spelling accuracy for both groups (with dyslexia $t(17)=7.95$, $p<.001$ ηp2=.79; without dyslexia $t(17)=3.56$, $p=.002$ ηp2=.43). Despite the data from MacArthur et al. (1996) indicating that students with spelling difficulties may struggle to produce texts free from spelling errors using spellcheck, the writers with dyslexia produced text with almost no spelling errors. There is a significant interaction between group and condition as, because of spellcheck, students with dyslexia decreased the amount of spelling errors in their texts more than the control group did.

There was a significant correlation between spelling ability on the WRAT-4 task and the percentage of errors in texts produced without spellcheck across all participants demonstrating that the poorer the WRAT-4 spelling score, the more spelling errors there were in text, $r=-.649$, $N=36$, $p<.001$. However, with spellcheck active, spelling ability on the WRAT-4 task no longer correlated with the amount of spelling errors in text, $r=.195$, $N=36$, $p=.255$.

Table 3. Means, standard deviations and ANOVA results for all measures

Measure	Students with dyslexia		Control group		ANOVA results C=Condition G=Group I=Interaction	ηp2 (effect size)
	No spellcheck M(SD)	Spell-check M(SD)	No spellcheck M(SD)	Spell-check M(SD)		
Spelling error percentage	4.35% (2.29)	0.03% (0.12)	0.82% (0.79)	0.17% (0.23)	C: $F(1,34)=75.24$** G: $F(1,34)=34.44$** I: $F(1,34)=41.23$**	.689 .503 .584
Real-word error percentage	0.39% (0.48)	0.98% (0.88)	0.35% (0.34)	0.32% (0.38)	C: $F(1,33)=4.57$* G: $F(1,33)=2.14$* I: $F(1,33)=18.05$*	.122 .167 .629
Essay word count	289.14 (94.62)	271.72 (84.06)	289.72 (81.81)	303.08 (94.13)	C: $F(1,34)=0.01$ G: $F(1,34)=0.65$ I: $F(1,34)=2.75$	.015 .007 .103
GRE score	3.06 (0.64)	3.33 (0.77)	3.11 (1.02)	3.39 (1.09)	C: $F(1,34)= 2.68$ G: $F(1,34)=0.05$ I: $F(1,34)=0.00$	.073 .001 0.00

*$p<.05$, **$p<.01$

Real-word Errors

The percentage of real-word errors by writers with dyslexia when spellcheck is active is larger than any other condition and this caused significant main effects for group and condition and a significant interaction, all with large effects sizes. This was not expected. In terms of the actual number of real-word errors, this represented 2-3 real-word errors per text by students with dyslexia using spellcheck, and about 1 real-word error per text in other conditions.

Word Count

The essays written averaged a little under 300 words long and the word count was not impacted by spellcheck condition. Word count of texts produced in either condition does not correlate with typing speed as measured by YAA-R (spellcheck r=.18, N=36, p=.289; no spellcheck r=.06, N=36, p=.735).

Essay Quality

Spelling errors and real-word errors were corrected, and essays were rated for quality. No differences were found in writing quality between the groups with or without spellcheck active. Spelling ability, as measured by the WRAT-4, did not correlate with the writing quality scores for either group in either spellcheck condition (dyslexia spellcheck, r=.21, n=18, p=.400; no spellcheck, r=.21, n=18, p=.400; no dyslexia spellcheck, r=-.36, n=18, p =.144, no spellcheck r=-.12, n=18, p=.632).

Interestingly, the percentage of misspelled words in the original texts (without spelling errors corrected) does not correlate either with the quality of the text produced with (r=.001, N=36, p=.994) or without spellcheck (r=-.043, N=36, p=.804) across all participants. Thus, while spellcheck reduced the number of misspellings, it does not seem to impact the quality of text in other ways.

