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RESEARCH ARTICLE

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How do technologies meet the needs of the writer with dyslexia? An examination of functions scaffolding the transcription and proofreading in text production aimed towards researchers and practitioners in education

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Technological reading and writing tools can help students with dyslexia improve their writing, but students do not use reading and writing functions as much as expected. However, research addressing relevant technological functions is scarce. This study explored the needs of writers with dyslexia and how technological writing tools developed for three Nordic languages meet these needs. Snowball sampling was used to identify different technological features, spellchecker, word prediction, auto-correction, text-to-speech and speech-to-text functions available in nine widely used programmes were investigated. The results indicated that students with moderate spelling difficulties can now achieve accurate spellings using the most sophisticated spelling aids; however, most of these features require time and attention, and this can disturb writing fluency and hamper text production. The implication of this study is that the underlying conflict between spelling accuracy and writing fluency must be actively managed, which necessitates competence in the use of technological tools for both students and teachers in school. Also, further development of tools for scaffolding transcription must consider the dilemma of achieving both writing fluency and spelling accuracy. Further, the accuracy of the aid for students with severe spelling difficulties remains unclear and must be investigated.

KEYWORDS
assistive technology, dyslexia, spelling accuracy, writing fluency

Practitioner Points

- Students with dyslexia need an accurate spelling tool and opportunities to achieve text production fluency.
- In available writing technology, there is a dilemma in terms of the relationship between accuracy and fluency.
- It is necessary to pay attention to the ways in which technological writing tools influence the writing process.
- It is possible and necessary to choose and adjust writing programmes according to the writer's writing difficulties and personal preferences.

1 | INTRODUCTION

Although technological writing tools can help writers with writing difficulties such as dyslexia (Adebisi et al., 2015; Batorowicz et al., 2012; Morphy & Graham, 2012; Nelson & Reynolds Jr, 2015; Svensson et al., 2021), Danish and Norwegian reports show that fewer students than expected use the reading and writing technology available in schools (Arnbak & og Klint Petersen, 2016, Mossige et al., 2021). There are many reasons for its limited use, including the availability of technology and technical support, instruction, stigmatisation and individual preferences (Svendsen, 2016a). Further, factors related to technological writing aids are also important. In this article, the needs of a writer with dyslexia during text transcription are discussed, and subsequently, different features in various Nordic writing aid programmes are examined to determine how and to what extent these needs are met.

Writing is a complex and resource-intensive activity requiring a writer to master several skills. Berninger (2000); Berninger et al., 1996; Berninger et al., 2002) describes the writing activity in her 'simple view of writing' by dividing it (1) *transcription*[1] (spelling, handwriting and keyboarding), (2) *executive functions* (planning, composing and reviewing the text) and (3) *text generation* (generating ideas and translating those ideas into language). According to Berninger, these three components cooperate to create text and compete for the limited resources of the working memory of the writer (Berninger & og Amtmann, 2003). For students with dyslexia, accurate and fluent spelling is the main problem in writing (Rose, 2009). Keylogging studies have shown that writers with dyslexia are extremely concerned about spelling when writing text: they write slowly, pause within words and phrases (Wengelin, 2002), focus on the word currently being written (Wengelin, 2007) and devote a substantial proportion of their editing work to correcting spellings (Torrance et al., 2016). Berninger and og Amtmann (2003) claimed that transcription demands many of the limited resources in the working memory of the writer when writing if spelling is not automatized, leaving few resources for text generation and executive functions. Therefore, the first need of the writer with dyslexia is a technological tool that can help ensure accurate spelling.

Many technological writing tools support spelling, such as spellcheckers, word prediction, autocorrection, text-to-speech and speech-to-text functions. Morphy and Graham (2012) demonstrated that writing using a word processor outperformed writing by hand in terms of writing quality, text length, development and organisation of the text, in addition to mechanical correctness and writing motivation, for all students. Using a meta-analysis, Perelmutter et al. (2017) revealed that assistive technology interventions have a large positive effect on writing error rates for adolescents and adults with learning disabilities. However, Svendsen (2016a) found that the abovementioned spelling tools were not always suitable for students with dyslexia. Students with dyslexia can also make different types of spelling mistakes compared to writers without dyslexia, such as homonyms, other real-word errors and compound words (Rønneberg et al., 2018; Moats, 1996; Rello et al., 2012; Tops et al., 2014). Therefore, these students have different needs for spelling aids than typically developing writers. Both Pedler (2007) and Rønneberg et al., (2018) claim that writers with dyslexia need a tool that provides more accurate spelling suggestions, indicating the need to address currently available technological tools.

In her doctoral thesis, Svendsen (2016a) observed her informants, students with large spelling problems employing time-consuming strategies: When having no idea about how a word was spelled, the students used the text-to-speech function together with a search process. This process consisted of four steps: (1) Finding the word in the word-prediction bar, from the words suggested by the spellchecker function, in a resource text or in Google search results. (2) Checking if it is the correct word by listening to it being read aloud using text-to-speech. (3) Copying the word and (4) Editing the word into one's own text (Svendsen, 2016a, p. 177). In addition to being time-consuming, this process also demands attention, which may disturb other aspects of writing, as described further down in the text. Even the 'normal' use of technological writing tools is time-consuming when there are many misspellings, for example, when writers have to choose from a list of similar suggested words (Rønneberg et al., 2022) or listen to suggestions. The second need for writers with dyslexia is a rapid spelling aid.

