44

UNIVERSAL ACCESSIBILITY AND FUNCTIONALLY ILLITERATE POPULATIONS: IMPLICATIONS FOR HCI, DESIGN, AND TESTING

William M. Gribbons
Bentley College

INTRODUCTION

Over the past decade, the topic of universal accessibility has received close attention in the field of system design. While considerable progress has been made in addressing the needs of the physically disabled and aging, the cognitively disabled have largely been overlooked (Gribbons, 1992, Newell, Carmichael, Gregor, and Alm, 2003). With nearly 45 million adult Americans suffering from the debilitating effects of illiteracy, the Universal Accessibility movement has clearly not been universal. While many have called for action (Dickinson, Eisma, & Gregor, 2003; Shneiderman, 2000), an extensive review of the leading human factors and HCI journals revealed a small number of studies focused on this critical issue. The topic of the less literate and learning disabled is also glaringly omitted from the leading HCI and human factors textbooks.

The research that does exist in literacy and learning disability studies has been confined, for the most part, to the fields of educational psychology, instructional design, and health-care informatics. Here, a rich research tradition dates back many decades. However, most of these findings are limited to the design of the classroom experience, standalone computer-based training systems, and paper-based communication products. Research in noneducational settings for general interface and interaction design is severely limited. Further, most of this work focuses on children and not the adult population.

The ubiquitous nature of the Internet has forced some progress on accommodations for the cognitively disabled. The Web Content Accessibility Guidelines 1.0 (1999) released by the W3C urges designers to accommodate this population. Unfortunately, many emerging guidelines tend to be vague and nonspecific.

This chapter will address the challenge of accommodating functionally illiterate users and/or users with learning disabilities in system design. It will explore the nature of this population and the magnitude of the problem, the relationship between literacy and learning disability, characteristics of the disability, and recommendations for design practice and usability testing. Ultimately, it is hoped that this effort will encourage further research in this critical area and the integration of that work in our profession's educational programs, guidelines, and best practices.

Defining the Population

Part of the challenge of addressing this population is building consensus on the most effective definition of this group. Common labels include "functionally illiterate," "cognitively disabled," and "the learning disabled" (a subset of the cognitively disabled group). An underlying assumption in this work is that the three categories are not mutually exclusive. For the purposes of this chapter, discussion will be limited to functionally illiterate and learning-disabled populations. Functional illiteracy, a lack of document and quantitative literacy needed to function in modern society, was selected since it provides the most comprehensive picture of the total population. This perspective brings to the discussion a very detailed set of demographics and statistics. Unfortunately, this perspective is weak on underlying causes and effective accommodations. Fortunately, the learning-disabled perspective, while focused most often on the school-age population, provides an extensive research base that defines the characteristics of this population, the underlying source of the disability, and possible accommodations. Learning disability is an umbrella term used to describe a wide range of disorders in information processing and it is generally believed that learning disabilities are linked to a dysfunction in the central nervous system. The larger cognitively disabled category was not chosen since it includes a much broader class of disabilities including Down syndrome, autism, emotional disabilities, and Alzheimer's disease. Naturally, these more severe disabilities require more extreme accommodations.

The causes of functional illiteracy are complex and often inextricably intertwined; these causes include a lack of educational attainment, dyslexia, other learning disabilities, and social deprivation. Further complicating matters, many adults with low literacy skills were never diagnosed with a learning disability as children and entered adulthood suffering the effects of the disability without knowing the cause. Consequently, it is all but impossible to characterize whether the cause of adult illiteracy is a product of low educational attainment, an underlying disability, or whether an undiagnosed disability was the cause of an individual dropping out of the educational system. While it may never be possible to determine how many in the lower-literacy population have learning disabilities, it is a safe assumption that the contribution to the population is significant.

Population Size

The current state of functional illiteracy in the United States presents a shameful picture. According to the 1992 National Adult Literacy Survey, some 23%, or nearly 45 million of approximately 200 million adult Americans, function at the lowest level of literacy, "Level 1." Those at Level 1 literacy are, for the most part, able only to read a simple form or understand rudimentary information in a short news article; others are not capable of even this (Kirsch, Jungeblut, Jenkins, & Kolstad, 1993). Within the context of these figures, it is surprising that greater attention has not been directed to this population, since its numbers are larger than all other disability groups combined.

The other literacy levels, two through five, represent progressively higher levels of literacy skills. Not surprisingly, one contributor to functional illiteracy is low educational attainment. The National Adult Literacy Survey states that "adults with relatively few years of education were more likely to perform in the lower literacy levels than those who completed high school or received some postsecondary education. (Kirsch, Jungeblut, Jenkins, and Kolstad, 1993). The National Center for Educational Statistics (2001) reported the following:

> "Between 1972 and 1985, high school completion rates climbed by 2.6 percentage points (from 82.8 percent in 1972 to 85.4 percent in 1985); since 1985, the rate has shown no consistent trend and has fluctuated between 85 and 87 percent. This net increase of about 3 percentage points over 29 years represents slow progress toward improving the national high school completion rates" (High School Completion Rates, Executive Summary). Kirsch, Jungeblut, Jenkins, & Kolstad, 1993.

Given this slow progress, it is highly probable that educational attainment will continue to be a key contributor to lower literacy skills among adults for the foreseeable future.

The consensus of most literacy experts is that people at Levels 1 and 2, the lowest levels, lack the essential skills to function successfully in society. In 2003, this survey was readministered and the results showed no significant improvement in prose and document literacy, with some improvement in quantitative literacy. Cleary the data from these two studies show the problem is large and gains in literacy—like increases in high school completion rates—will come slowly.

Unlike the measure provided by the National Adult Literacy Survey, there is no large-scale study measuring the prevalence of learning disabilities in the general population. There are, however, a range of estimates from a variety of sources. The National Dyslexia Association (n.d.) estimates that 70–80% of the population of students receiving special education services has deficits in reading and that 15–20% of the general population has language-based learning disabilities (how common are language-based learning disabilities simply to document the scope of the problem). The Interagency Committee on Learning Disabilities believes that 5–10% of the population is affected by learning disabilities. The President's Committee on Employment for People with Disabilities found that 10–14% of the adults in the workforce have learning disabilities. Finally, the National Institutes of Health estimated that 15% of the population in the United States has some type of learning disability (National Institute for Literacy, n.d.). Despite the probable link between those with learning disabilities and the larger lower-literacy population, no attempt has been made to validate this connection.

Not surprisingly, functional illiteracy and illiteracy are not problems confined to the United States. There are an estimated 876 million illiterate adults in the world, which represents nearly a quarter of the world's population. In developed nations, it is estimated that there are approximately 100 million functionally illiterate people (Kickbusch, 2001). In India alone, nearly 45% of the adult population is illiterate according to the 2001 Indian Census (Huenerfauth, 2002). These statistics and others clearly convey the global scale of this problem.

