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Audio-Supported Reading & Students with Learning Disabilities: Giving Voice to All Learners

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Introduction

There is considerable research and policy literature on the disproportionate impact that inaccessible instructional materials, print-based and digital, have on students with disabilities in general, and students with reading difficulties in particular. Since so much of the curriculum, whether print or digital, is text-based, difficulties with decoding, connecting, or deriving meaning from text can severely restrict academic achievement. Learning to read and make use of text remains a serious and widespread challenge for many children as well as their teachers and families (Goldberg & Goldenberg, 2022; White et al., 2021).

While acknowledging that notable progress has been made in addressing this problem through early identification and prevention, diagnosis, and remediation, the precipitous adoption of digital learning resources throughout K-12 has radically altered the process of schooling. Inclusively designed digital curriculum materials can offer easy and instantaneous media transformations: text, audio, video, images, etc., that can benefit all learners. Today nearly every student from middle school forward has a mobile device capable of accessing the internet, displaying multimedia, scanning print documents into digital, using text-to-speech or speech-to-text, providing definitions and offering language translation, and performing other tasks only fantasized about as little as 15 years ago. As a consequence, the needs of students with reading disabilities for regular access to compensatory strategies and tools can be more readily met.

Ultimately, text must be perceptually decipherable to be processed as language. Observedly, the end goal of reading is the comprehension of intended meaning contained in and conveyed by language. Audio representations serve to substitute for or blend in with visual representations of text not readily or completely available to the reader who struggles with fluency. For these learners, audio-supported reading (ASR) can increase the saliency of text and reinforce the meaning contained within it by:

- Offering students and teachers choices for engaging with text
- Allowing independent access to text across devices and platforms
- Accelerating the rate at which text is accessed for learning
- Reducing cognitive load for struggling readers
- Supporting word recognition when listening
- Adding audio cues for word naming and vocabulary
- Providing relief for students experiencing eye fatigue
- Enabling access to text from any location

This article provides detail on the nature of reading; the challenges of reading-related, learning disabilities; the supporting legal landscape; and practical considerations for how to accurately target ASR interventions to address the needs of students with learning disabilities.

Defining Reading

One simple way to answer the question, “What is reading?,” is to describe what reading looks like. How is it performed? How does it break down as learners practice it? Consider the following description: You are resting comfortably with a book placed 16 inches from your eyes. A sequential string of utterances accurately emerges from your mouth at an average rate of 175 words per minute. The pace, intonation, and inflection of the utterances vary slightly. This is reading as an observable and measurable sequence of behaviors. As students progress through the grades, the expectation is that speed, accuracy, complexity, and prosody of oralizations will improve in response to instruction.

While speech as the oral expression of language emerges quite naturally in most children, the deciphering of the code that graphically represents speech sounds (orthography) must be learned or acquired systematically. Theories abound about how the act of reading comes about in the individual (Colenbrander et al., 2022; National Reading Panel, 2000). There’s a building up of developmental processes that accounts for mastery or proficiency in reading. There are also bottom-up and top-down interpretations that explain expertise in reading. The bottom-up account requires that a match be made between the phonic elements of speech (sounds) and the graphic elements of text (letters and letter combinations). The top-down approach starts with a culturally relevant and developmentally appropriate story expressed in song, gesticulations, pictures, and animations paired with text. The combination of these processes results in the ability to read and the ability to learn from reading as an essential tool (Burkins & Yates, 2021).

Reading with Technology and Audio-Supported Reading

Ultimately, any code regularly available to the senses such as text or braille must be perceptually decipherable in order for that code to be processed as language. Thus, the end goal of reading is the comprehension of intended meaning contained in and conveyed by language. Reading, once understood narrowly as a sequential developmental process, restricted opportunities for those who could not break the code, rapidly name words, or fluently string together connected text. Today, climbing the "literacy ladder" through its implied dependencies, can be eased or even circumvented with technologies that boost fluency, reduce fatigue, and support vocabulary. Thus, in the modern world of digitally recorded information including text, reading is the capacity to independently extract meaning from connected text through the use of paper-based or digital media with the support of technology tools (Cline et al., 2006).

