Adoption of Assistive Technologies for Reading Disabilities: Cultural, Literacy, and Technological Aspects

General Exam Report
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1 Introduction

For people with disabilities, many aspects of daily life can be inaccessible. Legally, various disability laws, such as the Americans with Disabilities Act (1990) and the Individuals with Disabilities Education Act (1997) mandate that reasonable accommodations should be provided for employees and students with reading disabilities. Computer-based assistive technologies are one way to provide accommodations. For designers of assistive technologies, the goal is to develop tools and applications that help people with disabilities participate in work, school, or other aspects of daily life. However, any benefits of an assistive technology (AT) only occur if the technology is adopted and used. Unfortunately, studies have shown that, in general, at least a third of all assistive technologies are abandoned after purchase (Phillips & Zhao, 1993; Martin & McCormack, 1999; Riemer-Reiss & Wacker, 2000).

Such abandonments are problematic for multiple reasons. Abandoned technologies represent a waste of time, funds, and resources for the user as well as the other individuals involved in selecting and recommending the technologies (King, 1999). Moreover, negative experiences with an assistive device (e.g., difficulty using the technology, inaccurate matching between the technology and the user's needs, etc.) can lead to increased disillusionment about the potential of AT to positively impact the life of the user (Martin & McCormack, 1999). Understanding the various factors that lead to the adoption or abandonment of assistive technologies can work towards preventing these consequences.

However, translating the results of previous AT adoption studies into workable policies and practices reveals several weaknesses in these earlier efforts. As Dawe (2006) notes, earlier AT adoption studies lump together users with different disabilities, ranging from mobility impairments to sensory disabilities to cognitive disabilities. Although the findings highlight general themes about AT adoption, the diversity of both the assistive tools and the user populations are obscured. Moreover, these studies have tended to focus only on whether a technology is adopted or rejected. Emphasizing these end states neglects the actual underlying process involved in technology adoption (Rogers, 2003) and thereby limits potential interventions to prevent rejection.

In addition to Dawe's criticisms, early AT adoption studies also fail to consider the range of sociocultural and environmental contexts surrounding adoption. Some assistive devices are purchased medically, others through school systems. Each institution has different policies concerning funding and priorities (King, 1999). The individuals themselves may have different responsibilities as well. While in grades K-12, the schools hold the responsibility for insuring accommodations are provided, but afterwards it is the disabled person's responsibility for requesting and proving the need for accommodations (Cory, 2005). Finally, and perhaps most importantly, cultural views and stigmas vary across different disabilities and are likely to influence the actions of an individual with a disability (McDermott, 1993; Cory, 2005).

Given these weaknesses of previous AT adoption research, additional research is warranted in many areas. In a similar vein to Dawe's (2006) decisions to focus on AT for individuals with moderate to severe cognitive disabilities, my work focuses on assistive technologies for reading disabilities. Be it for work, school, or pleasure, reading is a critical skill in today's information society. As 7–15% of the population have reading disabilities (Sands & Buchholz, 1997), assistive technologies for reading have a real chance for positive impact... with the caveat that the technologies are actually adopted and used.

This paper is an investigation, analysis, and proposal of research on assistive technology for reading disabilities and the issues surrounding their adoption. The next two sections provide an overview of reading disabilities and the assistive technologies associated with them. Section 4 reviews previous studies of AT adoption among users with reading disabilities as well as other disabilities. Models of AT adoption are discussed in Section 5. The following section highlights the various gaps in the research and provides insights into why they have thus far been overlooked. Section 7 argues for what next steps should be taken and proposes two directions for research: investigating the use and potential of current digital literacy practices (Section 8) and designing technologies to specifically support the adoption process (Section 9. The findings, insights, and proposed research of the paper are then summarized in Section 10.

2 Overview of Reading Disabilities

The term reading disability refers to a collection of different conditions that involve a profound difficulty with reading. Various terms have been used across the years to describe these conditions: dyslexia, word blindness, phonological processing disorder, strephosymbolia (twisted letters), visual stress, etc. Because of the existence of various politics, histories, and assumptions around the different terms (Edwards, 1994; Wolf & Boulton, 2007), I choose to use the more neutral term "reading disability." This choice also does not restrict my work to any one condition.

2.1 Formal Definition

A reading disability (RD) is a specific learning disability (LD) that affects the ability to perform and learn the process of reading and related tasks like writing and spelling. More specifically, a reading disability is defined more by what it is not than what it is. For example, consider this formal definition used by Dickinson, Gregor, and Newell (2002): "a disorder manifested by difficulty in learning to read despite conventional instruction, adequate intelligence, and sociocultural opportunity" (p. 97]). In deciding if a person struggling with reading has a reading disability, other explanations need to be ruled out first. The person must have adequate intelligence and have had an opportunity to receive reading instruction. If any of these are lacking, the individual is said to not have an RD. If all are present, then the person's difficulty cannot be readily explained and is attributed to some form of an RD (Peer, 2001). Subsequent educational assessments are then used to confirm the diagnosis (Edwards, 1994; Ashton, 2001).

In addition to these alternative explanations, many definitions of reading disabilities also recommend ruling out any potential visual impairments before labeling a person as having an RD (Evans, 2001). Various vision problems like nearsightedness, farsightedness, astigmatisms, etc. can hinder the learning process by inducing physical strain and exhaustion when reading. Evans (2001) recounts several cases of children struggling with reading showing great improvement after receiving proper ophthalmologic care.

One final and important quality of the definition of a reading disability used here is that it is a learning disability. Because not only the process of but also the ability to learn and improve reading is affected, an RD is viewed as a persistent condition that likely existed from birth. Although there are forms of dyslexia acquired through head injuries or brain trauma (Edwards, 1994; Elkind, Black, & Murray, 1996), such conditions are not considered in my work. Similarly, a distinction is often made between learning disabilities and cognitive disabilities. Cognitive disabilities tend to describe conditions with more wide-ranging effects on a person's life and range from mild (e.g., attention-deficit disorder) to more severe conditions (e.g., autism and mental retardation). For the work discussed here, it is assumed that the people with RD have at most mild cognitive disabilities and that their general abilities to think and act are within a range of normal expectations for their age.

2.2 Prevalence and Demographics

Determining the number of individuals affected by a reading disability is difficult to determine, due in part to the vagaries of the definition and the usage of different terms to label the conditions. One particular complication is determining at what point difficulty with reading is severe enough to warrant the label of a reading disability. Another difficulty is that statistics on disabilities often combine reading disabilities with other learning disabilities. However, studies have shown that upwards of 90% of individuals with learning disabilities experience significant difficulties with reading (Kavale & Reese, 1992). With these difficulties in mind, current estimates indicate that between 5 and 15% of the world's population has some form of an RD (Sands & Buchholz, 1997; Evans, 2001). Moreover, variations of reading disabilities occur in all languages, even logographic languages like Japanese (Smythe, Salter, & Everatt, 2004).

Also of note is the large size of the RD population relative to other disability types. This is particularly noticeable in postsecondary education in the United States. In the 1990s, students with learning disabilities enrolling in postsecondary institutions were the fastest growing group of students with disabilities. According to a 1999 study, students with LDs comprise 46% (195,870 out of 428,280) of students registered with disability services at 2- and 4-year postsecondary institutions in the United States (Lewis et al., 1999).[1] The next largest group, mobility disabilities, is one-third the size.

2.3 Difficulties and Strengths

Given the umbrella nature of how reading disabilities are defined, it is of no surprise that individuals with RD exhibit a tremendous diversity of strengths and difficulties (Dickinson et al., 2002). Several common traits, however, have been identified. It is important to remember, though, that like many traits associated with learning, the strength or severity of any strength or weakness will vary across individuals.

Perhaps the most consistent trait associated with RD is a deficit in phonological processing skills. Phonological processing is one of the processes used by the brain when identifying a printed word. In the brain, word identification is achieved through two parallel, communicating processes (Perfetti, Zhang, & Berent, 1992). Visually, letters and words are identified by their shape, and phonologically, letters and letter groups are translated into sounds. As the orality of languages evolved before its written counterpart (Wolf & Kennedy, 2003), the phonological route tend to be the faster at word recognition, with the exception of frequent "sight" words (Ehri, 1997). In people with RD, the phonological route is impaired, requiring the person to rely more on the slower visual identification of words. This defect has actually been detected in neuroimaging studies that show that the brains of people with RD more resemble those of beginning readers in that brain activity during reading is less distributed in both groups as compared to the distributed processing seen in more advanced readers (Bilger, Laginess-O'Neill, & Howes, 1998; Sandak, Mencl, Frost,

& Pugh, 2004). The repercussions of the phonological processing deficit are that word identification occurs at a slower, less efficient rate with a higher tendency of misidentification. Similarly shaped words can also be mistaken for each other, usually due to reversing letters like ‘b’ and ‘d’ (Harman, 1982). Subsequently, reading rate and comprehension are negatively affected.

Memory difficulties are also reported by many individuals with LDs and RDs (Raskind & Higgins, 1998; Dickinson et al., 2002). Short-term memory problems are particularly frequent during reading as word uncertainty makes it more difficult for the reader to form a coherent understanding of the text and thereby pushes at the limits of working memory (W. Kintsch, 1998). Visual memory can also be affected, with some reporting getting lost in a text and having difficulty finding one’s place after looking away for only a short instance (Dickinson et al., 2002; Newell, Carmichael, Gregor, & Alm, 2003). These short-term and visual memory issues also have an impact on interface design. Users with RD have reported getting disoriented by complex menu systems and having difficulties recalling the locations of commands (Keates, 2002).