Making the Case for Including Functional Illiteracy

The lack of research addressing literacy and learning disability in the HCI discipline was understandable 10 or 15 years ago when this population was highly unlikely to interact with technology outside of an educational setting. With the ubiquitous nature of information technology in modern society (for example, the Internet, computers in all aspects of work, public kiosks, ATMs, electronic voting machines, e-health, and consumer electronics) this research gap is now indefensible. Accessible technology is no longer a luxury or an option; rather it is a prerequisite to gaining access to information that affects one's quality of life, participating in government, and contributing to the economy. A report from the Department of Commerce (2002) stated that "[b]etween December 1998 and September 2001, Internet use by individuals in the lowest-income households (lower socio-economic groups represent a disproportionately high percentage of the lower literacy population) increased at a 25 percent annual growth rate" (p. 56). The study also reported that "as of September 2001, about 65 million of the 115 million adults who were employed and 25 or over use a computer at work" (p. 57). While the percentage of workers using computers was significantly higher for "professional" positions, 20% of those working as operators, fabricators, laborers, farmers, and fishermen use a computer as part of their work (p. 58). Lastly, shifts in the economy from "hands-on work" to "information-and-technology work" will seriously disadvantage lower-literacy groups unless there is a corresponding increase in functional literacy skills.

If the size of this population alone were not enough to mobilize action, the cognitively disabled are a protected group under the Americans with Disabilities Act. Under the act, employers are required to provide workplace accommodations for employees who disclose their disability. That last stipulation of the act could very well be one of the reasons this population has been marginalized. Low literacy carries a stigma for most people and creates a reluctance to disclose—no disclosure, no requirement for accommodation.

Functional illiteracy and healthcare. Perhaps the most poignant case of a digital divide between the literate haves and the functionally illiterate have-nots is in the healthcare community. After a long delay, this community has made tremendous progress in implementing information technologies to enhance the quality of patient care, particularly in disseminating health-related information, managing patient care, accessing patient information, and promoting health services. As a result, the trend for seeking health-related information online is increasing dramatically. An estimated 70 million Americans have sought health information online (Cain, Mittman, Sarasohn-Kahn, & Wayne, 2000) from the nearly 10,000 or more health-related websites (Benton Foundation, 1999). Birru et al. (2004) estimated that between 40% and 54% of patients use the Internet to search for information on ailments and treatments. This development would be exciting, given the documented contributions of information to improved health, if it were not for the fact that equal access to this information does not exist for all Americans. Similar to the progression that played out in the larger development community, initial design efforts in the healthcare sector have focused first on the "typical" fully functioning user and then on the aging and physically disabled. Most healthcare materials—web-based or paper—are written well above the literacy level of the average American, approximately a 10th-grade level or greater. (Doak, Doak, & Root, 1996; Birru et al., 2004; Weiner et al., 2004).

The healthcare sector has both a moral and economic responsibility to address the needs of lower literacy populations. Morally, it is only right that all citizens benefit equally from the value information technology brings to the quality of healthcare services. Cashen, Dykes, and Gerber (2004) provided support for this position by reporting that literacy is a better predictor of health status than age, income, employment status, education, or race. There is clearly an economic motivation as well. A conservative estimate places excess healthcare costs tied to low literacy at $73 billion a year. (Rudd, Moeykens, & Colton, 1999). It is not surprising, then, that low-literacy adults are twice as likely to be hospitalized as their functionally literate counterparts (Birru et al., 2004).

In recent years the definition of the digital divide has shifted from economics to functional literacy. The availability of low-cost equipment and easy access to the Internet in public facilities has lessened the economic barriers. According to Shneiderman (2000), poor interface and interaction design remain as one of the defining variables between the technology haves and have-nots. And while we might hold out hope that we may one day eradicate illiteracy at the source, the fact that learning disabilities are lifelong and that fewer than one in eight low-literacy workers receives literacy training in the workplace (Sum, 1999, p. 156) strongly suggests that the burden falls on better design and appropriate accommodations.

CHARACTERISTICS OF THE POPULATION

Functional illiteracy is often referred to as the "invisible" disability. In many cases, the individual is unaware of the disability or the individual "hides" the disability. Findings from The National Literacy Survey (1993) suggest that as many as "66 to 75 percent of the adults in the lowest [literacy] level and 93 to 97 percent in the second lowest level described themselves as being able to read or write English 'well' or 'very well'" (The Literacy Skills of American Adults). In another study by Moon, Cheng, Patel, and Scheidt (1998), 70% of the participants reported they read "really well," while in actuality their reading scores reflected a 7th- to 8th-grade ability. Also contributing to the "invisibility" of this disability is the stigma attached to functional illiteracy and learning disabilities that increases an individual's reluctance to disclose the problem.

The learning disability label encompasses a wide range of information processing disorders, such as dyslexia (language), dyscalculia (mathematics), and dysgraphia (handwriting). They are thought to be neurobiological in origin and present themselves in various combinations and levels of severity. In addition, an individual with a deficit in one area may have strengths in other areas. Understanding the heterogeneous nature of the learning-disabled population is critical to formulating appropriate accommodations. Learning disabilities generally persist over a lifetime, but the manner in which the disability presents itself will change with life stages and accommodation strategies adopted by an individual (Gerber, 1998). The lifelong persistence of the disability, combined with the aforementioned lack of adult-literacy training, suggests this problem will not go away.

Overall, learning disabilities affect an individual's ability to develop and use reading, writing, reasoning, and mathematical skills (Karande, Sawant, Kulkarni, Galvankar, & Sholapurwala, 2005). In the absence of these fully developed skills, the individual's ability to access, process, and retain (learn) information is severely constrained. In addition, the many challenges and failures experienced by the learning disabled over a lifetime often result in a poor concept of self-worth and low self-esteem (Gerber, 1998).

One point at which some in the learning-disabled population break with the larger functionally illiterate community is at the level of underlying intelligence. Many individuals with one or more learning disabilities have normal or above normal intelligence (Rowland, 2004; Doak et al., 1996; Gerber, 1998). Consequently, once appropriate accommodations are provided to mitigate the effects of the disability, adequate intelligence exists to accomplish most cognitive tasks.

Functional illiteracy and aging. One remaining characteristic of this population is the disproportionately high rates of lower literacy levels in the aging population. Kirsch et al. (1993) reported, "Older adults were more likely than middle-aged and younger adults to demonstrate limited literacy skills. For example, adults over the age of 65 have average literacy scores that range from 56 to 61 points (or more than one level) below those of adults 40–54 years of age" (p. 5) (The Literacy Skills of America's Adults). In the most recent national literacy survey, 14% of the adult population is below basic prose literacy skills, with 26% of this group 65 years of age or older (NAAL, 2003). The cause for the disproportionate representation of older adults is likely a combination of a number of factors including higher school dropout rates for the older population, lack of special education services when they were in school, and the general decline in cognitive abilities associated with aging. Regardless of the cause, design accommodations that benefit lower-literacy populations are likely to have the added benefit of supporting the aging population as well.

The next section will move from this general overview to a detailed discussion of the functional characteristics of the learning disabled. A sizable portion of the research that fuels this discussion is from the study of dyslexia. The rationale for this focus is twofold: (a) dyslexia is the most common of the learning disabilities, affecting nearly 80% of the learning-disabled population (Karande et al., 2005); and (b) deficits associated with dyslexia are most likely to impact information processing as it relates to HCI.