Jackson (2021) defines audio-supported reading (ASR) as a technology-based technique for reading in which individuals read digital text in conjunction with listening to the text in an audio format such as text-to-speech. As we address throughout this article, students with reading disabilities primarily present with challenges related to fluency and the extent to which they can accurately decipher text. We view ASR as a practical and supportable intervention that has been documented to minimize the constricting impact of limited text decoding, thereby improving academic outcomes for many students with reading-related learning disabilities.

Defining Specific Learning Disability

In 1977, the U.S. Department of Education finalized the definition of "specific learning disability" under the Individuals with Disabilities Education Act (IDEA), and it has remained essentially unchanged since that time (42 Fed. Reg. 65082, 65083 (1977)):

> Specific learning disability—
>
> (i) General. Specific learning disability means a disorder in one or more of the basic psychological processes involved in understanding or in using language, spoken or written, that may manifest itself in the imperfect ability to listen, think, speak, read, write, spell, or to do mathematical calculations, including conditions such as perceptual disabilities, brain injury, minimal brain dysfunction, dyslexia, and developmental aphasia.
>
> (ii) Disorders not included. Specific learning disability does not include learning problems that are primarily the result of visual, hearing, or motor disabilities, of intellectual disability, of emotional disturbance, or of environmental, cultural, or economic disadvantage. (34 C.F.R. § 300.8(c)(10)).

Since the coining of the term “learning disability” in the early 1960s, a legacy of practices in special and remedial education have been dedicated to correcting or remediating learning challenges by relying heavily on measures of learning capacity (Intelligence Quotient or IQ). Thus, a learning disability has been evidenced when a significant discrepancy is observed between an individual’s measured intelligence and that individual’s measured academic achievement, as long as intelligence falls within an average or above average range. Further refinements to the definition exclude other possible reasons for underachievement, such as emotional disturbance, sensory impairment, or poor education.

Today, many favor abandonment of an IQ/achievement discrepancy approach in favor of one that relies on direct measures of student academic performance and progress (O’Connor & Sanchez, 2011; Vellutino et al., 2000). The time required to accrue measurement(s) of a significant discrepancy between IQ and achievement has been referred to as a “wait to fail” approach that neglects struggling learners at the optimal time of instruction when they are most likely to benefit from increased support from school personnel (Fuchs & Fuchs, 2006). Moreover, norm-referenced estimates of intelligence have proven increasingly problematic in meaningfully diagnosing capacity among culturally and linguistically diverse student populations (Abedi, 2006).

Because of the concerns over the utility and accuracy of standardized tests of general aptitude, the identification and diagnosis of specific learning disability has moved away from standardized measures of potential and achievement in favor of more direct measures of academic progress over time. The 2004 reauthorization of IDEA states that when making a determination as to whether a child has a specific learning disability, a local educational agency (LEA) must not be required to take into consideration a severe discrepancy between achievement and intellectual ability and may use a process that determines if the child responds to scientific, research-based intervention as a part of evaluation procedures (20 U.S.C. § 1414(b)(6); 34 C.F.R. § 300.307(a)).

Identifying Students with Reading Difficulties and Dyslexia

With respect to students with reading difficulties specifically, the term “dyslexia” is prevalent in both research and practice. As cooperatively defined in 2003 by the International Dyslexia Association, the National Center for Learning Disabilities, and the National Institute of Child Health and Human Development:

> Dyslexia is a specific learning disability that is neurobiological in origin. It is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction. Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede growth of vocabulary and background knowledge (Lyon et al., 2003).

A recent analysis undertaken to revisit the prevalence of dyslexia within the school-age population highlights the "unexpected" nature of this diagnostic category (Wagner et al., 2020). The fact that a disabling condition emerges as a discrepancy between anticipated outcomes (e.g., IQ and grade-level standards) and actual academic outcomes is, in many ways, somewhat unique among disability diagnoses. This uniqueness challenges educators, researchers, parents, and other stakeholders to review diagnostic criteria for both accuracy and relevance. One such recent review noted:

> Reliable data now validate the definition of dyslexia as an unexpected difficulty in reading in an individual who has the ability to be a much better reader. That dyslexia is unexpected is now codified in U.S. federal law (PL 115-391). Replicated studies using functional brain imaging have documented a neural signature for dyslexia. Epidemiologic, longitudinal data now demonstrate that dyslexia is highly prevalent, affecting 20% of the population, affecting boys and girls equally. These data further demonstrate that the achievement gap between dyslexic and typical readers is now evident as early as first grade and persists (Shaywitz et al., 2021).