Although reading disabilities are viewed primarily as being neurological in origin, some visual difficulties are associated with RD (Wilkins, Jeanes, Pumfrey, & Laskier, 1996; Jeanes et al., 1997; Evans, 2001). Chief among these is the notion of visual stress (also referred to as Meares-Irlen syndrome and scotopic sensitivity syndrome). During reading, some readers report perceptual effects such as color, movement, and blurring of letters. Prolonged reading usually acerbates these effects and can lead to headaches and difficulty in sustaining reading. One theory to the cause of visual stress is that black-on-white text with regularly-spaced lines forms an interference pattern that some people are sensitive to. Many researchers view visual stress as a condition separate from reading disabilities that affects an estimated 20–30% of the population to some degree, although there is some evidence that visual stress is more common among people with RD (Kriss & Evans, 2005; Singleton & Trotter, 2005). In general, visual stress is usually diagnosed by ophthalmologists or optometrists (Evans, 2001), although both a screening questionnaire (Singleton, n.d.; Singleton & Trotter, 2005) and computer-based assessments (Thomson Software Solutions, 2005; Singleton & Henderson, 2007) are in development.

Finally, one should not just focus on the negative traits associated with reading disabilities. Several positive abilities are also associated with them (Cottrell, 2003). Many individuals with RD show prowess with tasks involving spatial awareness and visualization skills (Dickinson et al., 2002; Cottrell, 2003). Some also show particular strength with creativity and lateral thinking (Cottrell, 2003; Powell, Moore, Gray, Finley, & Reaney, 2004) as well as in art and music (Edwards, 1994). While these abilities do not directly dismiss the challenges faced by people with RD, these strengths provide potential opportunities for compensating and accommodating the negative aspects of a reading disability.

2.4 Societal and Cultural Issues

Aside from its effects on reading, having a reading disability can impact the overall life of a person. In her case studies of young men with dyslexia, Edwards (1994) found that having dyslexia elicited additional burdens beyond academic difficulties. In struggling with reading while other students appear to have little or no difficulty, the students experienced severe amounts of self-doubt, low-confidence, and feelings of isolation. Many of them reacted to these troubles in negative ways: behavioural problems, extreme sensitivity to criticism, and psychosomatic pain.

Interactions with other people can also be troublesome. Due to misconceptions about what a learning disability is, some people doubt the existence of learning disabilities or assume that the person is merely lazy or unintelligent. Edwards (1994) notes that many of the students in her study had been teased or ridiculed by their peers. In interviews with college students with learning disabilities, Cory (2005) found that several of them had told professors of their disability and were informed that such disabilities do not really exist and that they need only try harder. Cory notes that this attitude is not uncommon; articles in the *Chronicle of Higher Education* have been written by professors questioning the legitimacy of requests for accommodations by students with LDs (Williams & Ceci, 1999; Zirkel, 2000).

The knowledge that a person has a learning or reading disability can cause people to lower expectations from that person. In a phenomenal study of an individual child with LD across several learning environments, McDermott (1993) found that the child's ability to perform various tasks was directly affected by the expectations of the people around him. When people around him expected to read poorly, he did. Otherwise, he still struggled but performed much better. As McDermott describes it, only when a proper unsupportive environment was present would the learning disability "acquire" the child into being disabled.

Given these negative associations of having a reading disability, it is of no surprise that some individuals avoid acquiring the RD label (Edwards, 1994; Cory, 2005). As the body shows no outwardly visible evidence of the person having a reading disability, an RD (as well as any LD) is considered to be an "invisible disability." This allows a person with an RD to potentially pass as normal, thereby avoiding the stigmas associated with the disability. However, passing as "normal" does come with some costs. Studies of success for people with LD have found that acceptance and recognition of one's disability is correlated highly with achievement (Spekman, Goldberg, & Herman, 1992; Gerber, Ginsberg, & Reiff, 1992). If hiding one's disability reflects not accepting its reality, then one's chances for future success could be limited. Furthermore, seeking out support and help from others requires disclosing about the disability to others. In studying the experiences of college students with invisible disabilities, Cory (2005), found that students with hidden disabilities are very strategic in choosing when and to whom they come out to in regards to their disability. Many, due to past negative experiences, will delay registering with disability services until a crisis necessitates it. Unfortunately, this is often too late to avoid poor or failing grades for that academic term.[2]

3 Assistive Technologies for Reading Disabilities

Given the inherent diversity among individuals with reading disabilities, one would expect that the available assistive technologies would also reflect this diversity. However, this is not true. In an overview of various ATs for postsecondary students with learning disabilities, Raskind and Higgins (1998) discuss multiple tools for supporting writing, organization, and mathematics, but only describe essentially one tool for reading: text-to-speech software. Despite nearly 10 years since the publication of that overview, AT for reading disabilities has remained largely unchanged.

3.1 Text-To-Speech Software

Text-to-speech (TTS) applications, like BookWise (Elkind, Cohen, & Murray, 1993) and Kurzweil 3000® (Laga, Steere, & Cavaiuolo, 2006) allow the user to listen to digital text be read aloud by a computer. This bypasses the phonological processing deficit found in RDs by using the reader's unhindered aural ability to understand language. In fact, many people with reading disabilities are quite fluent orally and are more than capable of comprehending spoken language (Sands & Buchholz, 1997).

In addition to reading text aloud, TTS systems often come with additional features. Many systems will optionally highlight the line and/or word being read to help the reader follow along. Some systems also allow the user to increase or decrease the speed at which the text is read. With time and practice, some users become comfortable listening to text read at faster than normal rates. A final feature offered by some systems is to support the digitization of printed texts. For example, some versions of Kurzweil 3000® come with an optical character recognition (OCR) system that allows the user to scan in printed documents and convert them into digital text as well as tools for correcting translation errors. However, the scanning process can be time-consuming as it typically needs to be done one page at a time (Laga et al., 2006), and OCR is highly sensitive to the resolution and background color of the text being recognized (Bigham, Kaminsky, Ladner, Danielsson, & Hempton, 2006).

Evaluatory studies have for the most part confirmed the effectiveness of TTS systems. One study involving middle school students showed that most students who used the TTS software improved both their reading rate and reading comprehension. However, some students' comprehension actually decreased. Further investigation suggested that those students did not possess strong enough auditory skills to find the system helpful. In a follow-up study with adults using the same TTS system, reading performance also benefited from use of the system with the improvements again dependent on the user's auditory skills (Elkind et al., 1996). In both these studies by Elkind et al., they found that the level of improvement was correlated with the severity of the reading disability. Readers who struggled the most benefited the most. However, in a study investigating the use of TTS for teenagers with severe reading disabilities, Farmer, Klein, and Bryson (1992) found no significant improvements with use of the system. As noted by the researchers, the findings had several possible explanations ranging from the participants not being appropriate for the users (possibly due to poor auditory skills), insufficient time practicing with the system, and limitations of the digital voice technology in 1992. Regardless of the reasons, it is important to recognize that TTS systems are not a panacea for alleviating the challenges of RDs.

3.2 Color Overlays

In contrast to the sophisticated technologies used in TTS systems to accommodate the phonological processing deficit, the typical accommodation for visual stress is much simpler: colored transparent sheets laid over the text. Eyeglasses with color-tinted lenses are another option. Both work by changing the background color of text from white to another color, which causes readers with visual stress to report less difficulty with sustaining reading and fewer incidences of headaches and eye strain (Evans, 2001). Meares, a school teacher, first noted this when she observed that some of her students who struggled with reading performed better on days when worksheets were printed on color paper (Irlen, 1991; Evans, 2001). Subsequent research has shown that use of overlays can improve both reading rate and reading accuracy (Jeanes et al., 1997). Interestingly, it has also been shown that the optimal color for an overlay differs across from person to person, requiring the need to carefully select an appropriate color per person (Jeanes et al., 1997; Smith & Wilkins, 2007). Systems like the Wilkins Intuitive Colorimeter have been developed to help optometrists and ophthalmologists in this identification process (see Jeanes et al. (1997) and Evans (2001) for descriptions of this system).

It is worth noting that the use and legitimacy of color overlays is a controversial topic. As Cornelissen (2005) states, there has been a history of "us versus them" attitude among researchers in regards to visual and phonological aspects of dyslexia. In fact, at the Third World Congress on Dyslexia in 1987, the plenary speaker, Isabelle Liberman, made the statement that "Vision has nothing to do with developmental dyslexia" while offering no evidence to support that extreme position (Cornelissen, 2005). To be fair, there have been reasons to doubt the research on overlays. Irlen's (1991) work on visual stress was often presented with a lack of scientific rigor (Kriss & Evans, 2005). Moreover, the biological underpinnings of visual stress are still not understood nor are the reasons for differences in color selection among individuals (Evans, 2001). However, in the last decade, double-blind masked studies, as well as other studies controlling for novelty and placebo effects have been conducted that show the efficacy of overlays (Jeanes et al., 1997; Evans, 2001; Kriss & Evans, 2005). Unfortunately, lead researchers in these efforts, such as Evans and Wilkins, are ophthalmologists by training and publish their findings more in their field's journals. Some of their findings are beginning to be presented in education and reading publications, however, so the results are beginning to be disseminated.

3.3 Other Assistive Tools

Most of the other assistive technologies for reading disabilities that exist are not in wide use, mostly due to many of them having been made solely for laboratory studies. For example, Pepper and Lovegrove (1999) found that users with RD identified words faster and more accurately when words were presented centered one at a time on a computer screen. This approach is believed to help reduce interference from the surrounding words. A less technical but similar approach is to use a piece of cardboard with a small window in it that allows the reader to see only one or two words at a time. Pepper and Lovegrove (1999) simulated this as well and found it to also improve performance, but not as much as the single word at a time. However, both approaches do obscure the layout of the text and would likely hinder looking back over a text. Plus, how both interact with other document elements like graphics and tables is unclear. The use of word and line highlighting in TTS systems like Kurzweil 3000® is a relative of the window approach, though, with the idea of emphasizing the words being read instead of obscuring the rest of the document.