A spellchecker that pinpoints misspellings with red underlines provides negative feedback for all writers; however, it can appear particularly negative for students with dyslexia who make many misspellings (Rønneberg et al., 2018). Therefore, a spelling aid that does not pinpoint misspellings during transcription is the third need for writers with dyslexia.

However, struggling with spelling also seems to be related to the poor overall text quality of writers with dyslexia (Connelly et al., 2006; Tops et al., 2014; Torrance et al., 2016). Both *text generation* and *executive functions* can be affected because of hyper-focusing on spellings (Berninger et al., 2008). During writing, an essential part of meaning construction occurs simultaneously with transcription (Rønneberg et al., 2022; Torrance et al., 2016), creating high demands on the working memory. Thus, the writer needs to remember what has been written while simultaneously planning to produce a coherent text (Rønneberg et al., 2022) and consider the purpose of writing, genre conventions, the reader and so on. Writers who struggle with spelling may lose the grip of their reasoning when searching for the correct spelling of a word (Mossige et al., 2012) or become uncertain (MacArthur, 2006). Rønneberg et al. (2022) found that fluent transcription[1] appears to be more important for the writer than accurate spelling to achieve text coherence.

As attentional difficulties often occur concurrently with dyslexia (Rose, 2009), some students are more likely to be easily disturbed than others by flashing word suggestions or red underlining during transcription. This is further emphasised when spelling suggestions appear at the same moment a word is written, or immediately thereafter (Rønneberg et al., 2018). However, O'Rourke et al. (2020) found that text quality, besides spelling accuracy, was not affected using a spellchecker when college students wrote shorter texts. In addition, Rønneberg et al. (2022) found

[1]Writing fluency is a process-based measure defined as writers' ability to produce texts in large chunks or spans, and it is optimally measured using the length of writers' translating episodes or production units (Abdel Latif, 2013). Writing fluency can also be measured by key-press latencies (the pause between each key press when writing on the keyboard). Torrance et al. (2016) report longer within-word and pre-word latencies for weak decoders than those for a control group.

few connections between less fluent writing and text quality among writers without dyslexia. However for writers with severe spelling difficulties, it could be difficult to achieve writing fluency because they cannot spell or read their own 'text written so far' without continuous support from text-to-speech, word prediction or spellchecker functions (Svendsen, 2016a, 2016b). Thus, the fourth need of writers with dyslexia is a technological tool that supports writing fluency or one that does not disturb the writer.

Revision is an important aspect of text production (Harris et al., 2008; Kellogg, 1996). Students with learning disabilities spend more time revising at the word level (proofreading) and less time revising meaning and content than their typically achieving peers (Graham et al., 2013). Owing to the number of misspellings and problems that students with dyslexia may struggle with, the writer could become exhausted and/or lose motivation to perform revisions at higher text levels. A tool with an accurate and fast spelling aid that does not disturb writing fluency can help a writer with dyslexia to not be more exhausted by the writing process compared to a writer without dyslexia; such a tool could thus provide a motivational surplus that will entail more revisions at higher text levels.

In their review of assistive technology interventions, Perelmutter et al. (2017) found mixed results concerning the use of different tools for different users and claimed that interventions need to be customised to the individual. This means that writers with dyslexia fifthly need a more easily adaptable tool.

In their review, Perelmutter et al. (2017, p. 160) addressed several research gaps regarding the effectiveness of contemporary word processing in adolescents and adults with learning difficulties specific to reading, writing and mathematics. This review addresses the question about how well the design of technological tools is adapted to the needs of students with dyslexia during text production, particularly for the special needs of students with dyslexia: a rapid and accurate spelling aid also for 'difficult' misspellings that are easy to customise for each user, and one that does not disturb writing fluency by demanding attention, for example, by pointing misspellings. Writers with dyslexia also require proofreading support.

The research question is as follows: How does Nordic reading and writing technology meet the needs of writers with dyslexia during the transcription and proofreading of text production?

To answer this research question, we examine how these needs are met based on the design and properties of different assistive writing programmes and the functions of writing tools widely used in education in Danish, Norwegian and Swedish. Analysing several tools from three different countries can provide us with a broader picture of what is possible and common, and we believe that the findings could be applied to tools from other countries that do not use English. We target programmes for students who have completed early literacy training (9 years and older) and are expected to produce coherent texts longer than three sentences. We examine these programmes from the users' perspective. The method is discussed first, followed by a presentation of technological tools, analyses of programmes and a description of the benefits and challenges of different features followed by discussions and conclusions.