A sizable number of researchers have proposed using a discrepancy between listening comprehension and reading comprehension as a readily measurable definition of dyslexia that is preferable to IQ-achievement discrepancy (Badian, 1999; Beford-Fuell et al., 1995; Spring & French, 1990). Poor readers who exhibit strong listening skills present a unique diagnostic profile.

Of particular interest is the assumption by Wagner et al. (2020) "that a discrepancy between listening and reading comprehension could serve as a proxy for dyslexia to be useful for studying prevalence at population levels, but not sufficient for identification at the level of the individual." The Wagner et al. study strongly recommended that the investigation of dyslexia should focus on those poor readers who exhibit strong oral comprehension. It also concluded that dyslexia occurs "throughout the reading spectrum," and therefore that identification and intervention should not be limited only to those learners whose achievement lagged below their peers on expected state standards. Indeed, a more flexible approach to identification could match struggling students with readily available supportive technologies like text-to-speech. The utility of using a discrepancy between auditory and text-based comprehension as a proxy for assessing the prevalence of dyslexia in a given population prompts its corollary, that supporting struggling readers with audio will have a positive outcome (Wood et al, 2018).

The Origin of Audio-Supported Reading

The concept of ASR was first elucidated by Jackson (2021) in an article focusing on students who are blind or who have low vision. Jackson defined ASR as a technique for reading in which users access digital text for displaying magnified print or refreshable braille along with text-to-speech. In the field of educating blind and visually impaired children, learning to read either braille or magnified print and learning to listen to spoken text have been approached as separate domains of learning within specialized curriculum. First, of paramount importance to the young child, is to establish a primary learning medium in either print or braille through a process known as the Learning Media Assessment. Then, learning to listen to text is introduced at a later time in the child's literacy development, largely for the purpose of compensating for the relative paucity of reading materials available in either braille or large print.

One notable exception to the separation of text reading from listening was proposed by Evans (1997), using an approach she called audio-assisted reading. In this approach, students who struggle with reading braille use tape-recorded material to follow along while reading hardcopy braille. Evans' proposed audio-assisted reading was intended explicitly for the purpose of building braille reading speed. The goal was to remove the listening component once speed of hand tracking and braille character recognition were hastened. Evans was particularly concerned with students whose braille reading skills were lagging behind those of their braille reading peers. Thus, she proposed to examine the potential effects that audio-assisted reading might have on correcting deficits in braille reading fluency. Audio-assisted reading had great intuitive appeal since it mimicked so well the widely applied practice of the read-aloud where a teacher serves as a model of proficient oral reading for students to follow along for the purpose of improving reading speed (Chard et al., 2002).

Audio-Supported Reading and Students with Learning Disabilities

Since Evans (1997) first proposed audio-assisted reading as a technique for building speed among struggling braille readers, several studies have investigated the utility of this approach with struggling readers who were not visually impaired, including those with learning disabilities. At this time, the remedial benefits of audio-assisted reading or text-to-speech for students with learning disabilities are not well established or understood (Knoop-van Campen et al., 2022). Some studies have found an association between text-to-speech and improvements in reading rate (Elkind, 1998), reading comprehension (Elkind et al., 1993; Higgins & Raskind, 2005, 1997; Roberts et al., 2012; Wood et al., 2018); reading fluency (Roberts et al., 2012); and reading endurance (Elkind, 1998; Elkind et al., 1996; Larson, 2015). Improvements in math performance have similarly been demonstrated for some students with learning disabilities who use text-to-speech for math problems (Helwig et al., 1999; Tindal et al., 1998).

At the same time, however, a number of studies have shown mixed results for efficacy with respect to audio-assisted reading or text-to-speech and students with learning disabilities (for example, see Elbaum et al., 2004; Esteves, 2007; Lesnick, 2006; Meloy et al., 2002). Studies such as these, that employ large sample sizes in which the precise nature of participants' reading disorder is not clearly defined, may show mixed results because the participating students may struggle for very different reasons, some of which may involve language processing difficulties that are independent of input modality. As a consequence, these individuals may not be able to exploit the auditory channel for building speed or improving comprehension (Nation, 2005). Moreover, with respect to comprehension, Knoop-van Campen et al. (2022) concluded that while audio may directly support the decoding challenges of students with dyslexia, inefficient use of comprehension strategies may account for lack of efficacy.