Another potential assistive tool for reading was studied by Frase and Schwartz (1979). Their research looked at whether or not breaking text into lines based on phase boundaries would aid reading comprehension. While comprehension was not significantly affected, reading rate did improve. The line breaks apparently aided the reader when scanning for information. To the author's knowledge, this approach has not been explored with people with RDs. By emphasizing phase boundaries, reading comprehension is supported and could possibly alleviate some of the reading effort. Moreover, the visual structure induced by the line breaks could support the visual memory difficulties mentioned in Section 2.3.

The most promising tool developed in recent years is the SeeWord project out of the University of Dundee (Dickinson et al., 2002; Gregor, Dickinson, Macaffer, & Andreasen, 2003) in Scotland. This project developed a front-end for Microsoft Word® designed for the needs of people with dyslexia and other reading disabilities. While the major contributions of SeeWord were insights about computer user interfaces for this user population, one small study looked at personal renderings of text. Six high school students with RD used the system to customize the font style, font size, line spacing, text color, and background color of text. When compared to reading black text on a white background, five of the subjects made roughly 50% fewer errors when reading text aloud with the customized rendering. This improvement was not significant, however, due to one subject making 54% more errors with the customized rendering. The mostly positive effect of the personalized typographies is very similar to the use of color overlays for visual stress. Moreover, their findings tie in well with recent work showing that people with RD are more sensitive to changes in font types and sizes (O'Brien, Mansfield, & Legge, 2005; Grounds & Wilkins, n.d.). In other explorations of SeeWord's potential, the developers included a feature that colored reversible letters like 'b' and 'd' differently in the belief that the colors would help prevent confusing similar looking words. In a think-aloud study with users with RD, the participants found that this coloring did not really help with word confusion, but the sporadic coloring helped break up the text and reduced their feelings of getting lost in the text (Newell et al., 2003). Despite its promising early studies, the SeeWord project has been inactive for several years now due to lack of funding.

4 Studies of Adoption of Assistive Technologies

Continuing on a theme of the research on ATs for RDs being limited in scope and effort, very few studies have been conducted on assistive technology adoption among users with reading disabilities. In an ongoing review of the literature, I have thus far found only one study that directly examines factors leading to AT adoption exclusively by individuals with RD: Elkind et al. (1996). Thus, to better my understanding of the issues and research surrounding AT understanding, I expanded my review of the literature and examined others studies on AT adoption, some of which include participants with LDs and RDs.

4.1 Background Theory

The study of the adoption of assistive technologies is a subset of technology adoption research (also known as the study of diffusion of innovations) in general. Although several researchers preceded him, Rogers (2003) is viewed as the pioneer of this work. His work included formulating and verifying models that describe the stages an entity (individual, company, village, etc.) goes through in deciding whether to adopt an innovation as well as understanding the social and communication networks that influence how innovations are spread.

Several important and relevant concepts about technology adoption were identified by Rogers, such as relative advantage, compatibility, trialability, and re-invention (Riemer-Reiss & Wacker, 2000; Rogers, 2003). *Relative advantage* is a perception of the benefits of using a technology as opposed to not using it. How well a technology meshes with a person's current needs is denoted as *compatibility*. *Trialability* is having the opportunity to test out a technology before fully adopting / purchasing it. This opportunity has been shown to be quite pivotal in informing the decision to adopt, failure to try out a technology can lead to inaccurate assumptions about the technology (Rogers, 2003). Finally, *re-invention* refers to the process by which a person adapts or modifies a technology to better meet his or her needs and improve its overall compatibility. While all of these concepts are relevant to AT adoption research, re-invention in the form of *repurposing* "regular" technologies to accommodate a disability is of particular interest to AT researchers and is thus often included in the definition of an assistive technology:

> *Any item, piece of equipment or product system, whether acquired commercially off the shelf, modified or customized, that is used to increase, maintain, or improve functional capabilities of individuals with disabilities.* *(Martin & McCormack, 1999, p. 414)*

In addition to identifying concepts like relative advantage and re-invention, Rogers and others also found that failure to adopt a technology comes in several varieties and developed terminology to delineate different types of adoption failure (Riemer-Reiss & Wacker, 2000; Rogers, 2003). *Rejection* typically refers to the conscious decision to not adopt a technology. *Discontinuance* or *abandonment* is the decision to reject and abandon a technology after having previously adopted it, and is usually separated into two types: *replacement* (rejection of one technology for an improved version) and *disenchantment* (rejection due to dissatisfaction). Disenchantment can additionally be separated into three types: *immediate* (occurring soon after the initial adoption), *gradual* (a prolonged process of using the technology less and less), and *explicit* (a conscious decision to abandon the technology after having used it for some time). The work discussed in this paper is mostly concerned with rejection and the different flavors of disenchantment discontinuance.

4.2 Overview of Studies

Table 1 lists the 11 studies on AT adoption I reviewed to develop a comprehensive understanding of issues related to AT adoption and its study. Six of the studies include participants with learning or reading disabilities, but the collection represents a complex range of disabilities including physical disabilities, sensory disabilities, mild to severe cognitive disabilities, etc. The range of assistive technologies considered in the studies is too vast to list here. Different methodologies and study sizes are also represented.

These earliest study shown in Table 1 is the seminal (1993) work by Phillips and Zhao. This study is one of the first large-scale, quantitative studies of the reasons behind AT abandonment. Its use of a structured survey for administration by mail or telephone served as a model for other studies in the table: Wehmeyer (1995, 1998), Martin and McCormack (1999), and Riemer-Reiss and Wacker (2000). Typically, the participant or a caregiver is asked to list assistive technologies, indicate whether or not the technology is still in use, and then answer a series of questions indicative of factors believed to be relevant to adoption and abandonment (e.g., cost, complexity, involvement of user in selection, etc.). Various statistical methods are then utilized to identify correlations and predictive factors of abandonment. The Wehmeyer studies (1995, 1998), however, are an interesting exception to this. Instead of asking if technologies had been abandoned, Wehmeyer asked participants whether or not specific types of AT were being used and if not, would using such a device be potentially beneficial and if so, why is one not being currently used? This shift allowed him to identify barriers to adoption instead of predictors of abandonment after adoption.

These survey studies typically look at a wide range of assistive technologies. Other studies in Table 1 focus more on specific AT and the issues of adoption associated with them: Elkind et al. (1996), Jeanes et al. (1997), Koester (2003), and my personal communications with Comden. The typical approach in these studies is to identify a set of users who benefit from the technology, train the users, configure the device for the user if necessary, and then let the user use the technologies for an extended time. Follow-up observations then determine if the AT is still being used and why the technology was or was not abandoned. The findings are then used to inform and facilitate future deployments of the technology. Typically such studies are smaller in size than the survey studies; both the Elkind et al. (1996) and Koester (2003) involved only 8 participants. The various studies reported in Jeanes et al. (1997) have n's of 30 or higher, but those studies were not primarily about adoption. Instead, the studies they conducted were aimed at addressing the controversies associated with overlays as discussed in Section 3.2. The larger study sizes and long-term usage were thus used to improve the statistical power of their studies and control for potential biases like placebo and novelty effects.

The remainder of the studies reviewed in Table 1 are qualitative in nature. With the exception of the personal communications with Comden about his experiences with AT support for University of Washington students with RDs, most of these studies take the form of case studies: Dawe (2006), Shinohara and Tenenberg (2007), and Deibel (2007b, 2008). In these studies, the goal is to develop a descriptive picture of some aspect of the participants' lives. Shinohara and Tenenberg's technology biography of a single blind individual, Sara, recounts the varied ways that Sara relates to the world through the tasks and tools that she uses. The deep description provides a realistic context for designers of ATs for blind individuals to think about. Dawe (2006) provides a set of rich perspectives and insights about the multiple stakeholders involved

	Study	Description	LD/RD?	Findings
1	Phillips and Zhao (1993)	Mail and phone survey of 227 adults with physical disabilities and their current and past technology usage	No	- 507 of 1732 (29.3%) devices reported as abandoned - Factors of abandoment: user not included in selection, poor device, performance, procurement difficulty, and changing needs of the user
2	Elkind et al. (1996)	Study of 8 RD adults using the BookWise TTS system for several months at home and/or work	RD[1]	- 4 of 8 had positive experiences with the software - Factors included: motivation to improve job, perceivable gains in reading performance, and ease of digitizing texts
3	Jeanes et al. (1997)	Long-term usage of colour overlays by K-12 students for treatment of visual stress	RD[2]	- 14 of 66 students still using overlays after 10 months - Longitudnal analysis controlled for placebo / novelty effects
4	Wehmeyer (1995, 1998)	Piloted mail survey of families caring for persons with mental retardation	No	- Only 10% of respondents used AT despite expected benefits - Cost and lack of information were main reasons for non-use
5	Martin and McCormack (1999)	Survey of AT abandonment in Ireland among 17 individuals with physical disabilities	No	- 35% abandonment rate (out of 46 devices) - High abandonment rate (86%) among users aged 20 to 30 - Males less likely to adopt new AT after initial abandonment
6	Riemer-Reiss and Wacker (2000)	Survey of 115 adults with disabilities to identify factors leading to AT discontinuance as suggested by Rogers' theory of diffusion of innovations (2003)	LD[3]	- 32.4% abandonment rate with 6.4% of AT never used - Significant predictors of adoption: relative advantage / compatability and user involvement in selection
7	Koester (2003)	Longitudnal study of 8 users new to speech recognition software	RD[4]	- 7 of 8 participants had abandonded software after 6 months - Reasons for abandonment: slowness and technical issues
8	Dawe (2006)	Technology-focused interviews of 12 families and 8 teachers of adolescents with moderate to severe cognitive disabiltiies	No	- Importance of including stakeholders beyond family - AT configuration and maintenance should embrace simplicity - Most of the AT used were repurposed technologies
9	Shinohara and Tenenberg (2007)	Embedded case study and technology biography of a single blind individual	No	- Workarounds can be inefficient but preferable by the user - Be sensitive to how technology can mark a user as disabled - A small n allows studies of a broad range of tasks and technologies
10	Comden (2007)	Personal communications with the manager of the Access Technology Lab at the University of Washington	RD	- Near (if not) zero usage of text-to-speech software provided by the univerity by students with reading disabilities - Students might be using freeware TTS systems on their personal computers
11	Deibel (2007b, 2008)	Includes a case study of a student with RD taking a computer animation course	RD	- Experiences with human readers and books-on-tape make the unnatural flow of digital text-to-speech distracting

[1] One subject had acquired reading difficulties due to brain injury.
[2] All participants were diagnosed as experiencing some visual stress when reading.
[3] 7.4% of the 115 participants were identified as having learning disabilities.
[4] Only one participant had specific disabilities with reading and writing.