Functional Characteristics of the Learning Disabled

Because of the tremendous diversity in the learning disability community and the high degree of overlap among discrete disabilities, it is easy to become overwhelmed by the complexity of the area. A more manageable strategy is to identify the functional characteristics shared across disabilities, with close attention to those that affect a particular interaction environment (Brown & Lawton, 2001; Bohman & Anderson, 2005). Figure 44.1 summarizes a number of proposed groupings.

After carefully examining these characteristics, I simplified this list into four dynamically interconnected categories:

1. Reading
2. Memory
3. Metacognitive
4. Search and navigation

These categories were selected because of their likely affect on the computer-interaction environment. In addition, many of the characteristics in Table 44.1 are directly linked to deficits in a common underlying process, such as metacognition or working memory. These four categories, as highlighted in the discussion that follows, are not mutually exclusive. For example,

Source	Deficiency
Rowland (2005)	• Perception and processing • Problem solving • Low resilience to frustration—not persistent • Memory • Attention
Jiwnani (2001)	• Difficulty with sequential operations • Difficulty with complex, cluttered displays and controls • Difficulty choosing from large sets • Timed responses— particularly when they involve text
Bohman and Anderson (2005)	• Memory • Problem-solving • Attention • Reading, linguistic, and verbal comprehension • Math comprehension • Visual comprehension
Cromley (2005)	• Poor decoding • Limited background knowledge • Low vocabulary • Dysfunctional beliefs about reading • Low-strategy use • Motivational Barriers • Working memory issues
Kolatch (2000)	• Trouble with abstract reasoning and organization • Short and long-term memory loss • Word finding and syntax development difficulties • Diminished capacity to organize, assimilate, and retain information (web section) (Introduction)
Web Aim	• Difficulty interpreting what is heard and read • Difficulty connecting information
The International Dyslexia Association	• Difficulties with accurate and/or fluent word recognition • Poor spelling and decoding abilities • Deficit in the phonological component of language • Problems in reading comprehension and reduced reading experience that can impede growth of vocabulary and background knowledge
The TRACE Center (2003)	• Memory difficulty recognizing and retrieving information • Perception difficulty taking in, attending to, and discriminating sensory information • Difficulties in problem solving • Difficulty evaluating outcomes • Difficulty generalizing previously learned information

FIG. 44.1. Functional characteristics of the learning disabled.

skilled reading draws on memory and requires the deployment of metacognitive strategies. Similarly, search and navigation place a load on working memory, draw on long-term memory, and require metacognitive monitoring. The following section will review each of these categories more closely, and the final section will offer recommendations for accommodating each of these categories in system design.

Reading

Given the prominent role of language in everyday communication as well as the more demanding software and web environments, reading is one of the first barriers encountered by the functionally illiterate. The alarming rate of poor prose and document-literacy skill was noted earlier. Also noted was the fact that poor reading is often tied to an underlying learning disability, inadequate schooling, or lack of exposure to reading. As in so many other cases in this area, an individual can suffer from all three conditions, two of them, or just one.

In dyslexic children, the learning disability affects reading at the most basic levels of phonological processing (Snowling, Deftry and Goulandris, 1996). Deficiencies at this basic level lead to further difficulties acquiring the complex skill of reading, building a rich vocabulary, and decreasing word-retrieval times. Most significantly, disabled readers allocate a disproportionately high amount of their attention to decoding letters and words, a process that is quickly automated by the nondisabled reader (van Gelderen et al., 2004). For the skilled reader, the process of automation frees the attention resource to focus on comprehension, the most critical component of the reading act. Skilled reading requires the management of a complex series of parallel actions, such as recognizing words, connecting those words to what came before, using those words to anticipate what will come next, and relating this combined experience to what one already knows. For the learning disabled, focusing most of the available attention on recognizing letters and decoding words severely compromises comprehension. Birru et al. (2004) reported that even when poor readers were able to read a passage, their inability to express answers related to the passage in their own words suggested minimal comprehension. Naturally, because reading is such a frustrating experience for the learning disabled, they are also less likely to read on a frequent basis, lowering the likelihood they will increase their reading skill through practice (Stanovich & West, 1989).

Given the difficulty experienced by this population at the most basic level of decoding, it becomes clear that the problem is greatly exacerbated by materials written at a grade level beyond their ability. When information is presented at a level beyond the capability of the reader, mental workload is increased significantly and comprehension is greatly diminished. From an accessibility perspective, grade-level readability is a persistent problem throughout the web development community. A recent study by West (2003) found that:

> "89% of government websites are not easily accessible to the citizenry because the site read at higher than an eighth grade level of literacy. Fully two-thirds of all sites have language consistent with a 12th grade reading level, which is higher than the average American [half of all Americans read no higher than the eighth grade level]." (p. 3)

In another review conducted by Croft and Peterson (2002) the investigators found the mean readability score of 145 asthma-related websites was above the 10th grade, with 27 of the websites at the maximum 12th-grade level. Finally, Graber, D'Alessandro, and Johnson-West (2002) conducted a study of the readability level of privacy policies on Internet health websites. The investigators found that the average readability of the statement was at a level equal to that of a second-year college student, far outside the reach of the average American.

Despite the presence of a reading disability, most of this population possesses average or above average intelligence. As a result, if materials are presented at the appropriate grade level, the learning-disabled reader is capable of understanding. In separate studies conducted by Nielsen (2005) and Birru et al. (2004), poor readers performed well when interacting with easier-to-read materials.

While there remains considerable disagreement on how best to measure grade-level reading, certain measures and tests have gained wide acceptance. One such test, the Flesch Kincaid Grade Level Readability test, measures readability by dividing the sentence length (number words divided by the number of sentences) by the average number of syllables per word (number of syllables divided by the number of words). The resulting calculation is then correlated with an appropriate grade level. While this is a far from perfect measure, it does provide a useful benchmark of readability when evaluating the suitability of text for a given population. Unfortunately, this test along with others, such as the SMOG Readability Formula and the FRY Graph Reading Index, apply only to prose and not to lists, labels, and headings. With this type of text, the use of familiar words improves accessibility. Designers can consult reference works, such as the *Word Frequency Book,* (Carroll, 1972), to identify the most commonly used words in the English language. A more complex form of language support can be found on the CAST website (http://www.cast.org/) where the sponsors provide a language tool to support low-literacy users visiting the CAST site.

Because the functionally illiterate commonly experience difficulty with reading, illustrations, audio output, and video are often offered as effective accommodations. While illustrations can assist the less-able reader (Doak et al., 1996; Weiner et al., 2004), positive effects vary with the reader and nature of the information. According to Beveridge and Griffiths (1987), illustrations contributed positively to reading performance in easier-to-read passages. In contrast, they also noted that illustrations degraded reading performance in the most difficult passages. In a study related to the supplemental use of animation, Larsen (1995) reported learning-disabled children had trouble due to the distraction of the animation. Similarly, Jiwnani (2001) reported system designers must be careful using auditory output since it can confuse the learning disabled. The pace of the output must be slow, free of background noise, and repeatable under the control of the user.