For students who struggle primarily as a result of word-level fluency difficulties (decoding or rapid word naming), the supportive or facilitative nature of listening while reading is clear. A recent review of technology-assisted reading fluency interventions for students with disabilities showed a moderate to strong effect on reading fluency and impactful variations in moderator variables such as student status, type of technology, and features of technology (Mize et al., 2022). Of note was one remediation recommendation from this study that indicated that technology-supported reading interventions targeting fluency were most effective when combined with vocabulary instruction.

Recent developments in ASR are primarily applicable for this group of readers who struggle at the word level. As documented by research meta-analysis, increased support for or facilitation of the reading process through speech concurrent with text can increase opportunity to learn by providing direct access to materials ordinarily delivered through visual reading (Košak-Babuder et al., 2019; Li, 2014). Without ruling out possible remedial benefits of ASR for students with learning disabilities, the claim made here is that students who struggle with decoding and word recognition while trying to engage with text alone may be better able to apply their cognitive capacity for language processing and comprehension while listening to text read aloud in sync with screen-presented text.

A History of Language and the Emergence of Text-Based Barriers for Readers with Learning Disabilities

As humans, we are processors of information, which we actively obtain from our surroundings through our separate senses, which act simultaneously as perceptual systems (Gibson, 1979). Our perceptual systems for seeing, hearing, and touching filter and integrate information through our active movements and engagement with the environment. Thus, we take in information from the outside world and construct mental representations of that information in our short-term, immediate memory (i.e., our fleeting conscious awareness) (Atkinson & Schiffrin, 1968). We then apply sense-making strategies from our working memory (Baddeley, 2007) to manipulate those representations based on our prior experience and our intentions or future plans (Miller et al., 1960). In humans, the flow and transformation of information is greatly facilitated by the use of language, which emerges in the child quite naturally and predictably (Chomsky, 1965; Piaget, 1926).

Humans' use of language goes a lot further than facilitating information processing in the individual. Shared and emerging language supports social learning (Bandura, 1995) and cooperation (Slavin, 1985). Since prehistoric times, language has been the principal means of communicating in face-to-face situations in order to form communities and advance society. So far, we are referring to language as common or shared by humans. This is often thought of as "deep structure" in language, which allows us as humans to reason analytically and reach consensus over shared experiences. Surface structure in language is something entirely different. Surface structure is spoken language and not at all universal. Spoken languages emerged in communities separated or isolated in space and time from one another. The basic grammar or syntax of deep structure allows us to learn multiple spoken languages through use and immersion.

Down through the ages, surface or spoken languages created content (wisdom, knowledge) which required preservation and transmission beyond face-to-face communication. Out of necessity, a means of rendering permanence and transportability to the spoken language emerged. Thus, a rule-governed, graphical representation of speech sounds (orthography) emerged as a standard for communicating and archiving spoken content across space and time. As a knowledge source, “books in print” appeared as substantive content down through the ages for teaching and learning. At the same time, books in print established a code (orthography) too difficult to decipher or interact with for many individuals with a print disability.

Use of content stored in libraries and distributed in the form of textbooks and ancillaries was until recently limited to those who could crack the code and make use of the language which the code conveyed. The skilled or proficient reader is smooth and automatic, having perfected grapheme/phoneme or letter/sound correspondence. The proficient reader is able to rapidly discern connected text well within the time constraints of immediate memory. Proficient readers can quickly recognize vocabulary and concepts to overcome chunking limitations in working memory. They can apply rules of text structure, and they can make predictions about what is to follow or what is to be inferred from the text.

Without the ability to rapidly decode text at the outset of a reading task, information cannot be readily processed for comprehension. Overcoming an inability to rapidly decode text has been addressed through a range of diagnostic and remedial approaches. It is not the intent of this paper to compare or evaluate the efficacy of such approaches, but rather to illustrate how superimposing speech along with text can compensate for slow or dysfluent reading and thus, enhance or make more efficient the overall reading experience. Accelerating the rate at which critical information from text and speech enters working memory reduces the likelihood of memory decay. For struggling readers whose language processing skills are intact, technology- enabled audio supports can overcome or compensate for the working memory and cognitive load challenges created by insufficient or ineffective reading rates.