Table 1: Descriptions and findings of the assistive technology adoption studies discussed in this paper. LD/RD column indicates if the study included participants with either LDs or RDs. The term used by the study is shown.

in selecting an AT for a person with a cognitive disability. She would later use this knowledge to inform the design of remote communication assistive device as part of her dissertation work (Dawe, 2007).

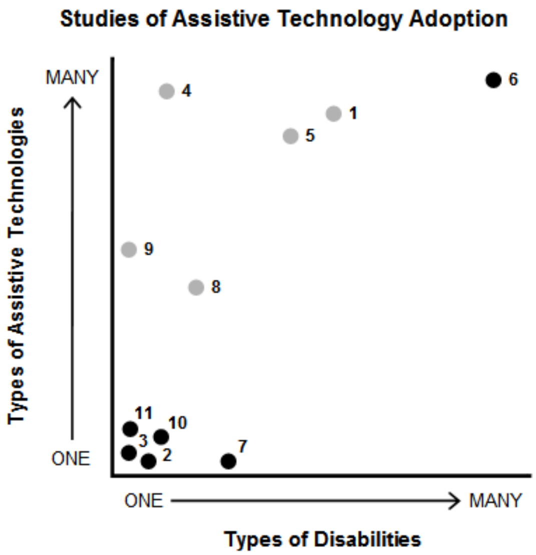
4.3 Insights

Of all the studies in Table 1, Elkind et al. (1996) is the only formal study that looked primarily at reading disabilities (with the exception of the one person with an acquired RD) and that investigated factors surrounding the adoption of an AT. While informative, the experiences of Comden working with students with RD are anecdotal and need solid confirmation (D. Comden, manager of Assistive Technology Lab at the University of Washington, 2007). My studies (Deibel, 2007b, 2008) were about the experiences of students with disabilities taking computer science courses, not AT adoption. It just happens that one of my participants had qn RD and commented about his dislike of TTS software. Jeanes et al. (1997) did look only at participants with an RD (visual stress) and measured long-term usage of color overlays, but their reasons were not from an adoption research perspective. However, they were able to determine that the improvement in performance on the Wilkins Rate of Reading Test (Wilkins et al., 1996) due to using an overlay was positively correlated with long-term usage of an overlay.

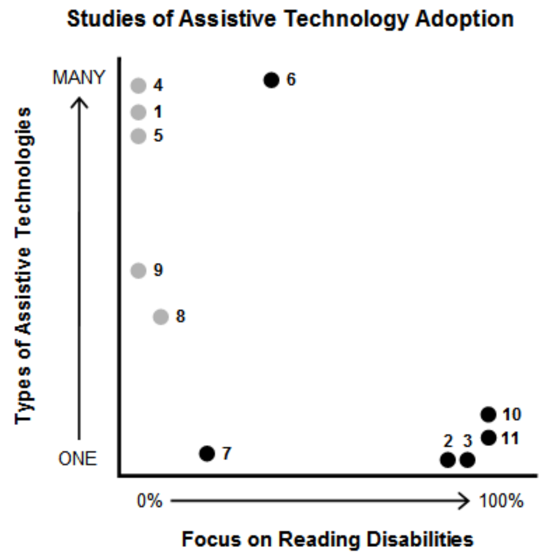
A weakness of the studies that consider more than one disability type is that the results are often not reported by the different types. Any nuances particular to a disability group are lost. Thus, although studies like Riemer-Reiss and Wacker (2000) and Koester (2003) included subjects with LDs or RDs, the lack of reporting the effects due to different disability types makes it difficult to determine how applicable the findings really are to that group. In contrast, the study by Elkind et al. (1996) presents separate findings for each participant and clearly identifies which participant had acquired dyslexia instead of a developmental RD. It is thus possible to tease out the nuances due to disability type.

To develop a perspective on what aspects of the AT adoption research space have been covered, consider the two plots shown in Figure 1. In both plots, the studies from Table 1 are distributed along axes representing the range of AT and disabilities considered. Figure 1(a) plots the studies according to the number of disability types versus the number of AT considered. Its companion, Figure 1(b), plots the same studies according to how much the study focuses on reading disabilities versus the number of AT considered in the study. Together, these plots show that with the exception of the Riemer-Reiss and Wacker (2000) study, research on AT adoption among users with RD have focused narrowly on only a few technologies. Little is known in general about AT adoption for this user population as evidenced by the spaciously vacant upper-right corner of Figure 1(b).

Despite all this, the findings from the Elkind et al. (1996) and Jeanes et al. (1997) are fairly consistent with those of the other studies. A significant performance increase noticeable by the user is generally a predictor of continued usage (Phillips & Zhao, 1993; Elkind et al., 1996; Jeanes et al., 1997; Martin & McCormack, 1999; Riemer-Reiss & Wacker, 2000), and if the AT integrates well with the user's environment and lifestyle, adoption is more likely to occur (Elkind et al., 1996; Martin & McCormack, 1999; Riemer-Reiss & Wacker, 2000). However, other significant factors like the importance of considering the opinion of the user in the selection process (Phillips & Zhao, 1993; Martin & McCormack, 1999; Riemer-Reiss & Wacker, 2000) and the importance of the AT being easy to repair and maintain (Phillips & Zhao, 1993; Martin & McCormack, 1999; Riemer-Reiss & Wacker, 2000; Dawe, 2006; Shinohara & Tenenberg, 2007), have not been explored in these RD studies. Moreover, there is little knowledge on what technologies (both assistive and those repurposed to be assistive) users with RDs actually use to support the reading process, unlike with blind



(a)



(b)

Figure 1: Distributions of previous research studies on AT adoption. Numbers correspond to the studies listed in Table 1. A black dot indicates the study involved participants with LDs or RDs. (a) Plot showing number of disabilities versus number of AT in the study. (b) Plot showing focus on reading disabilities versus number of AT in the study.

individuals (Shinohara & Tenenberg, 2007) and users with mild to moderate cognitive disabilities (Dawe, 2006). Similarly, unlike the data collected by Wehmeyer (1998) for adults with mental retardation, there is a lack of data on this user group's perceptions of the possible benefits of technology.

4.4 Summary

In summary, my overview of eleven assistive technology adoption studies reveals that the research involving people with reading disabilities has mostly been concerned with the adoption and usage of particular technologies. In these few studies, the researchers were the ones who introduced and provided the technologies to the users. Thus, there have been no "in the wild" studies of assistive technology usage among people with reading disabilities.[3] Neither are there studies about the repurposing of "regular" technologies for this user group. While other AT adoption studies have identified factors that influence the AT adoption process, the lack of knowledge about what technologies are currently used by individuals with RDs makes applying such findings a questionable academic exercise.

5 Models of Assistive Technology Adoption

In addition to studies on assistive technology adoption, my review of the research literature has also included models of AT adoption. Informed by studies such as those just discussed, these frameworks attempt to provide a general description of the actions, processes, and players involved in the adoption of an assistive technology. None of the models presented in this section were designed specifically with reading disabilities in mind, so it is worthwhile to discuss how well these models apply to AT adoption for individuals with RD.

5.1 Rogers's Diffusion of Innovations

Although a complete interpretation of the diffusion of innovations work of Rogers (2003) is beyond the scope of this paper, there are certain key elements to the theory worth mentioning. For example, a consistent

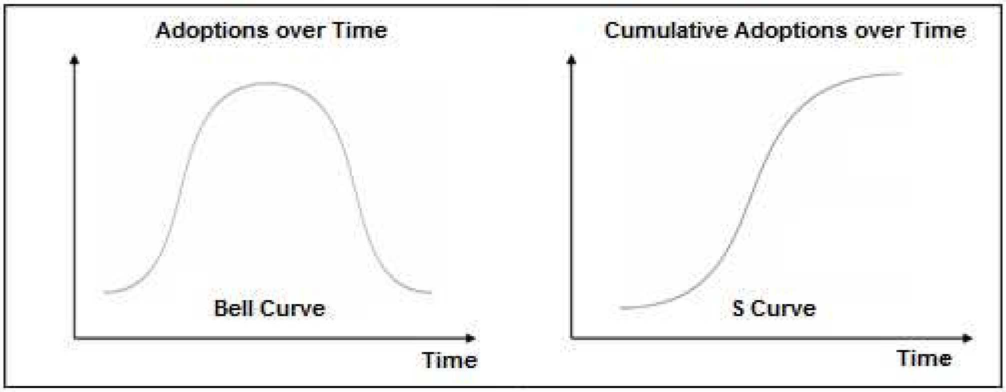


Figure 2: Example plots of adoption over time showing the typical bell curve and s-curves.

finding in most adoption studies is the shape of adoption over time as shown in Figure 2. The number of adoptions over time typically takes the shape of a normal Bell curve, while the cumulative number of adoptions over time takes the shape of an s-curve. The reasoning behind these structures is that adoption is slow in the beginning as awareness of the technology is limited. As more and more people use the technology, the public becomes more aware of the technology and thus the rate of adoption increases until the technology is in common use and has saturated the market. At this point, the number of adoptions drops off as there are fewer and fewer new consumers for the product.

