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Assistive Technologies and Academic Success for Students with Dyslexia: A Literature Review

Tara Dawn Horn[1]
Tonya Huber[2*]

[1,2] *College of Education, Texas A&M International University, Texas, USA.*
[*]*Email: Tonya.Huber@TAMIU.edu*

Abstract

According to research, one in ten school-aged children is diagnosed with dyslexia (Shaywitz (2008) as cited in Wang et al. (2018)) and "15-20% of the population as a whole may have symptoms of dyslexia" (Cowen, 2016). With so many students impacted, what does research provide about the assistive technologies available to aide students diagnosed with dyslexia in academic success? This literature review was conducted to determine affordances for students of all ages who could use modern technology to become more successful at reading, writing, spelling, and language comprehension. Helping students succeed in compulsory education could afford students with dyslexia the opportunity for successful academic attainment in higher education. Research indicates "people with dyslexia are vastly under-represented in universities" (MacCullagh, Bosanquet, & Badcock, 2017). The opportunity for all students to have an equitable education should be a fundamental right and the following literature review analyzes the assistive technologies available to allow students with dyslexia to thrive in an educational setting.

Keywords:
Assistive technology
Dyslexia, fixation duration
Livescribe Pen
Modality principle
Multimedia principle.

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1. Introduction

Dyslexia is a cognitive disorder that does not affect intelligence. "Dyslexia is a language-based learning disability in which individuals experience difficulty in performing language-related tasks such as word recognition or reading, writing, spelling, comprehension and sometimes speaking" (Chen & Keong, 2017). Online research revealed astounding statistics concerning dyslexia. Research suggests 32% of students with dyslexia drop out of school or do not graduate with a standard diploma allowing future academic attainment (Dunbar, 2019). However, the creative minds of many notable dyslexics have led to innovative inventions, such as the automobile, the iPhone, and the light bulb Dunbar (2019). With 40% of self-made millionaires including Richard Branson, Steve Jobs, and Charles Schwab and 50% of NASA employees having the learning difference dyslexia (International Dyslexia Association, 2016; Dunbar, 2019; Shaywitz, 2008) why is it we still only see a fraction of students in universities with dyslexia? Undergraduate and graduate level coursework requires a higher level of reading and writing skills, both of which present problems for students with dyslexia. Within the literature review, several assistive technologies (AT) available to students with dyslexia were analyzed to determine whether the affordances helped with academic success and possible academic attainment beyond compulsory education. "Assistive technology refer to the services and devices that enable people with disabilities to accomplish daily living tasks; assist them in communication, education, work, or

recreation activities; and ultimately, help them achieve greater independence and enhance their quality of life" (Dawson, Antonenko, Lane, & Zhu, 2019; Dell, Newton, & Petroff, 2016; International Dyslexia Association (IDA), 2006). Assistive technologies can enable students with a learning disability, in this case dyslexia, foster independence and complete assignments at the same level as their peers who do not display a learning disability. Table 1 clarifies key terms and definitions found within the literature review.

Table-1. Keyterms and definitions.

Key Terms	Definitions
assistive technology (AT)	Dawson et al. (2019) define *assistive technologies* as "the services or devices that enable people with disabilities to accomplish daily living tasks; assist them in communication, education, work, or recreation activities; and ultimately, help them achieve greater independence and enhance their quality of life" (p. 227).
dyslexia	Chen and Keong (2017) define *dyslexia* as "a language-based learning disability in which individuals experience difficulty in performing language-related tasks such as word recognition or reading, writing, spelling, comprehension and sometimes speaking" (p. 951).
fixation duration	Rello and Baeza-Yates (2017) define *fixation duration* as "how long the eye rests still on a single place of the text" (p. 33).
livescribe pen (LSP)	Harper, Kurtzworth-Keen, and Marable (2017) define the *livescribe pen* as "a smartpen equipped with a removable ballpoint ink cartridge, a microphone to enhance audio recording, a playback speaker, an infrared camera, and internal flash memory that can store handwritten notes, audio, and images" (p. 2472).
modality principle	Wang et al. (2018) define the *modality principle* as "the supplying visuals with narrated on-screen text" (p. 183).
multimedia principle	Wang et al. (2018) describe *multimedia principle* as "the learning from animation, video, screen-casting, and other instructional materials that involve pictorial and verbal information in the instructional method" (p. 182).