The Benefits of Audio-Supported Reading

ASR takes advantage of “dual modality text processing.” In this section, we describe the benefits of listening to text while looking at text, which include:

- Controlling cognitive load

- Extending task persistence
- Augmenting information processing
- Enhancing interaction with informational or expository text
- Exerting choice and control

Controlling Cognitive Load

At first glance, it may appear that listening to text while looking at text would overload the reader's ability to focus attention on the most relevant aspects of the text. Would not speech be redundant to what is conveyed in print and thus constitute what Sweller (2010) calls extraneous cognitive load? In fact, a recent meta-analysis of cognitive load research in multimedia learning environments identified extraneous cognitive load as the type of challenge most frequently studied (Mutlu-Bayraktar et al., 2019). Further, when comprehending complex, expository text, would not the requirement of having to multitask or pay attention to two distinct modalities simultaneously disrupt the flow of working memory? According to Mayer's (2014) Theory of Multimedia Learning, simultaneous presentation of two functionally equivalent sources of information would violate the redundancy principle (Kalyuga et al., 2004). Interestingly, a study comparing the understanding derived from both text and audio stimuli found higher comprehension in the audio cohort (de Oliveira Neto et al., 2015). A closer look at what is actually going on with ASR challenges the claim that the two modalities are functionally equivalent. An explanation is in order.

It has long been held that human cognitive capacity is constrained by how long information can be retained in immediate memory without being acted upon (Miller, 1956). Without rehearsal, short-term memory rapidly decays. It is also long held that this time-limited, focused attention is further constrained by the amount or quantity of information that can be retained before forgetting sets in. It is generally believed that humans can hold up to 7 (+/- 2) "chunks" of information in short-term storage for a relatively brief period of time (Baddeley, 1994). Thus, whatever content is represented in short-term memory must be integrated with and acted upon with previously learned content stored in long-term memory.

In the act of reading, considerable effort is devoted to processing phonemes, graphemes, morphemes, syntactic structures, and semantic interpretations. As shown above, in the proficient reader much of this effort is automatized through reading development. But for the struggling reader, having to pay attention to these separate processes imposes an excessive burden on cognitive load. In the working memory of the disfluent reader, processes devoted to decoding slow down and distract the reader from extracting the author's intended meaning. With the addition of speech, much of the effort devoted to decoding could be suspended as the text is being processed auditorily at much faster rates.

In ASR, concerns about exceeding one's cognitive load capacity would be warranted theoretically if all of the critical elements from two distinct modalities had to be processed simultaneously (i.e., looking at text at the same time as listening to speech). Certainly, devoting 100% of load capacity to each of two modalities would mathematically double the load. The subjective experience of audio-supported reading, once analyzed, tells quite a different story.

To illustrate, consider devoting 100% of load capacity to ASR and then dividing the load proportionally depending on relative sensory-perceptual and cognitive demands. When text is informational, requiring a reader to closely examine content for study purposes, or otherwise interact with the text in order to highlight or extract information, then much of the load will be devoted to visual modalities for processing. On the other hand, when text is highly familiar, redundant, or entertaining— such as a narrative or a piece of fiction—then the load can be disproportionately auditory. To be sure, this is not an either/or thing. Rather, the reader will be actively engaged in the process of ASR and in control of the distribution of cognitive load depending on the demands of the task and the ultimate purpose for reading.

Extending Task Persistence

Again, common sense might dictate that the combination of looking at text streaming on screen while listening to speech simultaneously may distract, confuse, or overly stimulate a reader to the point where comprehension is disrupted. To the contrary, technology's capability to allow a reader to control the rate at which text is presented and to decide which modality will take precedence during reading tasks allows for sustained engagement and freedom from distraction. Background on the evolution of technologies that support listening may illustrate this point.

Since the 1930s, fixed media for listening to text has undergone numerous transformations, from the use of sound scriber sheets of plastic, vinyl discs, open reel tape, and audio cassettes. As playback units advanced from phonographs, tape players, and cassette players, so did technologies for interacting with the media, such as variable speed control and beep marking or tone indexing. Both features dramatically changed the listening process from passive reception of human-recorded speech to active rate-controllable listening and ease of navigation, which more closely mimicked the proficient reader. A listener could increase the rate of presentation for highly familiar or less demanding content, and slow down for more challenging content and note-taking. The benefits of active listening over passive listening were well documented (Nolan & Morris, 1969). Because listeners could actively control the rate of information pick-up, they could persist at study and learning for longer periods of time.