The key to this process is the growing awareness of the technology among the intended user population. This awareness can come from seeing others using the technology or being told about it. This is the troublesome point when it comes to reading disabilities. Given the discussion from Section 2.4, individuals with reading disabilities tend to avoid disclosing about their disability and engage in tactics to hide their disability from others (Cory, 2005). As such, they are perhaps unlikely to be seen using an AT or talking with other users with RD about an AT. Thus, diffusion could be limited due to the low amount of communication.

Typically, diffusion researchers map the social networks of adopters to identify how adoption of the technology diffused through the population (Rogers, 2003). Understanding the social structure can also be used to more effectively promote diffusion within that network. Thus, developing an understanding of the social structure for AT for RD adoption is warranted given the concerns about a lack of communication. However, it is important to not just consider individuals with RD in the network. Other people with

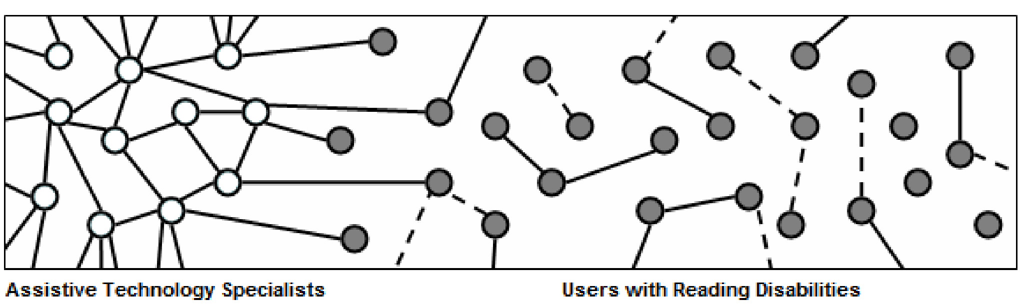


Figure 3: A possible social network involving AT specialists (white nodes) and users with RDs (gray nodes). An edge between two nodes indicates that the two communicate with each other. A dashed edge between two users with RD indicates that communication occurs but neither is aware of the other's disability.

knowledge about or interest in ATs (e.g., parents, teachers, and AT specialists like Comden) will have potential influence in such a network. Figure 3 shows how a social network of AT specialists and users with RD could appear. Due to professional organizations, mailing lists, etc., the AT specialists are likely well connected, meaning that knowledge of new ATs will likely spread quickly among them. However, the individuals with RDs are less connected and only a few talk with the AT specialists as suggested by the hesitancy of college students with RD to register with disability services (Cory, 2005). The figure also demonstrates that communication between two persons with RD might occur with neither knowing about the other's disability.

5.2 Baker's Basic Ergonomic Equation

In addition to the general models of adoption, there are also models designed specifically for the adoption of assistive technologies. One of the first such models is Baker's Basic Ergonomic Equation (Baker, 1986). Baker originally formulated his equation as a way of thinking about alternative communication systems and what makes a person decide to go through the process of using a device to communicate. He reasoned that the likelihood of using a communication device was a function of the time it took, the person's motivation, and the effort (both cognitive and physical) involved:

$$\text{Likelihood of Usage} \propto \frac{\text{Motivation}}{\text{Time} + \text{Physical Effort} + \text{Cognitive Effort}}$$

The basic premise is that the longer and harder it is to say something with the device, the higher the user's motivation must be if he or she is to use the device to convey a message.

Although Baker proposed this equation specifically for the domain of alternative communication systems, King (1999) realized it could be applied to AT usage in general: the longer and harder it is to perform a task with the device, the higher the user's motivation must be if he or she is to use the device to complete said task. King, also an expert in alternative communication systems, modified the equation by separating linguistic effort from cognitive effort:

$$\text{Likelihood of Usage} \propto \frac{\text{Motivation}}{\text{Time} + \text{Physical Effort} + \text{Cognitive Effort} + \text{Linguistic Effort}}$$

Here, cognitive effort refers to the thinking, sensing, procedures, configuration, and memory that a user must do or have to use a device. Linguistic effort refers to the symbolic / semiotic interpretation required by the user when interacting with the device.[4]

In general, Baker's Basic Ergonomic Equation appears applicable to assistive technologies for reading disabilities. Elkind et al. (1996) did identify motivation as a key factor in successful usage of their TTS system. The equation, however, is incomplete in some regards. Consider again the students with invisible disabilities in the study by Cory (2005). These were students enrolled in college with a clear motivation to receive an education and achieve future career goals, yet many chose to avoid seeking out help or support, due in part to their desire to control the impact of being labeled as having a disability. Refusing to use an assistive device is one form of control, so it seems appropriate to include a perception of stigma due to using the device in the equation.

Generalizing on this idea, the perception of stigma risk can be considered to be a component of the more general notion of the *social weight* of a device. As proposed by Toney, Mulley, Thomas, and Piekarski (2003), social weight is the attention a device attracts when used in social situations. As a bit of an extreme

For user u, assistive device d, task t, and context c, the liklihood of the user using the assistive device to perform the task given the context is defined as:

$$Likelihood(u,d,t,c) \propto \frac{Necessity(u,d,t,c) \cdot Motivation(u,t,c)}{Time(u,d,t,c) + Effort(u,d,t,c) + SocialWeight(u,d,t,c)}$$

where

$$Effort(u,d,t,c) = Physical(u,d,t,c) + Cognitive(u,d,t,c) + Linguistic(u,d,t,c)$$

Figure 4: Revised form for Baker's Basic Ergonomic Equation.

example, a thermos typically has a low social weight when used to pour a cup of coffee during a business meeting. Using an espresso machine to make a cup coffee in the same meeting, however, attracts a high amount of attention and thus has a high social weight. Toney et al. (2003) encourage the minimization of social weight when designing a device. For an assistive technology, social weight includes the perception of stigma as it is the user's opinion of the obtrusiveness of the device in a social situation. Moreover, social weight captures the opinions of people other than the user in terms of the device's desirability. Considering the social weight of an assistive device as perceived by the user thus enhances Baker's equation by including a previously missing social component.

However, the stigma or social weight of using a device depends on the context of where it is used. Consider a text-to-speech system being used in a private room versus a lecture hall. By playing the text aloud or wearing headphones in a lecture hall, the user is likely to attract the attention of the lecturer as well as the other students. In a private room, no one is around to notice, so the perceived stigma risk is likely lower. Ergo, context should be another parameter in the equation.

Another aspect missing from Baker's equation is a perception of the necessity of the device for completion of the task. For example, consider a person with paraplegia and a person with a reading disability. Without some form of assistance, the person with paraplegia is for all practical purposes immobile. However, even without an assistive device, a person with a reading disability can usually still read, albeit slowly and problematically. Thus, the necessity of using an AT could be less for that individual.

Additionally, consider the case of "Alan", a student with a reading disability, from my studies on the experiences of students with disabilities in computer science courses (Deibel, 2007b, 2008). At the time of the studies, he preferred books-on-tape over using a TTS system as the unnatural sounds of computerized speech made it difficult for him to follow along. As he noted, though, books-on-tape take a while to prepare, and this has made him fall behind in courses at times. Text-to-speech typically has a much shorter preparation time. Recently, I ran into "Alan" on campus, and he informed me that he was now using TTS because he was highly motivated to graduate this year (Personal communication with "Alan" from Deibel (2007b), October, 2007). To achieve this goal, he realized that although he prefers books-on-tape, the faster delivery time of TTS is a necessity if he wants to keep up in his courses and graduate.

Figure 4 shows the revised form of Baker's equation with the addition of context, social weight, and necessity.[5] Even before these changes, the original equation provided insights into the factors that influence the use of an assistive device. The amendments act to enhance this understanding. Given that both Baker and King work primarily with alternative communication systems, it is enlightening to see how a different perspective can provide new and additional insights into a model.

5.3 Kintsch and DePaula's Adoption Framework

Another model for the adoption of assistive technologies is the framework proposed by A. Kintsch and DePaula (2002). Working from many of the same AT adoption studies and literature referenced in this paper, they put forth a four-stage cycle of that describes a successful adoption process: development, selection, learning, and integration. Additionally, the frame these stages in terms of four stakeholder groups: the users, caregivers, AT specialists, and AT researchers / developers. This framing is particularly notable in that for each stage, A. Kintsch and DePaula discuss what information the stakeholders should communicate to the others.

From the perspectives gained in my various readings on assistive technologies and disability studies over the years, I have serious misgivings about this model of what makes an AT adoption process a success. Although they are careful to mention the importance of including both the user and the caregiver in the Selection process as well as the importance of trial periods, the learning phase largely overemphasizes the role of the caregiver. In this phase, while the user is learning how to use the device, the caregiver is also learning how to customize and maintain the AT. It is not made clear why only the caregiver and not the user is assigned such duties. A. Kintsch and DePaula also state that the caregiver should only help the user learn the device once he or she has become comfortable with it. Perhaps it is poor phrasing on their part, but this places the caregiver in the role of a gatekeeper and goes against their idea of the learning phase being a share event of understanding.