2 | METHOD

2.1 | Material and analysis

The writing programmes are selected based on the researchers' prior knowledge and additional knowledge based on web resources (NO: *Statlig spesialpedagogisk tjeneste*, *Dysleksi Norge*, *Lesesenteret*; DK: *Specialpædagogisk støtte*, Nota,[2] *EMU dansk læringsportal*). Reference literature (Aas, 2021; Eklöf & Kristensson, 2017) and social media (Nytt om IKT) were also used.

The first study was conducted in Norway. Nineteen programmes and applications used during text production were identified. To target the production of longer texts, we excluded technologies not suitable for writing longer

[2]https://nota.dk/.

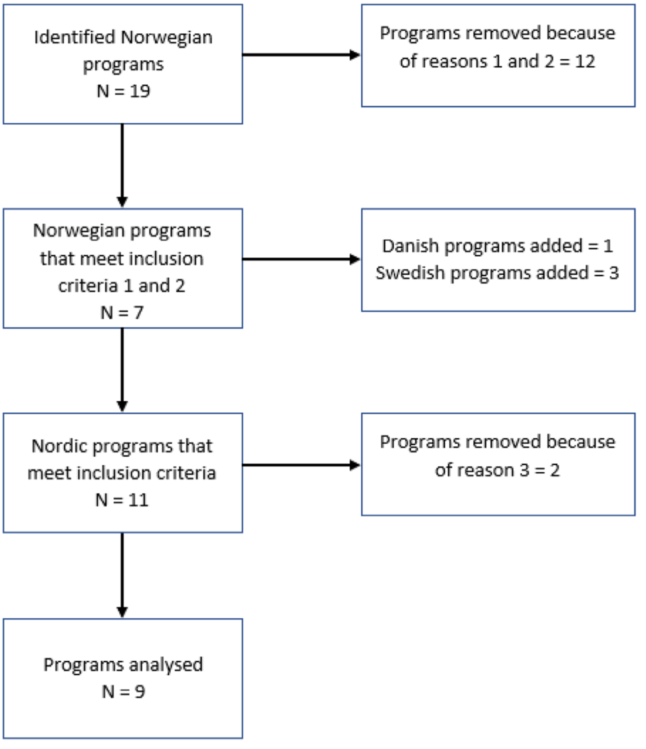

FIGURE 1 Flowchart for selecting writing programmes.

texts, such as telephones and devices without a keyboard. Further, programmes suitable for beginners that focus only on teaching sound-letter correspondence or spelling (e.g., STL+) and programmes for dictation only (e.g., Tuva) were excluded. Based on selection criteria (1) programmes were used on a Windows/Mac/Chromebook computer with a keyboard and (2) they were designed to produce coherent text and/or to support text production; 12 programmes were removed. The second search, performed among Swedish and Danish programmes, was limited to programmes that met criteria 1 and 2. One Danish and three Swedish programmes were selected in addition to the programmes used in both Denmark, Sweden and Norway. To avoid older programmes and programmes seldom used in Nordic schools, a third selection criterion was added: (3) programmes that are Nordic language programmes currently widely used in education. Two programmes were removed (ViTre and Writer (Apache Open Office)) based on these selection criteria (Figure 1). The standard word-processing software and software developed for students with spelling problems are listed in Table 1.

The functions are selected based on Svendsen (2016a), other researchers' prior knowledge,[3] and additional knowledge based on web resources (e.g., developers' home pages). We focused on the most widely used technological spelling aid functions for transcribing longer texts; these functions include a spellchecker, word prediction, speech-to-text (dictation), text-to-speech (speech synthesis) (author) and auto-correction (Alharbi et al., 2019). Functions that support planning or text revision at higher text levels, such as the grammar checker, the dictionary or a list of synonyms, are not included, and neither are new technologies based on artificial intelligence (AI), such as

[3]Researcher 2 has approximately 30 years of experience with assistive technology (AT) for dyslexics at all educational levels, has been an instructor for students, participated in international networks, is a nationwide consultant, and has collaborated with several AT developers. Researcher 3 has been a literacy counsellor for students with dyslexia since 2006, including being an instructor in the use of AT, participated in national and international networks related to research and development projects, and collaborated with AT developers.

TABLE 1 Programmes included in the review.

Program	App-writer	CD-ord/ IntoWords	Claro	Ling-Dys Pluss	Oribi Speak***	Stava-Rex	Google Docs	Pages	Word 365
Developer	WizKids	Vitec-MV	Claro-software	Lingit	Oribi	Oribi	Google	Apple	Microsoft
Language originally developed for	DK	DK	ENG	N	S	S	ENG	ENG	ENG
Available Nordic languages	DK N**** S	DK N S	S DK	N	S DK	S	DK N S	DK N S	DK N S
Spellchecker			x	x		x	x	x	x
Word prediction	x	x	x	x	x*				x
Text-to-speech	x	x	x	x	x*	x**	x*	X	x
Speech-to-text	x	x		x			x	x	x
Autocorrection								x	x
Dictionary	x	x	x	x	x	x	x	x	x

Note: X indicates that this feature exists in the specific program. The functions, however, will vary in the individual programmes.
*Only in browser.
**Only if another TTS program is installed.
***Extension to Google Chrome or MSEdge Browsers.
****AppWriter has been phased out in Norway over the past year in favour of Lingdys Skole.

