

**TOWSON UNIVERSITY
OFFICE OF GRADUATE STUDIES**

**INFORMATION INPUT AND RETRIEVAL
BY PEOPLE WITH COGNITIVE DISABILITIES**

By

Ruimin Hu

A Dissertation

Presented to the faculty of

Towson University

in partial fulfillment

of the requirements for the degree

Doctor of Science

Department of Computer and Information Sciences

**Towson University
Towson, Maryland 21252**

August 2012

**TOWSON UNIVERSITY
OFFICE OF GRADUATE STUDIES
DISSERTATION APPROVAL PAGE**

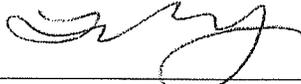
This is to certify that the dissertation prepared by **Ruimin Hu**

Entitled

INFORMATION INPUT AND RETRIEVAL

BY PEOPLE WITH COGNITIVE DISABILITIES

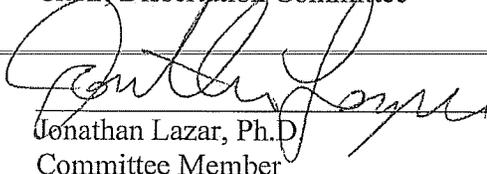
has been approved by the thesis committee as satisfactorily completing the dissertation requirements for the degree Doctor of Science in Information Technology.



Jinjuan Feng, Ph.D.
Chair, Dissertation Committee

8/1/12

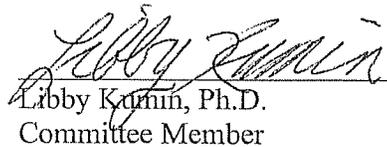
Date



Jonathan Lazar, Ph.D.
Committee Member

8/1/12

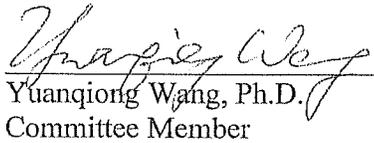
Date



Libby Kamin, Ph.D.
Committee Member

8/1/12

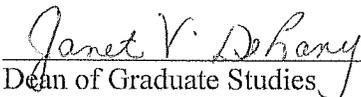
Date



Yuanqiong Wang, Ph.D.
Committee Member

8/1/12

Date



Janet V. Dehany
Dean of Graduate Studies

8/15/12

Date

ACKNOWLEDGEMENT

This dissertation is made possible by a world of good people. I must thank my committee members, Dr. Jinjuan Feng, Dr. Jonathan Lazar, Dr. Libby Kumin, and Dr. Yuanqiong Wang for their unfailing support, guidance, and patience.

My major advisor, Dr. Feng, spent enormous amount of time and energy overseeing, facilitating, and guiding my work, from research design, to data collection and analysis, and to numerous rounds of revisions of the manuscripts.

My committee members, especially Dr. Lazar, provided insightful comments and constructive criticism that greatly helped improve the quality of my work.

My fellow graduate students Yao Mao and Shaojian Zhu deserve credit for their technical support during various phases of my research.

My son, Steven Chang, also deserves credit for helping construct the research website during his summer break.

I owe a huge debt to organizations, families, and individuals for helping recruit participants for my research.

We would like to thank National Institute on Disabilities and Rehabilitation Research for partially funding this work through grant number H133G050354.

We would like to thank The Jess and Mildred Fisher College of Science and Mathematics for partially funding this work through the Fisher College General Endowment Grant.

ABSTRACT

INFORMATION INPUT AND RETRIEVAL BY PEOPLE WITH COGNITIVE DISABILITIES

Ruimin Hu

This dissertation reports studies on information input and retrieval by people with Down syndrome and other types of cognitive disabilities. The first study investigated the use of three input techniques (keyboard/mouse, word prediction, and speech recognition) by individuals with Down syndrome and neurotypical children. The results suggest that the performance of participants with Down syndrome vary substantially. The high performing participants with Down syndrome are capable of using the keyboard or the word prediction software to generate text with performance similar to that of the younger neurotypical participants. The second study investigated the use of different search methods and content structure during information retrieval by people with various types of cognitive disabilities. The results suggest that of the three conditions (narrow/deep structure, broad/shallow structure, and search engine), the participants were most efficient and successful when using the search engine, while the broad/shallow structure resulted in the longest time and highest failure rate.

TABLE OF CONTENTS

LIST OF TABLES	vii
LIST OF FIGURES	viii
CHAPTER ONE: INTRODUCTION.....	1
CHAPTER TWO: LITERATURE REVIEW.....	13
CHAPTER THREE: INFORMATION INPUT STUDY	33
CHAPTER FOUR: INFORMATION RETRIEVAL STUDY.....	71
CHAPTER FIVE: CONCLUSION	105
APPENDICES	114
APPENDIX A: Questionnaire for the Study on Information Input	114
APPENDIX B: Scripts for the Study on Information Input	116
APPENDIX C: Questionnaire (for Parent/Guardian) for the Study on Information Retrieval.....	118
APPENDIX D: Questionnaire (for Participant) for the Study on Information Retrieval	121
APPENDIX E: Structures and Contents of the Website for the Study on Information Retrieval	123
APPENDIX F: Task Specification for the Study on Information Retrieval	135
APPENDIX G: Code of the Custom Search Engine for the Study on Information Retrieval - Search.php.....	136

BIBLIOGRAPHY	142
CURRICULUM VITA	152

LIST OF TABLES

Table 3-1: General demographics of participants.....	42
Table 3-2: Detailed demographic background for each participant.....	43-44
Table 3-3: Input rates and word error rates of participants with DS under keyboard only and word prediction conditions.....	46
Table 3-4: Word error rates and input rates for two participants with the lowest and highest error rates.....	48
Table 3-5: Participants' preference ranking on the input methods	49
Table 3-6: Demographic information of the neurotypical participants	50
Table 3-7: Input rates and word error rates of the neurotypical children	51
Table 3-8: Speech input performance by the neurotypical children	52
Table 3-9: Subjective preference rankings of the neurotypical children	52
Table 3-10: Performance data under keyboard only and word prediction conditions...	56
Table 3-11: The best and worst cases of two participants under the speech condition	63
Table 3-12: Participant performance in punctuation, capitalization, and paragraph formatting.....	64
Table 4-1: Knowledge and skills required for information retrieval	84

LIST OF FIGURES

Figure 3-1: Performance distribution for eight participants under the keyboard only and the word prediction conditions.....	54
Figure 3-2: Data entry rate (words per minute) for the DS group and the neurotypical group under the keyboard only condition and the word predict condition	59
Figure 3-3: Word error rate for the DS group and the neurotypical group under the keyboard only condition and the word prediction condition	59
Figure 3-4: Performance distribution for two groups of participants under the keyboard only and the word prediction conditions.....	62
Figure 4-1: Narrow/deep, 4x4x4x4 web structure	78
Figure 4-2: Broad/shallow, 16x16 web structure.....	79
Figure 4-3: Customized “Google” search engine	80
Figure 4-4: Total average time of all tasks under each condition	90
Figure 4-5: Average time of each task under each condition	90
Figure 4-6: Number of failed attempts under each condition	91
Figure 4-7: Number of failed attempts under each difficulty level	92
Figure 4-8: Ratio between the numbers of actual pages (AP) visited and optimal pages (OP) under each condition	94
Figure 4-9: Ratio between the numbers of actual pages (AP) visited and optimal pages (OP) with difficulty level	94

Figure 4-10: Number of free trials under each condition96

Figure 4-11: Top preference on each condition97

CHAPTER ONE

INTRODUCTION

1.1 Introduction

There can be no doubt that the use of computers has become a defining feature in human experience: it permeates all aspects of our lives, from leisure to work, from home, to office, to on the go; it comes with a bewildering array of applications, from straightforward word processors to sophisticated design tools, from job-related tasks to video games, and so on. It is clear, as with any technology, the computer was first conceived and designed for an average person, a healthy person with no physical, motor, or cognitive disabilities. The same can be true with most applications that cater to the needs and abilities of a neurotypical user.

Therefore, there has always existed a technological—and in this case, digital—divide between individuals with disabilities and those without (e.g., Burghstahler, 2002; Norris, 2001; Strover, 2003). Historically, individuals with disabilities lag behind in adopting technologies, not because they are not motivated or have demonstrated fewer needs, but because neither hardware nor software is quite compatible with them (e.g., Adam & Kreps, 2006; Dobransky & Hargittai, 2006; Ellcessor, 2010; Goggin & Newell, 2003; Vicente & Lopez, 2010).

To make technologies accessible to everyone is not only a moral obligation; it is also a legal matter as well. Just as physical constructions such as public buildings must provide access to the disabled, laws have been enacted by governments to address accessibility issues concerning computer and information technology (e.g., Blanck, 1994; Wheaton & Patrizia, 2007; Henry, 2009; Jaeger, 2004). However, a call for accessibility or a law or regulation put in place does not automatically resolve the accessibility problem. It must be predicated by an understanding of what can help people with disabilities better access information given their specific impairments (e.g., Blanck, 2008; Jaeger, 2006).

Scholarly attention to the use of and access to computer and information technology has led to two distinct but related areas of study: usability and accessibility. To help ease the use and learnability of computer hardware and software, researchers as well as manufactures and developers, using both qualitative and quantitative methods, examine and test ways to improve efficiency, effectiveness, and satisfaction of computer use in a given context (e.g., Card, Moran, & Newell, 1983; Gould & Lewis, 1985; Lund, 1997; Nielsen, 1999). Whereas usability studies focus on all computer users without singling out specific physiological and psychological conditions, accessibility, an even more emerging research field, is to understand how specific adaptive choices and possibilities, whether they are assistive devices or modified applications, work best for people with disabilities (e.g., Carey, 2007; Christian, Kules, Shneiderman, & Youssef, 2000; Feng, Karat, & Sears, 2005; Hitchcock, 2001; Lazar & Jaeger, 2011; Pirolli & Card, 1995). It goes without saying that these two fields are reciprocal, knowledge from one informing the work on the other. Indeed, accessibility is hardly conceivable without

knowledge of usability; conversely, usability itself presupposes a certain level of accessibility.

Encouragingly, there have been usability studies in the last several decades, mostly focusing on perceptual and motor impairments (e.g., Brown, Jay, & Harper, 2010; Feng, Karat, & Sears, 2005; Shinohara & Tennenberg, 2009). Still, given the wide range of disabilities, the short life cycle of most applications, as well as the frequent releasing of new hardware and software, it is almost impossible to play the “catch up” game for researchers to obtain and provide knowledge of usability, and for designers in particular and society in general to use that knowledge to come up with timely assistive devices and/or adapted applications. This “catch up” paradigm, or what scholars recently coined as “retrofitting accessibility,” has fundamental limitations and the “born-accessible technology” approach that has accessibility built in is more promising (i.e., Wentz, Jaeger, & Lazar, 2011).

This deficiency in understanding usability—and accessibility—is more pronounced when it comes to people with cognitive disabilities. Not only is there a paucity of studies in this area, the findings are also less conclusive or generalizable. The need for more knowledge about usability concerning people with cognitive disabilities has become urgent.

As will be discussed in detail in the next chapter on literature review, part of the reason lies in the challenges cognitive disabilities pose to researchers. The biggest challenge remains the issue of “measurability.” Generally speaking, perceptual and motor impairments are relatively easier to be diagnosed and measured and knowledge thereof is more readily available. In contrast, it is difficult to diagnose and assess cognitive

disabilities, and more so to measure performances that are tied to certain cognitive conditions (e.g., Bohman, 2004). To complicate the matter, there is more diversity in cognitive disabilities that requires more efforts to understand each condition.

Although the Internet is playing an ever-bigger role in both workplace and everyday life, studies on usability and accessibility concerning individuals with cognitive disabilities in the context of web usage are absent or inadequate. Almost since its inception, the World Wide Web has generated heightened awareness of the issue of usability and accessibility. As will be reviewed extensively in Chapter Two, even though the World Wide Web Consortium (W3C) has for decades repeatedly issued guidelines (e.g., Web Content Accessibility Guidelines 1.0 and 2.0) for developers to design websites that address accessibility for users with disabilities and governments have passed laws requiring websites be made accessible by all users (e.g., World Wide Web Consortium, 1999, 2008; Wheaton & Patrizia, 2007), the majority of the websites, however, are still not accessible by the users with cognitive disabilities (e.g., Goodwin, Susar, Nietzio, Snaprud, & Jensen, 2011; Kuzma, Wesienborn, Philippe, Gabel, & Dolechek, 2009). One major reason is the lack of due attention given to cognitive disabilities. For instance, WCAG 1.0 that came out in 1999 essentially focused on perceptual and motor impairments and did not address cognitive impairment. WCAG 2.0 issued in 2008 started to address cognitive impairment, but it is still minor in comparison to perceptual and motor impairment.

One contributing factor to this reality is the lack of empirical research that provides insights into usability and accessibility for people with cognitive disabilities.

Even though there have been commendable and promising studies (e.g., Bryen, Heake, Semenu, & Segal, 2010; Burmeister, 2010; Frederici et al., 2005; Freeman et al., 2005; Johnson & Kent, 2007; Mulhern, 2009) that employed adapted websites or pages for people with cognitive disabilities to gain knowledge of their interaction patterns with the web, these efforts remain cursory and preliminary. This is primarily because the websites investigated only contained a few pages and the data collected from participants' interacting with these very limited numbers of pages cannot speak to the real world experience where individuals have to make decisions when dealing with numerous pages or a search engine with pages of returned links. Henceforth, such a void in research represents another urgent need, the need to understand what works best for people with cognitive disabilities to retrieve information on the web. To this end, i.e., to collect "real" and meaningful data, the second part of the research, for the first time, utilizes a website that simulates a real world website with a built-in, customized search engine and hundreds of web pages for participants with cognitive disabilities.

1.2 Research Studies

Even though there are countless and unexhausted ways and activities associated with the use of computers, the two most common and identifiable purposes are *information input* and *information retrieval*. On the one side of the equation of human-computer interaction, an individual enters information using a variety of input devices, the most common tool being a keyboard. On the other side of the equation, an individual retrieves information from the computer or computer-mediated communication, the most common place being the World Wide Web.

Information input is the process in which an individual enters data in a computer using a device or a combination of devices such as a keyboard, a mouse, voice recognition software, and so on. There is no doubt that the computer was seen first and foremost as an input device when it replaced the traditional typewriter. For many, inputting information is almost the essence of using the computer, and what are needed are a keyboard, a mouse, and some initial training. For people with disabilities, they face challenges and obstacles and must depend on non-traditional or modified input devices. Using computers with assistive devices for people with various types of perceptual and motor impairments has been studied extensively. However, research on computer technology used by individuals with Down syndrome as the target group is quite rare.

In contrast, information retrieval is the process in which an individual collects or gathers data with the use of a computer. It can include a wide array of activities such as finding a document in a computer, checking emails, and browsing the web. As the World Wide Web gaining popularity in society, individuals, regardless of people with disabilities or not, are relying more and more on the web to gather information. The two crucial steps in the process of information retrieval are first to carry out a search by inputting a key word or words in a search engine, and then to deal with the selection of the numerous returns from the search for the right information. Many researchers have voiced concerns over the lack of attention to adapted search engines and websites for people with disabilities, but only a disproportionately small number of studies have focused on gathering data about the usability of a search engine and web structure for people with cognitive disabilities.

Given the tremendous importance of information input and retrieval when using computer or computer related devices, it is unfortunate that existing research on this field is very limited. Two recent studies provide great insight on computer usage by people with cognitive disabilities. In a case study of the mobile phone use for young adults with cognitive disabilities, Dawe (2007) identified common themes in requirements, patterns of use, and desires for an accessible mobile phone-based remote communication system. Through a large-scale survey that collected computer usage information of approximately 600 children with Down syndrome, Feng, Lazar, Kumin, and Ozok (2010) explored the patterns the participants demonstrated and difficulties they experienced while using computers. Both studies highlighted the importance of computer related skills for people with cognitive disabilities and the lack of knowledge in this domain. There is a huge gap between the need of people with cognitive disabilities regarding information entry and retrieval skills and the existing knowledge of the users' abilities and special needs and how to improve the interaction. In order to fill this gap, we conducted two empirical studies focusing on each of the two skills.

The first study in the dissertation investigated the use of three input techniques (keyboard and mouse, word prediction, and speech recognition) by children and young adults with Down syndrome and neurotypical children. The results suggest that the performance of the participants with Down syndrome vary substantially. The high performing participants with Down syndrome are capable of using the keyboard or the word prediction software to generate text at approximately six words per minute with error rates below 5%, which is similar to the performance of the younger neurotypical participants. No significant difference was observed between the keyboard condition and

the word prediction condition. Recognition error rate observed under the speech input condition is very high for the participants with Down syndrome. The neurotypical children achieved better performance than the participants with Down syndrome on the input tasks and demonstrated different preferences when interacting with the input techniques.

In the second study in the dissertation, we observed the patterns, preferences, and challenges of the individuals with cognitive disabilities when searching information in a web-based environment. We investigated the impact of information structures with different width and depth. We also examined the use of search engine. The results suggest that individuals with cognitive disabilities demonstrate significant differences in search methods and content structure during information retrieval. Of the three conditions (narrow/deep structure, broad/shallow structure, and search engine), the participants were most efficient and successful when using the search engine, while the broad/shallow structure resulted in longest time and highest failure rate. Different interaction patterns and causes for failed search are also examined.

1.3 Research Participants

Existing literature suggests that the studies on cognitive disabilities, particularly those concerning assistive devices, tend to mix multiple conditions without paying due attention to the causes of the disability (diagnosis) or the specific functionality of the users. The result of these studies might be misleading due to the substantial differences among the users. The differences among the users can be contributed by different conditions (causes) such as Down syndrome, Autism, Fragile X syndrome. It is difficult

to generalize the findings on one particular condition to other conditions. Even within the same condition, large variance may exist in the functionality and the performance of the users and the findings are not readily generalizable to the entire population (e.g., Feng et al., 2008).

There are two approaches to address this problem: the diagnosis-based approach and the functionality-based approach (e.g., McGuire et al. 2006). The diagnosis-based approach focuses on one particular condition (cause of the disability), which makes it easier to generalize the result within the population with the same diagnosis. However, it will be difficult to generalize the results to people with other conditions. The functionality-based approach focuses on functionalities related to the tasks under investigation, making it easier to generalize the result to any population with similarly affected functionality. This approach requires expertise in defining the functional requirements of the tasks and analyzing users' functional abilities.

The first study of the dissertation on input techniques took the diagnosis-based approach and focused on people with Down syndrome. We decided to focus on users with Down syndrome for four reasons. First, Down syndrome is one of the most thoroughly studied and best understood genetic impairment. Compared to some cognitive conditions that remain difficult to diagnose, Down syndrome can be accurately diagnosed and its functional impact is well documented. Second, individuals with DS often display substantial variance in computer usage. As such, this population alone would provide sufficient depth for profile analysis and the profiles created will provide helpful insights to design. Third, different from many other conditions that do not affect motor skills, DS also affects fine motor skills that are critical for typing. Therefore, it would be

inappropriate to investigate DS together with other conditions in one study. Lastly, no empirical investigation regarding input techniques has been conducted for this population. Through this study, we attempt to gain in-depth understanding on the use of input techniques by people with Down syndrome and examine the degree of variance that exists within this specific population.

The second study on information retrieval adopted the functionality-based approach and examined individuals with cognitive impairments that affect the functionalities related to information retrieval tasks. We chose to employ functionality-based approach for this study for two reasons. First, the result of the study would be easier to be generalized because it is not based on one specific diagnosis, but on functionalities relating to the specific task. Second, different from input tasks that require substantial motor skills, information retrieval tasks involve limited motor skills (primarily mouse). Therefore, the impact of conditions such as DS on fine motor skills will be very limited, allowing us to include both conditions that affect motor abilities (e.g., DS, Cerebral Palsy) and those that do not (e.g., Dementia, Dyslexia). Lastly, the research literature suggests that it remains almost an uncharted territory with regard to information retrieval by people with cognitive disabilities using empirical studies, even though there is an abundance of publications that emphasize the necessity and urgency for websites and search engines to be adapted for individuals with CDs.

1.4 Research Significance

Through my dissertation work, I conducted empirical studies to investigate how people with cognitive disabilities enter information into their computer and how they find

information in the web environment. The studies provided comprehensive empirical data regarding the two skills of people with cognitive disabilities. The findings provide strong evidence that, contrary to the prevailing beliefs, many people with cognitive disabilities, when provided with sufficient training, are able to effectively enter data into computer and retrieve information online. This is a critical finding that may change the view of the capabilities of people with cognitive disabilities and therefore, may broaden their career choices. The data also allowed us to better understand the preferences, interaction strategies, and challenges experienced by people with cognitive disabilities. Based on the findings of the study, we developed guidelines and suggestions for designing computer interface that better support the target population.

1.5 Overview of Dissertation

The dissertation is arranged as follows:

Chapter One provides an overview of the literature and the dissertation studies on information input and retrieval, with statements on research justifications and significance.

Chapter Two is the detailed literature review on information input and retrieval concerning people with cognitive disabilities. Specifically, in the first part, the chapter reviews studies on information input with particular attention paid to the use of assistive devices by people with Down syndrome; in the second part, the chapter surveys research on information retrieval with a focus on the methods and strategies used in the context of the World Wide Web.

Chapter Three reports the study on information input. It contains three sections: methodology, results, and discussions. In the methodology section, the chapter provides the research design, research procedures, as well as the information on the participants. The results section reports the results on the effectiveness of different input devices such as voice recognition, word prediction, and keyboard and mouse for individuals with Down syndrome, and on the preferences the participants indicated in a survey. In the discussions section, the chapter offers an analysis of the results in conjunction with the research questions raised for the study.

Chapter Four reports the study on information retrieval. The research design section describes the comprehensive adapted website designed for the participants. The methodology section provides information on the participants and research procedures. The results section presents the results on the effectiveness of different information retrieval methods (i.e., the narrow/deep structure, the broad/shallow structure, and the search engine) used by individuals with cognitive disabilities, and on the preferences the participants indicated in a free trial session and a survey. The discussions section offers an analysis of the results in conjunction with the research questions raised for the study.

Chapter Five presents the conclusions of the research.

Additionally, research materials such as questionnaires, recruiting posters, sample responses, and data sets are included in the appendix section at the end of the dissertation.

CHAPTER TWO

LITERATURE REVIEW

Experience with any technology involves a learning curve, that is, an individual feels comfortable and competent with a certain technology after gaining knowledge through training and practice. For people with disabilities, technology presents more challenges. On the one hand, individuals with disabilities can experience varying degrees of difficulty working with technology due to their physical, motor, or cognitive impairments; on the other hand, technologies are often designed for and adopted by ordinary users and they are not user-friendly to people with disabilities.

Information input and information retrieval are two important aspects of computer usage. Information input is the process in which an individual enters data in a computer using a device or a combination of devices such as a keyboard, a mouse, voice recognition software, and so forth. Information retrieval is the process in which an individual collects or gathers data with the use of a computer. It encompasses a host of activities such as finding a document in a computer, checking email messages, and browsing the web. In this dissertation, we focus on information retrieval activities in the context of the web. Evidently, since its inception in the early 1990s, the World Wide Web has grown exponentially, becoming an extremely important tool for people to obtain information. Finding information online often involves multiple numbers of webpages and can be quite confusing and time-consuming. The task is even more challenging for

users with cognitive disabilities due to the limited capabilities in learning, understanding, and memory.

2.1 Cognitive Disabilities

2.1.1 Definitions

Even though there exists a general consensus in medical and legal communities that individuals with cognitive disabilities are the largest single disability group that accounts for over 1 billion people worldwide (World Health Organization, 2011), a clear and agreeable definition on cognitive disabilities remains elusive (Rowland, 2004).