Essentially, my complaint with A. Kintsch and DePaula's adoption framework is that it overprivileges the role of the caregiver and begins to devalue the independence of the user. As one of the major goals of assistive technologies is to improve the independence of people with disabilities (King, 1999), their suggested process seems counterintuitive. Moreover, the assumption that a caregiver is always present is unsupported when people with invisible disabilities are considered. The idea of having a friend, family member, or mentor to occasionally seek support from is frequently reported in the literature (Adelman & Vogel, 1990; Gerber et al., 1992; Spekman et al., 1992; Cory, 2005). Complete reliance on another person, however, is not.

While well intentioned, A. Kintsch and DePaula's framework does not seem appropriate to all disability types. By making a clear distinction between the user and caregiver roles, they inadvertently constrain the applicability of their model to disabilities where having a caregiver is the norm and the user is not expected to be in charge or capable of customizing or maintaining an assistive device. Although collapsing the two roles into a single user / caregiver role belonging to one or more individuals could begin to address these shortcomings.

5.4 Summary

The direct application of these three models to the adoption of AT among individuals with reading disabilities is problematic. In all cases, aspects of this user population identified shortcomings or challenges in understanding and promoting AT adoption. However, recognizing the existence of such shortcomings and challenges provided powerful insights. The tactical practice of not disclosing about having a reading disability suggests that different ways and appraoches for diffusing AT are necessary and should be considered and explored. The revised form of Baker's Basic Ergonomic Equation helped highlight the important of sensitivity to context and social weight. The discussion of the shortcomings of the A. Kintsch and DePaula framework suggested that users with reading disabilities are likely to need to know how to customize and maintain their own assistive devices.

Finding such insights also highlights a weakness of many of the studies reviewed in Section 4. Only two of the eleven AT adoption studies included any consideration of adoption models. Riemer-Reiss and Wacker (2000) frame their study of AT discontinuance exclusively around Rogers's (2003) concepts of technology diffusion: relative advantage, compatibility, etc. Dawe (2006) references Rogers (2003) and A. Kintsch and DePaula (2002) and uses both to highlight important aspects of the adoption process that her study needed to include.[6] Both studies benefited from the insights of the referenced adoption models, further emphasizing the importance of the discussion in this section.

6 Further Gaps of the Research

Thus far, this paper has shown that only a few assistive technologies have been developed for RD. Most studies of AT abandonment have either not included RD or those experiences are buried in the data. Models of AT adoption are problematic when applied to users with reading disabilities. In addition to these gaps, there are other limitations to the previous research worth considering

6.1 Reading on Computers

When it comes to computer-based assistive devices for reading disabilities, this invariably means that the user will be reading text displayed by a computer. For example, consider the years of the TTS studies mentioned in this paper: Farmer et al. (1992); Elkind et al. (1993, 1996); Sands and Buchholz (1997). At the time of these studies, computers at the time were mostly desktop systems. While laptops were in existence, they were notoriously more expensive and bulky. Reading on a desktop computer locks the person to one location and a limited set of postures. Additionally, these desktop computers most likely used CRT monitors for the display. Earlier studies of reading on computers noted that the flicker rate associated with such monitors was particularly problematic (Mills & Weldon, 1987; Muter, 1996; Dyson & Kipping, 1998).

However, advances in technologies have changed what reading on a computer entails. With the advent of portable computers such as laptops, PDAs, and tablet computers, the reader is no longer locked into one location. Posture options have also increased in number, although reading from a laptop still requires a posture not typical with the act of reading. Similarly, the evolution of display technologies away from CRT displays to LCD displays has increased the visual quality of electronically displayed text and have helped eliminate negative factors like flicker rate. Other studies have also determined important factors in the design of electronic reading devices (Gujar, Harrison, & Fishkin, 1998; Harrison, 2000; Waycott & Kukulska-Hulme, 2003).

These new options for how people can read on a computer apply directly to assistive devices for reading disabilities. Nowadays, users with RDs can potentially have and use an assistive device anywhere at anytime. This expanded utility can factor into the decision to adopt a technology, so diffusion studies should consider form factors beyond the desktop machine.

6.2 The Medical Approach to Reading Disabilities

To be fair, there is not a complete lack of research on ATs for RDs. TTS systems have in particular been studied to a great degree (Sands & Buchholz, 1997; Elkind, 1998/2001; Hecker, Burns, Elkind, Elkind, & Katz, 2002). However, this tunnel vision focus on text-to-speech and overcoming the phonological processing deficit is indicative of a medical model approach towards reading disabilities. In disability studies, the *medical model* views a disability as an imperfection or problem that needs treating or fixing (Clough & Corbett, 2000).

This is in contrast to the *social model* which views that the problems and challenges experienced by a person with a disability comes from the environment and not the person or the disability (Clough & Corbett, 2000).

Under the medical model, poor phonological processing is recognized as a key problem in people with RDs. Therefore, interventions should address the problem by either supplanting or treating the deficit. This intent is strongly suggested in the TTS studies as many have discussed TTS not as an accommodation but a tool for remediation with the goal of improving the phonological processing of the user (Farmer et al., 1992; Sands & Buchholz, 1997).

There are numerous problems with using the medical model to direct assistive technology research. By its nature, the medical model focuses on the disability and ignores the person and socioenvironmental context (Clough & Corbett, 2000). Moreover, attempting to replicate what "normal" readers do imposes unnecessary limits on possible approaches. In discussing new directions for telecommunications research, Hollan and Stornetta (1992) use an analogy about crutches and running shoes:

> *The crutch is designed specifically to make the best of a bad situation – to let someone hobble around until they are back in shape. On the other hand, shoes are to correct some of the problems of our natural condition, and in the case of athletic shoes, to enhance our performance.*
>
> *(Hollan & Stornetta, 1992, p.120)*

This analogy is also relevant to AT design. Just as Hollan and Stornetta argue that the focus on perfectly mimicking face-to-face communication constrained and limited telecommunication research, this medical model approach of trying to make a reading-disabled person "normal" also limits AT research. Instead of building reading "crutches," we should consider designing reading "running shoes." In other words, we should all consider technologies that enhance reading performance rather than just repair individual deficiencies.

6.3 Ignoring how Reading Changes Over Time

Another gap in the research on ATs for RDs is that most of the research tends to focus on early reading. While Elkind et al. (1996) did consider adults reading in the work place, much of the work has focused on interventions in early education (Jeanes et al., 1997; Sands & Buchholz, 1997). The emphasis is understandable; longitudinal studies show that the gap between successful and struggling readers widens over time (Cunningham & Stanovich, 1997). Early intervention can help narrow and perhaps prevent this performance gap.

However, it is unreasonable to believe that the same ATs used when a person is "learning to read" are going to be as applicable and helpful when the person is now "reading to learn." Educational practices for the inclusions of students with RD are different at the secondary school level (Peer & Reid, 2001). Part of this is due to the changes in the purposes of reading in higher grades. Deeper comprehension and analysis of the text is expected, and subject-specific reading skills begin to develop. Eventually, experts in a field develop specialized reading skills appropriate to their typical reading tasks (Wineburg, 1991; Peskin, 1998).

For advanced readers with RD, fundamental reading skills like word identification are still important tasks for ATs to support. After all, breakdowns in word identification impact comprehension. However, the same ATs should also offer additional support for the more advanced reading tasks these users experience.

6.4 Focus on Reading in Schools

A final limitation of previous research on ATs for RDs is that much of the work has focused on reading in schools (Farmer et al., 1992; Jeanes et al., 1997; Sands & Buchholz, 1997). The study by Elkind et al. (1996) is a rare exception. Reading does not take place only within the walls of a school. Reading can occur in the workplace (as studied by Elkind et al. (1996)), at home, and essentially anywhere else for a wide range of purposes including for pleasure.

Consider a "successful" implementation of the Kurzweil 3000® TTS system in a school (Careful Planning and. . . , 2005; Texas District finds. . . , 2005). Such an implementation involves the software being installed on computers in a lab. However, a student who uses these computers is typically only at school for 6–7 hours a day for 5 days of the week. The software is not available to the student outside of those times. As Laga et al. (2006) points out, unless the student has a personal copy of the software, informal reading outside of school will be unassisted. Although the AT has been successfully adopted and integrated into the school environment, the student has not been able to adopt and integrate it into his or her reading practices. An assistive technology should be able to support reading in the various locales where the user engages in reading.

6.5 Summary

Both technological and philosophical factors have also limited research on assistive technologies for reading disabilities. Awareness of these factors helps to define how the next steps in research should be approached. Portable computer technologies that can be used in multiple locales is such one path to explore. Building ATs that enhance the reading performance of the user instead of merely accommodating their weaknesses is another.

7 Next Research Steps

Many areas and paths for future research have been remarked upon over the course of this paper. Selecting which to engage in is a matter of prioritizing. At the heart of the discussion presented here is the ongoing need to understand the users and their relationships with the technologies that assist them in their lives.

In recent years, several other assistive technology research efforts have engaged in understanding the interactions between users with disabilities and assistive technologies through the use of participatory design (McGrenere et al., 2003; Moffatt, McGrenere, Purves, & Klawe, 2004; Wu, Baecker, & Richards, 2005). Participatory design (PD) is a form of user-centered design that emphasizes involving the users throughout the design process (Schuler & Namioka, 1993; Nesset & Large, 2004). Working together, technologists and users compromise on technology decisions though an iterative process of exploration and knowledge sharing. These decisions can take many forms, both intangible and tangible: brainstorming ideas for new technologies, formulating plans to address workplace problems, improving existing technologies, and completing the development and implementation of a technology. As participatory design advocates respect and mutual understanding for all parties involved, PD is particularly appropriate for working with marginalized or disadvantaged groups like people with disabilities (Wu et al., 2005).