ChatGPT. Further, the quality of the underlying text databases, online resources and machine learning are beyond the scope of this review, even though they are very important for gauging the quality of technological tools.

The topic considered in this review has not been systematically followed up with publications, and therefore, it is appropriate to use a snowballing approach (Wohlin, 2014) based on tools where familiarity with one or two tools (LingDys and Appwriter) with their features places one on the trail of the other tools. This process continues until no new tools and features are discovered (saturation). Therefore, we claim to provide a representative picture even if some tools should not have been captured. The analysis of the tools was conducted by all researchers by using the programmes, examining user manuals and websites and/or asking the developer of the tool by phone or e-mail. These categories are listed in Tables 2–4.

3 | TECHNOLOGICAL TOOLS AND FUNCTIONS

We first describe the central functions of technological writing tools, together with a presentation of the known benefits and challenges of each specific function. The programmes were then analysed in terms of how well they included features to meet writers' needs in terms of spelling accuracy, writing fluency and proofreading support. The programmes examined were Appwriter, CD-ord/IntoWords, Claro, LingDys Plus, Oribi, StavaRex, Google Docs, Pages and Word 365.

3.1 | Benefits and challenges of the spellchecker, word prediction and autocorrection functions

A spellchecker often checks and marks misspellings by underlining finished words. The writer can select from the alternative spelling suggestions for replacing specific words; the number of suggestions and their priorities may vary. The use of the spellchecker function appears to be successful for text outcomes (Perelmutter et al., 2017); however, students with dyslexia make more errors than others (Rello et al., 2012), and they are also reported to have problems with the identification and correction of spelling errors when using a spellchecker (MacArthur, 2006). For example, spelling errors such as homonyms, other real-word errors,[4] and compound[5] words cannot be detected using spellchecker technology (Svendsen, 2016a). Another problem is that students can fail to choose the correct option from a list of several suggestions for possible words because of their decoding problems (Svendsen, 2016a), and the list of suggestions could also generate new real-word misspellings (Pedler, 2007). The underlining of misspellings and the need for reading and selecting the correctly spelled word among different suggestions may take time, disturb writing fluency, and negatively influence other writing processes (Rønneberg et al., 2018). Increasing the visibility of suggestions can increase both perception and interaction costs, possibly reducing text entry speed (e.g., Jameson & Kristensson, 2017; Quinn & Cockburn, 2020; Quinn & Zhai, 2016) and in some cases, the interaction with a list of suggestions seems to eradicate all writing accuracy benefits (Arnold et al., 2016). However, the quality of spellcheckers has improved. More words are included, and newer spellcheckers suggest spelling options based on context (see word prediction). A recent study using Microsoft Word 2013 indicated that college students with dyslexia could reduce the number of misspellings in their texts to almost zero (O'Rourke et al., 2020).

Another type of spelling aid is a word prediction tool (and word completion) originally developed for persons with physical disabilities to limit the number of required keystrokes. Over time, the function has been developed into special writing software targeted at struggling writers, and it has now become increasingly integrated into standard software, primarily in smartphones and tablets, and recently in computer programmes such as MS Word. When

[4]Real word errors are unintended correctly spelled words (e.g. Norwegian *bake* instead of *bakke*, which are both real words).

[5]In Norwegian, it is possible to construct a new compound word by combining several words to create new words, such *velferdsselskaper* (welfare companies) and *barnevernsboliger* (child welfare housing) (Aftenposten 24.06.2021).

TABLE 2 Relevant features for spellchecking, word prediction and autocorrection

		App-Writer	CD-ord/ IntoWords	Claro	Ling-Dys Pluss	Oribi-Speak	StavaRex	Google docs	Pages	Word
1	Use of text context/context dependency	x	x	x	x	x	x	x	x	x
2	Suggestions based on typical misspellings (including phonetic errors)	x	x	x	x	x	x			X****
3	Suggestions based on previous use	x	x	x	x	x				
4	Use of joker characters	x	x		x					
5	Listening to spelling suggestions	x	x	x	x	x	x			
6	Listening to written words or text	x	x	x	x	x	x		x	x
7	Addition of single words	x	x	x	x	x	x	x	x	x
8	Addition of personal word lists	x***	x***	x***	x***		x**	x**		x**
9	Automatic word correction								x	x
10	Shortcuts for navigation and selection	x	x	x	x	x				
11	Toggling the spelling function on/off	2 actions*	1 action	3 actions	1 action	2 actions	2 actions	3 actions	2 actions	4 actions
12	Flexible wordlist presentation	x	x	x	x	x				
13	Rules for spelling suggestions	x	x	x	x					
14	Individual spelling rules	x	x							
15	Choice of number of word suggestions		x	x	x					

Note: X indicate the presence of this feature in a specific program. These features are explained in the text. For further detailed information, visit the websites of the programmes.
*The number of actions refers to the number of clicks required to toggle the spelling tool on and off.
**One list.
***Several lists.
****The feature works only during writing and not during proofreading.

applying the word prediction function while writing, word suggestions can adapt to the letters typed by the writer. Thus, the suggestions depend on the location of the cursor in the word. Word prediction enables the writer to select and complete words in a text using words suggested in the list during transcription.