“Cognition,” according to the Merriam-Webster Dictionary, denotes the mental faculty of processing and understanding information. In its broad sense, “cognitive disability” encompasses a wide array of conditions that hinder individuals’ ability to comprehend what they see and hear, and to make meaningful inferences from any form of verbal and non-verbal communication. Loosely defined, individuals with cognitive disabilities can be those who have learning disabilities (e.g., dyslexia and dysgraphia), attention disorders (e.g., ADHD and ADD), developmental disabilities (e.g., Asperger’s syndrome, Down’s syndrome, Fragile X, Autism, and cerebral palsy), and neurological impairments (e.g., Alzheimer’s, traumatic brain injury, and dementia). It should be noted that the categorizations of cognitive disabilities can vary greatly, often requiring researchers’ explanations and justifications at the outset that are aligned with the goals and objectives of the research. For instance, the latest, 2011 *World Report on Disability* produced by the World Health Organization refrained from providing a specific definition for cognitive disabilities while defining disability as “problems encountered in any and all three areas of functioning”: impairments, activity limitations, and participation restrictions. It should

also be noted that the categorizations of cognitive disabilities can be based on whether a certain condition is event-based (e.g., TBI), born-with (e.g., Down syndrome), or developed over time (e.g., Alzheimer's).

Depending on the contexts (e.g., employment, education, or medical attention), agencies and organizations define and identify categories of cognitive disabilities differently pertaining to their specific concerns. For instance, in job placements, companies often exclude severe cognitive impairments as such what used to be referred to as “mental retardation” from their definition of cognitive disabilities. On the other hand, in research literature on accessibility, more and more scholars have approached aging—a condition in which individuals suffers cognitive degeneration as a natural process—as part of cognitive disabilities (e.g., Curran, Walters, & Robinson, 2007; Fox, 2004).

2.1.2 Clinical and functional diagnoses

The different categories or subgroups that are lumped under the family of individuals with cognitive disabilities are clinically defined, serving well for the purposes of medical treatment. However, for the purpose of usability from an information input point of view, medical descriptions matter little, because they must be understood in a language that describes how cognitive disabilities affect mental and physical functions, and how a specific type of disability correlates to the motor skills. For the purposes of web accessibility from the perspective of information retrieval, nor are these definitions useful, for scholars in general and web designers in particular are more interested to know how these diverse conditions impact individuals functionally when they use the

Internet. Despite the fact that causes, symptoms, and treatments concerning cognitive disabilities are yet to be fully explored and explained, existing efforts from a broad range of fields such as medical science, psychiatry, and clinical psychology have yielded some common knowledge about cognitive disabilities. In general, individuals with mild or severe cognitive disabilities have more difficulty concentrating on tasks (they tend to have a shorter attention span and get distracted more easily); they possess limited power of perception and logical reasoning (they often fail to function in the abstract environment); they demonstrate relatively poor problem-solving skills; and they also experience short- and long-term memory problems (e.g., Cornish & Wilding, 2010; Engle, Sedek, Hecker, & McIntosh, 2005; Harris, 2005; Hogg & Langa, 2005).

Consequently, studies on information input and retrieval—essential to usability and accessibility research—have centered on functional definitions of cognitive disabilities. For instance, to operationalize cognitive disabilities in the context of web accessibility, scholars (e.g., Bohman, 2004; Bohman & Anderson, 2005; Rowland, 2004) have focused on common functional limitations or, to borrow a medical term, “symptoms,” of individuals with cognitive impairments. Consistent with the functional diagnosis, Rowland (2004) argued that the most common challenges individuals with cognitive disabilities faced when using the Internet include attention, memory, perception and processing, and problem solving. In the same spirit and in a frequently cited piece, Bohman and Anderson (2005) proposed a framework for researching cognitive impairments based on functional descriptors including memory, problem solving, attention, reading, linguistic, and verbal comprehension, math comprehension, and visual comprehension.

2.2 Studies on Information Input

There is a long history of human-computer interaction research focusing on people with perceptual and motor impairments. However, research on individuals with cognitive impairments and their interaction with computers started to emerge only during the recent years (Lazar, 2007). In those studies, researchers often combined users with different types of cognitive impairments into one group. For instance, in past research, individuals with Down syndrome (DS) have been grouped together with individuals with Autism or Williams syndrome (e.g., Dawe, 2006; Marcell & Falls, 2001). The results provide great insights to the impact of computer related techniques on users with cognitive disabilities. But the influence of the wide range of characteristics and functional differences among various types of cognitive impairments needs to be examined in more details. While Down syndrome, since its discovery over a century ago, has been studied extensively in a wide range of fields such as medical science, psychology, and education, the investigation of computer usage by individuals with Down syndrome remains rather limited. In addition, the majority of the existing research in human-computer interaction (HCI) involving individuals with Down syndrome used qualitative or indirect approaches such as interviews, observations, and surveys (e.g., Dawe, 2006, 2007; Feng, Karat, & Sears, 2010). Our study will be the first empirically controlled study involving people with DS that investigates the computer usage activities (e.g., data entry, target selection, and information retrieval) of computer users with Down syndrome.

2.2.1 General characteristics of Down syndrome

Down syndrome (DS) is caused by an underlying chromosomal abnormality (Lejeune, Gautier, & Turpin, 1959). According to the National Association for Down Syndrome (2008), Down syndrome is a genetic condition that causes delays in physical and intellectual development. It occurs in approximately one in every 800 live births in the United States. There are three types of Down syndrome due to different chromosomal abnormalities: trisomy 21 (95%), translocation (4%), and mosaicism (1%) (Roizen, 2005). Medical complications in Down syndrome include congenital heart disease, sensory (vision and hearing) impairments, orthopedic problems and other problems (Roizen, 1996). Individuals with DS also exhibit varying degrees of impairments in neurodevelopment and behavior: in the gross motor area, continued progress is slow, although significant physical disabilities are rare (Roizen, 2005); consequently, motor impairment causes difficulties with movements. In language acquisition, by 2 years of age, significant delays are evident. Even after children with DS are able to speak in sentences, problems with speech intelligibility interfere with communication. Receptive language is generally better than expressive language in individuals with DS at any age (Chapman, Hesketh, & Bird, 1991; Chapman, Seung, Schwartz, & Bird, 1998; Kumin, 1996). DS is one of the first symptom complexes associated with mental impairment to be diagnosed as a syndrome (Roizen, 2005). All individuals with DS experience some degree of learning disability. Some children progress within the lower ability range of the non-disabled children in ordinary schools; some children are more delayed, with moderate to severe learning difficulties (Buckley, 2001a, 2001b). In general, these children have poor verbal short-term memory skills, but their visual-motor skills are

relatively strong (Wang, 1996). Wishart (1996) summarized the characteristics of children with DS as low IQ, impaired hearing due to persistent fluid in the ear and auditory processing problems, delayed speech, possibly inarticulate speech patterns, poor memory skills, and poor motor coordination.

Another survey of children with DS found some behavioral and psychiatric disorders, for example, aggressive behavior (7%), Attention-deficit hyperactivity disorder (ADHD) (6%), and other disorders (Collacott, Cooper, Branford, & McGrother, 1998). Some individuals with DS may suffer from a deterioration of cognitive or psychological functioning in adolescence, as exhibited in the worsening of behavior or academic performance (Zoizen, 2005).

2.2.2 General computer usage by children with DS

The first published research study in human-computer interaction focusing solely on users with DS was a 2008 national survey in the USA, with the goal of collecting baseline data on computer usage by young adults with DS (Feng, Lazar, Kumin, & Ozok, 2008; 2010). There were 561 survey responses, covering a wide range of users with DS, from age 4 to 21. The survey consisted of four different sections, focusing on general computer usage, interaction techniques, usage of personal electronics, and demographic and background information. According to the responses, 83% of the children started using computers by age 6. Most of the children use computers for learning (80%) and entertainment (95%) purposes. The most commonly used computer applications include educational software, computer games, and the Internet.

Another area of human-computer interaction research studying young adults with DS is in website development. There was a design case study published in 2007, focusing on the development of a web site specifically for individuals with DS, and utilizing a participatory design methodology (Kirijian & Myers, 2007). The participatory design approach helped identify the design features that are easily accessible for individuals with DS. The web site was well received by the DS community. However, the study was largely practical and exploratory, focusing only on better implementation of existing web design guidelines. Therefore, the theoretical implications are quite limited.

2.2.3 Input techniques and children with DS

Regarding the use of input devices, the 2008 survey found that keyboard (85.6% of respondents) and mouse (93.2% of respondents) were the two most commonly used forms of input. In addition, touch screen (12.3%), joystick (7.5%), touchpad (5.5%), and trackball (4.9%), were also used by a significant percentage of participants. Keyboarding was noted to be a specific challenge, since only 10.8% of the respondents who used keyboards employed multiple fingers on both hands. Far more common was using one index finger (49.6%), or two index fingers (27.9%), or two fingers on only one hand (11.7%) when using the keyboard. Based on the data collected, input is clearly a challenge for people with DS. Theoretically, using a mouse is an abstract, spatial task and is challenging from both the cognitive and the motor perspectives for individuals with DS. However, the survey results suggest that the majority of the participants are capable of using the mouse to interact with computers, but challenges still exist for many children (Feng, Lazar, Kumin, & Ozok, 2008; 2010).

Although there are dozens of input techniques currently available for individuals to use, for this research study, three types of input techniques were examined: keyboard and mouse, word prediction software, and speech recognition. Keyboard and mouse clearly is the most commonly used form of input, as indicated in the 2008 survey on computer users with DS. It is necessary to conduct further research on this traditional method, and compare it with other assistive input methods.

For users with fine motor impairments, two commonly adopted alternative techniques are speech recognition and word prediction, which mitigate difficulty in typing as a result of the limited motor functions. According to MacArthur (1999), word prediction software was originally developed for individuals with physical disabilities to reduce the number of keystrokes required to type words. Many studies show that word prediction improved text entry rate (the number of words generated per minute) when used together with various input devices (Anson et al., 2006; Koester & Levine, 1996; Newell, Booth, Arnott, & Beattie, 1992; Wobbrock & Myers, 2006). Most theoretical work in word prediction assumes that a system that saves more keystrokes will be more beneficial to the user (Trnka, McCaw, Yarrington, & McCoy, 2009). However, the practical benefit of word prediction is less clear because word prediction, while reducing the number of keystrokes, also introduces extra work load such as additional browsing time and cognitive overhead (Koester & Levine, 1994, 1996; Venkatagiri, 1993).

There were a few studies assessing the benefits of word prediction for individuals with various disabilities. Early research on the word prediction software postulated that word prediction can provide valuable assistance to a wide range of users including those with various levels of spelling and/or language dysfunction and those with mild visual

and/or motor impairments (Zordell, 1990; Newell, Booth, Arnott, & Beattie, 1992; Newell, Arnott, Booth, Beattie, Brophy, & Ricketts, 1992). Tam, Reid, Naumann, and O’Keefe (2002) evaluated the effect of word prediction on written productivity from perspectives of the users with spina bifida and hydrocephalus. The analysis showed that participants perceived word prediction to have the potential to influence written productivity on some writing tasks. Similar to speech techniques, there is no empirical data that evaluate the usage of word prediction software by individuals with DS.

Speech-based applications allow users to communicate with computers or computer-related devices without the use of a keyboard, mouse, or any other physical interaction devices. Speech-based input techniques have been proven to be beneficial for individuals with physical disabilities that hinder the use of traditional input devices (e.g., keyboard and mouse) (e.g., Feng, Karat, & Sears, 2005; Harada, Landay, Malkin, Li, & Bilmes, 2006; Sears, Feng, Oseitutu, & Karat, 2003). It was also reported that speech recognition helps students (ages 9 to 18) with learning disabilities to improve word recognition, spelling, and reading comprehension (Raskind & Higgins, 1999). Compared to other alternative input techniques such as head controlled device and eye-controlled input, speech techniques can be acquired at fairly low cost and is a natural easy-to-learn input solution. However, speech technology also has several challenges. One is the existence of recognition errors and the difficulty to correct those errors (Sears et al., 2003); another is the potential increased demand for cognitive load. Both are particularly problematic for individuals with cognitive disabilities. In addition, most people with DS have speech intelligibility (understandable speech) problems due to both anatomical differences and physiological difficulties (e.g., low muscle tone) and expressive language

difficulties related to cognitive limitations, (e.g., difficulty with memory for verbal information) (Abbeduto & Murphy, 2004; Chapman & Hesketh, 2000). Therefore, the adoption of speech-based techniques among people with DS is quite limited. According to the Feng et al. (2010) survey, only 3.4% of the participants with Down syndrome have ever tried speech input technology. To date, very limited empirical evaluation has been reported to examine how individuals with Down syndrome interact with speech technology from the data entry point of view.

Existing literature suggests that the use of input techniques by individuals with DS is understudied. In order to help individuals with DS to interact with computers more effectively, a more detailed investigation of input technologies for people with DS is needed.

2.3 Information Retrieval and Accessibility Divide

Compared with studies on input, research on information retrieval on the World Wide Web bears even a shorter history. This is not difficult to understand: in the early days when the computer, seen as an auxiliary to or replacement of a typewriter, was predominantly used for word processing, how to develop and perfect assistive input devices drove the research agenda. With the advent of the World Wide Web and computers getting customarily networked, retrieving information both for work and entertainment has evolved into a major activity in the use of computers, and therefore studies on accessibility in the context of web has emerged as a new research field.

Since its inception, the concern on the unequal access to information technology, or the digital divide, or “haves” and “have-nots,” has become both a moral and legal concern (e.g., Blanck, 1994; Burghstahler, 2002; Henry, 2009; Norris, 2001; Strover,

2003; Wheaton & Patrizia, 2007). Whereas traditionally the concept of digital divide, primarily framed in differences in socioeconomics, is directed at the general populace, the accessibility divide has specifically geared toward issues concerning people with perceptual, motor, or cognitive disabilities. Distinct from other areas of investigation, the survey of research on information retrieval concerning individuals with CDs has to take into account legislative and regulatory factors (e.g., the government mandates) and the World Wide Web Consortium's efforts.

2.3.1 Government mandate

In the United States, as part of the protection of civil rights of persons with disabilities, a series of legislations have been passed. The rights to equal access to society by individuals with disabilities were recognized in Section 504 of the Rehabilitation Act of 1973, which expressly prohibited discrimination against people with disabilities in public and private programs that received federal funding. This recognition was extended to the digital world unequivocally in the Telecommunications Act of 1996. Section 225 of the Act required that providers of telecommunication services, whenever possible, should make their products accessible to people with disabilities. Even though Section 225 appeared as a passionate call rather than a binding legal duty, it could well be the first piece of legislation to address "accessibility" (Telecommunications Act, 1996). Two years later, in 1998, when the Rehabilitation Act was amended, information accessibility became both clearly defined and legally binding. Section 508 stipulates that federal agencies and those receiving federal funding/contracts for services must adhere to basic web accessibility guidelines, and that individuals with disabilities must "have access to

and use of information and data that is comparable to that provided to the public who are not individuals with disabilities” (Rehabilitation Act, 1998).

2.3.2 World Wide Web Consortium (W3C)

The enactment of relevant laws was the result of influences of organizations and individuals. The World Wide Web (W3C) played a key role. With the recognition of the fact that individuals with disabilities had been digitally disenfranchised due to accessibility challenge, W3C, the group that sets web standards, has also set the research agenda on accessibility. In 1997, the group launched what is now famously known as the “Web Accessibility Initiative” (WAI), which involved several task groups working on specific accessibility guidelines—from web page designs to web page tools—for the purposes of easy accessibility for individuals with disabilities. The WAI has since expanded and issued additional Web Content Accessibility Guidelines (WCAG). The guidelines identify specific techniques needed to facilitate the use of web pages by persons with disabilities and those using assistive technologies (see World Wide Web Consortium, 1999, 2008).

Granted, the legislative measures by governments and the guidelines issued by W3C or concerned organizations remain in “theory,” which needs to be translated into practice, meaning that web accessibility should and can be a reality that benefits individuals with disabilities when websites are designed with accessibility in mind and made available. However, as mentioned earlier, WCAG 1.0 in 1999 only had perceptual and motor impairments in its purview, neglecting cognitive disabilities, and WCAG 2.0 in 2008 only addressed inadequate amount of attention to cognitive disabilities.

Nevertheless, one problem with these documents is that they only include technical guidelines, providing no information on process—on maintenance. Admittedly, there have been enormous efforts and great strides made to provide better accessibility for individuals with disabilities. Unfortunately, there is still much to be desired. For instance, the U.K. Disability Rights Commission (2004) reported: “Most websites (81%) fail to satisfy the most basic Web Accessibility Initiative category.” Almost a decade later, according to the findings from numerous surveys of government, institutional, and commercial websites conducted by usability and accessibility scholars (e.g., Ellcessor, 2010; Goodwin et al., 2011; Kennedy, Evans, & Thomas, 2011; Vanndenbark, 2010; Vincente & Lopez, 2010; Wheaton & Patrizia, 2007), the situation has not improved much.

2.4 Cognitive Disabilities and Web Accessibility

Individuals with cognitive impairments encounter more obstacles when utilizing the online tool than people with physical and motor impairments. Comparatively speaking, research on web accessibility for people with CDs lagged behind. It is explainable in several ways. First, even though the web arguably emerged in the early 1990s, it really got to a head start around the mid 1990s, and then mushroomed afterwards. It is conceivable that during the formative years, the understanding of the web and information retrieval was still in its infancy. Since the design protocols for the general public were still being defined and developed, it would be unrealistic, and less motivating, for designers to commit energy and resources to individuals with cognitive disabilities. Secondly, as we mentioned above, there was more attention paid to the

usability and accessibility issues faced by people with physical disabilities and, accordingly, more efforts were made to develop various assistive devices.

In this context, we can see a general pattern in the literature on cognitive disabilities and web accessibility: at first, the majority of research started with a theoretic focus, which continues to this day as the web and web technologies are constantly evolving; later, more and more research moved forward with an emphasis on assistive technologies, and finally with a shift to specific designs employing universal accessibility guidelines or practical wisdom.

2.4.1 Theoretical framework and awareness studies

There are a number of studies on the theoretical framework of information retrieval for people with CDs. Holsapple, Pakath, and Sasidharan (2005) introduced a theoretical framework consisting of four elements—navigation structure, knowledge acquisition, task and content compatibility, and their interplay—and outlined a research agenda that identified important considerations on website interface designs for people with Alzheimer's disease. In line with WACG's general guidelines, or universal design principles for the disabled, various studies made specific suggestions on how to design such websites that facilitate information retrieval (Bigham, Brudvik, & Zhang, 2010; Burmeister, 2010; Myhill, Cogburn, Samant, Addom, & Blanck, 2008; Karreman, Geest, and Buursink, 2006; Freeman et al., 2005; Friedman & Bryen, 2007). It can be said these various studies are aimed to understand the nature of disabilities and its relation to the aspects of web design.

An interesting phenomenon is that the discourse on web accessibility has gained more traction when it is framed as potentially being relevant to everyone. An increasing number of studies extend individuals with CDs to seniors, who experience various signs of cognitive disabilities from the loss of memory, orientation, to the suffering from dementia. In this case, web accessibility is not only related to a specific group; rather, it is potentially relevant to every one of us, since we will all age in years. This notion is clearly expressed in the WHO's 2011 *World Report on Disability*: while currently there are over 15 percent of world population that is experiencing at least one form of disability, from a physiological and developmental point of view, everyone will experience different forms of disability in his/her life time. This notion also highlights the meaning of universal usability or universal design.

For instance, in examining the cognitive challenges faced by the seniors in website use, Burmeister (2010) argued that sudden adaptation to complex changes, as opposed to complexity itself, is cognitively challenging for older seniors, and that greater design effort needs to be devoted to mechanical cognition, to do with information processing and learning, than to pragmatic cognition, which concerns social interaction and communication. In addition to the main findings about adaptation to substantial change, two other cognitive considerations affecting website access for seniors were found to be: the importance of a flat navigational structure and that of providing functional, memory aids.

2.4.2 Applications and web accessibility

There is an underlying philosophical change when emphasis is shifted from assistive devices to web designs. When researchers emphasized the various assistive technologies, they basically took the existing web content and its design as given, and it was the responsibility of the individuals with disabilities to use the assistive devices to retrieve information, not the other way around. As Ellcessor (2010) argued, “attempts to regulate web content accessibility grappled with concepts of access and accessibility as related to usability, universal design principles, and disability status, emphasizing *variation of needs and preferences*, rather than mere accommodation of people with disabilities” (p. 290). In other words, a more important aspect of accessibility is to organize and present information that facilitates information retrieval for people with disabilities. It is only in recent years that we see research focusing on designing or comparing websites that cater to people with CDs.

Freeman et al. (2005) in a practical study to gain insights into the organization and presentation of information for better retrieval for people experiencing early-stage dementia, a cognitive disability, compared the use of two websites containing similar information. The researchers found that limiting the size of web pages and cognitive overload can lead to better information retrieval. Their findings confirmed the universal design guidelines set forth by W3C.

Karreman, Geest, and Buursink (2006), in an exploratory study, tested two websites that contain similar information but with one being designed as a regular website, the other being adapted on the basis of easy-to-read guidelines. Participants consisted of both individuals with CDs and with no disabilities. The researchers found

out that the adaptation of the website worked well for participants with CDs, and that users without identified cognitive disabilities were as effective with the adapted site as they were with the non-adapted site.

Sevilla, Herrera, Martinez, and Alcantud (2007) conducted a study on web accessibility for individuals with cognitive impairments. The study compared an existing commercial website and its cognitively accessible equivalent, concluding that the use of a simplified web browser and an adequate web design can facilitate people with CDs to use the Internet. In the paper, Sevilla et al. also discussed the need for more studies that would fine-tune their requirements regarding specific cognitive deficits and automating the process of creating and testing cognitively accessible web content.

2.4.3 Search engine and web structure

The massive amount of information on the web makes it extremely hard for almost anyone to retrieve correct data, let alone people with disabilities. When researchers conducted studies that test websites designed to provide easy accessibility, they focused on the static nature of a particular site or sites. In other words, the presumption is that the participants have already arrived at certain websites for information retrieval. In reality, the most challenging steps might well be for the individuals to first get to these websites and then browse them. It is clear that randomly browsing websites can lead an individual to nowhere or everywhere, with little efficiency. To find information, individuals in many cases must rely on a search engine such as “Google,” “Yahoo,” and so on. For people with disabilities, one big question is whether a search engine is built or designed in such a way to facilitate their search and whether results of a search can be listed in such a way to

facilitate information retrieval. Unfortunately, it has remained a neglected area of investigation. There have been only a few studies that attempted to address some of the important issues.

For instance, Svensk and Johansson (2004) tried to understand how people with cognitive disabilities navigate the Internet. In this case, they chose “Google” as an Internet search engine. One of the tasks was to ask individuals to carry out a search using Google’s image search box. Researchers observed the tasks performed by the participants and identified specific problems such as the participants’ inability to correctly spell the search words and to pick the right link with many search results.

Kirijian and Myers (2007) reported a participatory design case study on the development of a web site specifically for individuals with Down syndrome. The web site design for the study was well received by the Down syndrome community. However, the study was largely practical and exploratory, focusing on better implementation of existing web design guidelines, and thus lacking theoretical implications.

Existing research on web interaction for users with CDs share a notable limitation: the websites created and evaluated contained a very limited number of items that were unrealistic compared with the typical websites. In other words, the “research websites” are too simple to be representative of those interacted in real life. The motivation and intention underpinning the designs were not necessarily flawed: In order to follow the guidelines (e.g., limited number of items on each page and the broad/shallow navigation path), the researchers had to reduce the content of the website. Studies have discovered that entering a search word or a URL address as well as understanding the text on a web page proved to be problematic for people with cognitive

disabilities (e.g., Harrysson, 2003; Harrysson, Svensk, & Johansson, 2004). All these studies focused on obtaining information from a self-contained web environment. More advanced skills such as retrieving information using search engines for people with cognitive disabilities have been understudied.