Although PD has been very successful in AT research and development (McGrenere et al., 2003; Moffatt et al., 2004; Wu et al., 2005), this research approach is also application to AT research for reading disabilities. However, there are some challenges associated with the RD user population to be aware of. One is the diversity of the population as discussed in Section 2. Any subset of users with reading disabilities is likely to display a wide and potentially conflicting range of difficulties and needs. Identifying priorities and forming compromises is likely to be difficult and / or lead to ineffective designs (Newell & Gregor, 2000; Massimi, Baecker, & Wu, 2007).

Another challenge is that the type of technology to develop is unclear. In Wu et al.'s work (2005) with amnesia patients, the PDA-based orientation technology they developed was informed by previous effective accommodation approaches. Having a specific task to design a technology towards helps focus the participatory design process. For reading disabilities, however, the already existing assistive devices are exceedingly limited. Engaging in a brainstorming-focused participatory design practice like Kensing and Madsen's future workshops (1991) could identify a particular tool or task to design. However, the diversity of the population decreases this likelihood.

Ultimately, what is really needed next is what was said at the beginning of this section: a better understanding of users with RD and their relationships with the technologies they use to assist the reading process. Referring back to Figure 1(b), studies are needed to fill in the upper-right corner and to present an overview of what technologies are adopted and abandoned by users with RD. Otherwise, any approach involving user-centered design will be working blind with a user community of which we know painfully little.

At the same time, however, technology can still be developed. In the various flavors of user-centered design (Nesset & Large, 2004), the role of the technologist is to be aware of what technology is capable of both now and in the near future. Informed with knowledge about the users and their needs, technologies can be developed that are sensitive to and inclusive of the users (Newell & Gregor, 2000).

The next two sections describe my plans for conducting this parallel research threads. Section 8 discusses an investigation into the literacy and technology practices of users with reading disabilities. How to use technology to actively support the adoption process is detailed in Section 9.

8 Studying Technology Practices and Digital Literacies

Understanding the role and place of assistive technologies in the lives of users with reading disabilities could be conducted in one of the ways presented in Section 4: a large-scale quantitative survey or a smaller qualitative case study. A survey similar to those conducted Phillips and Zhao (1993) and Riemer-Reiss and Wacker (2000) does provide a broad summary of what technologies are currently in use and which are not. However, this binary view of technologies being used or not used neglects the complex process that underlies adoption and could perhaps overlook technologies that have been re-invented as assistive devices (Dawe, 2006). A qualitative case study in the same spirit as those conducted by Dawe (2006) and Shinohara and Tenenberg (2007) can capture both of these elements.

Moreover, as Shinohara and Tenenberg (2007) point out, the simpler logistics of smaller n studies allow researchers to explore a greater range of technologies and tasks. As noted in Sections 6.3 and 6.4, the existing research has focused nearly exclusively on reading in formal learning environments. A smaller qualitative study would permit observing a person with RD in a variety of reading contexts ranging from formal environments like school and the workplace to informal environments such as at home. Different purposes for reading could also be explored: learning, work, pleasure, etc. This comprehensive portrait of the reading tasks and situations of a person with a reading disability would be invaluable for understanding how, where, and when assistive technologies can positively integrate into the lives of users with RD.

8.1 Study Participants

Because people who struggle with reading read both less and less often than their peers (Cunningham & Stanovich, 1997) and will tend to choose careers with minimal amounts of reading (Edwards, 1994), the selection of people to include in this study should make some attempt to insure that the participants actually engage in reading on a regular basis. Thus, participant recruitment will likely include people enrolled in some form of school such as high school, college, or graduate/professional school. The choice of older readers is intentional so that expert reading skills can be considered. Additionally, emphasis will still be placed on reading for both formal and informal purposes.

8.2 Technology Interviews and Biographies

To develop these case studies of technology use, a combination of the methods utilized by Dawe (2006) and Shinohara and Tenenberg (2007) will be used. The idea is for the researcher to be directed by both the researcher and the participant. Semi-structured interviews similar to those used by Dawe (2006) and myself (Deibel, 2007b, 2008) will the source of control for the researcher. In a semi-structured interview (Taylor & Bogdan, 1998), the set of questions acts as a guide for the researcher and is mostly used only to promote dialogue at the beginning and low points in the interview. Primarily, the subject drives the interview by talking about whatever he or she views as important. The researcher can always interject for clarification or to probe an idea further, but it is the participant's own perspective that is of interest. Questions in these interviews will inquire at the very least about current and past ATs used by the participant, other technologies that have been helpful for the user, as well as desires for future technologies.

Also, to allow the participant to direct the discussion about what technologies are important to him or her, the technology biography approach utilized by Shinohara and Tenenberg (2007) will also be implemented. With this methodology, the user selects the technologies he or she views as important and then describes how they use the technology, what they like about it, what they do not like, what could make it better, etc. This technique will potentially be fruitful for enhancing our understanding of the user populations' interpretation of diffusion concepts like relative advantage, compatibility, and re-invention (Riemer-Reiss & Wacker, 2000; Rogers, 2003).

8.3 Digital Literacy

In addition the above inquiries, I will also investigate what is being read by the participants. The type of reading and the materials involved are important aspects that any assistive reading device should be able to support. Importantly, I will consider types of reading beyond typical literacy practices.

In recent years, literacy scholars have begun to expand the definition of literacy to include more than the traditional printed text (New London Group, 1996). A more universal definition of literacy is the skills and knowledge required to engage in production and consumption of information in a particular genre and medium. This expands the notion of literacy to include other semiotic domains beyond the printed text, including digital technologies like e-mail, instant messaging, video games, and web pages (Gee, 2003; Kist, 2004; Stone, 2007).

How people with reading disabilities engage in digital literacies is unknown. If the same performance gaps and hesitancy to engage in reading associated with traditional print literacies (Edwards, 1994; Cunningham & Stanovich, 1997) apply to digital literacies as well, then my studies will show that my participants do not engage in these literacies. However, a study by Stone (2007) suggests that the findings could be surprising. Stone observed how middle school students of color who were labeled as remedial readers engaged with their favorite websites. These observations, which took place outside of a formal school environment, revealed that these "struggling readers" engaged in advanced comprehension activities while viewing their favorite web pages. These tasks included recognizing contradictions between different websites and discussing why a particular site was more reliable. Corroborating and integrating multiple conflicting documents is an advanced skill more typically learned in late high school and college (Britt & Aglinskas, 2002), yet these remedial middle school students were automatically practicing them. Like the child with LD in the study by McDermott (1993), the reading abilities of Stone's students were dramatically changed once they were removed from the formal school environment that expected them to struggle.

Exploring the digital literacy practices of people with reading disabilities will provide a more comprehensive understanding of how reading disabilities affect literacy skills in general. Moreover, the findings could provide further insights into how the context and task influence the effects of having an RD. New domains for applying AT devices towards will also be found, and providing access to these domains could increase users' perception of their advantages of an AT.

9 Technology for Supporting the Adoption Process

Although the studies reviewed in Section 4 of this paper covered a wide range of disabilities and assistive technologies, the various factors that lead to AT adoption or abandonment were fairly consistent: seeing a benefit from using the AT, being involved with the selection of the AT, knowing how to use and configure the AT, etc. Moreover, these factors are not unique to AT adoption; Rogers (2003) notes that when an individual contemplates a new technology, the individual typically asks the following questions:

> *"What is this innovation?" "How does it work? "Why does it work?" "What are the innovation's consequences?" and "What will its advantages and disadvantages be in my situation?"*
>
> *(Rogers, 2003, p. 14)*

Given the consistency of these factors and questions, it becomes possible to develop a technology that supports AT adoption by directly addressing the issues known to influence adoption. This is achievable through the use of the HCI design methodology of semiotic engineering. Incorporating these concerns into the AT design process will hopefully reduce the chances of abandonment for the assistive technology being developed.[7]

9.1 Semiotic Engineering

Semiotics, the basis for semiotic engineering, is the study of signs, the symbols and representations used in communication, and their meanings (Souza, 2005). In semiotics, the meaning of a word or picture is dynamic, influenced by social, psychological, and cultural contexts. Understanding sign interpretation is about understanding communication.

In human-computer interaction, semiotic engineering studies the communication processes that take place between a designer and a user through the medium of the computer interface (Souza, 2005). Difficulties and confusion experienced by the user is treated as a breakdown in communication in that the designer's choice of signs (the interface) fails to convey their intended meaning to the user because he or she is applying a different meaning to those signs. Design and evaluation techniques in semiotic engineering thus involve identifying and preventing such breakdowns.

The critical observation of semiotic engineering is that the interface is only a partial realization of the designer's intended message to the user due to the computer's inability to reproduce the complexity of human language. Thus, the designer must carefully craft her intent into the interface. The interface components that convey and clarify this are referred to as the *designer's deputy* (Souza, 2005).