The word prediction function benefits from using large datasets and machine learning algorithms that use contextual information for anticipating the block of characters (letters, syllables, words and phrases) a person will write next (van den Bosch, 2011). These algorithms use information comprising characters and words preceding the current word, enabling the suggestions of the current word earlier than its unicity point[6] (Shannon, 1948). This information may be based on statistics, linguistics or syntactic (Lesher et al., 1999). In addition, adaptive models consider the distribution of words previously written by the user, which means that word suggestions can be adapted and prioritised according to their previous use (Tanaka-Ishii, 2007).

The benefits of word prediction are demonstrated in some studies on students who struggle with spelling and have limited vocabulary. In some tools, suggestions follow the cursor while writing, which allows close interactions with suggestions during transcription. Words presented in a list can encourage the writer to use longer or more difficult words (Nisbet et al., 1999), leading to the use of more complex vocabulary, improved writing quality and quantity and increased motivation to write (Peterson-Karlan, 2011; Tam et al., 2005). However, even though word prediction can save keystrokes, fewer keystrokes do not seem to lead to a corresponding increase in typing speed because of the higher cognitive load for handling word completion (Quinn & Zhai, 2016), reading or listening to suggestions carefully or the insertion of incorrect words by the program in the text.

In addition, spelling support is possible through autocorrection. When applying this function, spelling software replaces words automatically to correct typing errors when writing based on a database containing typical typing errors, contributing to the greatest possible flexibility and least possible disturbance in writing fluency during the transcription phase (Hiscox et al., 2014). In both computer and smartphone software, it is possible to add personalised autocorrection rules. An auto-correction tool can achieve accurate results using the same type of algorithm as that used in the development of word prediction. Further, autocorrection makes it possible to separate proofreading from transcription (Alharbi et al., 2019); however, the use of autocorrection can lead to confusing or embarrassing inadvertent mistakes that writers often fail to notice because they focus on the keyboard (Paek et al., 2010) or their internal thoughts about what to write next (Torrance et al., 2016). Consequently, annoying mis-corrections can cause many users to turn off the autocorrection function (Madison, 2011).

3.1.1 | Analysis of the features of the spellchecker, word prediction and autocorrection functions for accuracy, fluency and proofreading

Accuracy

To expand the available text database, all examined spellcheckers, word prediction and autocorrection tools provide the writer with an option to add a single word (7).[7] Further, some tools provide the option of adding word lists based on full texts (8), further expanding the database of words that the writer needs in a specific context, such as specific educational topics. These options enable the writer to improve the basis of achieving accurate word suggestions.

Some tools base spelling suggestions on various rules for typical misspellings to counter spelling difficulties (2). For example, these rules consider phonological errors, errors attributed to the confusion of letters and letter sequences as well as dialects or if the first letter in a word is misspelled. In some tools, specific rules for spelling suggestions can be selected or deselected, for example, the rules for vowel or consonant confusion, silent letters and single or double consonants (13). Moreover, some tools provide the writer with an opportunity to create individual

[6]A word's unicity point is the point at which the word is the only word available in the internal word model of the algorithm (e.g. a list of words) that fits the string of characters keyed in so far (Van den Bosch, 2011, p. 79).

[7]The numbers in brackets refer to numbers in tables.

TABLE 3 Relevant features for speech-to-text (STT).

		AppWriter	IntoWords	LingDys Pluss	Google (Docs)	Pages/ Apple	Word
	Languages	DK N	DK N	N	DK N S	DK N S	DK N S
16	Easy access to STT (Number of actions)	1–3*	2**	1 (icon)	1**	2	1 (icon)
17	Punctuation	Dictate or type	Dictate or type	Dictate or type	Dictate or type	Dictate or type	Dictate or type
18	Dictation not limited to specific program	x	x	x		X***	

Note: Only programmes with STT are included. X indicates the presence of this feature in a specific program. These features have been explained in the text. For further detailed information, visit the websites of the programmes.
*STT in a special box before insertion into the text.
**After opening the control box.
***Standard dictation in macOS system settings.

rules (14). Such rules improve the availability of accurate spelling suggestions despite spelling errors; however, they can also cause confusion if unnecessary alternatives block the most relevant suggestions.

In addition to supporting accuracy based on the above features, accurate spelling suggestions can be achieved because of the ability of the spelling tool to adapt to the textual context or the writer's language. Misspellings caused by word confusion and grammatical errors can be reduced when spellcheckers and word prediction tools present spelling suggestions based on the context of the sentence (1). However, this context-based method of specifying spelling suggestions assumes a minimum number of correctly spelled words in the text, which can pose an issue for writers with severe spelling difficulties. Further, some tools include the ability to adapt spelling suggestions depending on the writer's previous use of tools or choices during the writing of the current text (3).

Some tools have the option of applying 'joker characters' to search for specific suggestions in terms of identifying and selecting the right word (4). The characters * and? can be used to indicate parts of the words that the writer is uncertain about; for example, typing 'in*gent' to search for the word 'intelligent'.