Clearly, interface and interaction designers must choose word, sentence length, and sentence structure with due consideration for the readability level of the audience. Readability can be seen as the first barrier in software or web design encountered by the functionally illiterate population. If this population is unable to process the underlying language used in the display, all other accommodations are meaningless.

Memory

Long-term memory. The long-term and working memory systems each have implications for the functionally illiterate and learning-disabled population. As noted in the previous section, this population is less likely to read as often and, consequently, fails to benefit from a major source of acquiring domain knowledge. Without well-established domain models, interacting with web-based information or a software system is considerably more demanding. Cognitive science has long recognized that long-term memories supplement and extend the limited capacity of working memory. This topic will be explored further in the navigation-and-search section that follows.

Working memory. Cognitive science has also recognized the limited capacity of working memory and the major bottleneck it represents in information processing and human-computer interaction. While learning disabilities are very diverse in their causes and in how they manifest themselves, one consistent variable in all learning disabilities is working memory capacity. The dynamic interaction between memory capacity and the time information can be actively maintained also imposes severe constraints on the learning disabled. Debate has raged for years whether the learning disabled suffer from diminished working memory capacity or whether the complex dynamics of the underlying cognitive deficiencies place an excessive burden on a "normal" capacity (Daneman & Carpenter, 1980; Swanson, 1993; Vellutino et al., 1996; Ransby & Swanson, 2003). From the perspective of design accommodations, the precise source of the problem is insignificant.

Clearly, the attention devoted to low-level decoding places a heavy demand on working memory capacity. In addition, the increased likelihood of weaker mental models minimizes the opportunity to "offload" processing burden from the working memory. Further, the load imposed by metacognition, search, and navigation—as discussed in the sections that follow—places additional demands on this precious resource. Finally, the high level of anxiety and frustration experienced by this population also operates in working memory and will negatively affect performance on an information-processing task (Lee, 1999). Consequently, this issue, more than any other, guides many of the design and support recommendations in the final section. For example, limited working memory resource accounts for the problems the learning disabled experience with sequenced operations in software or in retracing their paths of travel navigating a website. Interface and interaction designs must compensate for the limitations of working memory or suffer the consequences of lower performance, increased errors, or abandonment of the task.

While the underlying learning disability can make the acquisition of expertise more difficult, it would be wrong to think this population does not bring some level of learning and a variety of conceptual models to an interaction experience. As with so many other variables in accessibility design, we must recognize that the goals and models of the lower-literacy population may not align with those of the general population. Dickinson, Eisma, and Gregor (2003) reported that "users made remarks which indicated that they were not trying to understand the system or find generic rules that could help them to use it better" (p. 63). In other words, they were not attempting to understand the model underlying the system; they were simply trying to get something accomplished. System design should focus on that goal and avoid excessive functionality and extraneous information. From a development perspective, it is always easy to imagine occasions when one user or another might need this feature or that piece of information. Unfortunately, the lower-literacy population comes to the system with a greatly limited need, for both functions and information. Accessible design must consider these needs. Interface clutter increases mental workload on users as they attempt to locate information and features that align with their needs, a difficult challenge given their attentional impairments.

Metacognitive

Another critical deficiency in most dyslexics is in metacognition, the process of thinking about thinking. Metacognition can take many forms, including strategic planning, monitoring, self-appraisal, document-processing strategies, and reading strategies. Metacognition operates actively in working memory, parallel to the main information-processing task. Consequently, this activity places yet another demand on the memory resource. Also, because these strategies are learned behaviors, it suggests an interaction with long-term memory. Research has shown that the learning disabled are generally deficient in the metacognitive area. While nondisabled learners acquire most of these strategies without formal instruction, studies have shown these strategies can effectively be taught to the learning disabled (Collins, Dickson, simmons, & Kameenui, 1998). Again, we must be reminded that skilled readers become skilled through years of practice with different reading materials that were processed to support diverse purposes. Because proficient readers and learners use these strategies on a frequent basis, they migrate, over time, to the level of an automatic skill. In contrast, the absence of persistent exposure to reading places the learning disabled at a further disadvantage.

Cromley (2005) indicated that the learning disabled are less likely to know when they do not understand and are less likely to reread, synthesize, generate questions, or make predictions. They are also more likely to "satisfice" and accept partial or incorrect information rather than persevering to gain a more complete understanding. A distinguishing attribute of good readers is their ability to monitor the information-processing activity; in other words, they ask themselves: "Do I understand what I am reading? Do I see the relevance of the information to the task? What do I expect to follow in the next passage? How does this relate to what I already know?" Corley and Taymans (2002) organized this activity in three parts: setting goals before the task and establishing a plan; monitoring comprehension and understanding while engaging the task; and evaluating one's learning after the task and making adaptations when faced with similar tasks. Danielson (2002), referencing users navigating the web, suggested that once goals are made, strategies are selected for achieving that goal. Further, strategies are constantly assessed and adjusted many times in a successful interaction experience. Given the mental demand of these activities, monitoring and adjusting activities pose a challenge for the disabled. Finally, Britt and Gabrys (2002) indicated that document literacy requires four metacognitive skills: sourcing (evaluating the credibility of source), corroboration (seeking independent confirmation), integration (creating mental representation of information), and search (a skill woven throughout the other three areas). The inability of the learning disabled to engage in self-evaluating activities is evident in the work of Birru et al. (2004). Although most of the participants in their study failed to answer the questions correctly, seven out of eight reported feeling "very comfortable" or "comfortable" with their Internet search experience. On the sourcing and corroboration skills, five out of eight used information provided on sponsored sites, yet still reported it was "very easy" to find trustworthy information on the Internet.

In short, metacognition requires a tremendous amount of cognitive activity, activity that occurs in parallel with the primary decoding task. All of this activity occurs in the executive control component of working memory. As noted in the preceding section, this is a limited resource for the learning-disabled reader who devotes much of this resource to low-level decoding.

We take for granted that nondisabled users engage in all of these activities effectively and effortlessly. Design support for this variable amounts to providing constant feedback to the disabled user, explicitly connecting the information to the task, establishing checkpoints where the system asks questions of the reader to monitor understanding, and engineering performance support in the form of cognitive scaffolding. On the matter of feedback, for example, Dickinson et al. (2003) noted that longer tasks are tolerated by the learning disabled so long as they receive frequent feedback on what is happening and confirmation they are proceeding correctly. In the absence of such feedback, the poor reader becomes anxious, a state that further degrades performance since anxiety occupies the working memory space.

Navigation and Search

The learning disabled have traditionally experienced tremendous difficulty reading paper-based materials. They experience this difficulty despite the fact the linear format found in most paper-based materials offers considerable support for the reader. In these materials, the author assumes the burden for communicating organization through meaningful structures, logical sequences, helpful transitions, and explicit connections. In contrast, the nonlinear web requires the reader to infer organization and build a coherent model of the subject matter as the information unfolds in less predictable ways (Britt & Gabrys, 2002). McDonald and Stevenson (1998) identified disorientation in the nonlinear environment as one of the most challenging elements of the web. While disorientation is an obstacle that can be overcome by able users, this barrier is often insurmountable for the learning disabled. This population, at best, experiences difficulty building a mental model of the information, monitoring where they are in the experience, or retracing their path. Each of these activities draws on their overtaxed working memory.