Thus, ASR further extends, over mere listening, a reader's opportunity to actively engage in the reading task by enabling visual monitoring of text. Miscues from phonemes, morphemes, or syntax, obtained from listening, can be verified or checked against the visual information accompanying the speech. Conversely, uncertainties in tactile or visual recognition can also be verified or checked against auditory information.

Augmenting Information Processing

Reading rates ordinarily increase with age/grade according to a developmental process and sequence of skill acquisition. The developmental process has been carefully documented (Rayner et al., 2001), in which typical readers are observed to use fewer ocular fixations per line as they advance in reading proficiency. A combination of cognitive anticipatory strategy and peripheral attention to physical features contained in text alert a reader as to where gaze should be directed in moving across a line and down a page of text. The precise sequence of skills involved in early reading are well documented, too, by the work of the National Reading Panel (2000). Thus, the mature reader achieves a level of proficiency where making meaning from text appears to be automatic.

Dysfluent readers who struggle primarily at the word level will likely process information contained in text more slowly and therefore are more likely to experience cognitive overload as newly decoded information is slowly combined with previously decoded information within the constraints of working memory. Ken Goodman's familiar example of "cowboys jumping on houses" nicely illustrates this point. The likelihood of confusing "horses" with "houses" in Goodman's example increases as reading rate is constrained because a reader has to hold in working memory the subject of the sentence in anticipation of what is to follow (Goodman, 1967).

In the field of reading research, there is a well-established relationship between words read correctly per minute and reading comprehension (Worthy & Broaddus, 2001; Meisinger et al., 2021; National Reading Panel, 2000). Highly fluent readers are generally good at comprehension. Text-to-speech bypasses inefficient decoding and word naming skills, thus allowing an individual to listen to text read aloud at substantially faster rates. These increased rates, therefore, augment the speed with which information is being processed, thus allowing the reader to utilize his/her full capacity of working memory and cognitive load to comprehend meaning. Augmented reading rate, accomplished through ASR, boosts reading comprehension and shortens the time required to complete academic tasks.

Enhancing Interaction with Informational or Expository Text

In the reading of expository text, a skilled reader must take a very active role in controlling reading rate; stopping to rehearse, ponder or interpret; or scanning backward or forward in search of text that would affirm or disconfirm the reader's sense of the author's intended meaning. In ASR, a reader relies on technology to vary the rate (on the fly) at which text is displayed. In more demanding passages, text may dominate the reading as in close reading. For less demanding passages, text-to-speech will take over to accelerate the rate at which meaning is extracted from text. The proportional contribution of text reading and listening through text-to-speech is determined by the reader, who controls the rate at which text is accessed. When a fast rate is called for, a switch to listening will occur; when a slower rate is desired, a switch to close, visual reading will be executed.

With these facilities afforded by ASR, a reader will become more strategic in choosing how to engage in the task of processing the information contained in text. To engage in passive listening alone would deny the reader access to other relevant cues such as paragraphing, sentence complexity, highlighting, or bolding of key words.

Exerting Choice and Control

One of the key attributes of ASR is its capability to bring the reading process under the executive control of the user. In earlier approaches to reading through listening (referred to above), the reader remained relatively passive. To explain this point further, it is important to note that proficient text readers typically execute a broad range of control strategies to adjust the rate at which they move through text, but those who only listen to text are perceived as merely sitting back and "letting it happen" at a fixed listening rate. This perception is based on the notion that audio input is run as a steady string of utterances from a dispassionate robotic voice. Quite to the contrary, current speech technology can change rate on the fly, stop, start, review, and jump forward under the control of the user. Speech technologies also have selectable high-quality voices.

The interactivity afforded by these technologies approximates the control typical readers impose on a reading task, which is key to effective strategic reading. Such control enables the reader to stop and think, re-read, jump ahead, and slow down for close reading. ASR supports the use of such strategies that in turn enable use of metacognition or "thinking about thinking" for deriving meaning from text which, again, is the ultimate goal for reading. Finally, ASR's capacity to allow a reader to control the rate at which text is presented helps to facilitate sustained engagement and freedom from distraction.