A few accurate suggestions are essential for making the process of selecting a spelling suggestion as quick as possible. In addition to the abovementioned methods for strengthening relevance and accuracy, it is possible to choose the number of suggestions in some tools (15). Furthermore, the writer may have easy access to select and insert spelling suggestions such as using keyboard shortcuts (10). To support the writers' selection of an accurate word in the list of suggestions, it is possible to listen to the words in the word list using speech-to-text and identify the accurate word using auditive feedback (5).

Fluency

When spellcheckers and word-prediction features direct the attention of the writer to spelling, they are more likely to disturb writing fluency. To avoid this disturbance, the writer can choose to neglect spelling suggestions by not looking at them, turning off spelling support (11), or moving the suggestion window away from their sight to the periphery of the screen (12). However, postponing spelling correction to separate proofreading after writing is completed could be a heavy burden for students who make many mistakes. For those who struggle the most with spelling, the text may become almost impossible to understand.

Automatic word correction software (9) is not available in programmes developed for struggling writers in Nordic languages. Standard word processing software offers autocorrection functions (Table 1); however, this software focuses on typographical errors and common misspellings (9), not misspellings typical of students with dyslexia, as seen with spellcheckers and word prediction functions (2, 4, 8, 13, 14).

Proofreading

Spellchecker and word prediction functions are relevant tools for proofreading. To contribute in the best possible way, the writer with dyslexia must use options available for supporting the abovementioned accuracy; for example, individual settings that provide the best possible text base for suggestions (8) and the best possible corrections based on typical misspellings (2). When applying word prediction for proofreading, suggestions in the word list are presented based on the current placement of the cursor in a specific word; the suggestions change according to the use of arrow keys. This flexibility of presentation can support the writer's assessment of spelling and choice of words.

3.2 | Benefits and challenges of the speech-to-text function

Speech-to-text (STT), also known as speech recognition or dictation, converts speech into digital text. Writers can dictate using the microphone, and text is produced in text fields or text-processing programmes. The quality of speech recognition depends on the voice and pronunciation of the user as well as the word resources in each language. To dictate a text, the words or sentences must be dictated clearly and fluently. STT has the potential to support writers in achieving spelling accuracy because dictation generates correctly spelled words and decreases the number of spelling mistakes (Kraft et al., 2019). This function may also encourage the writer to apply relevant and semantically accurate words to the text that would otherwise be deselected because of spelling complexity (Kraft et al., 2019). Further, this function can be used as a supplement to word prediction during keyboarding. Instead of choosing from among word prediction suggestions, it is possible to dictate 'problematic' words and then continue writing.

However, it is challenging for the writer that the dictation can be misinterpreted by the speech recognizer. STT functions produce each sentence using context, and therefore, the best result can be obtained if the writer dictates complete utterances. However, experience from senior student advisors on writing technology at xxxx University indicates that the dictation of very specific single words, such as technical terms, often yields a high degree of accuracy, whereas more frequent words with pronunciation similarities can result in inaccuracies. This indicates that the results at the word or sentence level may be inaccurate, and in some cases, the text may even be difficult to understand (Kraft et al., 2019).[8] Frequent misinterpretations can be an obstacle for some users. To find these misinterpretations, the writer needs to be a well-functioning decoder, which students with dyslexia are not, or use a strategy to carefully listen to every sentence directly after producing it to control misinterpretations and correct them (Stoklund & Bønding, 2021).

For some writers, the dictation of complete meanings could be challenging, creating a great demand for planning, both locally and globally (Evmenova & Regan, 2019; Stoklund & Bønding, 2021). An approach for preparing and processing the oral formulation of a text can require practice and control strategies (Stoklund & Bønding, 2021). Evmenova and Regan (2019) claimed that STT is not for everyone, but only for older students. However, a study by Kraft et al. (2019) of 10–12-year-old Swedish students showed that younger students also benefit from using STT.

Punctuation is another issue that can disturb text-production fluency (Kraft et al., 2019), and so is the difference between the language style of the spoken and written text when dictating the 'written language'. Wengelin (2021) found that lexical diversity in dictated texts was lower than that in written texts for adults; however, no such difference was found among younger students.

[8]A Norwegian example: *Vi hadde det så gøy* (We had fun) was interpreted as the geographical location *Vestvågøy*. A Danish example: *angående* (regarding) was interpreted as *andegård* (duck farm).

TABLE 4 Relevant features for text-to-speech (TTS)

		AppWriter	CD-ord/ IntoWords	Claro	LingDys Pluss	Oribi Speak	Pages	Word (immersive reader)
22	Easy access to TTS	x	x	x	x		X*	x
23	Choice between different voices	x	x	x	x		X*	x
24	Adaptation of speed	x	x	x	x	x	X**	x
25	Highlighting options	x	x	x	x	x	X*	x
26	Strategies for reading possible (stop at full stop)	x	x	x	x			
27	Possible to listen to single words or sentences during transcription	x	x	x	x	x	X*	

Note: X indicates the presence of this feature in a specific program. These features have been explained in the text. For further detailed information, visit the websites of the programmes.
*Must be selected and can be changed in the macOS system settings.
**In Pages if the "control panel" for reading is selected in the macOS system settings.