6. Discussion

6.1 Findings in context

This study is the first to evaluate the effectiveness of the technological tool spellcheck for MS Word 2013 for college students with and without dyslexia. An evaluation of the use of spellcheck had not been carried out for many years despite quite significant changes to the tool, and so was long overdue. One of the very few previous studies on the use of spellcheck indicated that writers with a spelling difficulty may have problems with the identification and correction of spelling errors even when using spellcheck (MacArthur et al., 1996). However, the current study can now report that spellcheck, as part of MS Word 2013, enables college students both with and without dyslexia to produce texts almost wholly free from

spelling errors. This is quite different from the poor spellers in the MacArthur et al. (1996) study. As expected, when students with dyslexia wrote essays without spellcheck active, their essays contained significantly more misspelled words than texts by their peers without dyslexia. However, when spellcheck was active, both groups produced text with almost no spelling errors. This is a very positive finding and confirms the efficacy of this technological tool to assist undergraduate level students with dyslexia.

There was no significant difference in text quality between groups. Unlike some previous studies the essays written by the students with dyslexia were not rated poorer in overall quality without spellcheck after being corrected for spelling errors. Furthermore, neither spelling ability or quantity of misspelled words correlated with text quality for either group, thus poor spelling did not appear to have a relationship with text quality beyond the number of misspelled words.

The college students with dyslexia in this study made a similar amount of misspellings (4.35%) as reported in other studies where college students with dyslexia used writing prompts from GRE (in handwriting studies; Connelly et al., 2006; Sumner et al., 2020.). This is much lower than the 11-14-year-olds in McArthur et al.'s (1996) study who wrote texts made up of 13.4% misspelled words. This difference is likely due to age related factors, for example, younger children with dyslexia, aged 9 years, in Sumner, Connelly and Barnett (2016) made even more misspellings at 21% of text (compared to 4% by an age matched group). College students with dyslexia may also be a group of students who succeed in reaching Higher Education due to having a milder spelling difficulty.

Using spellcheck, the college students in the current study, with and without dyslexia, corrected almost all of their misspelled words, whereas the young writers in MacArthur et al.'s (1996) study only corrected approximately 58% of their misspellings even though 100% were identified as misspellings by spellcheck. Microsoft Word 2013 (Microsoft, 2013) may contain a more effective version of spellcheck than Microsoft 4.0 (Microsoft, 1989) and developments to spellcheck in MS Word, as described in the section 'details of the spellcheck used in this study', are likely to have contributed to the improved performance in the current study. One of the most noticeable differences in user experience between spellcheck in MS word 4.0 and in MS Word 2013 is that, in the default settings of MS Word 2013, spelling errors are automatically underlined as soon as they are on the page, thus writers are alerted to them straight away. Therefore, writers today are more likely to revise their spelling errors as part of the writing process rather than as a separate stage after producing the whole text like the writers in MacArthur et al. (1996) did.

Spellcheck in MS Word 2013 may be better at suggesting the target word than spellcheck in MS Word 4. Alternatively, the errors made by college students may be closer to the target word than the misspellings by writers in MacArthur et al.'s (1996) and Pedler's (2001) studies, who were younger and not confirmed to have dyslexia.

Because of the way that spellcheck works, the misspelled words need to be similar to the target word for spellcheck to correctly suggest similar words. Pedler's (2001) results indicated that approximately one quarter of the misspellings in her sample were too far from the target word for spellcheck to suggest the correct word. Furthermore, MacArthur et al. (1996) found that spellcheck failed to suggest the target word for 41.6% of identified misspellings. However, a study investigating autocorrect when used by UK college students with dyslexia (Hiscox, Leonaviciute and Humby, 2014) found that it corrected large proportions of their misspellings. Importantly, for autocorrect to do this, the misspelled words must have been very similar to the target word and far from similar words. College students with dyslexia may tend to produce misspellings close enough to the target word for spellcheck to present the target word in the replacement candidate list, thus this group can make good use of spellcheck. It is possible that college students with dyslexia have a milder difficulty than other individuals with dyslexia who do not succeed in public examinations in the UK and reach university.