In summary, existing literature suggests that there is a big gap between the need of individuals with CDs to use computers and the web and our knowledge in the related domain. The two studies reported in the dissertation were motivated to fill this gap by empirically investigating how people with CDs enter information into computer and retrieve information online.

CHAPTER THREE

INFORMATION INPUT STUDY

3.1 Research Questions

In this study, we investigate how children and young adults with DS enter information to computers using three input techniques. The reason to focus on individuals with DS has been explained in Chapter One. Both quantitative and qualitative approaches were adopted to investigate the following research questions:

- What is the typical range of data entry performance for individuals with DS?
What are typical performance profiles for high or low performers?
- Do individuals with DS employ specific interaction strategies when using the three input techniques?
- How can we improve the design of computer interface to accommodate the special needs of individuals with DS?

3.2 Methodology

Two groups of participants were recruited for the study: children and young adults with DS, and neurotypical children. For both groups, a within-group design was adopted to examine three types of input techniques: keyboard and mouse, word prediction software, and speech recognition. Each participant used all three input techniques to transcribe three pre-defined text documents. Due to the special needs of the participants and the

small sample size, this study is not intended to provide a solid statistical comparison between the three techniques. Instead, we aim at collecting performance data that can inform design and provide insights into future research.

3.2.1 Participants

Eight participants with DS (two females and six males) and five neurotypical children (two females and three males) took part in this study. All participants were native English speakers, and had previous computer experience. All participants were familiar with the keyboard and mouse technique. The etiology of DS for all participants with DS was trisomy 21. Participants with DS ranged from 10 to 28 in age, with an average age of 18.75 (stdev = 6.94). Seven of the participants lived with their parents, and one lived in a group home that housed other people with different types of special needs.

The allowed age range (10 to 28) is large for a typical study investigating neurotypical children and young adults. However, we think the age range is acceptable for people with DS for several reasons. First, for the purpose of observing how the participants use the three input techniques, the comparison is made within each participant and the age difference among the participants would not affect the statistical test results. Second, although age is an important factor that affects the participants' computer abilities (especially at very young ages such as from birth to kindergarten), the pace of growth and development tends to slow down and gradually level off during teenage years for individuals with DS (Roizen, 2005). Therefore, the performance difference between a 10-year-old and a 28-year-old with DS tends to be smaller compared to that between two neurotypical people. Third, regarding computer skills,

there are many other factors that can be equally or more important than age, such as access to computers and training programs, computer experiences, etc. Due to lack of access to computers and related training during early childhood and school years, many people with DS in their 40s or older are not as competent on computers as younger people with DS. Fourth, a previous survey study indicates that children with DS start using computers at fairly young age. Out of the 561 responses, 405 (72%) of the children had started using computers by the age of five and more than 80% had started by the age of six. Only less than five percent of the children started using computers when they were older than 10. Therefore, we allowed comparatively broader age range (10 to 28) when recruiting participants with DS. We interviewed every participant's parents before the study to determine whether their child was appropriate to participate. During the interview, we considered not only age, but also their reading level, the number of years that they have used computers, and the number of hours that they use computer every week.

The neurotypical children were between 10- and 13-years old, with average age of 11.2 (stdev = 1.30). The age range of the neurotypical children is much smaller primarily because we would like both participant groups to have similar reading level and computer experiences. Since most people with DS can acquire a reading level of the third grade, we aimed for neurotypical children with similar reading levels. As they get older, many neurotypical children would take advanced keyboarding classes and other computer related training programs that are currently not part of the curriculum for children with DS; the additional training may become a substantial confounding factor and bias the result.

The primary goal to include the neurotypical group in the study is not to examine whether there is difference in data entry speed or error rates between the two participant groups. For one thing, we already know that children with DS are delayed in cognitive, motor, and perceptual abilities, so lower performance by the majority of the participants in the DS group would be well expected. For another, we do not think that the data entry speed would carry much weight due to the large variance in performance for people with cognitive disabilities. Our primary goal to include the neurotypical group is to better understand the gap between the two groups. We are also interested in examining whether they interact with the input devices differently (e.g., different interaction strategy). The answer to these questions would shed light on the design of input applications for children with DS (e.g., whether a one-for-all solution would be effective or whether a customized solution for children with DS would be needed).

We are fully aware of the difficulties and challenges involved in selecting and grouping participants for any research. A group is seen from the lens of presumed common traits, but each participant in any group can have exceptions and unique individuality. For our participants with Down syndrome, while we work on the assumption that as a group, they generally are expected to have lower performance than the neurotypical children, we are cognizant that some users with Down syndrome, given early intervention and proper training, are capable of being close to the same performance as their neurotypical peers.

As to the selection of input devices, we acknowledge a weakness that is associated with the nature of this experimental design and that will be addressed in detail later. Briefly, users in general had lots of previous experience with keyboard usage, but none

with word prediction and speech recognition, and there was not enough time to do a longitudinal study.

3.2.2 Apparatus

All participants used the same laptop computer to complete the transcription tasks. The laptop was a PC running Windows Vista. A keystroke level logging software, Spector Pro, was used to record the key strokes entered by the user, the starting time and ending time of each task, and screen shots. Participants had the option to use the touch pad on the keyboard or an external mouse.

Participants entered the scripts in Microsoft Word™ under the basic keyboard condition. Under the word prediction condition, participants entered the text in Microsoft Word™ with the assistance of the prediction software WordQ™. WordQ™ allows the user to select different vocabulary levels, from “starter” to “advanced.” In this study, the “starter” level was used. When a user types a letter, WordQ™ provides a list of words that the system proposes in a text box below the current cursor location. If the intended word appears in the list, the user can enter the word either by typing the number next to the word or by clicking on the word. When a user types a word or picks a word from the list box, a list of next likely words appears. The list box can show six to nine candidate words at a time, depending on the user’s preference. WordQ™ also provides “speech” and “read” functions as well. When the “speech” function is on, the typed word is read out aloud using synthesized speech. The “read” function can read highlighted words and sentences. These functions help check typing errors and can be activated based on the user’s preference.

Under the speech condition, all participants used a speech recognition application, ViaVoice™ for Windows™, developed by IBM. ViaVoice allows users to dictate text using a generic speech profile. In order for the program to recognize each individual's speech more accurately, the user is always recommended to create his/her own profile. To create a profile, the user is required to read several paragraphs of pre-defined text on the computer screen in a normal and relaxed voice. This process typically takes approximately 15 to 20 minutes. In our study, all participants created and used their own speech profile when completing the transcription task using speech.

3.2.3 Tasks

When evaluating input techniques for text generation, both transcription and composition tasks have been commonly adopted. Compared to transcription tasks, composition tasks involve more skills such as spelling, grammar, and related knowledge or experience in the specific topic. In addition, composition tasks also demands higher cognitive load than transcription tasks. Previous research suggests that people with DS have difficulty in all those areas. If the participants in this study work on composition tasks, a large portion of the difference between the two groups will be contributed by differences in language skills, not the skills related to input devices. Therefore, we chose transcription tasks over composition tasks to control the potential confounding factors that would be introduced by the composition tasks.

All participants completed three transcription tasks, each using one of the three input solutions. Three scripts, each containing approximately 200 words, were selected from books and standard reading test materials for the transcription tasks. Two factors

were taken into account when selecting the scripts: the average reading level of individuals with DS and their general interests. On the reading ability, Byrne (1997) indicated that some teenagers with DS who start their secondary school education are only able to read and write at the same level as the typical 8- and 9-year-olds (grade 3). Buckley (2001b) stated that the average level of reading skill of a typical 8- or 9-year-old is adequate to read many daily newspapers and books and to write letters and is often reached by adolescence with DS. Based on this information, we chose three scripts at the reading level of approximately 8- to 9-years old. Before this study, we conducted informal interviews with a number of people with DS and their parents; information on their interests was collected. Common themes that were mentioned include sports, music, animals, and art. Accordingly, the scripts used in the study covered three different subjects: sports, music, and animals.

For direct comparison purposes, all participants used the same script for the speech condition. The other two scripts were randomly assigned to the keyboard condition and the word prediction condition.

3.2.4 Procedure

Of the eight DS participants, seven did the study at their home; one in an office. Since the entire study took approximately two to three hours, we arranged the study into two sessions. During the first session, the researcher interviewed the participant and his or her parent(s), and asked them to fill in a questionnaire to collect demographic information as well as information such as participant's health conditions, educational background, and computer experience.

Following the interview, the participants completed two transcription tasks, one using the keyboard and mouse, the other the speech-based dictation software. The order of the two conditions was randomized. Under the keyboard and mouse condition, the participant was presented a hard copy of the transcript and was told to enter the transcript using MS Word.

Under the speech condition, the participants first completed the ViaVoice built-in training session to create a personal profile, which took approximately 15 to 20 minutes. Then the researcher initiated the application and took about 10 to 15 minutes to show the participant how to dictate text to the computer. The participant was also given time to try entering some text. The formal study commenced right after the training session. We did not provide the participants additional time for training with the speech application as we did with word prediction primarily because the participants only dictated the script to the speech software and did not need to identify or correct any recognition errors, which substantially simplified the task. We acknowledge that identifying and correcting recognition errors is a crucial step of speech-based text entry. But multiple empirical studies would be needed to examine the error identification and correction behavior of people with DS. As one of the earliest studies on speech application usage by people with DS, we chose to focus on the very basic performance measures such as speed and recognition error rate.

At the end of this session, we installed the word prediction software WordQ™ on the participant's home computer, demonstrated to both the participant and the parent(s) on how to use it, and gave step-by-step instructions and demonstration on all basic functions. Since all participants knew how to use MS Word™, the major challenge with

the word prediction software is to understand the candidate word list and learn to browse and enter the desired word in the list. We explained the word list in detail so that the participant understood why the list is needed and how the list should be used. The participant was then given time to generate some text using the candidate word list; the session ended when the participant could use the list successfully. Each participant was given at least one month to get familiar with WordQ™.

Before the second session, we called multiple times to make sure that each participant had used the software at least three times and was comfortable using the candidate word list. In the second session, the participants completed the transcription task using WordQ™. At the end of this session, we interviewed the participants about their perceived satisfaction regarding all three input solutions. The same protocol was adopted for the five neurotypical participants.

Under all three conditions, the participants were told that the task was completed either when they had entered the entire script or when they had worked on the document for 45 minutes.

3.3 Results of Participants with DS

Seven out of the eight DS participants completed transcription tasks using all three types of input techniques. One participant (P8) only used two input techniques (keyboard and word prediction). He did not use speech recognition application due to stuttering and short attention span caused by Attention Deficit Hyperactivity Disorder (ADHD).

3.3.1 Demographics

The demographical information of the participants varies substantially. Table 3-1 lists participants' age, the number of years that they have used computers, and the number of hours that they use computers per week.

	Age	Number of Years Using Computer	Number of Hours Using Computer Per Week
P1	26	9	14
P2	16	12	15
P3	15	1-2	12
P4	28	1	1
P5	17	13	1
P6	26	15+	18-21
P7	12	3	5
P8	10	1	7

Table 3-1 General demographics of participants

The following background information was obtained through semi-structured interviews with parents as well as observations during the study (see Table 3-2). While the participants were different in many ways such as their upbringings and life styles, all participants had interventions on physical, speech and occupational therapies from birth or preschool age. All of them attended or are attending public schools that provide the Individualized Education Plan (IEP). The IEP, which implements school-based interventions, is mandated by the Individuals with Disabilities Education Act (US Department of Education, 2007). The IEP is evaluated and revised each year, and remains

in place as long as the individual who receives special education or related services in the school continues to express the need.

P1 worked in a grocery store, and was an assistant coach in a high school swimming team. He started to learn computer skills in his IEP in middle school and at home. Every day he used his own computer to play music, surf the web, and communicate with his friends. He was able to use multiple fingers on both hands for keyboarding. His performance on word prediction was the best among all participants.

P2, who was in the 10th grade, had spinal cord injury as the result of an accident. The injury affected the motor functions in his hands. He started to learn computer skills by playing games. The family acquired various assistive computer devices, such as trackball, a special and portable keyboarding device, and the AlphaSmartTM word processor. His IEP included computer courses. He enjoyed playing computer games, including many educational games.

P3 was a 9th grader. He picked up some computer skills by watching his family members using computers. His IEP did not include computer skills. He took a keyboarding class in the 8th grade. At school, he used the computer several times during lunch time each week. He could type using multiple fingers in both hands.

P4 was the eldest participant. He learned limited keyboarding skills once a week in high school. The IEP he had received in school did not include computer skills. After high school, he lived in a group home with no access to computers. He used the computer only when he visited his parents on weekends. He participated in this study in his parents' home. He typed on keyboard with one finger on the right hand.

<p>P5 was a 10th grade student. He started learning computer skills by playing educational computer games. His IEP included computer skills. But he just started learning keyboarding at the time of the study, and only used computer once a week mostly at school. He was left-handed. He primarily typed on the keyboard with his index finger on his left hand, and only used the right hand to hold the shift key for a capital letter.</p>
<p>P6 worked as an assistant teacher in a preschool. She learned typing in high school and other computer skills at home. She had an IEP that did not include computer learning. Every day, she spent most of her time on computer communicating with friends using Facebook and email, and browsing websites. She was able to compose clear, correct and complete sentences in email messages. She was able to type with multiple fingers of both hands. Her typing was the fastest with a relatively small number of errors.</p>
<p>P7 was a 5th grader. Her attention span was short; she was talkative and easily distracted. Her IEP included computer skills. When typing on the keyboard, she mostly used the index finger of her right hand, only occasionally with both hands.</p>
<p>P8 was the youngest of the participants. His attention span was short due to ADHD. He was easily distracted by things around him. He also had stuttering. He had one year of experience working with computers. He picked up some computer skills by watching his parents working on computer, and then learned at school through his IEP. He used computer every day at school or home. He played games and viewed web sites about sports. He typed on keyboard with one finger on the right hand.</p>

Table 3-2 Detailed demographic background for each participant

All eight participants were familiar with the traditional input technique of the keyboard and mouse. None of the participants had previously used word prediction or speech recognition. According to parents' reports, the major difficulties participants faced when using the computer were: using complete sentences to compose email messages (language), logging on to the computer (cognition/memory), spelling (language), and typing (motor). These difficulties could be attributed to cognitive, perceptual, and motor impairments. Five out of the eight participants (P2, P4, P5, P7, and P8) were reported to have low muscle tone problems that hinder their dexterity and coordination. They were only able to use a single finger in one hand to type on the keyboard. Participants P1, P3, and P6 did not have muscle tone problems and were able to use multiple fingers on both hands.

During the experiment, the two youngest participants (P7, 12-years old and P8, 10-years old) kept changing sitting positions and were easily distracted. Unlike the other participants, it was very difficult for them to type on the keyboard consecutively.

3.3.2 Productivity and error rate

In order to control the total time of the experiment sessions, the participant was given a time limit of 45 minutes to complete each of the tasks. Under the keyboard and mouse condition, one participant (P8) did not finish within the time limit, three (P4, P5, and P7) gave up before reaching the 45-minute time limit due to fatigue or lack of patience.

Under the word prediction condition, two participants (P4 and P5) did not finish within the time limit, two (P7 and P8) gave up before reaching the 45-minute time limit due to fatigue or lack of patience.

Table 3-3 summarizes the input rates and the error rates of each participant under the two conditions. The input rate was computed using the total number of words entered divided by the time (minutes) that a participant spent on the task. The error rate was the ratio between the number of errors in the text and the number of actual words entered.

	Input Methods	Input Rate (No. Words/M)	Word Error Rate (%)
P1	typing	6.35	4.06
	prediction	5.94	1.4
P2	typing	3.88	2.2
	prediction	4	1.5
P3	typing	3.77	12.65
	prediction	5.44	10.14
P4	typing	1.49	10.93
	prediction	1.18	11.86
P5	typing	1.98	3.7
	prediction	2.42	7.74
P6	typing	8.7	6.5
	prediction	5.52	6.91
P7	typing	2.34	4.88
	prediction	2.48	2.02
P8	typing	1.79	1.08
	prediction	1.05	0

Table 3-3 Input rates and word error rates of participants with DS under keyboard only and word prediction conditions

The average input rates by typing and by word prediction were 3.7 (stdev=2.54) and 3.5 (stdev=1.99) word per minute respectively; the average error rates by typing and by word prediction were 5.75% (stdev=4.09) and 5.2% (stdev=4.53) respectively. A paired sample t-test shows that there is no significant difference in either the input rate or the error rate between the two conditions ($t(7)=0.57$, n.s.; $t(7) = 0.67$, n.s.).

The input rate for the speech recognition condition is more complicated than the other two conditions because the recognition error rates are very high for most participants. A substantial number of words were captured when participants made unintentional sound. Previous research shows that the identification and correction of speech recognition errors is a very challenging process (Sears et al., 2003). Since recognition errors are all correctly spelled words, it might be difficult to understand and find those errors. Considering the limited cognitive abilities of the participants, we did not ask the participants to correct any errors. Therefore the final text entered is quite different from the original text and the input rate alone can hardly reflect the performance. To provide some preliminary ideas of the participants' performance, we report the performance of two participants with the lowest and highest error rates. Table 3-4 lists the error rates and the average number of words generated per minute by the two participants. The word error rate was computed using the following formula:

Error rate = 1 - (number of correct words / actual number of words in the original script)

The error rates vary dramatically, ranging from 38% to 90%. The text generated by P7 using the speech recognition software is hardly readable. Since the participants did not need to identify and correct errors under the speech recognition condition, the task time was mainly spent on dictating the text. The 90% error rate in P7's document may be partially attributed to her fast dictation speed. During dictation, she spoke at a rate of 150 words per minute. This speed is considered fast even in everyday conversation in which an average person speaks about 125 to 150 words per minute. At this speed, the participant might not have left enough time for pauses between phrases and sentences that are critical for speech recognition engine to decipher the speech.

	Word Error Rate (%)	Input Rate (No. Words/M)
P1	38.36	50
P7	89.96	150

Table 3-4 Word error rates and input rates for two participants with the lowest and highest error rates

3.3.3 Subjective ratings and preferences

At the end of the study, participants were asked to rank their preference on the three input methods, with 1 being the most preferable, 3 being the least preferable. Table 3-5 summarizes the results:

	1	2	3
P1	speech	mouse & keyboard	word prediction
P2	speech	word prediction	mouse & keyboard
P3	mouse & keyboard	word prediction	speech
P4	word prediction	Speech	mouse & keyboard
P5	speech	word prediction	mouse & keyboard
P6	mouse & keyboard	word prediction	speech
P7	word prediction	mouse & keyboard	speech
P8	speech	mouse & keyboard	word prediction

Table 3-5 Participants' preference ranking on the input methods

Participants' attitude towards speech-based interaction falls on the two ends of the scale, with four participants choosing it as their first preference and three participants choosing it as their last preference. The word prediction software and the keyboard solutions fall in the central area, with four participants listing the word prediction software as the second choice and three participants listing the keyboard solution as the second choice.

3.4 Results of Neurotypical Children

3.4.1 Demographics

We also studied five neurotypical children who have approximately the same reading level. They followed exactly the same procedure as the participants with DS to complete the study. Table 3-6 summarizes the demographical information of the five neurotypical children.

	Age	Year(s) of Using Computer	Time of Using Computer Per Week (Hours)
S1	12	8	4
S2	10	6	4
S3	10	7	6
S4	11	8	6
S5	13	8	27

Table 3-6 Demographic information of the neurotypical participants

The applications frequently used by all of the children were web/Internet, games, and educational software. Three of them also used Email. Microsoft WordTM was not a frequent application that they used. According to interviews with the children, they learned some basic computer knowledge, such as turning on/off power, opening applications and viewing web pages. At elementary school, the children did not have standard keyboarding training. Four out of five participants who were in elementary school used two index fingers to type. Only one participant (S5), an eighth-grader, had taken a keyboarding class, and was able to type on the keyboard with multiple fingers on both hands. No significant difficulties related to computer usage were reported by the neurotypical participants and their parents.

3.4.2 Productivity and error rate

	Input Methods	Input Rate (No. Words/M)	Word Error Rate (%)
S1	typing	6.57	0
	prediction	5.82	1
S2	typing	5.02	2.23
	prediction	5.25	4.76
S3	typing	4.76	0.5
	prediction	5.58	2.49
S4	typing	5.24	5.15
	prediction	4.96	6.04
S5	typing	22.66	0
	prediction	9.52	0

Table 3-7 Input rates and word error rates of the neurotypical children under keyboard only and word prediction conditions

Table 3-7 summarizes the input rates and error rates of the neurotypical children. The average input rate was 8.85 (stdev=7.75) for the typing condition and 6.23 (stdev=1.87) for the word prediction condition. The average error rate was 1.58% (stdev=2.20) for the typing condition and 2.86% (stdev= 2.52) for the word prediction condition. Due to the small sample size, no statistical analysis was conducted to compare the performance between the typing and the word prediction conditions.

Table 3-8 shows that speech recognition did not work well for this group either, but the error rate was substantially lower than the DS group. The difference between the

lowest and the highest error rates is also much smaller compared to that of the participants with DS.

	Word Error Rate (%)	Input Rate (No. Words/M)
S5	26.03	92
S3	31.06	82

Table 3-8 Speech input performance by the neurotypical children

3.4.3 Subjective preference

	1	2	3
S1	speech	mouse & keyboard	word prediction
S2	speech	word prediction	mouse & keyboard
S3	word prediction	speech	mouse & keyboard
S4	word prediction	speech	mouse & keyboard
S5	mouse & keyboard	word prediction	speech

Table 3-9 Subjective preference rankings of the neurotypical children

Table 3-9 summarizes the subjective preference ranking of the neurotypical children. Two of the participants rated speech recognition as the most preferable method. They stated that speech input was fast and fun. A more advanced user, S5, took into consideration the input accuracy and pointed out that speech input is interesting but made too many errors, and that the word prediction function was annoying.

3.5 Discussion

The goal of this study is to examine the efficacy of three input techniques as used by children and young adults with DS. The data collected through the study provide preliminary understanding as to the efficiency and accuracy of the three input techniques. More importantly, the result also provides useful insight as to the profiles of users with DS, the difference between the individuals with DS and the neurotypical children, and the potential of the speech and word prediction techniques.

3.5.1 The profiles of users with DS users

To date, there is very limited literature on how fast and accurate children with DS can enter information into the computer. This study provides preliminary information in this regard. The performance data collected from the eight participants vary substantially, suggesting that one design is unlikely to fit the needs of all children with DS. Instead, offering different design options targeting for specific user profiles might be a more effective solution. According to a recent study of expert users with Down syndrome (Lazar, Kumin, & Feng, 2011), the highest performers with DS might not need any types of adjustments or adaptations, since advanced users with DS need no modifications. The variance in performance demonstrated by the participants with DS in this study is consistent with the findings by Lazar et al. Of course, any modification should also take into account the impact of training; computer users can improve their performance through practice and experience.

Figure 3-1 demonstrates the data entry rate and error rate under the keyboard condition (data points marked in diamond shape) and the word prediction condition (data

points marked in square shape) for the DS group. Data points of the same participant were connected using a straight line accompanied with the corresponding participant number.