3.2.1 | Analysis of speech-to-text function features for accuracy, fluency and proofreading

Accuracy

STT is available in both standard software and programmes created for writers with dyslexia (Table 1), and it is increasingly available across various technological tools (Tables 1 and 3). Newer programmes are based on increasing online textual databases, and therefore, the quality of speech recognition has increased significantly in recent years, as well as for Nordic languages, except New Norwegian, which is still not available (Table 1).

Fluency

Unlike word prediction, transcription fluency may be stimulated by dictating. Focusing on sentences and meaning without focusing on spelling can be positive for writing fluency at the sentence level and probably increase the speed of text production.

However, various factors can challenge fluency achieved through STT. One factor is the accessibility of STT function during the transcription phase. If the STT function can be activated by just one action (button or shortcut key) (16); the writer can easily turn the function on and off depending on the writing situation. Fluency can be affected by the availability of STT in writing programmes (18). If the writer has to dictate and move text from one program or window to another, it can delay and disturb the writing process, whereas younger writers may support the structure and transition from spoken to written language. We assume that these young writers are 'knowledge tellers' more than 'knowledge transformers' (Scardamalia & Bereiter, 1987), who focus on isolated meanings rather than textual coherence. Another factor is the need to dictate or use a keyboard for inserting punctuation during text production, which can affect fluency (17) and require specific attention.

Proofreading

STT can be incorporated as a proofreading tool to add or reformulate the text by marking the text to be replaced. However, this approach to revision necessitates the use of other tools such as text-to-speech, which makes it advantageous to have access to all functions in the same program, which is not currently the case for all Nordic programmes (Table 1).

3.3 | Benefits and challenges of the text-to-speech function

Text-to-speech (TTS) involves a computer-based synthetic voice that reads digital text; this function can be part of the operating systems of digital devices or specific assistive technology programmes. Over the last 10–20 years, the quality of these synthetic voices has increased significantly, and the newest voices are close to those of human voices. The TTS function is used for reading and text revision. During transcription, the use of TTS enables immediate auditive feedback at the typed letter, word or sentence levels (Arendal, 2019). Thus, TTS can support the writer in identifying misspellings, inaccuracies and ambiguities at the sentence or text level, which can be corrected using a spellchecker or word prediction, or by reformulating the word or sentence via STT. In addition, listening to parts of the text while writing can support the writer in maintaining focus on the immediate content and coherence for those reading is difficult.

3.3.1 | Analysis of features of text-to-speech function for accuracy, fluency and proofreading

Accuracy and fluency

The TTS function is available in a wide range of programmes (Table 4). Listening to misspellings may be easier with some voices than others, depending on both the voice quality and individual preferences. Currently, there are several different male and female voices (23).

To minimise the disturbance to the writer during writing, the TTS function should be easily accessible in the same program used to produce the text (Table 1). Further, it should be easy to turn on/off with as few actions as possible (22) and to choose to listen to either single words or sentences during transcription (27). Single words are useful to ensure the correct spelling, and sentences are useful to achieve text coherence. However, focusing on accuracy can interrupt the writing process, and therefore, the use of TTS may be more useful for revision.

Proofreading

To optimise the use of TTS for revision and proofreading, some programmes enable writers to shift between different highlight options, to focus on words, sentences or paragraphs while listening to the text (25). Further, the revision can be optimised by changing the reading speed (24). For example, when focusing on higher text levels, the speed can be increased and whole sentences may be highlighted. The opportunity to adjust the TTS to stop at each full stop can help when listening for revisions (26). Different voices may also express language tones differently, making it preferable to choose between them (23).

4 | DISCUSSION

This study described and examined research on writing technology and analysed selected programmes and functions in terms of how they meet the needs of writers with dyslexia from the perspective of a user. Recent research on assistive technology for writers with dyslexia has highlighted both the specific possibilities and limitations that need to be examined further from a practical technological perspective. The results of this analysis confirm that it is relevant to discuss the method in which different functions and features supplement each other to meet the needs of writers with dyslexia.

For accurate spelling, spellcheckers and word prediction functions include several features that enable settings and customisation based on individual needs and preferences. Further, the increasing use of context and machine learning enhances the possibility of obtaining accurate spelling suggestions from technology for Nordic languages as well as English (O'Rourke et al., 2020). Increasing access and the quality of speech-to-text can contribute to reducing the number of misspellings (Kraft et al., 2019). Overall simultaneous access to both spelling aids and STT increases opportunities to achieve accurate spelling. However, until Nordic STT technology improves, there remain some challenges in relying on STT in terms of the possible failed recognition of spoken words.