As one examines the factors affecting readers' ability to navigate, a number of variables emerge:

- Basic navigation skills related to the interface
- Topology formats: nonlinear, hierarchical, and mixed topologies
- Depth versus breadth of the structure
- Navigational aids

Interaction skills. While there is limited research examining the effects of learning disabilities on navigation, the work of Zarcadoolas, Blanco, Boyer, and Pleasant (2002) suggested learning-disabled users can quickly learn and retain basic web-interaction skills. These skills include the behavior of links and the act of scrolling. Participants in this study did require training and prompting to use graphic links. Overall, the positive reaction to the linking convention is encouraging since Zarcadoolas et al. also found the participants, when given a choice, preferred following links rather than using search. Worth noting, Birru et al. (2004) found that users in their study, although comfortable with the linking convention, would seldom click on more than one or two links to answer questions. Finally, although basic scrolling behavior was understood, none of the participants in the Zarcadoolas et al. study scrolled to view additional information. Without additional corroborating evidence it is difficult to generalize from these limited studies. However, the behaviors exhibited in these studies warrant close scrutiny as we continue to study and observe this class of users.

In contrast to the relative ease with which this population learned basic interaction behaviors, a more significant challenge is faced navigating the larger system. Danielson (2002) suggested users begin the navigation task with a decision about whether they are looking for a specific item, a group of items, or general information about the contents of a domain area. As noted in the metacognitive area, the learning disabled are generally weak at planning tasks, which immediately places them at a disadvantage in the navigation area. Unfortunately, there is little or no research that directly examines the learning-disabled population and the structural issues of nonlinear versus hierarchical, or depth versus breadth. There is, however, considerable speculation on these issues since performance differences for general-population users are typically discussed within the context of working memory capacity.

Topology. The work of McDonald and Stevenson (1998) shed some light on the issue of the efficacy of hierarchical, nonlinear, and mixed (hierarchical with referential links) topologies. Most significant perhaps for the purposes of this discussion, they found novices benefited most from the mixed structure since it offered a balance of freedom and control. The referential links supported exploration of a site without the support of a well-formed mental model, while the hierarchical framework served to constrain movements and minimize disorientation. While the strict hierarchical structure provided the greatest control and guidance for participants, it proved inefficient when participants wanted to make distal movements in the structure. Finally, the nonlinear structure simply provided too many options and placed the heaviest demands on expertise and working memory. In an earlier study, McDonald and Stevenson (1996) found users stopped reading too soon when faced with too many decisions related to “what” and “how much” to read. In each of these situations, it is easy to speculate that the problems faced by the participants in these studies would only be exacerbated for the learning disabled, given their underlying deficiencies in working memory and metacognition.

Depth vs. breadth. The efficacy of breadth versus depth in the hierarchy is also open to speculation. As with topology, the depth issue is framed by limitations of working memory and the users’ ability to distribute the navigation workload to their own conceptual models of the domain. In this discussion, we see greater diversity of opinion. In the world of web design, best practice favors breadth over depth, resulting in a greater number of choices at the highest level. A study by Larson and Czerwinski (1998) suggested that a medium depth produced the best search performance over either the broader or the deeper options. Benard (n.d.) suggested depth versus breadth is not the best framing mechanism. Instead, he suggests the shape of the hierarchy is the best predictor of search performance, finding a broad first level, a narrow middle level, and a broad base to be most efficient. While not based on a controlled study, Kolatch (2000) proposed a simpler top-level interface, offering fewer choices and a deeper structure for cognitively disabled users. Kolatch was careful to point out that this contradicts most research on the topic (web section Analyses). Until new research suggests otherwise, the balanced structure proposed by Larson and Czerwinski (1998) provides guidance consistent with our understanding of the adverse effects of too many choices and the mental load imposed by deep structures.

Navigation aids. Danielson (2002) suggested that a variety of visual navigational aids can mitigate the aforementioned problems encountered in navigation. Navigational aids fall into two categories: index and table of contents lists, and site maps. Danielson noted that graphical site maps are superior to lists and table of contents at conveying the relationships between distal nodes on the site. The study also showed that the site maps benefited nonknowledgeable users more than the knowledgeable. Finally, when compared to a control group without site maps, Danielson reported that subjects with maps were less likely to abandon the task, reported information-seeking confidence, moved deeper into the site, and made more movements outside the hierarchy. Given the previously defined tendencies of the learning-disabled population, it’s highly probable that they would benefit from the assistance offered by site maps. Supporting this theory, Mirchandani (2003) found detailed site maps helped the disabled user find information within a click or two. See the ADA Insights website (http://www.adainsights.org) for an example of a site map designed to support disabled users. As a visualization, the benefit of the site map is its ability to shift the cognitive load from working memory to the visual and thereby transform the load-intensive cognitive task to a less labor-intensive perceptual task. A more extensive navigational support tool can be found on the CAST website (http://www.cast.org/) The tool displays a taxonomical view of the site, the user’s current location, the user’s navigational path, quick links to frequently visited areas, and a notepad that allows the creation and storage of notes. Combined, this support helps compensate for deficiencies in monitoring skills.

Search. In contrast to navigation, research is slowly emerging related to the learning disabled and the search task. Not surprisingly, this research reports the learning disabled experience tremendous difficulty with search tasks. At the most basic level, the poor spelling displayed by many in the lower-literacy population creates a major barrier to successful searches. Search engines, such as Google, that offer alternative spellings are best. Weak self-monitoring skills also decrease the likelihood that the user will recognize that a mistake was made. Even when search terms were spelled correctly, Birru et al. (2004) found that subjects rarely retyped search terms to locate more relevant items—a serious problem since they also found the low-literacy adults in this study rarely used optimal search terms as they attempted to retrieve health-related information. Birru et al. (2004) concluded by highlighting the benefits of a categorizing search engine as one means of minimizing the adverse effects of poor search and long lists of results. This engine would sort results by category and minimize the need to evaluate long, unsorted lists. This is a good example of a technology assuming the burden for a weak metacognitive skill in the disabled population.

DESIGN ACCOMMODATIONS

There are three approaches to accommodating the needs of the learning-disabled population. Each of these recommendations is based on the previously discussed characteristics of this population.

1. Assistive technologies: Building technologies customized to compensate for the disability;
2. Layered design: Designating special sections of the website or software for a disabled population;
3. Universal design: Adopting design practices that enable the learning-disabled population while benefiting the larger population as well.

The following sections will briefly review the first two categories and provide more detailed recommendations for the third category, universal design. This emphasis is based on three considerations. First, the initial two categories require greater effort and increase development costs. Second, they benefit a smaller portion of the population, typically the most severely disabled. Third, universal design principles are less likely to increase development time or costs and will likely benefit a larger number of the disabled and fully functioning populations.

Assistive technologies. A number of studies have demonstrated the benefits of assistive technologies for the disabled (Brown, 1992; Cole & Dehdashti, 1998; Newell & Gregor, 2000; McGrenere et al., 2003). A typical application in this genre is a stand-alone computer-based educational system, designed to assist severely disabled children. Other, less intrusive accommodations, including software agents and embedded scaffolding, have been explored by Shaw, Johnson, and Ganeshan (1999); Quintana, Krajcit, and Soloway (2003); and Shneiderman (2003).