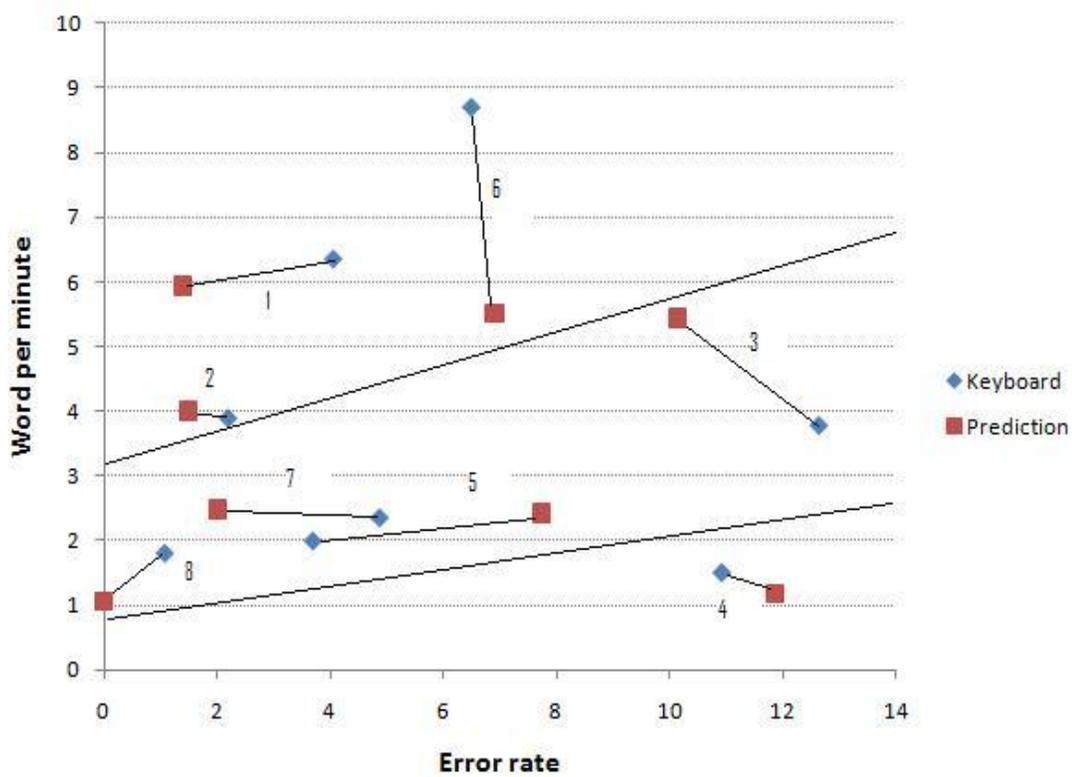


Figure 3-1 Performance distribution for eight participants under the keyboard only and the word prediction conditions. The two data points of the same participants were connected using a straight line accompanied by the corresponding participant number.

In our effort to group the participants into appropriate profiles, we need to consider both data entry rate and error rate. In the context of this study, we assume that data entry rate carries higher weight than error rate because a user has to reach specific level of productivity in order for data entry tasks to be feasible. In other words, if the data entry rate is too low, the user may choose to avoid data entry tasks when using

computers. For example, in a field study that investigated people with physical disabilities that hinder the use of keyboard and mouse, we observed that the participants avoided the use of emails or Microsoft Word because of low typing speed (Hu, Zhu, Feng, & Sears, 2011). We do not believe that this assumption applies in all circumstances. For instance, for life critical tasks (e.g., medical field), the consequences of errors can be devastating and errors can hardly be tolerated. However, for the DS population in the context of everyday data entry tasks, we expect error tolerance level to be much higher and data entry rate comparatively more important than error rate. Based on this assumption, we drew two lines to categorize the eight participants into three groups (see Figure 3-1). P1, P2, and P6 belong to the top region: the high performance group. They averaged 6.31 in data entry rate and 4.25% in error rate under the keyboard only condition. P3, P5, P7, and P8 belong to the middle region: the average performance group. This group averaged 2.47 in data entry rate and 5.58% in error rate under the keyboard only condition. P4 belongs to the bottom region: the low performance group. His data entry rate is 1.49 and error rate is 10.93% under the keyboard only condition. The specific performance measures for participants in each group are summarized in Table 3-10.

	Input Methods	Input Rate (No. Words/M)	Word Error Rate (%)
High Performance			
P1	typing	6.35	4.06
	prediction	5.94	1.4
P2	typing	3.88	2.2
	prediction	4	1.50
P6	typing	8.70	6.5
	prediction	5.52	6.91
average performance			
P3	typing	3.77	12.65
	prediction	5.44	10.14
P5	typing	1.98	3.7
	prediction	2.42	7.74
P7	typing	2.34	4.88
	prediction	2.48	2.02
P8	typing	1.79	1.08
	prediction	1.05	0
low performance			
P4	typing	1.49	10.93
	prediction	1.18	11.86

Table 3-10 Performance data under keyboard only and word prediction conditions

It is interesting to study each user group and examine whether the participants in the same group have any characteristics in common. We found that computer experience (number of years that the participants have used computers) can be a good predictor for performance. All three participants in the high performance group had used computers for about 10 years or more. Only one participant in the average group used computers for

more than 10 years. The other three participants in this group only used computers for three years or less. The participant in the low performance group only used computers for one year. The number of hours using computers per week is another potential predictor for performance. All three participants in the high performance group used computers for around 15 hours every week. Three out of four participants in the average group used computers a few hours per week. The participant in the low performance group only used computers for one hour every week.

The performance level of the participants directly influences the way the participants use computers and the types of tasks that they complete on computers. The high performers use computers as one of their daily routines. Computers have become one integral part of their everyday life. They use computers for a variety of tasks, especially communication-related tasks that involve substantial amount of typing. For the average and low performers, they only spent limited amount of time on computers. Most of them did not use computers every day. And they used computers primarily for games or web surfing and rarely for communication purposes or other types of tasks that demand typing. It seems that the high performers have established an ideal cycle between their skills and what they do on computers: their skills allow them to complete more advanced tasks on computers, and those tasks reinforce and further improve their computer skills. For the average and low performers, such kind of positive cycle has not been established.

Due to the large variance in cognitive, motor, and linguistic abilities among people with DS, we do not expect that all people with DS be able to reach the high performance level. However, in the study, we observed a notable gap between the

achieved data entry performance and the cognitive and motor abilities among the average and low performers. For example, most participants have sufficient fine motor skills in both hands to type using multiple fingers, but they only employ the index fingers when typing. Additionally, many participants are capable of remembering a large amount of information such as user name and password, schedules, website urls, game statistics, but they did not know the location of letter keys on the keyboard. We suspect that the low performance is largely due to the lack of motivation, training, and exposure to technology, rather than limitations in ability. It is possible that a higher percentage of the users with DS be able to join the high performance group given effective training and sufficient access to information technology.

3.5.2 Comparison between participants with DS and neurotypical participants

It is well expected that the neurotypical participants would achieve better performances than the participants with DS regarding data entry rate and error rate. The primary objective to include neurotypical participants in the study is to observe and better understand the gap between the two groups. In addition, we also would like to examine whether there is any difference in the interaction patterns between the two groups.

3.5.2.1 *Productivity and error rate*

The non-parametric Mann Whitney U test suggests that the neurotypical participants generated text at a faster rate than the DS group under both the keyboard and mouse condition ($Z = 1.9$, $p < 0.05$) and the word prediction condition ($Z = 1.76$, $p < 0.05$) (see Figure 3-2). The same test also shows that the neurotypical participants generated text at

a lower error rate than the DS group under the keyboard and mouse condition ($Z = 1.9, p < 0.05$). There is no significant difference in error rates between the two participant groups under the word prediction condition ($Z = -0.95, n.s.$) (see Figure 3-3).

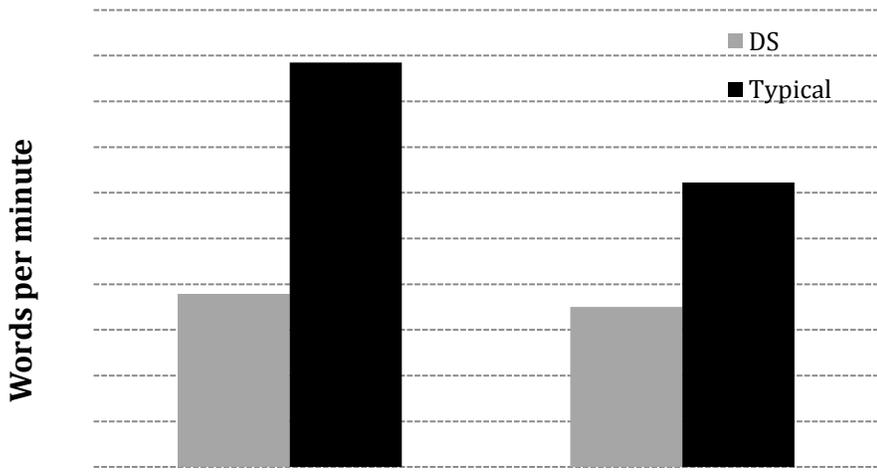


Figure 3-2 Data entry rate (words per minute) for the DS group and the neurotypical group under the keyboard only condition and the word prediction condition

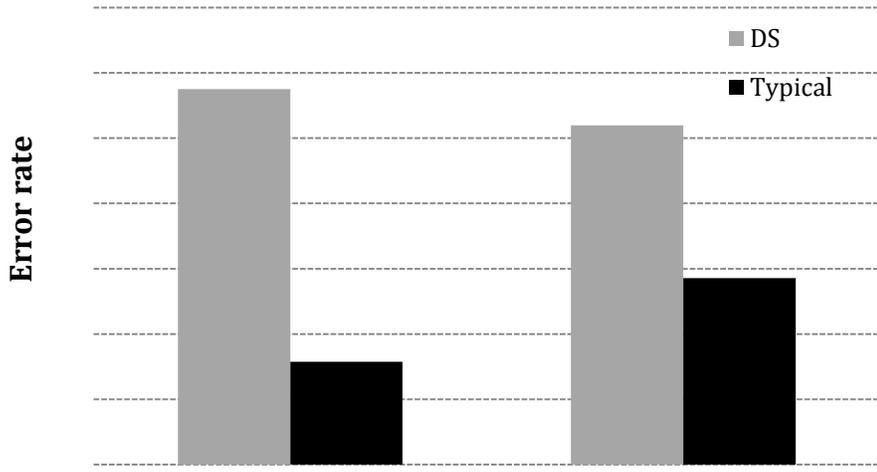


Figure 3-3 Word error rate for the DS group and the neurotypical group under the keyboard only condition and the word prediction condition

According to the statistical analysis, the neurotypical group achieved significantly higher input rate and lower error rate than the DS group under the keyboard condition. The average input rate of the neurotypical group was 6.23 wpm under the keyboarding condition, approximately double the average input rate of the DS group (3.5 wpm). The gap in the error rate was larger than the input rate. The average error rate of the participants with DS under the typing condition was 5.75%, more than three times higher than that of the neurotypical children (1.58%). Under the word prediction condition, the neurotypical group is also significantly faster than the DS group, but the gap between the two groups is smaller than the keyboard only condition (6.2 vs. 3.5).

3.5.2.2 Individual difference

Overall, there is a larger variance in the performance of participants with DS than that of the neurotypical participants (see Figure 3-4). As demonstrated in Figure 3-4, the performance of all five neurotypical children is quite similar except that of one participant (S5), who is clearly an outlier of the group. The data entry rate of S5 is substantially higher than that of any other participant in the study, especially under the keyboard and mouse condition. This participant was 13-years old, the eldest in the neurotypical group. He had taken typing classes and needed to use computers for many class projects that required substantial amount of data entry. His high performance was a reflection of his training and constant practice of data entry tasks. This also confirms one of the reasons that we did not include older neurotypical participants in the group. Starting from middle school, the gap in computer skills and usage between the neurotypical children and DS children greatly widens due to a number of factors other

than perceptual, motor, and cognitive capabilities. We limited the age range of the neurotypical group in order to control the influence of those confounding factors.

There is limited variance in the performance of the other four neurotypical children. Interestingly, the performance of these four neurotypical children is quite similar to that of the three high performing participants with DS. This result suggests that individuals with DS, with sufficient training and exposure to computers, may be able to substantially narrow the gap between themselves and the neurotypical children regarding data entry tasks. At the same time, we acknowledge that it is inappropriate to directly compare the high performers in the DS group and the neurotypical group because the average age of the three DS participants doubles that of the four neurotypical children and the computer experience even triples. This result actually presents more questions than it answers. It suggests that some DS users could reach the performance level of a 10- to 12-year-old neurotypical child, but it does not tell at what age or after what specific training did those DS participants reach their current performance level. From what we have known about expert users with DS who can achieve high performance comparable to that of an average user (i.g., Lazar, Kumin, & Feng, 2011), it would be interesting to conduct more longitudinal studies to investigate what factors (e.g., medical conditions) as well as interventions (e.g., training) are more likely to transform an individual with DS into an “expert user.” Likewise, it would also be interesting to follow the progress of the average and low performing DS participants to study whether and how their data entry performance improves as they grow older and gain more experience with computers.

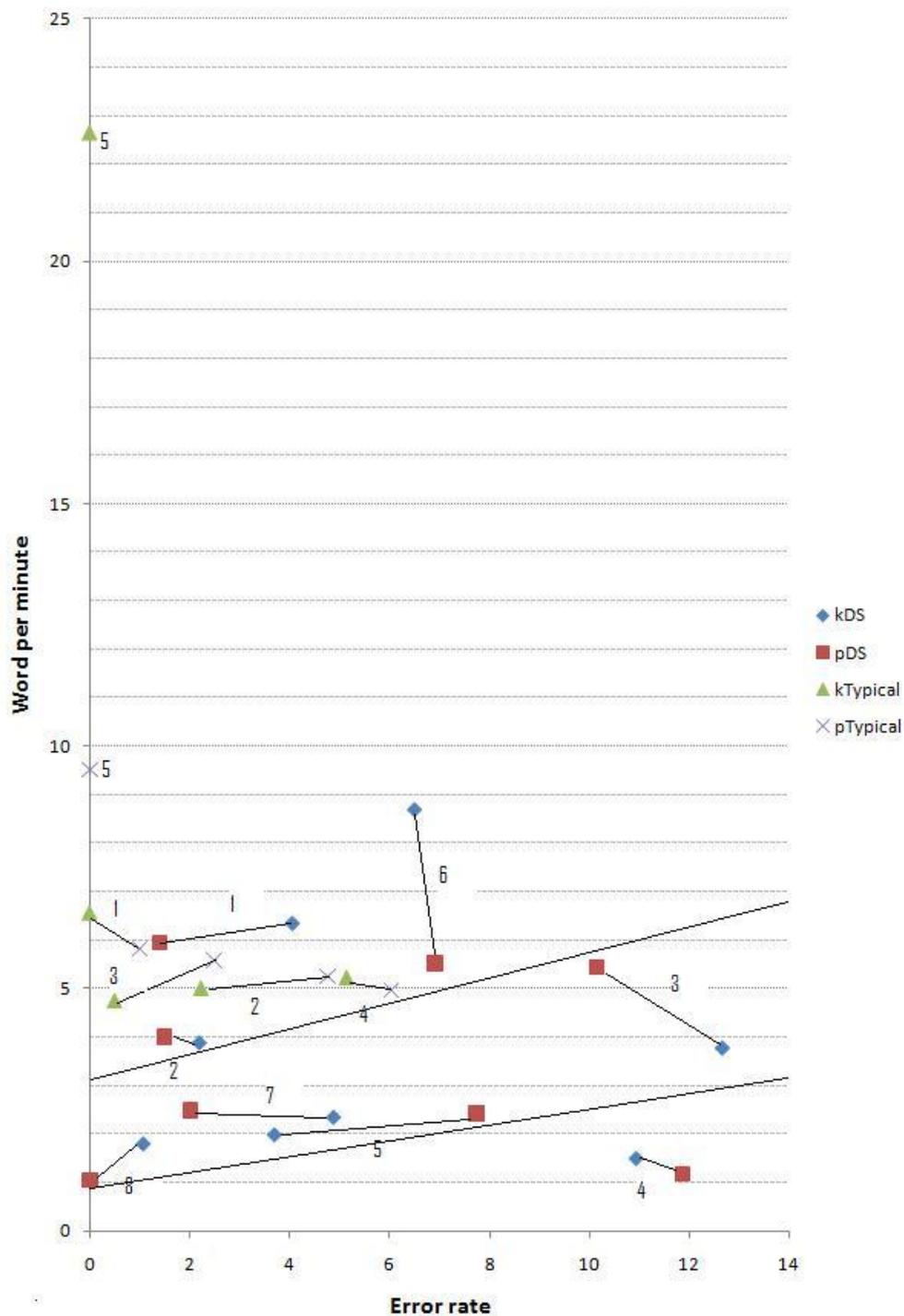


Figure 3-4 Performance distribution for two groups of participants under the keyboard only and the word prediction conditions. The two data points of the same participants were connected using a straight line accompanied by the corresponding participant number.

The variance in performance remains larger for the DS group than the neurotypical group under the speech condition. Table 3-11 lists the best and worst cases of the two groups regarding input error rate and the corresponding data entry rate (number of words per minute) for speech recognition.

		Word Error Rate (%)	Input Rate (No. Words/M)
DS Group	best	38.36	50
	worst	89.96	150
Neurotypical Group	best	26.03	92
	worst	31.06	82

Table 3-11 The best and worst cases of two participants under the speech condition

In the neurotypical group, input error rates for the best and the worst cases were not substantially different, while in the DS group, the differences between the two cases were pronounced. A similar pattern appears in data entry rate. The neurotypical group recorded no substantial difference, while the DS group had a dramatic difference. Based on our observation, the participant with the best performance could enunciate, use inflections, and properly pause, and therefore spent longer time in dictation. Given the limited time to learn to use word prediction, the input error rates for the participants with DS could be less convincing. However, given the same amount of training provided to both the neurotypical and DS groups, it is telling that one group demonstrated more differences than the other.

3.5.2.3 Interaction patterns or preferences

We also observed interesting interaction patterns or preferences that differ between the

two groups. When using the word prediction application, all of the participants with DS used the default setting of five candidate words (the minimum number allowed) in the list box, while all of neurotypical participants changed the setting to nine words (the maximum number allowed). The preference to fewer candidate words by DS users could be due to language, reading, and other impairments. A shorter word list might help reduce browsing time and complexity of the task when a choice had to be made among multiple selectable items. The preference to fewer options as demonstrated in using word prediction by individuals with DS can be extended to other features designed for users with similar cognitive impairments. For instance, the same idea can be incorporated into various interface designs such as links on a web page or items listed in a menu.

	Punctuation	Capitalization	Paragraph
P1	×	×	×
P2	√	√	×
P3	×	×	×
P4	×	×	√
P5	×	×	√
P6	√	√	×
P7	×	×	×
P8	×	×	×
S1	√	√	√
S2	√	√	√
S3	√	√	√
S4	√	√	√
S5	√	√	√

Table 3-12 Participant performance in punctuation, capitalization, and paragraph formatting. “√” means participants correctly copied the specific element. “×” means participants did not enter the specific element in text.

We also observed that the DS participants tended to ignore the punctuations, capitalization, and formatting details while the neurotypical participants did not (see Table 3-12). The punctuations used in the three pieces of text are quite basic, including only comma, period, and apostrophe. Among the eight DS participants, only two participants (P2 and P6) entered the punctuations in a consistent manner. The other six participants consistently ignored the punctuations, even the periods at the end of sentences. So the text generated by those participants was not easy to read. Similarly, only P2 and P6 used capitalization appropriately. All other participants did not capitalize the first letter of each sentence or on occasions when capitalization was needed. Regarding formatting, only P4 and P5 entered the text in the form of multiple paragraphs as demonstrated in the original text. Other participants just entered the entire text in one single paragraph. In contrast, all five neurotypical participants entered punctuations consistently and accurately, used capitalization whenever appropriate, and followed the paragraph structure of the original text.

It would be interesting to further study why the two groups differ so consistently and dramatically regarding punctuations, capitalization, and general formatting. All the DS participants attended regular schools and had received classroom training on writing. They understood the use of punctuations, capitalization, and paragraphs. However, they did not pay sufficient attention to those elements when entering text on computer, even during transcription tasks when they just need to copy those elements. This finding highlights the need to provide training in related skills in order to improve the quality of documents generated by people with DS.

3.5.3 Speech input

The recognition error rates of the participants with DS were quite high in the study. The error rate of the best input performance (by P1) using speech recognition was approximately 40%. The error rates of the other participants were so high that the text generated was almost or completely unreadable. The error rates were also much higher than those of the neurotypical children.

Even though all DS participants received speech therapy from early age, most of them, however, still had stuttering, flat tone, and difficulty pronouncing specific speech sounds. While their speech might have been understandable by people in face to face situations where nonverbal communication such as gestures, facial expressions, and environmental situational cues would help the listener understand what is being said, it seems that their speech was not clearly recognizable by the speech recognition software.

However, we do not believe that the results suggest that the DS users were incapable of using speech recognition techniques. Instead, the data highlights the obvious and massive difficulty that DS users face during initial interaction with existing large vocabulary commercial recognizer and standard speech interface. It is highly possible that differently designed tools and more proper training—not just training for research in a short period of time, but more training over time—can provide different or more positive results.

For example, for the DS population with trisomy 21, who tended to have substantial speech intelligibility problems, speech recognition may not be feasible as an independent input tool. But it is possible to serve as one option adopted in multimodal input solutions or to be used when the vocabulary size is quite small. For some high

functioning individuals with DS who have good speech intelligibility, they could potentially use speech recognition to input text when they are too tired to type, and then use the keyboard and mouse to modify the text. In addition, it is possible that speech recognition might be appropriate for individuals with mosaic DS, who generally score 10-30 points higher on IQ tests and exhibit fewer medical complications than do those with trisomy 21 or translocation DS (de Moreira et al., 2000). They tend to have higher speech intelligibility than those with the other two types of DS and are more likely to benefit from speech input.

3.5.4 Input with word prediction

For users without any disabilities, it is expected that word prediction would reduce the number of keystrokes needed to enter text because the word can be selected from the candidate list. However, the impact on actual data entry rate is unclear due to the additional browsing time and cognitive overhead. Before the study, we expected that participants with DS would benefit more from the word prediction software because most users with DS had difficulty in spelling and typing. The candidate list may potentially help them with both spelling and typing. The potential challenge with word prediction is the more complicated cognitive process. With the keyboard and mouse only data entry, users only need to recall the spelling and enter the letters. While with word prediction, users need to switch between the text document and the candidate list, browse the candidate words, determine whether the needed word is in the list, then select or enter the word. Before the study, we did not know whether the DS users can understand and

master the data entry method with word prediction. Neither did we know whether the benefit of word prediction would outweigh the challenges.

The study results suggest that with training, all of the participants understood how to use the word prediction software, and the possible benefits of the software. However, the word prediction software did not improve the word entry rate, neither did it reduce the error rate for the DS participants as a group. We conducted a case-by-case analysis for each participant and found that the participants can be categorized into three groups based on the impact of the word prediction software: improved, no change, deteriorated. The use of word prediction actually lowered the performance for three DS participants (P1, P5, and P6). Whereas P1 and P6 were able to use WordQTM without frustration, P6 had a much higher entry rate using the keyboard and mouse than word prediction (8.7 vs. 5.5) with a similar error rate. P1 had much a lower error rate using the keyboard and mouse than word prediction (4.1% vs. 1.4%) with a similar word entry rate. We suspect that they had higher performance with keyboard and mouse since they had mastered the typing skills well. P5 also had a lower error rate under the keyboard and mouse condition (7.7% vs. 3.7%) with a similar entry rate. For those three participants, the additional browsing time and the cognitive overhead outweigh the benefits of word prediction.