Another limitation is the need for navigation across programmes. For many students, combining different reading and writing functions may be helpful; for example, dictating text with an STT function in combination with inserting punctuations by keyboard, typing the text with a keyboard and using TTS during revision (Svendsen, 2016b; Wengelin, 2021). Based on our examination of the programmes, different functions are available in different programmes (Table 1). This entails the need for the writer to learn and apply the different programmes, requiring both an overview of the possible features and a specific strategic approach to navigate these features, which is a challenge, especially for students with dyslexia who experience difficulties with motor coordination, concentration or personal organisation (Rose, 2009). Different features across various programmes are also challenging for teachers and instructors, who need to be aware of the opportunities to help students with dyslexia to make optimum use of these tools. This points to the necessity of high-quality teaching that builds on the knowledge of difficulties faced by an individual writer and explores the functions that accommodate their specific needs. This teaching must not only strengthen the writer's use of the actual functions but also strengthen students' strategies for managing the application of the functions.

However, it is important to consider the possible effects of positive and negative interactions with programmes when introducing specific tools and combinations of tools. Studies on negativity bias and loss aversion indicated that negative outcomes are consistently more potent than positive ones. Thus, the elements of the negative progress during interactions with computers have a disproportionately strong negative impact on user preferences (Quinn & Cockburn, 2020). Thus, students can choose not to use the function. Given this perspective, it is even more important for writers who depend on technological tools to be aware of the specific relevant options for each tool and to know how the tools can be combined at different stages of the writing process.

Another relevant focus for understanding the possibilities and limitations of writing tools is the varying levels of difficulty faced by writers with dyslexia. Can context-based writing tools and machine learning accommodate students with very pronounced spelling problems? Although the analysed writing tools include advanced spelling features, using these features requires linguistic attention, which is likely to create barriers for writers who struggle the most. An example is word prediction, which despite its special features, relies on correct letter sequences to suggest correct words; other examples include a context-based spellchecker or a word-prediction suggestion. If a student misspells many words in a sentence, the text might not provide a suitable basis for relevant suggestions based only on the context.

For students with pronounced difficulties and other students with dyslexia, user competence is to select the right technological tools for text production, use and customise the tools and combine them. This competence must develop over time for each student under skilled instruction. Svendsen (2017) shows that, in an instructional context, technological writing tools have the potential for the inclusion of struggling writers, and Young and MacCormack (2014) claim that the effect of a specific tool increases when embedded within quality instructions.

4.1 | Limitations of this study

This study examined writing aids from the user's perspective. The quality of the underlying text databases, online verbal resources and machine learning is very important for the quality of spelling aids; however, this is beyond the scope of this article. Tools for other aspects of text production such as planning, grammar control and dictionaries were also excluded. The analysis included programmes widely used in educational settings in Norway, Denmark and Sweden; programmes with similar purposes and functions were excluded from the assessment. The inclusion of an even wider range of programmes may have provided more detailed insights into the functions relevant to writing. However, the aim of this study was to serve as a guide for practitioners within education; hence, a selection based on current relevance seems appropriate. Further, none of the researchers struggled with writing or using assessment functions and programmes as users, which can be considered another limitation. The analysis was conducted on programmes for three Nordic orthographies with different depths (Seymour et al., 2003), which is more of a strength than a limitation, providing insight into different writing tool traditions.

5 | CONCLUSIONS

A student with dyslexia needs an accurate spelling tool to support the transcription and proofreading parts of text production, and therefore, it is necessary to provide them with opportunities to achieve text production fluency, easy access to adapt technology to individual preferences and the possibility to combine different programmes and functions. An analysis of these functions suggests an underlying dilemma in terms of the relationship between accuracy and fluency. The analyses showed that spellcheckers, word prediction tools, and autocorrection tools offer various options and features to help writers with dyslexia achieve spelling accuracy; however, spellcheckers and word prediction tools can also disturb writing fluency. This makes it necessary to focus on the methods using which these functions affect writing flow for individual writers and the ways to adjust programmes according to the writers' writing difficulties and personal preferences. Students with dyslexia are often preoccupied with spelling, and therefore some may need specific support to focus less on the spelling and to develop other aspects of the writing process.

Future studies should focus on examining whether some writing tools have the potential to support writing fluency and whether writers with dyslexia can develop specific strategies based on writing tools that support the best possible fluency during transcription. The analysis suggests the potential of STT as a tool that can strengthen fluency at the sentence level because STT works better when dictating sentences. However, challenges related to planning and overall text coherence when using STT must be investigated further because the use of STT draws attention to the punctuation and control of whether words are correctly interpreted by the STT function.

To revise the texts, spellcheckers, word prediction and TTS are considered as tools that can accommodate the needs of the writer. Although TTS and the various settings included in these functions can direct the attention of the writer towards inaccuracies and ambiguities at the word, sentence and text levels, spelling tools can contribute specifically to achieving spelling accuracy.

Further development of tools for scaffolding text production must consider the dilemma of achieving writing fluency and accuracy. Further, they should be as user-friendly as possible and offer all necessary functions on a flexible and easily accessible basis in the same program, and as such, help establish a foundation that enables the writer to focus on writing rather than on technology.

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CONFLICT OF INTEREST STATEMENT

There are no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data derived from public domain resources.

ETHICS STATEMENT

There are no conflicts of interest. All sources are available.

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