2. Search Strategy Methodology

Searches were conducted using the WorldCat database with *Boolean* operators between key terms to narrow each search. Search terms included the key terms "dyslexia" *AND* "assistive technology." Several additional searches were conducted adding the key terms "students" AND "education" AND "fluency" to try and locate relevant sources. With advancements in technology rapidly occurring, only articles written between 2015 and Jan. 2020 were included in the final review of literature. The search located 17 relevant sources as shown in the Audit Trail Table 2. After a closer look, duplicate articles were removed from the list. Also, articles which only mentioned technology or that did not include students with dyslexia were excluded. Articles with acquired dyslexia because of stroke were excluded. Five articles remained and were chosen for the literature review, including two quantitative studies and three qualitative studies. Table 3, the methodology table, includes participants, findings, and detailed methodology of these five articles. Three of the studies were conducted in the United States, one in Malaysia, and one in Spain.

Table-2. Audit Trail.

Database	Dates Reviewed	Search Terms	Sources Located	Relevant Sources
WorldCat	2015 - 2020 Jan.	"dyslexia" AND "higher education" AND "assistive technology"	48	4
WorldCat	2015 - 2020 Jan.	"dyslexia" AND "fluency" AND "assistive technology" AND "children"	29	2
WorldCat	2015 - 2020 Jan.	"dyslexia" AND "assistive technology" AND "students"	99	5
WorldCat	2015 - 2020 Jan.	"dyslexia" AND "assistive technology" AND "education"	110	5
WorldCat	2015 - 2020 Jan.	"literacy" AND "dyslexia" AND "undergraduate" AND "technology"	10	1

Table-3. Methodology.

Authors & Publication Year	Participants	Methodology	Findings
(Chen & Keong, 2017)	12 secondary students (7 female, 5 male) medically diagnosed with dyslexia and 12 typical secondary students (8 female, 4 male) without dyslexia Malaysia	"Qualitative approach via observations and structured individual interviews allows a more in-depth examination in this experience" (p. 952). Researchers and research assistants used a structured guide of questions.	"The findings of the present study revealed that a majority of participants with dyslexia has indeed yielded the perception of excellent learning quality and high engagement during the reading task which implied that the Screen Reader did serve as a great reading aid" (p. 962).
(Dawson et al., 2019)	Individual 5th-grade student with dyslexia, who reads on a low 2nd grade level, but has excellent language comprehension United States	Qualitative research was conducted using focused interviews and participant observations.	"Parents report that homework time is less cumbersome and more productive and that he has even sought out additional content related to the curriculum by using the tool to access information far above his reading level. He is also reading for pleasure more often using AT" (p. 238).
(Harper et al., 2017)	Individual 4th-grade elementary student identified with dyslexia United States	Consensual Qualitative Research employing both interview and focus group methodologies. Member checking was utilized to increase validity and credibility.	"The study's findings reveal its impact as an assistive technology on both academic success for children with disabilities as well as non-academic gains" (p. 2471).
(Rello & Baeza-Yates, 2017)	92 participants (46 with dyslexia) Spain	Quantitative Research Experiments and Questionnaires "Eight experiments were conducted to study the effect of eight text presentation parameters on readability" (p.33).	"Larger font sizes and spacings improve readability" (p. 45).
(Wang et al., 2018)	73 college students identified with dyslexia (18 participants in one of each of the four multimedia learning conditions) ages 18-56 United States	Quantitative research utilizing 2 multimedia and 2 modality presentations were conducted. Both computerized retention test and recall test were administered.	"This study lends support to the claim that individuals with dyslexia benefit from visualization (Taylor, Duffy, & Hughes, 2007) and further provides evidence of the robustness of the multimedia principle in general and with special populations" (p. 189).