Three participants (P2, P4, and P8) achieved similar performance under both conditions. Among them, P4 and P8 had difficulty finding a word in the list box when using word prediction. P8 even felt very uncomfortable with the word prediction application.

Only two participants (P3 and P7) achieved higher performance under the word prediction condition. P3 achieved a higher data entry rate (5.44 vs. 3.77) using word

prediction with moderate increase in the error rate (12.7% vs. 10.1%). P7 reduced the error rate using word prediction (4.9% to 2.0%) without slowing down the data entry.

Overall, the benefit of the word prediction is not evident in this study. We do not believe the results negate the potential for word prediction technology. Instead, we believe the primary reason that prevented the participants from taking advantage of the prediction technique is the nature of the task. In this study, we adopted transcription tasks as opposed to composition tasks in order to fully control the level of difficulty. However, when trying to enter the text, the participants were busy looking at the text presented on paper or the keyboard, not the computer screen. Therefore, many of them did not see the candidate words presented in the word list and did not take advantage of the word prediction software. In addition, when working on the transcription task, the participants did not need to think about the correct spelling of a word. But in reality, spelling is a great challenge for children with DS when using computers. The difficulty in spelling would be more notable in composition tasks and the word prediction software may help the children overcome that difficulty. So we believe the potential of the word prediction technique needs to be further examined through composition tasks.

3.5.5 Subjective preference

Even though the text generated was almost unreadable, four DS participants rated speech recognition as their first choice because it allowed them to generate the text in the shortest time. This suggests that DS users might give higher weight to effort than quality when assessing data entry methods.

The fact that more DS participants prefer speech recognition and word prediction input methods than the keyboard solution even though they still relied heavily on traditional keyboard and mouse methods is quite interesting and significant. It may suggest a lack of access to the speech technology or the word prediction software. It may also suggest that individuals with DS may not have enough confidence in using speech recognition and word prediction input methods due to the lack of training and experience, and that they have to depend on the traditional methods. Therefore, the current programs such as the IEP from which many individuals with DS learn to interact with computers need to give more attention to other input methods. In other words, instead of solely focusing on keyboard usage, individualized programs should also include speech and word prediction, as well as other assistive devices.

From the standpoint of research, the result suggests that more studies are needed to identify the unique learning curve of individuals with DS and to gain a clear knowledge of what method or combination of input methods work best for them. With this knowledge, the strengths and weaknesses of various input methods can be identified and analyzed, and new versions of input applications that address the technological needs of individuals with DS can be developed.

CHAPTER FOUR

INFORMATION RETRIEVAL STUDY

4.1 Research Questions

In light of the research on information retrieval conducted on people with disabilities, there have been encouraging findings that contribute to our understanding of web accessibility and information retrieval by people with CDs. Broadly speaking, due to their cognitive limitations, individuals with cognitive impairments tend to be more comfortable with customized presentation of information, such as the modified structure of menu (e.g., Abascal & Nicolle, 2001; Bohman, 2004; Crow, 2008; Friedman & Bryen, 2007; Jacko & Salvendy, 1996; Jacko, Salvendy, & Koubek, 1995; Lee & MacGregor, 1985; Lopes & Carrico, 2010; Miller, 1981; Paap & Roske-Hofstrand, 1986; Rotondi, Sinkule, & Haas, 2007).

Customized presentation of information mainly involves the consideration of hierarchical menu design: broad/shallow vs. narrow/deep. Since early on, researchers have paid attention to the issue of breadth vs. depth tradeoff in an effort to understand what kind of structure or combination of structures works better for a particular group of users. The majority of studies have yielded consistent findings, that is, the broad/shallow structure with more choices and fewer levels performs better than narrow/deep structure

with more levels and fewer choices. Several studies are worth noting here for they are quite relevant and illuminating:

Investigating menu design in general, Kiger (1984) found that the broad/shallow structure works better for the average user. Larson and Czerwinski (1998) extended the study on menu design to the web page design, arriving at the same conclusion: users achieved better performance (with regard to time and error rates) with broad/shallow structure than with narrow/deep structure. The researchers found that narrow/deep structure required more cognitive overload and the users were more likely to get lost. One decade later, to repeat Larson and Czerwinski's study on web design, but to extend it to blind users of screen readers—Hochcheiser and Lazar (2010) found that the broad/shallow structure also works better for the blind users. The researchers suggested that the results might not be true to other groups, and future studies would be needed. To date, no systematic studies have been done to examine what structure works better for users with cognitive disabilities.

As mentioned earlier, existing studies on web accessibility by individuals with cognitive disabilities only used very limited number of web pages; the research websites or pages deviated significantly from the real-world websites and pages. Moreover, none of these research websites or pages contained a sufficient database of information and a modified search engine, two very common components or aspects in web information retrieval. Therefore, the experience participants had in the research was markedly different from what they would get when searching information in the real web environment.

In response to the prevailing limitation, the study employs a database that contains over 200 books and a modified search engine. As will be explained in more details, this amount of items (books) can provide enough options for the different levels and choices of menu structures (i.g., broad/shallow and narrow/deep) adopted in the research design and enough material for a self contained information retrieval process that simulates a real-world process. During the web browsing trials, individuals with cognitive disabilities are presented with two information structures with different width and depth. A broader and shallower structure offers more items at each level, resulting in more browsing time but a shorter path. A narrower and deeper structure offers fewer items at each level, resulting in less browsing time at each level but a longer path. The first research question is:

- With the same amount of information, what kind of information structure that works best for individuals with cognitive disabilities?

Using a search engine is a more advanced information retrieval technique. As previous studies suggest, individuals with cognitive disabilities may have a different experience using a search engine. In this study, in addition to using free web browsing, the participants carry out searches using a search engine. Their search experience and patterns are documented and analyzed. The second research question is:

- Can people with cognitive disabilities use a search engine effectively to find information? And what are specific challenges they experience when using search engines?

Computer users have used different methods to retrieval information. At this point, no study has been conducted to understand what preference people with cognitive disabilities will have for information retrieval. The third question of this study is:

- Do individuals with cognitive disabilities prefer using free browsing or the search engine when retrieve information online?

4.2 Design and Development of the Website for the Study

4.2.1 Context and rationale

In the study conducted by Loy and Batiste (1998), web accessibility was broken down into three areas: computer accessibility (hardware and software systems to gain access to the computer), browser accessibility, and web accessibility (web page content and structure). Based on the nature and scope of our study, the accessibility discussed here focuses on page content and structure.

One of the challenges for this study to get started is selecting a realistic website for participants to perform the required retrieval tasks. Except the report on the development of a web site for individuals with Down syndrome (Kirijian & Myers, 2007), scholarly attention to this important area remains largely neglected. There is a need to conduct empirical research in more realistic setting. For individuals with CDs, using an existing, mainstream website to conduct the study could be too challenging and therefore inadequate. Since too much information is on existing websites, some of them were not structured well, and search engines return too many and even irrelevant results, it is difficult to control the study and collect statistical data with an existing website on the web.

Previous research was conducted with the knowledge that conventional websites are not suitable for individuals with CDs (e.g., Freeman et al., 2005; Karreman et al., 2006; Kirijian & Myers, 2007; Sevilla et al., 2007; Svensk & Johansson, 2004). Therefore, they designed simpler websites specifically for them. These websites tend to yield better performance. However, they deviate significantly from “real websites.” For example, they have a very limited number of pages with very limited information. More importantly, they are self-contained without a search engine, which is a very common advanced tool for information retrieval. Therefore, the information retrieval experience from the research design fails to reflect the real-world experience.

In light of these limitations, the current design makes every effort to “simulate” the real websites by adding more pages with significant information categorized and arranged in a conventional way. A website called “Mini Library” was specifically designed and developed for this study. The site simulates an online library, and contains descriptions of 256 books under four main categories: “Animal,” “Entertainment,” “Places,” and “Sports,” the contents of which match both the interest and reading level of individuals with CDs. Moreover, a search engine is built in the website. As such, the participants’ experience can be comparable to their real-world experience.

It is worth noting that, the initial findings that suggest different web menu structures and designs for individuals with cognitive disabilities act as a call to more systematic and rigorous studies, because these findings enrich the research tradition and suggest a new direction. As reviewed earlier, in studying menu design, Larson and Czerwinski (1998) found that the average users prefer the reasonably broad/shallow structure. When extending the users to blind users in the web context, Hochheiser and

Lazar (2010) arrived at the same finding that, contrary to conventional belief, blind users also prefer the broad/shallow structure.

4.2.2 Web content structures

For the free web-browsing task, the web content structure is crucial. The website is structured strictly with consideration in breadth and depth. Beginning early in the 1980s and later, a few studies (Miller, 1981; Kiger, 1984; Norman, 1988; Paap & Roske-Hofstrand, 1986; Wallace, Anderson, & Shneiderman, 1987) on menu design with consideration in breadth and depth were conducted. The results from these research studies concluded that there was a tradeoff between breadth and depth on menu structures. Generally speaking, links on web pages are organized in a way similar to menu structure. Zaphiris and Mtei (2000) conducted a study in which procedures applied to menu design were also applied to web link structure. The paper concluded that the time for completing tasks increases as the depth of the website structure increases. This conclusion is true for ordinary people, who can browse webpages efficiently. We need to examine depth versus breadth in hierarchical web structure for individuals with CDs.

In this study, the same web pages are organized into two different hierarchical structures: narrow/deep structure, and broad/shallow structure. In narrow/deep structure (see Figure 4-1), it contains four levels, with four links at each level (4x4x4x4). Advantages are fewer items in a page, larger targets, and easy to click, which are generally recommended for users with CDs. But users need to take longer path and more clicks to reach target, and are likely to get lost, which represents a huge challenge for users with CDs. In the broad/shallow structure (see Figure 4-2), there are two levels with

16 links at each level (16x16). Advantages of this type of structure are shorter path and fewer clicks to reach target, and less likely to get lost. Disadvantages might be smaller targets that are more error prone, as well as busy, more information-laden pages that can be visually overwhelming.

4.2.3 Search engine

The website provides a Google custom search engine that allows users to search the items (books) they intend to find within the website (among 256 books) by entering keyword(s). The search engine is self-contained in the website, and only returns results within the site. The search engine is signed up as the education edition, which does not contain any ads or other irrelevant information. Similar to the real search engine experience, the returned results from a search include all items containing the searched keyword or term. That is to say, if an individual wants to search a book about a sport, say, swimming, when a word “swimming” is used in the search engine, the returned results will include all the books about swimming in the website and all the pages such as categories or subcategories that contain the key word “swimming” as shown in Figure 4-3. In this case, these categories or subcategories are in other two structures.



Figure 4-1 Narrow/deep, 4x4x4x4 web structure

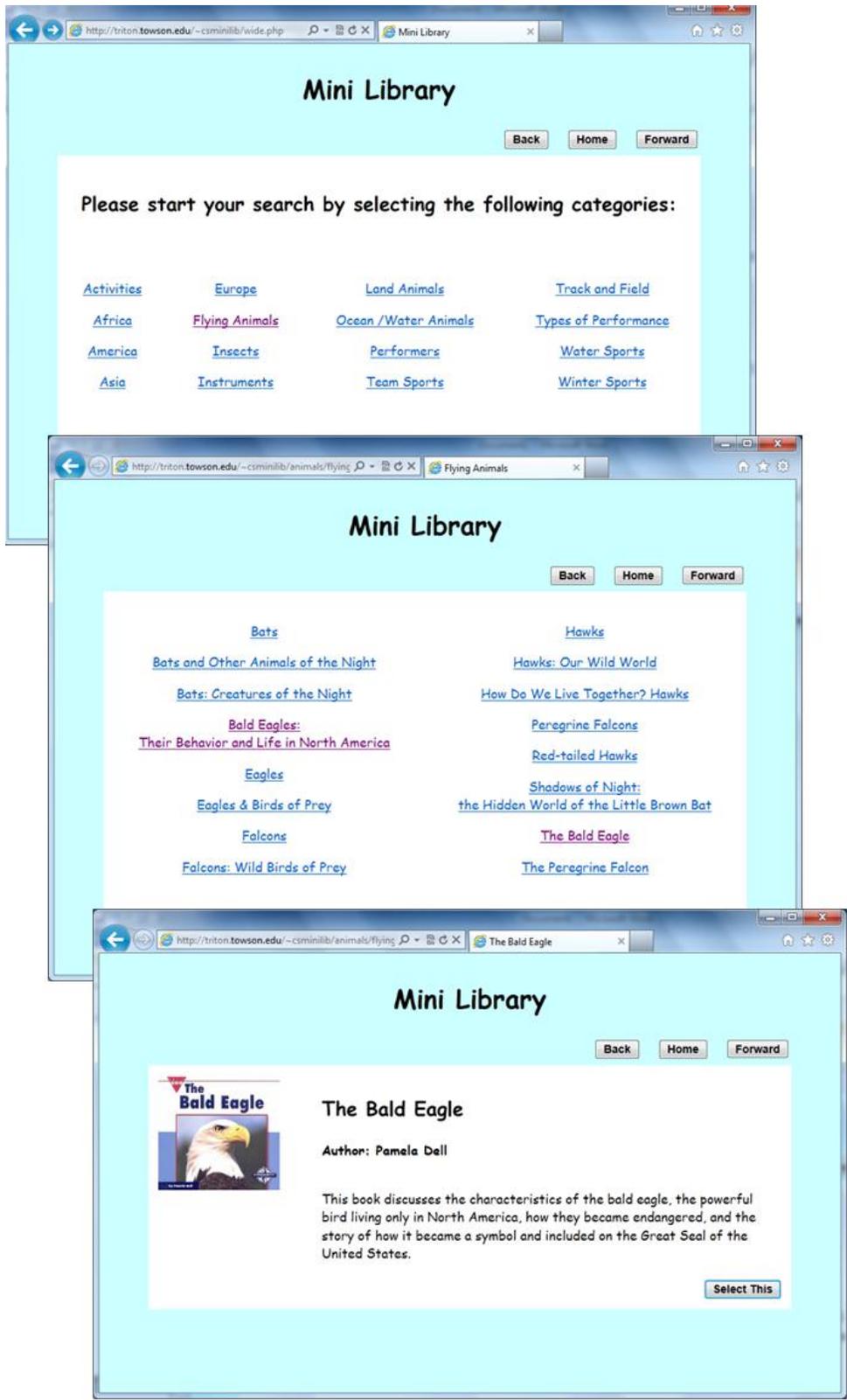


Figure 4-2 Broad/shallow, 16x16 web structure



Figure 4-3 Customized “Google” search engine

Behind the web page interfaces, a log program was configured. Statistical performance data, i.e., time to complete a task, time spent on each page, pages visited, number of clicks to find an item, keyword typed, number of time to submit search queries, and whether the target book is found, were logged. It is worth noting that there are two scenarios that define an unsuccessful search: one is that a wrong item is found; the other is that the participant gave up the search.

4.2.4 Page design

With considerations of the page structures, topics of web contents, and the data log program, the website is also designed under the guidelines and recommendations of WAI (W3C) and some previous researches on cognitive disabilities (e.g., Engelen, 2001; Karreman, Geest, & Buursink, 2006; Nielsen, 1999; Rotondi, Sinkule, & Haas, 2007).

The website includes the following features:

- Simplify web contents, with text and only relevant, non-text materials such as pictures of book covers.
- Contrast colors are used. The color for text is black; the color for background is white.
- Each line of text contains no more than 80 characters. Text is not justified (aligned to both the left and the right margins).
- Font used for text is Comic Sans MS and the font size is 14.
- Text does not require the user to scroll to read. (However, a page that contains the results of a search using the search engine may require the user to scroll to read, if the returned list of items is long, as typical with any search engine results.)

- Maintain consistency on page layout, functionality of links and buttons for easy navigation.
- When input is needed (for using the search engine), instructions are provided. For example, when non-existing term is entered or a word is misspelled, a prompt, “Sorry, no results. Please check, and type your keyword again!” is provided.
- Reading level of information (book descriptions) is at grade 3-6.

Although extensive studies have suggested that non-text elements such as icons, graphics and pictures facilitate the understanding of web contents (e.g., Engelen, 2001; Federici et al., 2005; Gould & Lewis, 1985; Johnson & Kent, 2007; Lazar, 2007; Nielsen, 1999), some researchers, however, question the utility of these elements, which could lead to distraction if not designed or used appropriately (e.g., Rowland, 2004; Svenk & Johansson, 2004). Since this study explores the way of information retrieved by people with cognitive disabilities in a strictly structured website, uncertain elements on the site without losing text-based information were removed. For this reason, the website avoids using icons for categories and their sub-categories. Only book cover pictures are used in the pages with book descriptions.

4.3 Methodology

4.3.1 Participants

In the previous study, we only focused on the users with Down syndrome. This diagnosis-based approach has its pros and cons. On the one hand, it allows better understanding of one very specific population. On the other hand, the result is difficult to be generalized to people with other types of cognitive disabilities. In addition, the results of the input study suggest that there is wide variation in performance within the users with Down syndrome. The observations made on top-performers may not apply to those with low performances. Therefore, in this study, we adopted the functionality-based approach instead of the diagnosis-based approach. The requirement of participant recruitment is not based on the specific diagnosis (or causes of the disability), but on the functionality of the individual.

In this study, we examined individuals with various types of cognitive disabilities that affect the ability of information retrieval. To recruit eligible participants, the characteristics associated with cognitive disabilities were identified and individuals were expected to meet the requirements for the research.

The key of this study is to associate the characteristics of cognitive disabilities with knowledge and skills required for information retrieval. These knowledge and skills are listed in Table 4-1.

Free browsing	Using a search engine
<ul style="list-style-type: none"> • Reading skills needed to find text combined with pictures; • Orientation skills needed to understand how to reach a specific page and how to navigate back and forth; • Analytical, judgment/decision-making skills for determining the path; • Problem-solving skills when encountering difficulties (e.g., not sure which path to take, or lost in the website). 	<ul style="list-style-type: none"> • Typing/spelling skills needed for entering keywords; • Reading skills needed to understand purely text-based information and process retrieved items; • Analytical, judgment/decision-making skills for finding the most related items; • Problem-solving skills when the retrieved items do not fit or the page that the user selected do not fit (e.g., need to try other items, or even refine the search keyword).

Table 4-1 Knowledge and skills required for information retrieval

Individuals with cognitive disabilities exhibit varying degrees of physical, perceptual and cognitive impairments. In general, impairments affecting information retrieval include low muscle tone, poor short-term memory and verbal memory (but their visual-motor skills are strong), short attention span, significant delay in language, mild to moderate mental impairment, and orientation (e.g., Cornish & Wilding, 2010; Engle et

al., 2005; Harris, 2005; Hogg & Langa, 2005) With these impairments, when individuals retrieve information on the web they may encounter difficulties in typing keywords, reading information, and using abstract thinking/association/decision making skills to solve problems. Participants should meet the following criteria:

1. Participants should have documented cognitive disability that results in difficulties or deficits involving problem-solving, attention, memory, reading, or writing. The disabilities include, but are not limited to, Down Syndrome, Autism, Traumatic Brain Injury (TBI), Dementia, Dyslexia, Attention Deficit Disorder (ADD), Cerebral Palsy, and Fragile x syndrome.
2. Participants should have prior experience with computer and the Internet. Participants have varying degrees of experience with the Internet ranging from sending emails, visiting websites, watching sports games, and etc.
3. Participants need to be 15 or older. At this age, many people with cognitive disabilities could master sufficient reading skills and are easier to follow directions.

There were total 23 participants (nine males and 14 females) who participated in the study. The participants had different types of cognitive disabilities including Down syndrome (13), Cerebral Palsy (2), Neurological Impairment (1), Fragile X syndrome (1), and other forms of cognitive disabilities (6). The ages of the participants range from 16 to 48, with an average age of 27.2 (SD=7.98). Participants' disabilities and computer experience information were collected from interviews and a questionnaire.

4.3.2 Tasks

The study adopts a within-group design. Each participant performed four search tasks under each of the following three conditions:

1. find target items by free browsing in the broad/shallow, 16x16 structure;
2. find target items by free browsing in the narrow/deep, 4x4x4x4 structure; and
3. find target items through a search engine built in the website.

In addition to performing four tasks under each of three conditions, each participant searched three books with any structures/technique he/she preferred to use. There are a total of 15 tasks. The tasks are defined and assigned with the following considerations:

4.3.2.1 Level of difficulty of tasks

Information retrieval tasks are performed under three different conditions (i.e., 16x16, 4x4x4x4, and search engine), each of which contains a set of four tasks with four different levels of difficulty respectively. The following factors are used to measure the level of difficulty:

- whether multiple books in the category fit the requirement. If the answer could be any book among multiple options in a category, the task is easier. If only one specific book fits the requirement, the task is more difficult;
- whether or not the keyword(s) is in the book title. If the keyword is in the book title, the task is easier. If the keyword is not in the title, the task is more difficult;

- whether or not a user needs to find a question answer in the book description.

Finding a book to answer a question requires more reading, comprehension, and logic skills. Therefore, the task is more difficult.

The following criteria were used to define four groups of tasks with four levels of difficulty:

1. Find any one of books in a category (“easy”), e.g., “Find any one of books about China.”
2. Find a specific book with keyword(s) in the book title (“medium”), e.g., “Find a book about how to improve swimming.”
3. Find a specific book without keyword(s) in the book title (“difficult”), e.g., “Find a book about singers, Jonas Brothers.”
4. Find a specific book with a question whose answer is in the book description (“most difficult”), e.g., “Find a book to answer this question: Where are bald eagles living?”

4.3.2.2 Search criteria under the search engine condition

As shown in Table 4-1, knowledge and skills required for using a search engine are more complex and advanced than free browsing.

Under the search engine condition, only the input box and the “Search” button of the search engine are displayed on the web page. Participants use the simple search option, which returns best match results. With this option, only a single criterion, a word or a phrase, needs to be entered. There are no Boolean operators, such as “and,” “or” and

“not,” or other advanced search options required. The description of the search task is intended to give the participant a simple search term.

4.3.3 Procedure

The study was conducted at participants' homes or work places. The website was launched on a university's server. Participants used any computer connected to the Internet and any type of browsers to perform information retrieval tasks.

Before a participant started actual tasks, the researcher asked a parent/guardian to sign a consent form, interviewed the participant and his or her parent(s)/guardian, and asked them to fill in a questionnaire to collect demographic data including health conditions, educational background, cognitive ability, and computer and Internet experience. Following the interview, a brief training session was offered to introduce to the participant the research website and tasks. Participants were exposed to all three conditions during the training session.

During the formal study session, the participant completed a total of 12 randomized tasks under three conditions, and three randomized tasks under any condition(s) selected by the participant. To reduce fatigue, after the completion of tasks under each condition, participants could take a break.

Upon the completion of the tasks, the participant was asked questions on subjective satisfaction, frustrations and strategies to solve problems.

4.4 Results

23 participants completed the study. All participants conducted four search tasks under each of the three required conditions. In addition, they completed three free trial tasks under the condition that they chose. Participants also answered a survey at the end of the study.

As indicated in the preceding section, efficiency and efficacy can be measured in two areas: the time spent finding an item, and the success rate or error rate using a particular method. Additionally, the total number of pages visited using a particular method can also be a good indicator of the effectiveness of information retrieval.

4.4.1 Task time

According to the research design, each participant was asked to find an item using three methods: the narrow/deep path, the broad/shallow path, and the search engine. These three methods are also called three conditions. Under each condition, each participant was asked to perform four tasks ranging from “easy,” to “medium,” to “difficult,” to “most difficult.” The time each participant spent on each task was logged through an application.