Scaffolding and agents offer performance support to the disabled user in the early stages of interaction with a new product. Shneiderman (2000) described this approach as "evolutionary learning." As the user becomes more proficient with the requirements of the system and task, the scaffolding is slowly torn down, either under the control of the user or through intelligent software agents. Most typically, the agent replaces or supports a deficient metacognitive process by assisting with planning, monitoring, self-appraisal, strategy setting, and feedback. Quite simply, this burden is shifted from the users' working memory to the system. Shneiderman (2000) and Quintana, Krajcik, and Soloway (2002) highlighted the efficacy of this approach for supporting less-knowledgeable and disabled populations.

Layered design. The layered design strategy requires the design of two versions of the system: one for the functionally literate users and one for the functionally illiterate. While it is generally preferred not to separate disabled and fully functioning populations, layered design is simply an extension of a practice that has been used for years for separating domain experts from nonexperts or native speakers from non-native speakers. In this case, one area of the site would be written at the population average 8th-grade level, while another section of the site would be written at the 5th-grade level or lower. Lobach, Arbanas, Mishra, Campbell, and Wildemuth, (2004) described the benefits of a two-tier literacy system in their study. Sites such as this may include other assistance, such as agents, site maps, illustrations, and the like.

Universal design. In contrast to the first two approaches, universal design accommodations are seamlessly embedded in the system interface and interaction design. This class of accommodations is less likely to affect development costs or create an obstacle for the nondisabled. Consequently, these accommodations are more likely to be embraced by the wider development and user communities. Further, it is widely accepted in the accessibility community that these accommodations improve the usability of the product for all users (Shneiderman, 2000; Dickinson, Eisma, & Gregor, 2003). The following recommendations are organized in the previously defined categories, although support for a given recommendation is often found in multiple categories. Finally, recommendations designated with an identify recommendations that require additional research and warrant close monitoring. All others enjoy wide support in the literature.

Reading

When designing the language component of any system, support the following:

- Maintain an appropriate reading level (use readability formulas to establish a benchmark; measure word difficulty and sentence length);
- Use active voice;
- Use the *Word Frequency Book* to identify common words;
- Place information and instruction in context;
- Employ lists;
- Chunk information;
- Present content in sequence;
- Repeat information from screen to screen (do not assume the user will carry over);
- Maintain consistency in language and procedures;
- Communicate directly and concretely;
- Emphasize actions users must complete;
- Highlight critical information, information structure, or new information;
- Use familiar terms, and avoid acronyms and jargon;

- Use visual and auditory prompts;
- Provide definitions of critical terms through direct linking to glossary;
- Use illustrations to complement text, communicate structure, and emphasize connections;
- Highlight (using circles, arrows, and the like) critical areas of an illustration and explicitly connect to the text;
- Avoid the gratuitous use of animations and other movement;*
- Use 12-point type;
- Use familiar typefaces (there is conflicting research regarding the efficacy of serif versus sans serif);*
- Avoid tight letter-spacing (makes low-level decoding more difficult);
- Pace auditory output slowly, and allow user control to repeat output;
- Avoid background noise with auditory output;
- Provide "looser" versus tighter line spacing;
- Support easy, user controlled, style changes;
- Make it "look easy" by lowering information density;
- Limit use of italics and uppercase (effects are much more severe than for the general population);
- Maintain higher contrast;*
- Avoid light text on a dark background;
- Use ragged right formats to preserve consistent word space.

Memory

In an effort to decrease mental workload, support the following:

- Maintain consistency in all aspects of the design;
- Leverage existing knowledge, behaviors, and tasks;
- Avoid splitting attention between two tasks;
- Focus on the user goals;
- Limit information and features to what is really needed;
- Limit chunking complexity for audio output (particularly IVR);
- Focus on behaviors and tasks rather than facts;
- Partition tasks in reasonably sized groups;
- Avoid the need to retain information over long tasks or across multiple screens;
- Support mental calculations, decisions, and comparisons;
- Complete mathematical calculations;
- Limit choices;
- Provide a list of options for entry fields;
- Complete information automatically in forms and fields whenever possible;
- Employ advanced organizers;
- Use mnemonics;
- Minimize screen clutter;
- Provide extra time for tasks;
- Eliminate the anxiety of timeouts.

Metacognitive

In an effort to strengthen or replace deficient metacognitive processes, support the following:

- Maintain a consistent design;
- Convey associations between new information or process and that which is known;
- Communicate goal or purpose of the site immediately;
- Communicate prerequisite knowledge for the task and provide convenient links;
- Communicate required sequences or organizational structures;
- Allow the user to interact with the information;
- Use checklists to support self-monitoring;
- Minimize choices that require fine discriminations or close monitoring;
- Design for immediate/early success (which lowers anxiety and builds confidence);
- Align with user goals, and provide reward or convey value proposition (motivation);
- Support cooperative work activities;
- Provide reminders;
- Provide source information for material presented;
- Minimize embedded links;
- Avoid taking user to other pages for ancillary information;
- Employ error prevention and recovery support;
- Query when choices or decisions are required;
- Review information entered or validate the successful completion of a process;
- Use auditory and visual cues to mark stages of a work cycle, helping the user self-monitor.

Navigation and Search

In an effort to improve the effectiveness of search and navigation, support the following:

- Make information and features supporting goals readily accessible to minimize navigation and search;
- Provide persistent presentation of path history;
- Offer persistent opportunity to exit, backup, or return to start;
- Use redundancy: repetition, signal design, and channel;
- Provide status indicators;
- Minimize scrolling;
- Label all links;
- Provide linked paths for probable scenarios;
- Maintain alerts onscreen until dismissed by user;
- Place information or process in context;
- Partition information into categories defined by clear rules;
- Use site maps, tables of contents, and indexes;
- Use a topology that is primarily hierarchical with referential links to areas aligned with goals;*

- Maintain a medium breadth and depth—not too broad, not too deep;*
- Use clear, thematic labels at each level;
- Provide productive terms for search;
- Offer suggested spellings;
- Use categorizing search engines;
- Provide performance support for evaluating search results (corroboration and sourcing).

Guidance for Usability Testing

To produce the best data and protect the well-being of participants, support the following:

- Avoid embarrassment or humiliation (anxiety lowers performance);
- Consider ethical obligations when screening for lower-literacy samples (full-disclosure issues, informed consent, and IRB);
- Minimize anxiety in testing situation;
- Test in context (actual work environment);
- Avoid using the term "testing" since this population equates the term with failure;
- Break tasks in the test script into small, yet logical, units;
- Shorten test times to minimize effects of fatigue on performance and to compensate for attention deficit;
- Use direct interaction protocol since users may not freely think aloud (inadequate working memory to support both think-aloud and to acclimate to the task);*
- Accommodate slower processing speeds when setting performance levels (e.g., task times);
- Expect participants to report exaggerated levels of performance or system quality in self-reporting as a means of covering poor literacy skills.