Without spellcheck active, roughly one word in every 300 was a real-word error in essays by writers with and without dyslexia, which is fewer than the younger writers in MacArthur et al.'s (1996) sample with roughly 15 in every 300 words. Because writers with dyslexia did not make more real-word errors than the control group, this indicates that the cause of their real-word errors may not be wholly related to spelling ability, but could instead be due to errors in word selection, or typing, or other factors unrelated to dyslexia. It is not easy to distinguish a cause from the errors alone. For example, one writer used the word 'moral' when the appropriate word choice was 'morale', this could have been due to mistyping, misspelling or poor word choice. Furthermore, the occurrence of real-word errors is so low that the data are not suitable for correlations with typing or spelling abilities to investigate possible causes.

Spellcheck had no impact on the amount of real-word errors found in texts by writers without dyslexia. However, with spellcheck, writers with dyslexia increased the amount of real-word errors to 0.98% of total text. This increase may indicate that writers with dyslexia might occasionally select the wrong word from spellcheck's candidate list to replace the spelling error, thus increasing the amount of real-word errors in their texts. The clearest example of this is from text produced by a writer with dyslexia: '*In my experience it is rare to see anyone writing down equations or attempting mental arrhythmia*.'. In this case, it is likely that the target word is '*arithmetic*' but has been accidentally replaced with '*arrhythmia*' via spellcheck.

This confirms to some extent the results from MacArthur et al. (1996) and Pedler (2001) that poor spellers may have difficulties identifying the target word from a list of similar words and accidentally select the wrong word from the list. Alternatively, poor spellers may fail to properly read the first suggested word before clicking on it (and after inserting into text). While spellcheck is not effective for real-word

errors, other software is available to compliment spellcheck by focusing on identifying real-word errors and draw the writer's attention to these. It is important to note that the number of real-word errors made by college students with and without dyslexia is much lower than found by MacArthur et al., (1996) who found 5 times this number. Real-word errors do not seem to be particularly problematic for college students with dyslexia.

The current study demonstrates that spellcheck enables writers with and without dyslexia to produce texts free from spelling errors. Importantly, spellcheck does not appear to impact text quality beyond spelling accuracy. There is general agreement that to revise spelling errors, the writer must possess sufficient spelling knowledge (Hacker et al., 1994; Hayes, 2004) and writers who do not possess sufficient spelling knowledge are therefore poorer at revising their spelling errors. However, in practice, when writers use word processing programs (which is often expected of college students) spellcheck is available to assist with revision. Importantly, this study indicates that spellcheck facilitates successful spelling error revision for college students with and without dyslexia.

6.2 Practical implications

Spellcheck supports spelling revision and this has a particularly large impact on texts by writers with dyslexia. Previous research indicated that writers have limited success using spellcheck to revise their spelling errors (MacArthur et al., 1996). However, in the current study writers with dyslexia revised almost all of their spelling errors when they had access to spellcheck, even though their proportional baseline level of misspellings meant revising larger numbers of misspelled words than the control group. Concerns that spellcheck is not useful during initial production (Berninger et al., 2008) are still valid and untested, however, the final products demonstrate that writers with dyslexia are at least capable of successfully revising their spelling errors with spellcheck.

Furthermore, the proficient spelling revision demonstrated here means that we need to recognize that, with the appropriate technological tool, college students with and without dyslexia are equally capable of producing texts without spelling errors. Even under time pressure, the writers in the current study corrected almost all of their misspellings. Thus, while additional time may allow writers to improve the quality of their texts, if spellcheck is available and encouraging revision during text production, then spelling accuracy is likely to be high even when writing under time pressure without reducing the text quality.

Text quality was measured using essays with corrected spellings. Neither spellcheck nor group had any effect on text quality. Thus, writing with spellcheck supports spelling revision and interestingly, spellcheck does not appear to impact text quality beyond spelling accuracy. While this may be seen as reason to provide spellcheck to college students with dyslexia, it should be noted that college

students without dyslexia also increased the accuracy of their spellings. If spelling contributes to grades, then any writer not using spellcheck is at a disadvantage compared to those writing with spellcheck active. The purpose of exams is not usually to monitor the accuracy of spelling, but unfortunately spelling errors do influence readers judgements of quality (Figueredo & Varnhagen, 2005; Johnson et al., 2017; Marshall & Powers, 1969). All college students should be made aware of the impact that spelling has on judgments of text quality and be given the option to use spellcheck in writing that contributes to academic achievement.