A Repeated Measures ANOVA test using the task time as the dependent variable and condition and difficulty level as the independent variables suggests that there is marginal significant difference in task time among the three conditions ($F(2, 44) = 2.79$, $p < 0.1$). The broad/shallow condition results in the longest task time and the search engine condition resulted in the shortest task time (see Figure 4-4). There is significant

difference in task time among tasks with different difficulty level ($F(3, 66) = 7.05, p < 0.001$). Difficult tasks resulted in longer task time than easy tasks (see Figure 4-5).

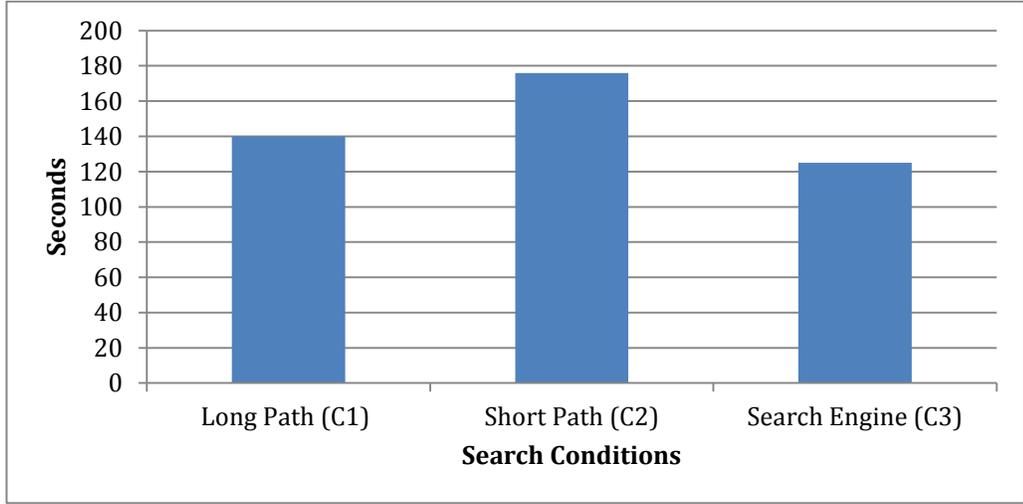


Figure 4-4 Total average time of all tasks under each condition

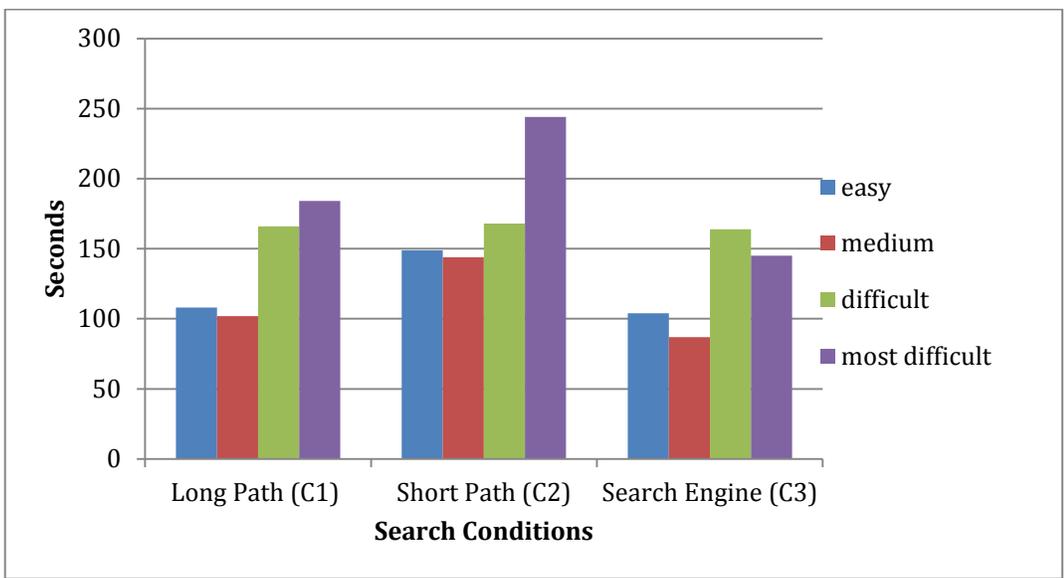


Figure 4-5 Average time of tasks with difficulty level under each condition

4.4.2 Failed attempts

In the study, each participant worked on four tasks under each condition. There are three possible outcomes for each task: success (meaning participant found the right book), failure (meaning participant found the wrong book), and incompleteness (meaning participant gave up the task before finding any book). Both failure and incompleteness are failed attempts. We counted the total number of failures and incompleteness under each condition.

A Repeated Measures ANOVA test using the number of failed attempts as the dependent variable and condition as the independent variables suggests that there is significant difference in the number of failed attempts among the three conditions ($F(2, 44) = 9.76, p < 0.001$). Participants made the fewest failed attempts when using the search engine and the highest number of failed attempts when using the broad/shallow structure (see Figure 4-6).

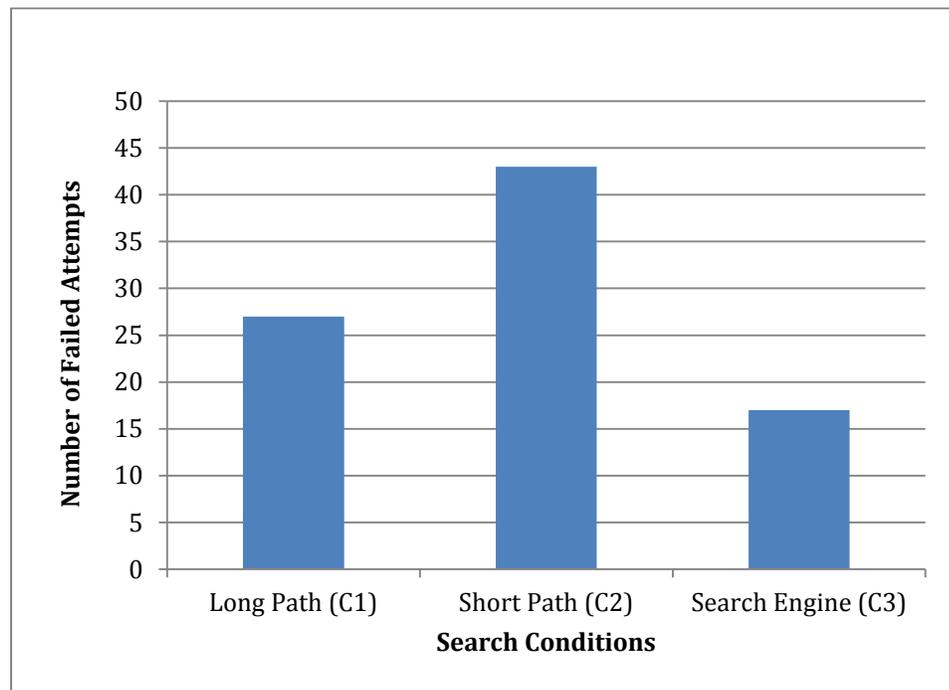


Figure 4-6 Number of failed attempts under each condition

We also counted the total number of failed attempts under each difficulty level.

A Repeated Measures ANOVA test using the number of failed attempts as the dependent variable and difficulty level as the independent variables suggests that there is significant difference in the number of failed attempts among tasks with different difficulty ($F(3, 66) = 13.80, p < 0.001$). Participants made the fewest failed attempts for the easiest tasks and the highest number of failed attempts for the most difficult tasks (see Figure 4-7).

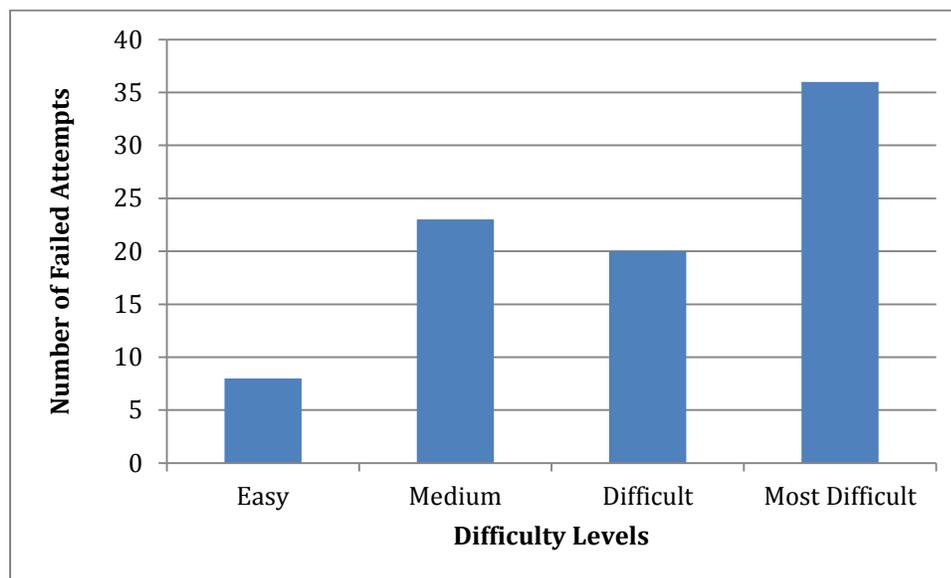


Figure 4-7 Number of failed attempts under each difficulty level

4.4.3 Pages visited

In this particular study, the third indicator of efficiency is the number of pages visited for each task. In general, more pages visited would result in more time spent and the user is more likely to get lost, thus resulting in lower efficiency. However, it is not comparable with all the conditions due to the structure of the searches and the associated content. For

instance, with the narrow/deep (C1), the participants would in theory visit more pages than under other two conditions. According to the hierarchical structure, the optimal number of pages needed for each task is five (four category pages plus the target book page) under the narrow/deep condition, three (two category pages plus the target book page) under the broad/shallow condition, and two (search page plus the target book page) under the search engine condition.

The ratio between the number of actual pages (AP) visited and the optimal pages (OP) needed under each condition is an indicator of how effective the task is completed. Higher ratio suggests that the user visited higher percentage of pages that are not on the optimal path and the made more detour.

A Repeated Measures ANOVA test using the ratio between the number of actual pages visited and the number of the optimal pages as the dependent variable and condition and difficulty level as the independent variables suggests that there is significant difference in the ratio among the three conditions ($F(2, 44) = 3,78, p < 0.05$). The ratio is lowest under the search engine condition (1.59 in average). The narrow/deep condition resulted in lower ratio than the broad/shallow condition (1.88 vs. 2.64 in average) (see Figure 4-8).

There is also significant difference in the ratio among tasks with different difficulty level ($F(3, 66) = 4.40, p < 0.01$). Difficult tasks resulted in higher ratio than easy tasks (see Figure 4-9).

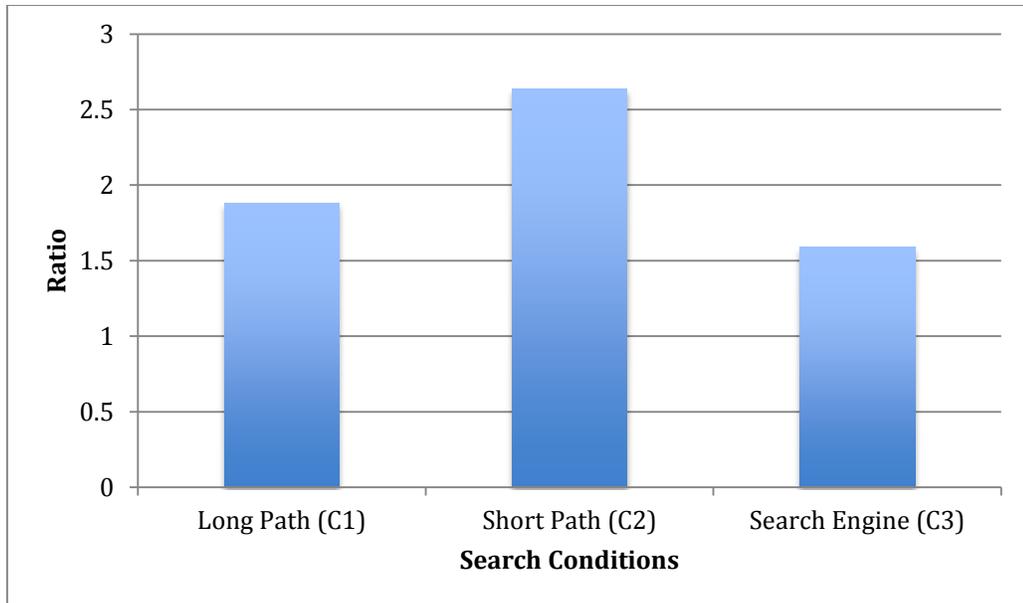


Figure 4-8 Ratio between the numbers of actual pages (AP) visited and optimal pages (OP) under each condition

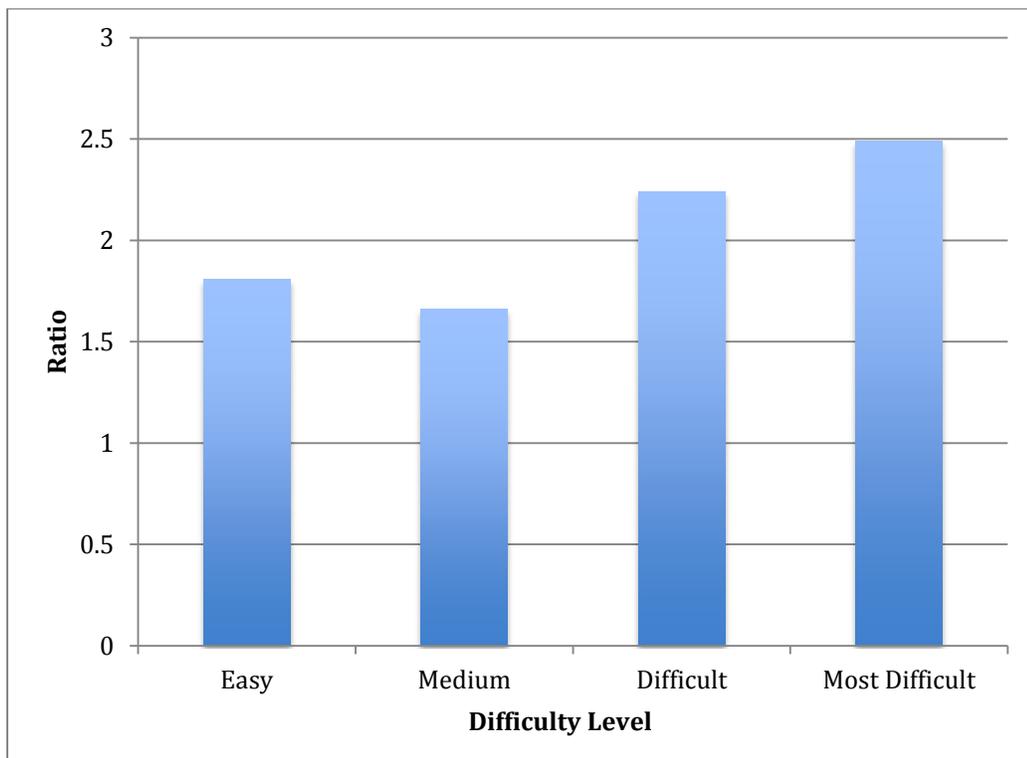


Figure 4-9 Ratio between the numbers of actual pages (AP) visited and optimal pages (OP) with difficulty level

4.4.4 Preference

We examined the participants' preferred method through two approaches. After the participants completed the required tasks under three conditions, they were asked to perform three additional tasks using any of methods at their own choice. In addition, the participants were asked to rank their preferred method in a survey at the end of the study.

4.4.4.1 Preferences based on three free trials

As designed, there were a total of 69 trials (23 x 3). We counted the number of times that each method was used during the 69 trials. During 18 of the trials, the participants started with one method and switched to another method one or more times. In those cases, we counted the last method that a participant used in the trial as the preferred method. Of all the trials, the narrow/deep (C1) was used 16 times; the broad/shallow (C2) was used nine times; the search engine (C3) was used 44 times (see Figure 4-10). A Chi-square test shows that there is significant difference among the three methods used ($\chi^2(2) = 29.83, p < 0.001$). The participants overwhelmingly prefer the search engine method.

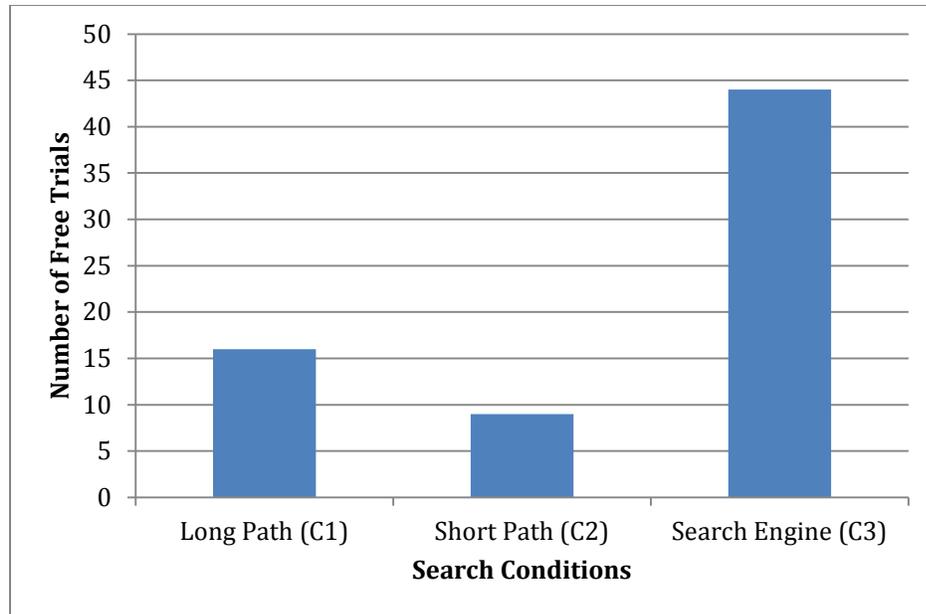


Figure 4-10 Number of free trials under each condition

As to the 18 trials in which participants switched from one method to other methods, seven started with the narrow/deep condition (C1); 10 started with the broad/shallow condition (C2); and one started with the search engine condition (C3). However, eventually, four ended with the narrow/deep condition (C1); two ended with the broad/shallow condition (C2); and 12 ended with the search engine condition (C3). Furthermore, there were seven trials in which participants switched method more than twice. Among those seven trials, six ended with the search engine condition (C3). The result further confirmed that the search engine method is more preferable than the other two methods.

4.4.4.2 Preferences based on survey ranking

14 out of the 23 participants indicated that the search engine (C3) was their top choice; eight indicated the narrow/deep structure (C1) as their top choice; only one person

indicated the broad/shallow structure (C2) as the top choice (see Figure 4-11). A Chi-square test shows that there is significant difference among the three methods used ($\chi^2(2) = 11.05, p < 0.005$). The user ranking was consistent with the preferences demonstrated in the free trials.

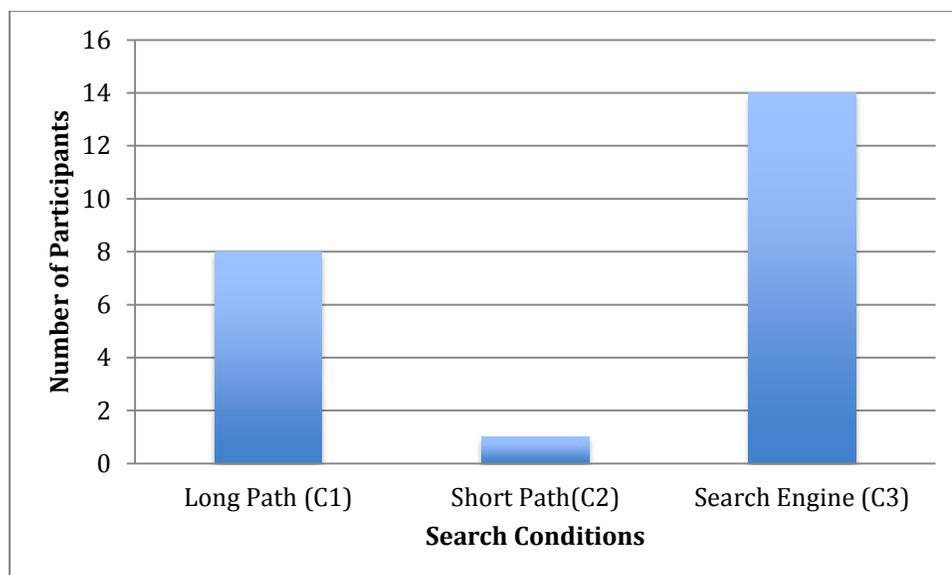


Figure 4-11 Top preference on each condition

4.5 Discussion

The goal of this study is to examine how individuals with CDs acquire information online and how different information structures impact performance. The study attempts to collect empirical data on the preferred method(s) for the target group.

The study also seeks to gain knowledge about specific factors that positively or negatively impact efficiency, success rate, and user satisfaction. Ultimately, the findings from this study can inform both web design and future research on usability and accessibility issues that address and benefit individuals with CDs.

4.5.1 Impact of three methods on performance

The result clearly suggests that, for people with cognitive disabilities, the search engine method is more efficient and reliable than free browsing. Using the search engine method, the participants found the books more quickly and failed less often. They also visited fewer unnecessary pages when using the search engine method.

Using the search engine method, participants took an average of about two minutes to find a book and the overall failure rate is about 18%. This result is quite encouraging because it shows that the participants generally have the ability to use the search engine to find information in a website.

The four-level, narrow/deep structure yielded better performance than the two-level, broad/shallow structure. Using the four-level, narrow/deep structure, participants took an average of two minutes 20 seconds to find a book and the failure rate was 30%. The performance is not as good as when using the search engine method but it confirms that the participants also have the ability to find information by following the links and browsing the web pages.

Using the two-level, broad/shallow structure, participants took an average of about three minutes to find a book and the failure rate was as high as 47%, meaning that they only found half of the desired books. This suggests that presenting a page with numerous links (16 in this case) is not a good solution for people with cognitive disabilities because they are slow in reading the links and they tend to forget the pages that they have already visited and often make repetitive visits.

4.5.2 Preferences

The advantage of the search engine method over the free browsing methods is also reflected in user preference. The participants overwhelmingly favor the search engine method over the free browsing methods. Of the 69 free trials, 44 were completed using the search engine method, which counts for 64% of the trials. Even though 11 participants started with the free browsing method, they all switched to the search engine method in the end. 23% of the free trials were completed using the four-level, narrow/deep structure. Only 13% of the trials were completed using the two-level, broad/shallow structure.

Participants' ranking over the three methods is also consistent with their choices when completing the free trials. Among the 23 participants, 14 chose the search engine method as their top choice, which counts for 61% of the participants. Eight (35%) chose the four-level, narrow/deep structure as their top choice. Only one participant chose the two-level, broad/shallow structure as their top choice. This further confirms that presenting a page with numerous links (16 in this case) is not a good solution for people with cognitive disabilities.

4.5.3 Causes for failed attempts

4.5.3.1 Free browsing

The study provides first-hand data on factors that accounted for the failed attempts by the participants. Some of the causes were rather general, not necessarily related to a particular disability condition. For instance, a participant's lack of experience with the computer or retrieving information from the web can lead to more unsuccessful trials. It

is conceivable that a neurotypical user, without much knowledge about the computer use, can also register similar failed attempts.

Based on our observations and research log, most failed attempts appeared with two different scenarios. Some participants seemed not to understand the content structure at all, clicking a wrong category at the very beginning or struggling between the right or wrong categories throughout, never reaching or close to reaching the right page; others seemed to understand the content structure but selected wrong books or even reached the right page but moved away without recognizing the book already available on the screen.