3. Findings

3.1. Online Reading Affordances

A qualitative study performed by Chen and Keong (2017) involving 12 secondary students medically diagnosed dyslexic and 12 typical secondary students, from Malaysia, was conducted to observe student engagement and perceived learning using online reading affordances. The study used three online reading applications: Screen Reader mode, Printed Text mode, and Standard Guidelines mode. The passage length for each application was comparatively the same. The Screen Reader mode used black text on a beige background, 16-18 font, one and a half inch spacing, and the passage was read aloud to the participant in bulleted points using a Screen Reader. Standard Guidelines mode was read by the reader using a bulleted format, black text on a beige background, one and a half inch spacing and 16-18 font. The only difference between Standard and Screen Reader mode was the use of a Screen Reader. Printed Text mode used a white background with black text, single-spaced, a 12-14 font, and was read by the reader in paragraph form. The authors found that Printed Text mode yielded low engagement and satisfaction, as well as little improvements in learning. The Standard Guidelines mode made readers feel comfortable with use of a black on beige design, larger spacing, and larger font size. Therefore, increased confidence and comprehension for the reader was reported. Similar findings were reported for the Screen Reader mode where the black text on beige background was used with larger spacing and font size. Bulleted points were read aloud to the reader and the "majority of participants with dyslexia yielded the perception of excellent learning quality and high engagement during the reading task which implied that the Screen Reader did serve as a great reading aide" (Chen & Keong, 2017).

3.2. Livescribe Pen

Two consensual qualitative research studies were conducted each including only one participant. Both studies were performed in the United States, and with children approximately the same age. Both studies aimed to highlight AT affordances in school and at home.

The first consensual qualitative research study involved one fourth-grade elementary student from the United States and utilized interview and focus group methodologies. The researchers highlighted the effectiveness of the Livescribe Pen. The Livescribe Pen (LSP) assistive technology is "a smartpen equipped with a removeable ballpoint ink cartridge, a microphone to enhance audio recording, a playback speaker, an infrared camera, and internal flash memory that can store handwritten notes, audio, and images" (Harper et al., 2017). Specifically, the study focused on how the LSP could impact curriculum accessibility, foster academic independence, and improve study skills and homework. The classroom English-Language Arts (ELA) and the special education teacher worked together to record required reading assignment with the LSP. The student was able to access the readings at home. The student could also record responses to writing prompts rather than write them by hand. Finally, the LSP was utilized daily for all language arts and mathematics assignments which required the student to read assignments for completion. Informed consent forms were used; and to increase validity, member checking was utilized. Interviews were conducted for one year with the student, the parent, the parent and student together, and the teachers.

Table-4. Available Assistive Technologies.

Assistive Technology	Description	Application
Audible	An audio library of both books and novels.	Reading Assistance
Beeline Reader	Guides readers from one line to the next with color and is compatible with Firefox, Chrome, iOS, PDF, EPUB, Android and platforms like Bookshare.	Reading Assistance
Bookshare	Library of audio textbooks. Partly funded by the Office of Special Education. Free to students with a dyslexia diagnosis or other print disability.	Reading Assistance
Mercury Reader	Web browser extension where users can adjust font sizes, screen color, Also, removes distractions, like ads, from web pages.	Reading Assistance
Natural Reader	Listener can hear different file formats by dragging and dropping files. (txt., .doc, PDF, .docx, EPUB, RTF)	Reading Assistance
Read&Write	Listen to emails and documents. Includes text prediction, a highlighting feature, grammar and spell check. Works with PC, Mac, iPad, Google, and Android.	Reading and Writing Assistance
Siri	Supports spelling and grammar through speech-to-text capabilities.	Writing Assistance
Speak It!	Within Google Chrome or Mozilla Firefox, students can select web pages to be read aloud.	Reading Assistance
Voice Dream Reader	A text-to-speech app that will adjust reading speed, color, font size, and spacing. It also allows the reader to play, pause, and listen to documents.	Reading Assistance