Writing in word processing programs is available to some college students with dyslexia but is not typically available to all students under exam conditions in UK universities. The intention of providing word processing programs (and sometimes spellcheck) is to provide support for writers with dyslexia. However, if most college students are typically used to writing with word processing programs with spellcheck active then writing without it is an unfamiliar writing experience for them. Thus, there could be some concern over whether removing the familiar writing tools is putting some students at a disadvantage when instead we should be focusing on better supporting writers with dyslexia.

6.3 Theoretical implications

With spellcheck active, writers do not need to rely on their own spelling knowledge in the same way as they do when spellcheck is not available. Thus, with spellcheck, poorer spelling knowledge does not impede the writer's ability to successfully revise spelling errors. Spellcheck changes how we revise by alerting writers to the potential errors and providing words that the writer can use to replace the error, the writer needs only to read and recognize the target word and it increases spelling accuracy. Generally, with spellcheck, writers with and without dyslexia are equally capable of producing texts without spelling errors. This means there is a gap between theory and practice, especially concerning writing by individuals with dyslexia.

To address this gap, spellcheck needs to be recognized as part of the writing environment and become part of the way we conceptualize writing processes. Revision models are useful as a guide for revision processes, for example, the writing model by Hayes and Berninger (2014) encompasses writing processes and indicates relationships between processes involved in writing and the writing environment. It is suggested that spellcheck should be incorporated into the writing environment level of Hayes and Berninger's (2014) writing model. Their writing environment includes text-written-so-far, task materials, transcribing technology and collaborators and critics, none of which currently account for spellcheck. Collaborators and critics refer to social factors in the immediate physical environment that influence the writing process. More specifically, it means people in the presence of the writer. Spellcheck is not a person and is not physically

present. However, it identifies spelling errors, acting as a critic, and the select and replace function assists with revision, acting as a collaborator. Spellcheck could potentially be accounted for by Hayes and Berninger's writing model as part of collaborators and critics, if the writing environment is expanded to include spellcheck.

It is worth noting that spellcheck does not fit into transcribing technology. Transcribing technology only refers to the physical implements used for text production that dictate the method of transcription, pens and pencils for handwriting or keyboards for typing (Hayes & Berninger, 2014). Spellcheck does not change the method of transcription.

6.4 Limitations

It was assumed that a small age range (18-22 years old is a relatively small age range for adults) would be sufficient to prevent one group from having a meaningful advantage in writing skill/experience over the other. However, although mean ages only differed by 1 year, the dyslexia group included many students who had been attending their undergraduate course for one to two (and for one student, three) years more than the control group, who were all in their first year. This increased experience of writing at college level may have increased the general quality of their writing and so, while texts by writers with dyslexia tend to be poorer than texts by their peers (Connelly et al., 2006; Sumner et al., n.d.; Tops et al., 2013), in the current study writers with dyslexia produced text of equal quality to a group of less experienced writers. Even faster typing by the writers without dyslexia did not give them an advantage over the writers with dyslexia. Closer matching for age and writing experience in the control group would have avoided this issue. In addition, the impact of spelling ability on text may have been better investigated by comparing writing to spelling ability matched groups. However, spelling matched writers would likely be younger, with little or no experience writing at undergraduate level. When Sumner and Connelly (2020) matched their group with dyslexia (aged 20 years old) with a spelling ability-matched group, these were 13 years old, midway through secondary school. Thus, a spelling matched group would be quite disadvantaged in terms of writing experience.

The study was carried out in English; it is not known how effectively spellcheck supports revision in other orthographies. Furthermore, college students with dyslexia can be considered a subgroup of adults with dyslexia (Coleman, Gregg, McLain, & Bellair, 2009). They are academically inclined and capable of keeping up with the writing demands placed on undergraduates. Thus, findings are best generalized to college students rather than the broader population. However, college students are regularly expected to complete long, well-formed texts using word processing programs, typically assumed to be used with spellcheck. Thus,

research into spellcheck and writing is particularly pertinent for this group, whose academic achievements are heavily influenced by written work.