The causes for these failed attempts are twofold, supporting the clinical diagnosis about individuals with cognitive disabilities. First of all, many participants lacked perceptual and logical strength, failing to detect the connection between a category and subcategory. Of the 43 failed attempts in the two-level, broad/shallow structure, 21 either started and ended with a wrong category, or struggled between the right and wrong categories and ended with a wrong category. Of the 43 failed attempts under this condition, there were 12 give-ups, nine of which were the results of selecting wrong categories. Of the 27 failed attempts in the narrow/deep, four-level structure, selecting the wrong categories accounted for 13 failed attempts and for all the four give-ups in the condition.

The second major cause seems to be the low comprehension level. In the two-level, broad/shallow structure, 21 out of the 43 failed attempts did end in the right category but selected a wrong book. In the narrow/deep, four-level structure, 14 out of 27 failed attempts were in the right category at the end but picked a wrong book. The lack for reading comprehension is also supported by the data from trials at the “difficult” and

“most difficult” levels. Books at the “difficult” level did not have the keyword(s) in their titles, and at the “most difficult” level, participants needed to find out an answer to a question from a book description as the part of the trial. At both levels, participants’ reading skills played a bigger role.

As noted previously, the four-level, narrow/deep structure showed a tremendous advantage over the two-level, broad/shallow structure. In comparison, the four-level structure had much fewer failed attempts than the two-level structure, and appeared to help the participants alleviate the problem of making logical connections. Additionally, participants were more likely to give up trials when they were navigating in a wrong category or categories.

4.5.3.2 Search engine

The study suggests that participants with cognitive disabilities are able to use the search engine to find information online within a reasonable amount of time. However, there are still needs for improvement in both efficiency and reliability. On average, participants spent an average of two minutes finding each book and the failure rate is nearly 20%,

We observed that the participants in general were able to find a simple keyword or keywords for the search. However, they frequently mistyped words (e.g., piano as “pino”; China as “Chiua”; basketball as “baseketball”; and guitar as “guitar”). When participants mistyped words, the search engine prompted a message: “Sorry, no results were found. Please check your spelling, and retype your keyword!” After seeing the prompt, participants were all able to enter the right keyword(s) and successfully conduct

the search. Of the 92 trials of keyword searches, 70 searches had the right keyword(s) the first time; 21 searches had a misspell the first time but fixed the misspell after the prompt.

These findings are significant because it was believed previously that keyword search is challenging to the individuals with CDs (e.g., Friedman & Bryen, 2007; Karreman, Geest, & Buursink, 2006); our study suggests that they, given the right prompt, are all capable of conducting successful searches using a keyword or keywords. It appears that the most challenging part for individuals with CDs is not their inability to use a keyword or keywords to conduct a search. Rather, it is how the searched information, in this case, returns, is organized or structured that makes a huge difference. For example, even though, except that one person who gave up, 91 out of 92 keyword searches got the right keywords, there were still 17 searches that failed in the end. These failed searches were mostly the result of the traditional organization of the returns. The data also suggests that individuals with CDs are less likely to use the “Home” button to make an adjustment in their search, and that they are more comfortable to use the “Back” button. They face more challenges when they need to make a decision on the right link among multiple returns and choices.

4.5.4 Interaction Strategy

As mentioned earlier, the process of information retrieval involves trial and error, meaning that individuals use different strategies to correct mistakes during a search. For example, it is very common to navigate a wrong path, enter a word with a spelling error in a search engine, or get lost at a certain point. For ordinary users, they use different strategies to get back on track. They may choose the “Back” button to adjust the search;

they may click the “Home” button to start all over; they may do a new search in the search engine; and in many cases, they may spend time trying to figure out the logical relationship of the pages and links.

For the participants with cognitive disabilities, they seemed to stick to a limited number of strategies that are influenced by their cognitive limitations.

When browsing the pages, participants almost exclusively used the “Back” button to continue their information retrieval when they got lost or went to a wrong page. Very rarely did they use the “Home” button. Of all the trials, only two participants used the “Home” button to restart the search. (The researcher’s observation that participants rarely used the “Home” button is consistent with the observations reported by parents.) The heavy reliance on the “Back” button might be attributed to the lack of short memories, a logical reasoning, and other intellectual impairments.

The problem of getting lost or lack of orientation became aggravated during the broad/shallow (C2) information-retrieving tasks. Participants were more frustrated, more error prone, and gave up more often. The seemingly “random” returns from the tasks using the broad/shallow structure (C2) required more decision-making to pick up the right link, the decision-making often demanding more intellectual input. Participants, limited by their cognitive impairments, generally had a hard time figuring out the logic relationship between a category and its subcategories, failing to see the hierarchical structure on their own. They also lacked the general knowledge base on which they could associate a particular book with a relevant category.

Base on observations, the participants adopted two strategies when using the search engine. If they entered the right key word(s), got a list of returns, and chose a

wrong link or a link without appropriate information, they tended to use the “Back” button exclusively, which was consistent with their pattern under the free browsing condition. When they entered a key word or a phrase with a spelling error, they were prompted a message “Sorry, no results were found. Please check your spelling, and retype your key word!” In this case, the majority of the participants were able to retype the key word(s) and continue with the search.

CHAPTER FIVE

CONCLUSION

This research on two fundamental skills—information input and information retrieval—has collected first-hand data about the computer use of people with cognitive disabilities. The findings of the studies have in some cases confirmed and in other cases challenged what we have already known in existing literature. More importantly, they have significant implications for research and design that can enrich our knowledge of related domains and benefit computer users with cognitive impairments.

5.1 Implications, Limitations, and Future Research: Information Input Study

Overall, the findings from the input study extend existing knowledge about how individuals with cognitive disabilities, specifically Down syndrome, interact with input technologies. In this study, individuals with DS demonstrate their own unique patterns and preferences when using the three input techniques.

5.1.1 Diversity of cognitive disabilities and potentials

The results strongly suggest that there is large variation in the abilities and potentials among individuals with DS. In this study, some individuals with DS can be as good as neurotypical users when using the input techniques, while others are very slow and error

prone. The three groups of user profiles established based on the data collected provide a better understanding of the abilities of this user group. These results have significant implications for future research and design. The newly acquired knowledge should be used in the design and modification of information input devices that not only serve the general CD population, but also are specific and customized enough to meet the needs of different subgroups of the population.

5.1.2 Optimal use of input devices

The newly acquired knowledge of interactive patterns in this study sheds light on new research and design. For instance, in the study, participants predominantly used a short list in the word prediction method, suggesting that the word prediction software can be automatically customized to offer the short list to people with DS, which may reduce browsing time and errors. Further research is needed to investigate what the optimal number of the words and what the level of the words in the list should be in order to achieve the higher success rate. If we also take into consideration the different levels of cognitive disabilities in one subgroup, future researchers and designers can then focus on potentially providing assistive devices with different levels of difficulties.

In the case of individuals with DS, it is important to understand their functional abilities and inabilities in comparison with people with other types of cognitive impairments. As we already know, a person who suffers brain injury may lose some verbal ability, but may still be able to enunciate; some individuals with DS, however, typically have problems pronouncing words clearly. So in this case, for people with DS who have challenges with speech, speech recognition may not be their first choice. (Of

course, even this statement is conditional: if individuals had continuing speech pathology, their challenges with speech will be lessened.) Future research should aim to find the best method or combination of methods that work best for a particular disability group.

At the same time, however, efforts should also be made to improve adaptive devices that appear challenging or even incompatible to individuals with cognitive disabilities. Take some participants with DS for example. Due to their speech intelligibility issues, they understandably experience the lowest success rate using voice recognition among all the input methods. Nevertheless, the participants in the study rated voice recognition as their top choice. Researchers and designers should not rule voice recognition out as a potential effective input method for individuals with DS simply because they have speech intelligibility issues. Instead, collaborations should be made with linguists and speech therapists to understand the unique speech patterns of the individuals with DS and develop voice recognition applications that can recognize even the slurred speech.

5.1.3 Limitations and future research

This information input study had a number of challenges and limitations. As with any research study focusing on participants with cognitive impairments, it is hard to get access to a large number of participants.

Related to the methodology, the participants completed the input tasks on the research computer, under the observation of the researchers, and therefore might have felt uncomfortable or distracted. The order of the three conditions is not completely randomized due to logistical reasons. The word prediction condition was always

completed after the speech and the keyboard only conditions during the second experiment session since the participants needed time between sessions for training. The participants were allowed one month to get familiar with the word prediction software. However, the specific amount of time that they spent using the software was not fully controlled. It is possible that some participants spent longer time learning and getting familiar with the software than the others did. For speech recognition, all participants received the same amount of training offered by ViaVoice (between 25 and 35 minutes). It is possible that, due to the speech intelligibility problems that some individuals with DS have, a much longer training time might be needed, both to train the participants, and also to train the speech engine. Still, the inherent limitation of the study is that it was a one-time event, not an ongoing process where the participants had the opportunity to learn and practice, which would likely make a difference.

Finally, for the purpose of comparison, goal-directed tasks, specifically transcription tasks, were used in this study. However, participants are typically less motivated to perform goal-directed tasks that are not of their choosing, as compared to exploratory tasks, where the participants have much more freedom. While this discrepancy is noted in the research literature, it is unclear what impact this discrepancy would have for participants with DS. It is quite possible that, for individuals with DS, the motivational aspect of a task might have a much higher influence on performance.

5.2 Implications, Limitations, and Future Research: Information Retrieval Study

Overall, the findings from this study support existing knowledge on the characteristics of the individuals with CDs, providing strong empirical evidence on the urgent need to

organize information in a way that is appropriate to the targeted users. In addition, the findings also provide new understandings regarding interface design for people with cognitive disabilities.

5.2.1 Design of search engine

The knowledge of the characteristics and preferences of people with CDs can help conceptualize and modify better and more functional search engines. For instance, search engines can incorporate assistive devices (e.g., speech recognition) and provide different options to arrange returned information after a search. For example, the total number of returned links can be varied based on user needs. The number of links on each page can also be reduced to avoid information overload.

5.2.2 Hybrid method

The 18 trials that included mixed methods are particularly interesting. In comparison with any single method that used only the narrow/deep structure, or the broad/shallow structure, or the search engine, the 18 trials that used mixed methods achieved the highest success rate at 83.33%. Even though the mixed-method resulted in more time spent (148 seconds), the high success rate, in the context of the participants' own trial and error, seems to warrant further investigation. The preliminary results may suggest a new framework in which multiple methods are made available at the same time for information retrieval.

Additionally, it would be beneficial to conceptualize a new, hybrid information retrieval method with which an individual can switch from one method to another at ease

without being lost in the process. For instance, an individual browsing an item can switch to an adapted search engine at any moment during the search task. If so, as a new universal accessibility principle, all web pages should either embed a search engine or make a search engine available.

5.2.3 Design to promote more effective strategy

The result raises a good question of how to strike a balance for web developers and designers. Two key usability factors are success rate and efficiency. In an ideal situation, an individual with CDs should adopt a method or strategy for information retrieval that are both efficient and successful. However, in reality, there is usually a tradeoff between efficiency and success rate: faster performance tends to result in more errors. In this case, should an individual prefer a method or strategy that is slow but with fewer errors or a strategy that is fast but with more errors? We hypothesize that the success rate might be more important than efficiency for individuals with cognitive disabilities because it is challenging for them to recover from errors. Further studies are needed to validate this hypothesis.

5.2.4 Limitations and future research

The study only examined two different information organization structures: the two-level structure with 16 links on each page, and the four-level structure with four links on each page. In reality, many websites have a structure that is much deeper than four levels. The study result suggests that many users with CDs could interact with the four-level

structure effectively. Future studies are needed to investigate structures with more levels and how well users can navigate in those structures.

The same as the majority of empirical studies, this study only examined the initial interaction with the website by individuals with cognitive disabilities. The participants were given limited time to get acquainted with the website. It is possible that, with more practice, the performance might improve and the interaction strategies may evolve. So future longitudinal studies will be helpful to understand how people with cognitive disabilities learn to navigate within a new website and how their interaction strategies evolve.

Finally, the current findings are presented as general patterns from the entire group of participants. There are other confounding variables that might have contributed to performances at the individual level, such as an individual's socio-economic status, living style (with parents or alone), experience with computers and the Internet, computer related training, knowledge base, etc. In future studies, we plan to collect those types of information and study the relationship between those variables and performance.

5.3 Summary

The information input study examined how children with and without DS interact with three input solutions: the keyboard and mouse, the word prediction software, and the speech-based input. The results suggest that some individuals with DS have the necessary skills to enter text at a productive speed with acceptable accuracy, while others are very slow in data entry and the text generated contains a substantial number of errors. The word prediction software achieved comparable results with the keyboard and mouse

solution. The speech-based solution was extremely error prone when used by children with DS. Three user profiles were created for children and young adults with DS based on the data collected in the study. The group with DS showed a larger variance than the neurotypical group regarding both data entry speed and accuracy. In addition, the two groups also demonstrated different preferences and interaction patterns when completing the data entry task. The results of the study provide insights into the performance of individuals with DS and may have valuable implications for both design and future research.

The information retrieval study examined the impact of different web content structure and the use of search engine on information retrieval tasks performed by individuals with cognitive disabilities. The results suggest that the current content predominantly organized in the broad/shallow structure as reflected by many commercial websites does not work well with people with CDs. Given their cognitive limitations, people with CD achieved higher speed and higher error rate with pages with fewer content items

The results also suggest that the challenges people with CDs face when using a search engine are not as insurmountable as previously thought. Individuals with cognitive disabilities, on the contrary, have shown an overwhelming enthusiasm and preference for the search engine method, with data presenting strong evidence that they can achieve comparatively high efficiency and satisfaction using this method. In this regard, more efforts and energy should be devoted to developing and designing new search engines, or adding new functionality to the existing search engines, and to empowering people with

CDs with confidence and skills to effectively engage in information retrieval using search engines.

APPENDICES**APPENDIX A****Questionnaire for the Study on Information Input**

Please provide the following information by checking or writing the appropriate response.

1. Demographics:

Gender: Female Male

Age: _____

Native language: _____

Computer experience: _____ years

2. What kinds of tasks do you perform using computers? (Check all applicable)

- Create Word documents
- Check and send emails
- Communicate with friends online
- View Web sites
- Play games
- Watch movies and listen to music
- Other(s) (Please specify):

3. How do you normally enter data when using a computer? (Check all applicable)

- Keyboard and mouse/touch pad
- Speech application
- Mouth stick
- Touch screen
- Other(s) (Please specify):

4. How often do you use the computer? (Circle one)
- Every day
 - Every two days
 - Every three days
 - A week
 - Every two weeks
5. Which type of Down syndrome and impairments do you experience?
6. What kind of difficulty do you have when you use the computer?
7. Have you ever seen a speech pathologist?
8. Do you have low muscle tone problem?
9. How long can you type without feeling tired?

(After the study)

10. Please rank the following data input techniques by your preferences (1—most preferable, 3 or 4 — least preferable)

Mouse and key board _____

Speech-based application _____

Word Prediction software _____

Other(s) (Please specify): _____

11. Other notes or comments:

APPENDIX B

Scripts for the Study on Information Input

Script 1: The Olympic Ideals

The Olympic motto is “Swifter, Higher, stronger.” These words express the athletic ideals of the Olympics.

But the Olympics are special partly because they are more than just athletic competitions. The Olympics have a creed to express the main idea behind Olympic competition. It says that “The most important thing in the Olympic Games is not to win but to take part, just as the most important thing in life is not the triumph but the struggle. The essential thing is not to have conquered but to have fought well.” This means that all Olympic athletes are winners, whether they win or lose. It also means that the same thing is true in everyday life. What matters most is trying hard at something you love to do, even if you fail.

The Olympics show how well people from different countries can get along. The Olympic emblem has five colored rings linked together to represent this spirit of goodwill. The rings are blue, yellow, black, green, and red. At least one of these colors is on the flag of each country taking part in the Olympics. The rings also stand for parts of the word—Europe, Asia, Africa, Oceania, and the Americas.

Script 2: Music

Music making began thousands of years ago. When people celebrated a hunt, signaled dangers, worshiped, or told stories, they danced, clapped, banged on hollow logs, shook pebbles, and chanted. Later they made primitive instruments from stone, bone, shells, and metal. Variations of some are used even today.

Music grew from one century to the next. In the early and middle ages, new forms of music developed. Christianity inspired church music. Music became polyphonic—played and sung in two or more melodic parts. Notations were invented. Music was no longer a one-time performance. Now it would be written and preserved for other musicians and generations.

Every country has its own sounds, rhythms, instruments, songs, and dance. The music reflects the culture and the people. The diverse sounds have influenced both classical and popular music.

Music became popular with a bang. It first spread by radio. Then by phonograph records, the jukebox, television, tape, videos, compact disks, and concert tours. Everyone has a favorite kind of music that brings comfort and pleasure. Music makes work easier in factories, in offices, or at home. It inspires all kinds of artists who listen to music as they create. Music is good for everyone.

Script 3: A Pelican's Bill

One of the best fishermen in the world does not use a line or a hook. It skips using any kind of bait. Instead, this creature just swoops down and opens its beak. In minutes, the bird is having its favorite meal.

A pelican is built to fly down, catch fish, and eat them. Its body is very light. Its wings are very large. They spread out between seven and eight feet, so flying is fast and easy. A pelican can stay up in the air for twenty-four hours without coming down. When it spots a fish under the water, the pelican opens its big bill. It acts like a built in net. It is fifteen to twenty inches long. The pelican dives and it scoops more than three gallons of fish and water in one gulp. A sharp hook on its upper jaw helps to catch the slippery fish that try to swim away.

When it gets back to land, the pelican tips its head and all the water runs out. Now all it has left are the fish waiting at the bottom of its bill. Although there is space inside the bill, it is not very strong. The muscles cannot hold today's catch for long. The pelican must hurry up and eat its dinner.

APPENDIX C

Questionnaire (for Parent/Guardian) for the Study on Information Retrieval

Please provide the following information by checking or writing down the appropriate response.

1. Gender of your child : Female Male Age: _____

2. Computer experience: _____ years; Internet/Web experience _____ years.

3. Which type of disabilities was your child diagnosed? How does the disability affect your child's learning?

4. Does your child currently attend a regular or a special education school? (*check one*)
 Regular School _____ Special Education School _____ Other _____
 Doesn't attend school currently _____

5. If your child attends a regular school, is your child primarily in regular education classes, or only in special education self-contained classes?

6. How did s/he first learn about the Internet? (*check one*)
 At school _____ From friends _____ From you or other parent _____
 From sibling(s) _____ Other (Please Specify) _____

7. What are your child's objectives when using the Internet? (*Check as many as appropriate*)
 Learning _____ Fun _____ Communication _____
 Other (Please specify) _____

8. How often does your child use the Internet/Web? (both at home and at school) (*check one*)

Every day _____ Every two day _____ Every three days _____
 A week _____ Every two weeks _____

9. Approximately how many hours per week does your child use the Internet/Web? (Combined school and home)? _____

10. What kinds of websites does your child usually visit? (*Check as many as appropriate*)

Sports _____ Movies _____ Animals _____ Personal homepages _____
 Entertaining comics _____
 Music _____ News _____ Educational _____ Travel _____ Other _____

11. Does your child usually use menu items on the menu bar or icons on the tool bar when browsing the Web? (*Check as many as appropriate*)

Home  _____ Back  _____ Forward  _____
 Bookmarks/Favorites _____ Refresh  _____ Print  _____
 Help _____ Others _____

12. Does your child type URL addresses to visit websites? (*check one*)

Yes _____ To some extent _____ No _____

Comments (if any): _____

13. Do you set easy accesses, e.g., create shortcuts or bookmarks/favorites, for your child to browse Web pages? (*check one*)

Yes _____ To some extent _____ No _____

Comments (if any): _____

14. Does your child use a keyword search engine to retrieve information?

Yes _____ No _____

If yes,

1) What kind of search engines is used?

2) What kind of difficulty does s/he have?

3) When encountering difficulty in the process, how does s/he deal with it?

15. Does your child get lost easily when browsing Web pages? (*check one*)

Yes _____ To some extent _____ No _____

Comments (if any): _____

16. Does your child find information s/he intends to retrieve on websites? (*check one*)

Yes _____ To some extent _____ No _____

Comments (if any): _____

17. Notes or comments:

APPENDIX D

Questionnaire (for Participant) for the Study on Information Retrieval

1. Please rank the following information retrieval structures or techniques on the website by your overall preferences (1—most preferable and 3 least preferable)
 - Narrow and deep structure (4x4x4x4) _____
 - Broad and shallow structure (16x16) _____
 - Search engine _____

2. Of the three information retrieval structures or techniques, which one is the easiest for you?
 - 4x4x4x4 structure ____ 16x16 structure____ Search engine _____
 - Comments (if any): _____

3. Of the three information retrieval structures or techniques, which one is the fastest for you?
 - 4x4x4x4 structure ____ 16x16 structure____ Search engine _____
 - Comments (if any): _____

4. When performing the tasks in the 4x4x4x4 structure, did you have any problem?

If so, how did you solve the problem?

5. When performing the tasks in the 16x16 structure, did you have any problem?

If so, how did you solve the problem?

6. When performing the tasks using the keyword search engine, did you have any problem?

If so, how did you solve the problem?