CONCLUSION

Ten years ago, our concern for the effects of lower literacy was confined exclusively to the processing of print media. With the explosion of information technology in the workplace and the role of the Internet as the repository for information of all types, literacy has become a major barrier for millions of Americans as they compete for work and attempt to improve the quality of their lives. While the problems encountered by lower-literacy populations with print media are significant, the problems become greatly exacerbated with the increased mental workload imposed by computer systems.

As advocated in this chapter, many of the barriers to accessibility for this population require simple modifications in the interface and interaction design. Accessible design is an art, in which the needs of one group are carefully balanced against those of another, and the designer recognizes that "accessible for most" is more achievable than "accessible for all." As one reviews the introductory list of design accommodations required by the lower-literacy population, HCI professionals will recognize most, if not all, of these variables as ones considered in each and every interface design. The difference—and a significant one—is that fully capable users have flexible learning, problem solving, and interaction skills that allow them to adjust to less-than-perfect design specifications. The learning disabled, in contrast, lack cognitive flexibility and suffer varying degrees of performance degradation in nonoptimum design environments. By increasing our understanding of this sizable population and embracing the design practices outlined here, we may finally ensure that universal accessibility is truly universal.

References

Benard, M. (n.d.). *Criteria for Optimal Web Design*. Retrieved January 13, 2006, from http://psychology.wichita.edu/optimalweb/structure.html

Benton Foundation. (1999). *Networking for Better Care: Health Care in the Information Age*. Retrieved December 28, 2003, from htpp://www.Benton.org/library/health/

Beveridge, M., & Griffiths, V (1987). The effects of pictures on the reading processes of less able readers: A mis-cue analysis approach. *Journal of Research in Reading, 10,* 29–42.

Birru, M., Monaco, V., Charles, L., Drew, H., Njie, V., Bierria, T., Detlefsen, E., & Steinman, R. (2004).Internet Usage by Low-Literacy Adults Seeking Health Information: An Observational Analysis. *Journal of Medical Internet Research, 6*(3), Retrieved December 12, 2005, from http://www.jmir.org/2004/3/e25/

Bohman, P., & Anderson, S. (2005). A Conceptual Framework for Accessibilty Tools to Benefit Users with Cognitive Disabilities. *Proccedings of the W4A at WWW2005*, ACM, 85–89.

Britt, M., & Gabrys, G. (2002). Implications of Document-Level Literacy Skills for Website Design. *Behavior Research Methods, Instruments, & Computers, 34*(2), 170–176.

Brown, C. (1992). Assistive Technology Computers and Persons with Disabilities *Communications of the ACM, 35*(5), 36–45.

Brown, D, &, Lawton, J. (2001). Design guidelines and issues for website design and use by people with a learning disability. Centre for Educational Technology Interoperability Standards. Retrieved March 28, 2007 from http://www.cetis.ac.uk/members/accessibility/links/disabilities/cogdis.

Cain, M. M., Mittman, R., Sarasohn-Kahn, J., & Wayne, J. (2000). *Health E-People: The Online Consumer Experience*. Oakland, CA: Institute for the Future, California Health Care Foundation.

Carroll, J. (1972). The American Heritage word frequency book. New York: Houghton Mifflin.

Cashen, M., Dykes, P., & Gerber, B. (2004). eHealth Technology and Internet Resources: Barriers for Vulnerable Populations. *The Journal of Cardiovascular Nursing, 19*(3), 209–214.

Cole, E., & Dehdashti, P. (1998). Computer-Based Cognitive Prosthetics: Assistive Technology for the Treatment of Cognitive Disabilities. *Proceedings of the Third International ACM Conference on Assistive Technologies,* ACM: Arrington, VA, 11–18.

Collins, V., Dickson, S., Simmons, D., & Kameenui, E. (1998). *Metacognition and its Relations to Reading Comprehension: A Synthesis of the Research*. National Center to Improve the Tools of Educators, University Washington.

Corley, M., & Taymans, J. (2002). *Adults with Learning Disabilities: A Review of the Literature*. Retrieved December 30, 2005, from http://www.ncsall.net/?id+575

Croft D. R., & Peterson M. W. (2002). An Evaluation of the Quality and Contents of Asthma Education on the World Wide Web. *Chest, 121*(4), 1301–1307.

Cromley, J. (2005). Metacognition. *Cognitive Strategy Instruction, and Reading in Adult Literacy*. Retrieved January 17, 2006, from http://www.ncsall.net/index.php?id=773

Daneman, M., & Carpenter, P. (1980). Individual Differences in Working Memory and Reading. *Journal of Verbal Learning and Verbal Behavior, 19*, 450–466.

Danielson, D. (2002). Web Navigation and the Behavioral Effects of Constantly Visible Site Maps. *Interacting With Computers, 14*(5), 601–618.

Dickinson, A., Eisma, R., & Gregor, P. (2003). Challenging Interfaces/Redesigning Users. *CUU 2003*. British Columbia, Canada, 61–68.

Doak, C., Doak, L., & Root, J. (1996). *Teaching Patients with Low Literacy Skills*. Philadelphia: J.B. Lippincott Company.

Dropout Rates in the United States. National Center for Educational Statistics. Retrieved December 10, 2003, from http://nces.ed.gov/pubs 2002/dropoutpub_2001/11.

"Fact Sheet:" Workforce Literacy. National Institute for Literacy, Washington, DC, Retrieved January 4, 2006, from http://www.nifl.gov/nifl/facts/workforce.html

Gerber, P. (1998). Characteristics of Adults with Specific Learning Disabilities. Retrieved December 28, 2003, from http://www.idonline.org/ld_indepth/adult/characteristics.html

Graber, M. A., D'Alessandro, D. M., & Johnson-West (2002). Reading Level of Privacy Policies on Internet Websites. *The Journal of Family Practice, 51*(7), 642–645.

Gribbons, W. (1992). The Functionally Illiterate: Handicapped by Design. *Proceedings of the International Professional Communications Conference*. IEEE, 302–307.

Huenerfauth, M. (2002). Design Approaches for Developing User Interfaces Accessible to Illiterate Users. *American Association of Artificial Intelligence Conference (AAAI 2002), Intelligent and Situation-Aware Media and Presentations Workshop*. Edmonton, Alberta, Canada.

Jiwnani, K. (2001). *Designing for Users with Learning Disabilities*. Retrieved December 28, 2005, from http://www.otal.umd.edu/uupractice/cognition/

Karande, S., Sawant, S., Kulkarni, M., Galvankar, P., & Sholapurwala, R. (2005). Comparison of Cognitive Abilities Between Groups of Children with Specific learning Disability Having Average, Bright Normal and Superior Nonverbal Intelligence. *Indian Journal of Medical Sciences, 59*(3), 95–103.

Kickbusch, I. (2001). Health Literacy: Addressing the Health and Education Divide. *Health Promotion International, 16*(3), 289–297.

Kirsch, I. Jungeblut, A., Jenkins, L., & Kolstad, A. (1993). *Adult Illiteracy in America: a first look at the results of the National Literacy Survey*. Washington: Department of Education, Center for Educational Statistics. Washington, DC.