3.3. Assistive Applications

Another qualitative research study conducted by Dawson et al. (2019) used observations and interviews with a fifth-grade student who had excellent language comprehension skills but read on a low second grade level. Despite efforts made by the boy's teachers, parents, and school interventionist, the boy continued to display difficulties in reading and writing and had underdeveloped handwriting and spelling skills. The case study highlights different reading and writing AT available to dyslexic students. The *Read&Write* assistive technology indicated promising results for the fifth-grade boy after being implemented at school and at home for homework. His writing scores increased with the use of speech-to-text and word prediction features. His reading also showed improvements with the text-to-speech function. A list of more assistive technology affordances educators may consider to aide students are described in Table 4.

3.4. Online Text Presentation

The literature review also included two quantitative studies. An eye tracking study performed on 92 participants from Spain highlighted the importance of customizable text and how to ensure the computer screen is readable for dyslexic students (Rello & Baeza-Yates, 2015). Forty-six people with dyslexia were studied and another 46 acted as a control group for the study. Eight experiments with four to eight conditions per experiment were studied. All students participated in each of the experimental conditions. The experiments set these independent variables: gray text on a white background, gray background with white text, font size ranging from 14-26 points, character spacing, line spacing, paragraph spacing, column width, and text with background color variations such as black/yellow, brown/green, blue/yellow, off-white/off-black, black/white, black/creme, and dark brown/light green. Eye fixation duration was used as the dependent variable. Studies have shown that when a person reads their eye jumps and rest on parts of the text. When reading, the eye does not move from word to word across the text. Therefore, fixation duration "denotes how long the eye rests still on a single place of the text" Rello and Baeza-Yates (2015) and is an indicator of text readability. Rello and Baeza-Yates (2015) identify "three studies that show why fixation duration is also a valid indicator for people with dyslexia":

1. First, "dyslexic readers show the typical word frequency effect in which low-frequency words are fixated longer than high-frequency words" (Hyöna & Olson, 1995; Rello & Baeza-Yates, 2015).
2. Second, "when dyslexic readers were given a text appropriate for their reading level, their eye movements (fixations, saccades, and regressions) were much like those of normal readers at that particular age level" (Olson, Kliegl, & Davidson, 1983; Rello & Baeza-Yates, 2015; Pirozzolo & Rayner, 1978).
3. Third, "normal children's eye movements could be similar to the dyslexic readers' eye movements when they were given a text that was too difficult for them" (Rayner, 1986, in Rello and Baeza-Yates 2015).

Rello and Baeza-Yates (2015) used base texts, multiple choice comprehension questions, and questions over preferences with the participants. They found that for readability and preference among dyslexics the font sizes should be 18, 22, and 26 points on a 17-inch computer screen. Black font on white or white on black is more readable compared to other colors. Spacing ranging from zero, +seven, to 14% was more readable. (p. 42) Font style should be set to Roman or sans-serif, and Arial, Courier, Verdana, or Helvetica was the preferred typeface. The experiments proved that setting parameters for online text could be beneficial for dyslexic students and make the online text more readable.

3.5. Modality and Multimedia

The final article for the review of literature investigated the effects multimedia and modality might have on the reading performance of a dyslexic student. This quantitative study utilized 73 college students from the United States, identified with dyslexia, ages 18-56. Twenty-one participants were male, and 52 participants were female. The students were divided equally to test the multimedia and modality principle. The modality principle "is the supplying of visuals with narrated on-screen text" (Wang et al., 2018). Multimedia principle is "the learning from animation, video, screen-casting, and other instructional materials that involve pictorial and verbal information in the instructional method" (Wang et al., 2018). In this experimental study, subjects were randomly chosen and placed into to one of four learning conditions. "An experiment in which participants are assigned at random to treatments is known as a true experiment" (Galvan & Galvan, 2017). To test the theory, "the cued-recall have been used and validated in previous studies" (Wang et al., 2018); (Ritzhaupt, Gomes, & Barron, 2008). An experiment has a control which does not change during the test. "The current study utilized a multimedia presentation entitled *Discovering Australia*, which has been used and validated in previous studies of multimedia learning with typically developing individuals" (Wang et al., 2018); (Ritzhaupt et al., 2008).