6.5 Indications for future developments

It seems necessary to establish whether spellcheck is a part of the everyday writing environment not just for more accurate generalizability but also to best conceptualize the environment and processes involved in everyday writing. Linked to this idea, investigation into familiarity with spellcheck for younger writers would help to uncover whether including spellcheck into typical everyday writing shapes how we write. For example, do we place less emphasis on production of correct spellings if we are used to correcting them easily with spellcheck? Does this impact other areas of writing, such as revision strategies and word choice? Furthermore, if writing with word processing programs and spellcheck are part of everyday writing and influence how we write, for most effective writing, should writing with word processing programs be taught explicitly, in the same way that handwriting is (not just touch typing, but incorporation of writing tools), and how?

Investigation into the use of spellcheck in exams and university policy is needed. It is important to establish an evidence for such policies. Comparison of grades given to exam scripts by students who handwrite, type without spellcheck or type with spellcheck, may indicate any trends that might support or draw into question university policies on using spellcheck. An investigation using real exam scripts would have strong ecological validity, however it is important to also use the same exam scripts with corrected spellings to check for influence of spelling errors. Such studies could lead to recommendations for students regarding use of spellcheck in exam conditions and also recommendations for markers. For example, students may be advised to use word processing programs with spellcheck for their exam responses. Markers are currently advised not to take spelling errors into consideration if students have difficulties with spelling, however studies such as this could indicate whether this advice successfully prevents spelling errors from affecting markers judgements.

It would be interesting to use behavioral data, such as keystroke logging, to find out how writers incorporate spelling revision into text production and the role of spellcheck in that. For example, keystroke logging would allow examination of the role of the automatic underlining that occurs during writing and whether it impacts when writers respond to spelling errors. For a detailed description of keystroke logging see Vandermeulen, Leijten & Van Waes (2020, this special issue). Furthermore, while writers with dyslexia are equally capable of producing texts free from spelling errors as a control group are, real time data could indicate whether achieving this is more difficult and time consuming for writers with dyslexia.

The spellcheck in Microsoft Word 2019 (the latest version at the time this paper was written) proposes a shorter replacement list (3 words) and most words that

appear on the suggestion list are accompanied by synonyms, allowing the writer to check the meaning of the word before selecting it potentially reducing the possibility of mistaking similar looking words for the target word. Further research should investigate whether these developments in spellcheck are reducing problems experienced with older versions, such as the number of real-word errors in texts. In fact, as spellcheck and other aspects of the typical writing environment are modified, further research is required to keep the field of writing research up to date with the day to day experiences of writers. Emerging writing support software must be investigated for all populations and should be evaluated in terms of how well it supports good writing practices (writing behavior and text quality). Other studies in this special issue have evaluated a range of writing support software for college students (Benetos & Bétrancourt, 2020 - this special issue; Cotos, Huffman & link, this special issue; Luna, Villalón, Mateos & Martín, this special issue;), secondary school students (Vandermeulen et al, this special issue; Palermo & Wilson, 2020 - this special issue), and children (Carvalhais, Limpo & Richardson, 2020 - this special issue). Writing support should benefit users and may particularly benefit certain populations. Research into writing support software will highlight where and how it can be improved for writers.

7. Concluding remarks

This study confirms that spellcheck does facilitate spelling revision. This enables writers with and without dyslexia to improve their spelling accuracy and produce texts free from spelling errors. Writers with dyslexia use spellcheck to successfully revise almost all of their spelling errors. They may occasionally replace misspellings with words suggested by spellcheck that do not match the target word, but this appears to be quite rare. Spellcheck is often part of the writing environment and clearly changes how writers revise their text, having a particularly positive impact on the spelling accuracy of texts by writers with dyslexia. Thus, spellcheck needs to be accounted for in the environmental levels of writing models. Apart from spelling accuracy, spellcheck does not appear to impact text quality, thus it does not provide any additional advantage or disadvantage if used in exam conditions.

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