Kirsch,I, Jungeblut, A., Jenkins, L., & Kolstad, A. (1993). *Executive Summary of Adult Literacy in America: A first Look at the results of the National Literacy Survey*. Retrieved October 27, 2003, from http://www.nces.ed.govnaal/resources/execsumm.asp

Kolatch, E. (2000). *Designing for Users with Cognitive Disabilities*. Retrieved December 28, 2005, from http://www.otal.umd.edu/uuguide/erica/

Larsen, S. (1995). What is "Quality" in the use of Technology for Children with Learning Disabilities? *Learning Disability Quarterly, 18*(2), 118–130.

Larson, K. & Czerwinski, M. (1998). Web Page Design: Implications of Memory, Structure and Scent for Information Retrieval. *Proceedings of CHI* 98, USA, ACM, 25–32.

Lee, J. (1999, Spring). Test Anxiety and Working Memory. *The Journal of Experimental Education, 67*, 218–240. Retrieved December 4, 2005, from ProQuest database.

Lobach, D., Arbanas, J., Mishra, D., Campbell, M., & Wildemuth, B. (2004). Adapting the Human-Computer Interface for Reading Literacy and Computer Skill to Facilitate Collection of Information Directly from Patients. *MEDINFO 2004*, Amsterdam, IOS Press, 1143–1146.

McDonald, S., & Stevenson, R. (1996). Disorientation in Hypertext: The Effects of Three Text Structures on Navigation Performance. *Applied Ergonomics,* 27, 61–68.

McDonald, S. and Stevenson, R. (1998). Effects of Text Structure and Prior Knowledge of the Learner on Navigation in Hypertext. *Human Factors, 40*(1), 18–27.

McGrenere, J., Davies, D., Findlater, L., Graf, P., Klawe, M., Moffatt, K., Purves, B., & Yang, S. (2003). Insights from the Aphasia Project: Designing Technology For and With People who Have Aphasia. *CUU 2003*. ACM: Arlington, VA, 112–118.

Mirchandani, N. (2003). *Web Accessibility for People with Cognitive Disabilities: Universal Design Principles at Work*. Retrieved December 28, 2005, from http://www.ncddr.org/du/researchexchange/v08n03/8_access.html

Moon, R., Cheng, T., Patel, K., & Scheidt, P. (1998). Parental Literacy Level and Understanding of Medical Information. *Pediatrics, 102*(2). Retrieved from Medline.

National Assessment of Adult Literacy (NAAL). *A First Look at the Literacy of Americas Adults in the 21st Century*. (2003). National Center for Educational Statistics, U.S. Department of Education, Institute of Educational Sciences, NCES 2006-470, Washington, DC.

National Dyslexia Association (n.d.). *What is Dyslexia?* Retrieved November 10, 2003, from http://www.interdys.org

Newell, A., Carmichael, A., Gregor, P., & Alm, N. (2003). Information Technology for Cognitive Support. *In The Human Computer Interaction Handbook*. Eds. Julie Jacko and Andrew Sears. Mahwah, NJ: Lawrence Erlbaum Associates, 464–481.

Newell, A. & Gregor, P. (2000). User Sensitive Inclusive Design: In Search of a New Paradigm. *CUU 2000*. Arlington, VA: ACM, 39–44.

Nielsen, J. (2005). *Lower-Literacy Users*. Retrieved December 9, 2005, from http://www.useit.com/alertbox/20050314.html

Quintana, C., Krajcik, J., & Soloway, E. (2002). A Case Study to Distill Structural Scaffolding Guidelines for Scaffolded Software Environments. *CHI 2002*. Minneapolis, Minnesota: ACM, 81–88.

Ransby, M., & Swanson, H. L. (2003). Reading Comprehension Skills of Young Adults with Childhood Diagnoses of Dyslexia. *Journal of Learning Disabilities, 36*(6), 538–555.

Rowland, C. (2004). *Cognitive Disabilities Part 2: Conceptualizing Design Considerations*. Retrieved December 28, 2005, from http://www.webaim.org/techniques/articles/conceptualize/?templatetype=3

Rudd, R. E., Moeykens, B. A., & Colton, T. C. (1999). *Health and Literacy: A Review of Medical and Public Health Literature*. New York: Josey-Bass.

Shaw, E., Johnson, W., & Ganeshan, R. (1999). Pedagogical Agents on the Web. *Autonomous Agents 1999*. Seattle, WA, 283–290.

Sheiderman, B. (2000). Universal Usability. *Communications of the ACM, 43*(5), 84–91.

Shneiderman, B. (2003). Promoting Universal Usability with Multi-Layer Interface Design. *CUU 2003*. Vancouver, British Columbia, Canada, 1–8.

Snowling, M., Defty, N., & Goulandris, N. (1996). A Longitudinal Study of Reading Development in Dyslexic Children. *Journal of Educational Psychology, 88*(4), 653–669.

Stanovich, K., & West, R. (1989). Exposure to Print and Orthographic Processing. *Reading Research Quarterly, 24*, 402–433.

Sum, A. (1999). *Literacy in the Labor Force*. National Center for Education Statistics, US Department of Education, Washington, DC.

Swanson, H. L. (1993). Working Memory in Learning Disability Subgroups. *Journal of Experimental Child Psychology, 56*, 87–114.

TRACE Center, University of Wisconsin. *A Brief Introduction to Disabilities*. Retrieved November 23, 2003, from htpp://trace.wisc.edu/docs/population/populat.htm.

U.S. Department of Commerce. (2002). *A Nation Online: How Americans are Expanding Their Use of the Internet*. Economics and Statistics Administration, National Telecommunications and Information Administration. Washington, DC.

van Gelderen, A., Schoonen, R., de Glopper, K., Hulstijn, J., Simis, A., Snellings, P., & Stevenson, M. (2004). Linguistic Knowledge, Processing Speed, and Metacognitive Knowledge in First and Second Language Reading Comprehension: A Component Analysis. *Journal of Educational Psychology, 96*(1), 19–30.

Vellutino, F., Scanlon, D., Sipay, E., Small, S., Chen, R., Pratt, A., & Denckla, M. (1996). Cognitive profiles of Difficult to Remediate and Readily Remediated Poor Readers: Early Intervention as a Vehicle for Distinguishing Between Cognitive and Experimental Deficits as Basic Causes of Specific Reading Disability. *Journal of Educational Psychology, 88*(4), 601–638.

W3C (1999). Web Content Accessibility Guidelines 1.0 [Electronic edition] Retrieved April 3, 2007, from http://www.w3.org/TR/WAI-WebContent/

Weiner, J., Aquirre, A., Ravenell, K., Kovath, K., McDevit, L., Murphy, J., Asch, D., & Shea, J. (2004). Designing an Illustrated Patient Satisfaction Instrument for Low Literacy Populations. *The American Journal of Managed Care, 10*(11), 853–859.

West, D. (2003). *State and Federal E-Government in the United States*. Center for Public Policy, Brown University, Providence, RI. 1–29.

Zarcadoolas, C., Blanco, M., Boyer, J., & Pleasant, A. (2002). Unweaving the Web: An Exploratory Study of Low-Literate Adults' Navigation Skills on the World Wide Web. *Journal of Health Communication, 17*, 309–324.