"In the first phase of screening, a trained researcher conducted phone interviews in which she took a detailed developmental history for each of the potential participants" (Wang et al., 2018). Participants who displayed spelling and reading difficulties along with attributes of dyslexia were placed into the second phase of selection. Next, the participants undertook several norm-referenced tests to further screen for dyslexia. Therefore, for this research the participants underwent phone interviews, surveys, and a series of screening

assessments which was adequate to ensure candidates were qualified for the study and did indeed have dyslexia.

The selection process for the study was not random. Chosen from five Southeastern universities from within the United States, participants were recruited from the school's disability resource centers. Of the 73 participants, 63 already had medical diagnoses, but all underwent the same phone interviews, norm-referenced screening test, and demographics surveys. For recall, the multimedia principle results were not statistically significant, but it "was approaching statistical significance" (Wang et al., 2018). However, the results did show to be statistically significant for recall in modality. The interaction between multimedia and modality for recall also showed not to be of statistical significance. However, for recognition performance multimedia and modality results were both of statistical significance.

4. Discussion

4.1. Strengths and Weaknesses

The multimedia study conducted by Chwen and Keong (2016) highlights that improvements of multimedia designs can enhance the quality of learning materials available for dyslexic students. Improving multimedia design technologies could possibly enable dyslexic students to successfully attend online education beyond high school. As seen in Table 5, weaknesses of the study include the presentation was only comprised of passages on a 12th grade reading level. Readings of greater difficulty would alter the results. Within the study, only short-term retention measures were used to test comprehension. Long term retention studies would have provided very different results.

Last, within the multimedia study the materials used pictures which directly reflected the text. Using other pictures might have resulted in a different outcome. The experiments were conducted on undergraduate and graduate students, which leave opportunity for future study of elementary through high school students.

The case study by Harper et al. (2017) brought awareness to how assistive technologies, in this case the Livescribe Pen, could help improve both academic and non-academic areas for students. Academic gains included fostering academic independence in school and at home with outside studies and homework. The student displayed motivation outside of school to complete assignments and found more enjoyment inside of school. However, "a limitation of a one-year study is the inability to fully conceptualize the long-term implications of happiness, motivation, and self-determination have on student success in later years" (Harper et al., 2017).

Another case study on assistive technologies written by Dawson et al. (2019) brings needed awareness to the assistive technologies available to dyslexic students. "Most members of the typical Individualized Education Plan (IEP) team have had little or no preparation specific to why or how assistive technology may benefit learners with different needs despite the fact that such training is mandated within the Individuals with Disabilities Education Act (IDEA)" (Edyburn, 2004; Dawson et al. 2019). The authors disclose the case study is based on events and interviews of the head researcher's son. Even though research is sometimes born out of necessity, having an independent researcher unrelated to the student, would improve reliability and validity of the research.

Two more studies give evidence of how web designers and online developers can improve readability for dyslexic students by implementing proven parameters within their designs. Rello and Baeza-Yates (2015), provide evidence that larger text size, fonts, and colors increase readability for dyslexics. However, the use of only one unit of measure places a limitation on the study. The researchers mention comprehension could have been used as a possible measure, instead of only a control, to enhance the study. Finally, the study also does not measure "interaction effects among variables" (Rello & Baeza-Yates, 2015). Wang et al. (2018) reported results indicating the use of images along with narrated text helped to improve recall and recognition for dyslexic students.