9.2 Designing for Adoption

For the design of assistive technology, semiotic engineering suggests several approaches for supporting the adoption and configuration processes. In particular, the configuration difficulties reported by Dawe

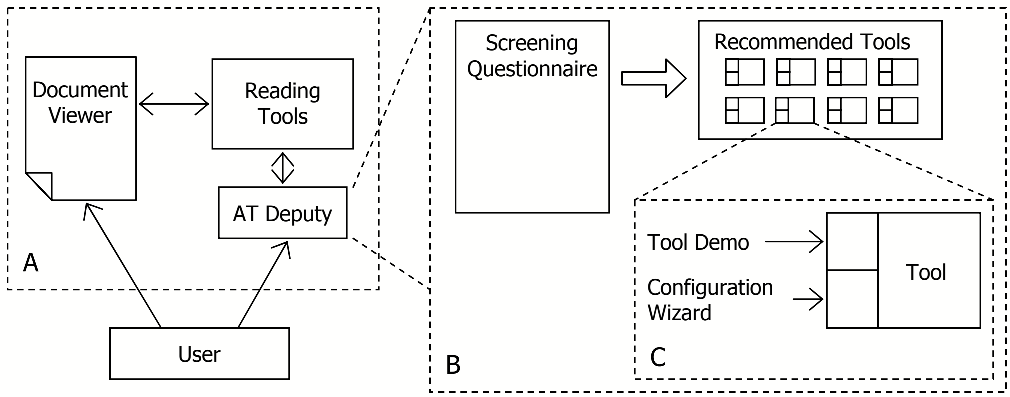


Figure 5: An assistive application for people with reading disabilities designed using semiotic engineering. A: Overall application. B: Detail of AT Deputy. C: Detail of a reading tool.

(Dawe, 2006) indicate a failure of the interface to convey the designers' intent. Various semiotic evaluation techniques could be used to identify the sources of these breakdowns as well as potential remedies (Souza, 2005). Moreover, semiotic engineering's focus on the communication of the designer's intent to the user also implies that this message should be considered at the beginning of the design process and integrated into all stages of development.

Depending on the nature of the AT in question, the designer's intent is likely to vary for different applications. However, the factors influencing AT adoption suggest that the designer's deputy should at the very least be capable of conveying information relevant to the following questions:

- What does this AT do?
- Why will this AT help people with my disability?
- Will this AT help me with my ability?
- How do I configure this AT?
- How do I use this AT?

Each question addresses information known to influence a user's decisions about using a technology. Some apply more to the stigmatization issues surrounding the assistive technology. Other questions address technical challenges in using the technology.

Being able to find answers to these questions will aid users during the adoption process. More importantly, however, by designing the AT's interface to address these questions, the designer must consider the issues surrounding technology adoption and identify how to address them.

9.3 An Assistive Application for Reading Support

As a proof of concept for using semiotic engineering in AT development, I propose creating a tool for supporting users with reading disabilities is being developed (Deibel, 2006). A schematic of this application is shown in Figure 5. Because of the diversity citedickinson-seeword-2002 and the complex stigma issues surrounding reading disabilities (Cory, 2005; Elkind et al., 1996), a single accommodation will have limited applicability. Instead, a document viewer is paired with a collection of interoperable reading tools (see (Deibel, 2006; Dickinson et al., 2002; Elkind et al., 1996) for examples). To aid the user in identifying which tools to use, an intelligent recommendation system is also included: the AT deputy.

As suggested by its name, the AT deputy embodies a large portion of the designer's deputy. First, it presents the user with a screening questionnaire (section B of Figure 5). These questions help pinpoint which tools will be most effective for the user. The user is then presented with these chosen tools. To further support the adoption process (and communicate the designer's intent), each tool contains both a demonstration of the tool and a configuration wizard (section C of Figure 5). Through the combination of the screening questionnaire, the tool demos, and the tool configuration wizards, the AT deputy embodies the five questions from the previous section.

As an example of using this system, a user takes the questionnaire which identifies him as having difficulty with phonological processing. Because of this finding, the system suggests two tools: a text-to-speech tool and a tool that respells words phonetically. After viewing a demo of the TTS tool, the user decides against the text-to-speech tool as being too visible, but decides to give the respeller a try. The system then helps the user configure the respeller. As the user wants to avoid having his text looking childish, the system guides him to have the respellings use IPA format and to appear only on demand.

10 Summary of Proposed Research

This paper has presented an overview of assistive technologies for reading disabilities and the issues surrounding the adoption of said technologies. Overall, the research on these topics has been very sparse with most of the research investigating either text-to-speech or color overlays. Additionally, various factors involving technology, educational and literacy practices, and the culture surrounding disabilities have constrained previous research and work to a narrow domain. To address these limitations, I propose two parallel paths for research to take next:

- Exploration of the technology use and digital literacy practices of users with reading disabilities
- Development of a reading support system through semiotic engineering that directly supports the adoption process.

A summary of the this proposed research and next steps follows.

10.1 Continued Review of the Literature

To further my understanding of the adoption process, I intend on reading more of Rogers (2003) seminal text on the topic. Additionally, there have been multiple studies that I have come across in the process of composing this paper that I wish to explore further, as well as recommendations received from other researchers when I attended the ASSETS conference in October, 2007 (Deibel, 2007a). Of particular interest is the work of Scherer (2007). Scherer's work has investigated the challenges of matching a person with a disability to the appropriate assistive technologies.

10.2 Study of Technology and Digital Literacy Practices

As discussed in Section 8, a combination of semi-structured interviews and technology biographies will be conducted to help fill in the gap in research in regards to how assistive and regular technologies are used by individuals with reading disabilities. A wide range of literacy practices will also be considered, with an emphasis on digital literacies. Specific digital literacy studies of the user population might also be conducted. As the planning for this work is still in its infancy as well as for reasons of time and space, further description and discussion of the proposed studies in unavailable at this time.

10.3 Developing the Assistive Technology Deputy

As a technology contribution, aspects of the technology adoption support system will be developed as a proof of concept of the ideas. Developing and evaluating the complete system is beyond the scope of a dissertation, and it is more important to test the efficacy of various components before building the whole system. Thus, only certain elements will be developed.

One of these is the screening questionnaire used to identify the strengths and needs of the user. Developing this expert system alone will require significant effort in bringing together various RD screening practices as well as finding ways to bring in the experience and insights of disability specialists. Even if the remainder of the AT deputy system is never built or proves to be ineffective, the screening questionnaire will be of particular value to people working in disability services as it will be a new assessment tool that aids in understanding the needs of a person with reading disabilities.

A document viewer that allows for easy integration of different reading tools will also be produced. Such an application will effectively be a test bed for researching the effectiveness of assistive reading tools. Moreover, the viewer will permit the study of how different accommodations interact.

A few assistive tools will also be developed to show the range that the system is capable of providing. In particular, the tests and procedures for determining the optimal color of an overlay for treating visual stress will be implemented. This will involve automating both the clinical assessment tool, the Wilkins Rate of Reading Test (Wilkins et al., 1996), and the ophthalmologic procedures used in the application of the Intuitive Colorimeter (Evans, 2001). Other assistive tools, such as the phonetic respeller mentioned in Section 9.3 may be developed.

11 Parting Thoughts

The work proposed here is but a step in the development of better technologies for assisting people with reading disabilities. With the lack of previous research in this area, a foundation needs to be established. Elkind et al. (1996) helped establish this foundation, but further attention towards newer technologies, multiply literacies, and the different contexts and purpose of reading need consideration. Through studies of the technology and literacy practices of people with RDs, the foundation will become stronger. At this point, delivering and supporting the adoption of ATs for RDs can truly begin, and perhaps the ideas of the adoption-supporting technology also proposed here will prove fruitful.

Notes

1. This statistic is very likely an underestimate of the number of students with learning disabilities at universities in the United States. Studies have indicated that students with invisible disabilities like LDs and RDs tend to delay registering with disability services (Cory, 2005). As the numbers from the NCES study (Lewis et al., 1999) only include students registered with disability services, the actual number of college students with LDs and RDs is likely higher.
2. The strategic efforts used by students with reading disabilities to control how others perceive them is markedly similar to the tactics used by the students in a study by Gomez, Stone, and Hobbel (2004). During ethnographic observations of a class of remedial reading students (not RD but behind in learning to read), the researchers found that the students engage in conscious efforts and strategies to avoid the remedial label and instead be viewed more as regular youth. Such tactics of identity included selecting reading materials outside of the recommended options and subverting the teacher's lessons plans by talking off-topic. Comparisons of how these two populations (reading disabled and remedial readers) avoid stigma-associated labels could be illuminating.
3. An "in the wild" study is my term to describe a study that looks at technologies that a person has adopted on their own volition and not because a researcher introduced the person to the technology.
4. What actually distinguishes cognitive and linguistic effort is not made clear by King (1999). Interpreting the messages and symbols offered by a device does involve cognition. However, King's choice to separate the two is useful in highlighting the importance of considering both the procedures and the messages of the system. This insight is similar to and in line with the principles of semiotic engineering (Souza, 2005) discussed in Section 9.
5. Several of the elements in this revised equation are worth discussing. First, I deliberately chose to limit the parameters of $Motivation$ to the user, task, and context with the idea that motivation being device-independent makes motivation be more about wanting to do an action than wanting to use a device. Second, context was included as a parameter for all aspects of the numerator. This is meant to reflect the perspective that a disability is only a problem when the socioenvironmental context is not accommodating (Sears & Young, 2003). Finally, the numerator is framed as $Necessity \times Motivation$ instead of $Necessity + Motivation$ deliberately emphasize how the perception of the necessity of the device for the task can overpower either a high or low motivation to perform a task.
6. Dawe's use of the A. Kintsch and DePaula framework (2002) is appropriate given her focus on moderate to severe cognitive disabilities as her disabled participants were for the most part incapable of procuring assistive devices on their own. Their level of independence was far lower than most individuals with reading disabilities. It was also expected that either a family member or teacher would be heavily involved in the usage and maintenance of any assistive device.
7. The remainder of this section comes mainly from Deibel (2007a).

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Appendices

A List of Abbreviations

AT	Assistive Technology
LD	Learning Disability
OCR	Optical Character Recognition
PD	Participatory Design
RD	Reading Disability
TTS	Text-To-Speech