In addition to supports that may significantly increase reading pace and fluency, many of today's readily available utilities — from browsers to eBook reader software — can add vocabulary support to reading in the form of automated lookup. Nearly every application designed to "read" structured text is able to summon word definitions and/or synonyms and antonyms that also can be read aloud. This functionality can improve word-level understanding in context, and for students with attentional or focus issues it provides them with ancillary support within the core area of focus, thus adding a positive spin to the mantra "if you don't go anywhere, it's hard to get lost."

Considerations for the Future

More research is needed relative to ASR and students with learning disabilities. Building on the prior discussion of the application of ASR to the reading experiences of students who are blind or visually impaired, the following discussion presents key considerations to help guide future work concerning the use of the ASR technique by students with learning disabilities.

Not All Students with Learning Disabilities are Likely to Benefit Equally from ASR

Unlike visual, hearing, or orthopedic impairments, the presence of a learning disability has many manifestations. For example, an unusual or unexpected difficulty with reading can be limited to decoding text fluently, or weak vocabulary knowledge, or to the solving of mathematical problems. A pronounced difficulty with learning could also be attributed to distractibility, impulsivity, problems with metacognition, self-regulation, or motor planning. Thus, in contrast to challenges resulting from sensory or physical challenges, learning disabilities are best described as a complex and heterogeneous group of conditions, each one of which can substantially interfere with learning. Given this heterogeneity, it is likely that not all students with learning disabilities will benefit from ASR in equal ways.

While the compensatory benefits of listening to text are experienced by many with reading challenges, not all individuals comprehend text any better when text is read aloud. The mechanisms through which children acquire and use language are complex and multi-dimensional. Difficulties with processing one's own native language can certainly limit or impair reading comprehension, whether text is delivered directly or mediated by listening (Nation et al., 2004). For example, there are individuals who read text out loud with adequate fluency but do not comprehend proficiently (Schwanenflugel et al., 2006). Comprehension, either through reading text or listening to text, may be similarly problematic. Thus, the process of deriving meaning from text, however presented, may be impaired at the language processing level.

On the other hand, individuals with reading challenges that are manifested at the word level through difficulties with decoding, rapid word naming, or vocabulary knowledge may be among the most likely candidates to profit from listening to text read aloud. Here, the same compensatory benefits derived by individuals who are blind or visually impaired can be experienced. For students with specific learning disabilities who struggle at the word level, it is likely that using ASR with existing technology can result in benefits similar to those enjoyed by individuals who are blind or visually impaired.

Students with Learning Disabilities Might Not Use Each Modality Equally All of the Time

To any reading task, readers bring an organized conceptualization of their own background knowledge. What do I know (declarative knowledge)? How do I do things (procedural knowledge)? Referred to as schema, this knowledge base resides in long-term memory (LTM) with relative permanence, according to the information processing theory. For any given passage of text, a variable combination of both new (novel) information and familiar (previously stored) content is displayed for the user on screen and by voice.

In discussing ASR in relation to students who are blind or have low vision, Jackson (2021) explained that ASR does not require the reader to use digital text/braille and text-to-speech equally 100% of the time. Rather, the user can decide when to use each of the two modalities in a strategic manner. Similarly, students with learning disabilities who experience challenges with decoding or rapid naming at the word level can elect to listen primarily and use vision to monitor the input when text is highly familiar. On a different task, when text is difficult and demands close attention, the user with word-level reading challenges can elect to pause, reflect, and question the text using whatever resources are available to working memory. Thus, the combination of inputs from screen and voice need not result in cognitive overload since the proportion of modalities (vision and hearing) is selected by the user whose active working memory is monitoring comprehension during the reading task.

Conclusion

Given the increasingly widespread availability of digital materials and technology today, efforts to prevent or remediate specific reading difficulties of students with learning disabilities, which have not yet succeeded, need not result in a failure to learn. ASR has the potential to benefit students with specific reading-related learning disabilities, in particular those who experience challenges with respect to word-level reading. This article has presented an overview of the concept of ASR for students with learning disabilities. It has been argued that a nuanced perspective on this topic is appropriate, with consideration given to such issues as which students with reading-based learning disabilities are most likely to benefit from ASR, how new technology can support students with learning disabilities in their metacognition and sustained engagement, and how students with learning disabilities can be supported to develop the appropriate strategies to utilize each modality in a purposeful and effective manner.

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