Weaknesses listed by the researchers include lack of a comparison study with participants who do not have dyslexia. Second, the use of a more difficult reading passage could have produced different results. Third, long-term retention of comprehension was not included in the study. Finally, the online text purposefully utilized familiar pictures to mirror some or all of the passage. The use of other pictures could have provided different results.

5. Future Studies and Conclusion

Research on assistive technologies for students with dyslexia is limited even though "dyslexia affects 20 percent of the population and represents 80-90 percent of all those with learning disabilities" (Yale Center for Dyslexia and Creativity, 2017). Dyslexic children struggle to become literate with a learning difference that is hard to remediate. More research in the areas of assistive technologies could improve quality of education and life for dyslexic students. The studies also indicate more research on assistive technologies for dyslexics of any age, as well as multimedia and online text design could prove beneficial.

Table-5. Methodology strengths and weaknesses.

Authors and Publication Year	Strengths	Gaps & Weaknesses
(Chen & Keong, 2017)	Highlights the improvements of multimedia designs can improve the quality of learning materials available for dyslexic students. Improving multimedia design technologies would enable dyslexic students to attend higher education beyond high school. "As learners with dyslexia form a significant minority of the online learning population, the inclusive dyslexia-friendly guidelines derived from the present study would better inform the future implementation of online reading affordances acknowledging differences and similarities between online learners" (p. 963).	Evidence suggest the Screen Reader should be an optional affordance and not required as some of the participants found the Screen Reader to be distracting. "There were also those who perceived the Screen Reader as distracting, which made their reading less engaging and/or less preferred to be used" (p. 962).
(Dawson et al., 2019)	Highlights several forms of assistive technologies that enable dyslexic students to learn more independently to that of their peers. As disclosed in research conducted by Edyburn (2004) in Dawson et al. (2019), the study also brings attention to the fact that "most members of the typical Individualized Education Plan (IEP) team have little or no preparation specific to why or how assistive technology may benefit learners with different needs despite the fact that such training is mandated by the IDEA" (p. 227).	This case study is based on the true story of the first author's son. Even though research is sometimes born of necessity, having an independent researcher unrelated to the student, would improve the reliability of the research on the assistive technologies mentioned.
(Harper et al., 2017)	Brings awareness to how assistive technologies improve both academic and non-academic areas. These gains included fostering independence, homework success, and "the higher aspirations the entire team had for this student" (p. 2479).	"A limitation of a one-year study is the inability to fully conceptualize the long-term implications of happiness, motivation, and self-determination on student success in later years" (p. 2481).
(Rello & Baeza-Yates, 2015)	Provides evidence that with larger text size and certain parameters readability for dyslexics can increase. "These findings can have impact on screen text presentation recommendations and on the text options chosen by developers, designers, or content producers when they target people with dyslexia" (p. 45).	The use of only one unit of measure places a limitation on the study. The researchers mention comprehension could have been used as a possible measure instead of only a control variable. The study also does not measure "interaction effects among variables" (p. 43).
(Wang et al., 2018)	A comparison of the online elements used by learners with dyslexia, and without, and how both groups benefitted positively from the use of the technology.	Researchers state that a comparison study with normal functioning students was not conducted (p. 190). The multimedia presentation comprised of only 12th grade level text. If readings with greater difficulty were used, then the study could have ended with different results. Only short-term retention measures were used to test comprehension. Long term retention studies would have provided very different results. Graduate and undergraduate students were studied, possibly altering results. Last, the materials used pictures that directly reflected the text. Using other pictures might have resulted in a different outcome. Increasing the sample size would allow for both a qualitative and quantitative approach to gathering data.

The findings highlighted within this literature review bring insight and awareness to the affordances dyslexic students could use to obtain academic success. Dyslexia cannot be cured and even with remediation and interventions, most dyslexic students will continue to fall behind their peers in the areas of reading and writing. Literacy is fundamental to navigating through our world, and modern technology could be the bridge dyslexic students need to excel.

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