7. Other notes or comments:

APPENDIX E

Structures and Contents of the Website for the Study on Information Retrieval

1. Animals

1.1. Flying

1.1.1. Bat

1.1.1.1. Bats

1.1.1.2. Bats and Other Animals of the Night

1.1.1.3. Bats: Creatures of the Night

1.1.1.4. Shadows of Night: the Hidden World of the Little Brown Bat

1.1.2. Eagle

1.1.2.1. Bald Eagles: Their Behavior and Life in North America

1.1.2.2. Eagles

1.1.2.3. Eagles and Birds of Prey

1.1.2.4. The Bald Eagle

1.1.3. Falcon

1.1.3.1. Falcons

1.1.3.2. Falcons: Wild Birds of Prey

1.1.3.3. Peregrine Falcons

1.1.3.4. The Peregrine Falcon

1.1.4. Hawk

1.1.4.1. Hawks

1.1.4.2. Hawks: Our Wild World

1.1.4.3. How Do We Live Together? Hawks

1.1.4.4. Red-tailed Hawks

1.2. Land

1.2.1. Bear

1.2.1.1. Bears for Kids

1.2.1.2. Black Bear

1.2.1.3. Face to Face with Polar Bears

1.2.1.4. The Bear

1.2.2. Elephant

1.2.2.1. Elephant

1.2.2.2. Elephants

1.2.2.3. Elephants: A Cultural and Natural History

1.2.2.4. Elephants of Africa

1.2.3. Lion

1.2.3.1. Face to Face with Lions

1.2.3.2. Lion

1.2.3.3. Lions

1.2.3.4. Lions: A Portrait of the Animal World

1.2.4. Zebra

1.2.4.1. A Zebra's World

1.2.4.2. Endangered Zebras

1.2.4.3. The Zebra

1.2.4.4. Zebras

1.3. Insects

1.3.1. Ant

1.3.1.1. Ants

1.3.1.2. The Ant: Energetic Worker

1.3.1.3. The Life and Times of the Ant

1.3.1.4. Tiny Workers: Ants in Your Backyard

1.3.2. Bee

1.3.2.1. Bee

1.3.2.2. Bees

1.3.2.3. Bees Bees Bees

1.3.2.4. Bees & Other Stinging Insects

1.3.3. Butterfly

1.3.3.1. Beauty Butterflies

1.3.3.2. Butterfly

1.3.3.3. Butterflies

1.3.3.4. The Life Cycle of a Butterfly

- 1.3.4. Grasshopper/Crickets
 - 1.3.4.1. Cricketology
 - 1.3.4.2. Grasshopper
 - 1.3.4.3. Grasshoppers
 - 1.3.4.4. Leaping Grasshoppers
- 1.4. Ocean /Water (Aquatic)
 - 1.4.1. Dolphin
 - 1.4.1.1. Dolphins
 - 1.4.1.2. Dolphins and Porpoises
 - 1.4.1.3. Dolphins for Kids
 - 1.4.1.4. Face to Face with Dolphins
 - 1.4.2. Shark
 - 1.4.2.1. Great White Sharks
 - 1.4.2.2. Shark
 - 1.4.2.3. Shark Attacks
 - 1.4.2.4. Shark Life
 - 1.4.3. Whale
 - 1.4.3.1. Face to Face with Whales
 - 1.4.3.2. The Life Cycle of a Whale
 - 1.4.3.3. The Whale
 - 1.4.3.4. Whale
 - 1.4.4. Penguin
 - 1.4.4.1. Face to Face with Penguins
 - 1.4.4.2. Growing Up Wild: Penguins
 - 1.4.4.3. Penguins
 - 1.4.4.4. Penguins of the World
- 2. Entertainment
 - 2.1. Activities
 - 2.1.1. Camping
 - 2.1.1.1. Camping
 - 2.1.1.2. Camping Made Easy

- 2.1.1.3. Camping: Outdoor Adventures
- 2.1.1.4. Camping: The Great Outdoors
- 2.1.2. Fishing
 - 2.1.2.1. A Kid's Guide to Flyfishing
 - 2.1.2.2. Fishing For Fun!
 - 2.1.2.3. Fishing: The Complete Guide to Basics
 - 2.1.2.4. Let's Go Fishing
- 2.1.3. Gaming
 - 2.1.3.1. Learn How to Play Poker Like a Pro
 - 2.1.3.2. Super Sports/Kids On The Net (Cool Sites)
 - 2.1.3.3. The MONOPOLY Companion: The Players' Guide
 - 2.1.3.4. Wii Player - Your Complete A-Z Guide to the Nintendo Wii
- 2.1.4. Hiking
 - 2.1.4.1. Hiking: Healthy For Life
 - 2.1.4.2. Hiking
 - 2.1.4.3. Hiking: The Great Outdoors
 - 2.1.4.4. Hiking: Outdoor Adventures
- 2.2. Instruments
 - 2.2.1. Drum
 - 2.2.1.1. Drumming
 - 2.2.1.2. Guide to the Drumset
 - 2.2.1.3. Making Drums
 - 2.2.1.4. You Can Teach Yourself Drums
 - 2.2.2. Guitar
 - 2.2.2.1. Acoustic Guitar Basics
 - 2.2.2.2. Guitar
 - 2.2.2.3. How to Play Guitar
 - 2.2.2.4. Play Guitar in 10 Easy Lessons
 - 2.2.3. Piano
 - 2.2.3.1. Children's Piano Method
 - 2.2.3.2. I Can Do It! Piano Book

2.2.3.3. Piano

2.2.3.4. Play Piano in a Flash for Kids

2.2.4. Violin

2.2.4.1. Beginning Violin Theory for Children

2.2.4.2. The History of the Violin

2.2.4.3. The Violin

2.2.4.4. Violin Method

2.3. Performers

2.3.1. Actors

2.3.1.1. Miranda Cosgrove

2.3.1.2. Robert Pattinson: Eternally Yours

2.3.1.3. Taylor Lautner

2.3.1.4. Tom Hanks

2.3.2. Composers

2.3.2.1. Bach: Introducing

2.3.2.2. Handel

2.3.2.3. Ludwig Van Beethoven

2.3.2.4. Mozart

2.3.3. Dancers

2.3.3.1. Confessions of a Backup Dancer

2.3.3.2. Dancer

2.3.3.3. Patrick Swayze: One Last Dance

2.3.3.4. The Dancer

2.3.4. Singers

2.3.4.1. Burning Up

2.3.4.2. Demi Levato

2.3.4.3. Miles to Go

2.3.4.4. Taylor Swift: Love Story

2.4. Types of Performance

2.4.1. Acting

2.4.1.1. Acting

- 2.4.1.2. Acting: The Basics
- 2.4.1.3. Acting: Onstage and Off
- 2.4.1.4. Acting: The First Six Lessons
- 2.4.2. Dancing
 - 2.4.2.1. Ballet and Modern Dance
 - 2.4.2.2. Conditioning for Dance
 - 2.4.2.3. Dancing: Mind & Body
 - 2.4.2.4. Jazz Dance Class
- 2.4.3. Other
 - 2.4.3.1. Juggling: From Start to Star
 - 2.4.3.2. The Boy Magician
 - 2.4.3.3. The Circus
 - 2.4.3.4. You Must Be Joking!
- 2.4.4. Singing
 - 2.4.4.1. 101 Singing Tips
 - 2.4.4.2. How to Sing
 - 2.4.4.3. Sing Today!
 - 2.4.4.4. The Act of Singing
- 3. Places
 - 3.1. Africa
 - 3.1.1. Algeria
 - 3.1.1.1. Algeria
 - 3.1.1.2. Algeria: Enhancement of the World
 - 3.1.1.3. Algeria in Pictures
 - 3.1.1.4. Welcome to Algeria
 - 3.1.2. Egypt
 - 3.1.2.1. Ancient Egypt
 - 3.1.2.2. Egypt
 - 3.1.2.3. Egypt: 1880 to the Present
 - 3.1.2.4. Egypt: Cultures of the World
 - 3.1.3. Senegal

- 3.1.3.1. Senegal
- 3.1.3.2. Senegal: A “Spy” Guide
- 3.1.3.3. Senegal: Cultures of the World
- 3.1.3.4. Senegal: Enhancement of the World
- 3.1.4. South Africa
 - 3.1.4.1. South Africa
 - 3.1.4.2. South Africa: A Question and Answer Book
 - 3.1.4.3. South Africa: Cultures of the World
 - 3.1.4.4. South Africa in Pictures
- 3.2. America
 - 3.2.1. Brazil
 - 3.2.1.1. Brazil
 - 3.2.1.2. Brazil: Country Files
 - 3.2.1.3. Brazil: Enhancement of the World
 - 3.2.1.4. Destination Detectives: Brazil
 - 3.2.2. Canada
 - 3.2.2.1. Canada
 - 3.2.2.2. Canada: A Question and Answer Book
 - 3.2.2.3. Canada from A to Z
 - 3.2.2.4. Wow Canada!
 - 3.2.3. Mexico
 - 3.2.3.1. Destination Detectives: Mexico
 - 3.2.3.2. Look What Came From Mexico
 - 3.2.3.3. Mexico
 - 3.2.3.4. Mexico: One World
 - 3.2.4. The United States
 - 3.2.4.1. The 50 States
 - 3.2.4.2. The United States: A Question and Answer Book
 - 3.2.4.3. The United States: A State-by-State Guide
 - 3.2.4.4. The United States of America
- 3.3. Asia

3.3.1. China

3.3.1.1. China

3.3.1.2. China: Country Files

3.3.1.3. China the Land

3.3.1.4. Destination Detectives: China

3.3.2. India

3.3.2.1. A Visit to India

3.3.2.2. Destination Detectives: India

3.3.2.3. India

3.3.2.4. India: A Question and Answer Book

3.3.3. Japan

3.3.3.1. A Look at Japan

3.3.3.2. A Visit to Japan

3.3.3.3. Japan

3.3.3.4. Japan: The Culture

3.3.4. South Korea

3.3.4.1. Frommer's South Korea

3.3.4.2. South Korea

3.3.4.3. South Korea: Countries of the World

3.3.4.4. Teens in South Korea

3.4. Europe

3.4.1. France

3.4.1.1. A Visit to France

3.4.1.2. Destination Detectives: France

3.4.1.3. France: Cultures of the World

3.4.1.4. France: Enhancement of the World

3.4.2. Germany

3.4.2.1. A Visit to Germany

3.4.2.2. Germany

3.4.2.3. Germany: Countries of the World

3.4.2.4. Germany: Cultures of the World

- 3.4.3. Great Britain
 - 3.4.3.1. England
 - 3.4.3.2. Great Britain
 - 3.4.3.3. Great Britain: Facts About Countries
 - 3.4.3.4. United Kingdom: Countries of the World
- 3.4.4. Italy
 - 3.4.4.1. A Visit to Italy
 - 3.4.4.2. Destination Detectives: Italy
 - 3.4.4.3. Italy: Countries of the World
 - 3.4.4.4. Italy: Enhancement of the World

4. Sports

4.1. Team Sports

- 4.1.1. Baseball
 - 4.1.1.1. Baseball and Softball
 - 4.1.1.2. Baseball Now
 - 4.1.1.3. Baseball's Greatest Hitters
 - 4.1.1.4. Yogi Berra
- 4.1.2. Basketball
 - 4.1.2.1. Basketball Greats
 - 4.1.2.2. Basketball: Steps to Success
 - 4.1.2.3. Great Moments in Basketball History
 - 4.1.2.4. Michael Jordan
- 4.1.3. Football
 - 4.1.3.1. All About Football
 - 4.1.3.2. NFL Power Players
 - 4.1.3.3. Peyton Manning
 - 4.1.3.4. Sports Heroes: Football
- 4.1.4. Soccer
 - 4.1.4.1. How Soccer Works
 - 4.1.4.2. On the Field With ... Mia Hamm
 - 4.1.4.3. Soccer

4.1.4.4. Soccer Around The World

4.2. Track and Field

4.2.1. Jumping Events

4.2.1.1. Above and Beyond

4.2.1.2. Complete Book of Jumps

4.2.1.3. Jumping Events

4.2.1.4. Winning Jumps and Pole Vault

4.2.2. Marathon

4.2.2.1. Marathon Runner's Handbook

4.2.2.2. Marathon: The Ultimate Training Guide

4.2.2.3. Marathon: You Can Do It!

4.2.2.4. The First Marathon

4.2.3. Sprint

4.2.3.1. Fundamentals of Sprinting

4.2.3.2. High Performance Sprinting

4.2.3.3. Michael Johnson: Sprinter Deluxe

4.2.3.4. The Art of Sprinting

4.2.4. Throwing Events

4.2.4.1. Complete Book of Throws

4.2.4.2. Throwing Events

4.2.4.3. Throws

4.2.4.4. Throws Handbook

4.3. Water Sports

4.3.1. Boating

4.3.1.1. Boating: Outdoor Adventures

4.3.1.2. Canoeing

4.3.1.3. Kayaking

4.3.1.4. Whitewater

4.3.2. Diving

4.3.2.1. Diving: Action Sports

4.3.2.2. Diving & Snorkeling: Hawaii

4.3.2.3. Scuba Diving

4.3.2.4. Springboard & Platform Diving

4.3.3. Surfing

4.3.3.1. Extreme Surfing

4.3.3.2. Surfing

4.3.3.3. Surfing the World

4.3.3.4. The Surfing Handbook

4.3.4. Swimming

4.3.4.1. How to Improve at Swimming

4.3.4.2. Swimming for Fun!

4.3.4.3. Swimming in Action

4.3.4.4. Swimming: Steps to Success

4.4. Winter Sports

4.4.1. Ice Hockey

4.4.1.1. Ice Hockey

4.4.1.2. Ice Time: The Story of Hockey

4.4.1.3. Paul Kariya

4.4.1.4. Wayne Gretzky

4.4.2. Ice Skating

4.4.2.1. Figure Skating School

4.4.2.2. Ice Skating

4.4.2.3. Ice Skating: Steps to Success

4.4.2.4. The Complete Book of Figure Skating

4.4.3. Sledding

4.4.3.1. Bobsledding and the Luge

4.4.3.2. Iditarod Dream

4.4.3.3. Sledding

4.4.3.4. Sled Dogs Run

4.4.4. Snowboarding

4.4.4.1. Snowboarding!: Shred the Powder

4.4.4.2. Snowboarding Basics

4.4.4.3. Snowboarding in Action

4.4.4.4. Snowboarding Know-How

APPENDIX F

Task Specification for the Study on Information Retrieval

Types of books	Tasks		
Easy: <u>Any one</u> of books in a category	(E1) Find any one of books about guitar.	(E2) Find any one of books about lions.	(E3) Find any one of books about China.
Medium: Specific book <u>with</u> keyword(s) in the book title	(M1) Find a book about red-tailed hawks.	(M2) Find a book about how to improve swimming.	(M3) Find a book about piano method for children.
Difficult: Specific book <u>without</u> keyword(s) in the book title	(D1) Find a book about Babe Ruth and other baseball players.	(D2) Find a book about singers, Jonas Brothers.	(D3) Find a book about Magic Johnson and other basketball players.
Most Difficult: Book <u>with a question</u>	(MD1) Find a book to answer this question: What is the world-famous historical site in Egypt?	(MD2) Find a book to answer this question: What kinds of things did come from Mexico?	(MD3) Find a book to answer this question: Where are bald eagles living?
Free Search: Use any of methods to search these three books	(F1) Find a book about Wii game. (F2) Find a book about teen life in South Korea. (F3) Find a book to answer this question: When was the first marathon?		

APPENDIX G

Code of the Custom Search Engine for the Study on Information Retrieval

Search.php

```

<?php
session_start();
ob_start();
?>
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN"
"http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dtd">
<html xmlns="http://www.w3.org/1999/xhtml"><!-- InstanceBegin
template="/Templates/main.dwt" codeOutsideHTMLIsLocked="false" -->
<head>
<meta http-equiv="Content-Type" content="text/html; charset=utf-8" />
<meta name="google-site-verification"
content="VWC7f6Uz9hUJ5ixU5xt1E5A5J9WOWefODXuj0pYA71c" />
<title>Mini Library</title>
<link rel="stylesheet" href="http://triton.towson.edu/~csminilib/ds.css" type="text/css"
/>
<script language="javascript" type="text/javascript"
src="http://triton.towson.edu/~csminilib/cookie.js"></script>

<!-- InstanceBeginEditable name="style" -->
<script src="https://www.google.com/jsapi?key=ABQIAAAA5s3KzHx-
GsEAWGj0i_UetBTNWuWIPZiXWSeTk-ZxpjkoCojrlhQr977D6umyN9vRD0-
fo2oyCc3mFw" type="text/javascript"></script>

<script language="javascript" type="text/javascript"
src="http://triton.towson.edu/~csminilib/cookie.js"></script>

<script language="Javascript" type="text/javascript">

```

```

var request = null;

try {
    request = new XMLHttpRequest();
} catch (trymicrosoft) {
    try {
        request = new ActiveXObject("Msxml2.XMLHTTP");
    } catch (othermicrosoft) {
        try {
            request = new ActiveXObject("Microsoft.XMLHTTP");
        } catch (failed) {
            request = null;
        }
    }
}

if (request == null)
    alert("Error creating request object!");

function logkey() {
    var key = document.getElementById("keyword").value;
    var url = "searchlog.php?key=" + escape(key);
    request.open("GET", url, true);
    request.send(null);
    onClick();
}

google.load("search", "1");
function onClick(){
    var searchresults=document.getElementById("searchcontrol")
    var searchKeyword=document.getElementById("keyword");
    var searchControl = new google.search.SearchControl();
    var searcher= new google.search.WebSearch();

```

```

var options = new google.search.SearcherOptions();

searcher.setUserDefinedLabel("Mini Library");
searcher.setSiteRestriction
("016871601969439274438:duiiuvtokuy");
options.setExpandMode(google.search.SearchControl.EXPAND_
MODE_OPEN);
searchControl.addSearcher(searcher,options);
searchControl.draw(searchresults); // Execute an initial search
createCookie
("minilib", searchKeyword.value, 1); //save key words
searchControl.execute(searchKeyword.value);
searchControl.setNoResultsString
("Sorry, no results. <br>Please check, and type your keyword
again.");
searchControl.setLinkTarget
(google.search.Search.LINK_TARGET_SELF);

//Will remove web icons
Var resultDivLayer=
searchresults.childNodes[0].childNodes[1].childNodes[0];
var webIconLayer=resultDivLayer.childNodes[0];
resultDivLayer.removeChild (webIconLayer); //command it to
show web icons!!
}

function OnLoad() { // Create a search control
var searchresults=document.getElementById("searchcontrol")
searchresults.innerHTML=
"<div width='400' height='25'><p></p></div>";
//set focus in the textbox

```

```

var txtBox=document.getElementById("keyword");
if (txtBox!=null )
    document.all.inputbox.focus();

var searchKeyword=readCookie("minilib");
document.all.inputbox.value = searchKeyword;
var searchControl = new google.search.SearchControl();
// Add in a full set of searchers
var searcher= new google.search.WebSearch();
var options = new google.search.SearcherOptions();
searcher.setUserDefinedLabel("Mini Library");
searcher.setSiteRestriction
("016871601969439274438:fhtypum4xm");
options.setExpandMode
(google.search.SearchControl.EXPAND_MODE_OPEN);
searchControl.addSearcher(searcher,options);
searchControl.setResultSetSize
(google.search.Search.LARGE_RESULTSET);

searchControl.draw(searchresults); // Execute an initial search
searchControl.execute(searchKeyword);

searchControl.setNoResultsString ("Sorry, no results. <br>Please
check, and type your keyword again.");
searchControl.setLinkTarget
(google.search.Search.LINK_TARGET_SELF);
}
google.setOnLoadCallback(OnLoad);
</script>

<!-- willl hide Google's title and search box-->

```

```

<style media="screen" type="text/css">
    .gsc-search-box {
        display:none;
    }
</style>
<!-- InstanceEndEditable -->
</head>

<body bgcolor="#CCFFFF"><center>
<!-- InstanceBeginEditable name="php" -->
<?php
if(!isset($_SESSION["userid"]))//judge if set userid
{
    header( 'Location: login.php' ) ;//redirect now
    ob_end_flush();
}
else
{
    $name = $_SESSION["userid"];
    include ("DBcontrol.php");
    $pagename = "Search";
    logNow($pagename, $name);
}
?><!-- InstanceEndEditable -->
<table width = 800 border=0 bgcolor="#CCFFFF">
<tr>
    <td align="center"><h1 align="center">Mini
        Library</h1></td>
</tr>
<tr>

```


BIBLIOGRAPHY

- Abascal, J. & Nicolle, C. (2001). Why inclusive design guidelines? In J. Abascal & C. Nicolle (Eds.), *Inclusive Design Guidelines for HCI* (pp. 2-16). London and New York: Taylor & Francis.
- Abbeduto, L. & Murphy, M. (2004). Language, social cognition, maladaptive behavior, and communication in Down syndrome and fragile X syndrome. In M. Rice & S. Warren (Eds.), *Developmental language disorders: From phenotypes to etiologies* (pp. 77-96). Hillsdale, NJ: Erlbaum.
- Adam, A. & Kreps, D. (2006). Web accessibility: A digital divide for disabled people? In E. Trauth, D. Howcroft, T. Butler, B. Fitzgerald, & J. DeGross (Eds.), *Social inclusion: Societal and organizational implications for information systems* (pp. 217-228). Boston, MA: International Federation for Information Processing.
- Anson, D., Moist, P., Przywara, M., Wells, H., Saylor, H., & Maxime, H. (2006). The effects of word completion and word prediction on typing rates using on-screen keyboards. *Assistive Technology*, 18(2), 146–154.
- Bigham, J., Brudvik, J., & Zhang, B. (2010). Accessibility by demonstration: Enabling end users to guide developers to web accessibility solutions. *Proceedings of ASSETS Conference on Assistive Technologies* (pp. 35-42).
- Blanck, P. (1994). *Communications technology for everyone: Implications for the classroom and beyond*. Washington, DC: The Annenberg Washington Program.
- Blanck, P. (2008). Flattening the (inaccessible) cyberworld for people with disabilities. *Assistive Technology*, 20(3), 175-180.
- Blansett, J. (2008). Digital discrimination. *Library Journal*, 133(13), 26-29.
- Bohman, P. (2004). Cognitive disabilities part 1: We still know too little, and we do Even less. Retrieved on October 30, 2010 from http://webaim.org/articles/cognitive/cognitive_too_little.
- Bohman, P. & Anderson, S. (2005). A conceptual framework for accessibility tools to benefit users with cognitive disabilities. *Proceedings of the International Cross-Disciplinary Workshop on Web Accessibility* (pp. 85-89).
- Brown, A., Jay, C., & Harper, S. (2010). Using qualitative eye-tracking data to inform audio presentation of dynamic web content. *New Review of Hypermedia & Multimedia*, 16(3), 281-301.

- Bryen, D., Heake, G., Semenuk, A., & Segal, M. (2010). Improving web access for individuals who rely on augmentative and alternative communication. *Augmentative and Alternative Communication, 26*(1), 21-29.
- Buckley, S. (2001a). *Living with Down syndrome*. Portsmouth, UK: The Down Syndrome Educational Trust.
- Buckley, S. (2001b). *Reading and writing for individuals with Down syndrome: An overview*. Portsmouth, UK: The Down Syndrome Educational Trust.
- Burghstahler, S. (2002). Web-based distance learning and the second digital divide. In M. Hricko (Ed.), *Design and implementation of Web-enabled teaching tools* (pp. 83-97). Hershey, PA: Idea Group.
- Burmeister, O. (2010). Websites for seniors: Cognitive accessibility. *International Journal of Emerging Technologies and Society 8*(2), 99-113.
- Byrne, A. (1997). *Teaching reading to children with Down syndrome*. Unpublished Doctoral Dissertation. University of Portsmouth.
- Card, S., Moran, T., & Newell, A. (1983). *The psychology of human-computer interaction*. Hillsdale, NJ: Erlbaum.
- Carey, K. (2007). The opportunities and challenges of the digital age: A blind user's perspective. *Library Trends, 55*(44), 767-784.
- Chapman, R., Schwartz, S., & Bird, E. (1991). Language skills of children and adolescents with Down syndrome I: comprehension. *Journal of Speech and Hearing Research, 34*, 1106-1120.
- Chapman, R., & Hesketh, L. (2000). Behavioral phenotype of individuals with Down syndrome. *Mental Retardation and Developmental Disabilities Research Reviews, 6*, 84-95.
- Chapman, R., Seung, J., Schwartz, S., & Bird, E. (1998). Language skills of children and adolescents with Down syndrome II: Production deficits. *Journal of Speech, Language and Hearing Research, 41*, 861-873.
- Christian, K., Kules, B., Shneiderman, B., & Youssef, A. (2000). A comparison of voice controlled and mouse controlled web browsing. *Proceedings of ASSETS Conference* (pp. 72-79).
- Collacott, R., Cooper, S., Branford, D., & McGrother, C. (1998). Behaviour phenotype for Down's syndrome. *The British Journal of Psychiatry, 172*, 85-89.

- Cornish, K. & Wilding, J. (2010). *Attention, genes, and developmental disorders*. New York: Oxford University Press.
- Crow, K. (2008). Four types of disabilities: Their impact on online learning. *TechTrends*, 52(1), 51-55.
- Curran, K., Walters, N., & Robinson, D. (2007). Investigating the problems faced by older adults and people with disabilities in online environments. *Behaviour & Information Technology*, 26(6), 447-453.
- Dawe, M. (2006). Desperately seeking simplicity: how young adults with cognitive disabilities and their families adopt assistive technologies. *Proceedings of the ACM Conference on Human Factors in Computing Systems*, 1143-1152.
- Dawe, M. (2007). Understanding mobile phone requirements for young adults with cognitive disabilities. *Proceedings of the ACM Conference on Human Factors in Computing Systems*, 179-186.
- de Moreira, L., San Juan, A., Pereira, P., & de Souza, C. (2000). A case of mosaic trisomy 21 with Down's syndrome signs and normal intellectual development. *Journal of Intellectual Disability Research*, 44, 91-96.
- Disabilities Rights Commission. (2004). *The web access and inclusion for disabled people*. Retrieved on October 30, 2010 from http://www-hcid.soi.city.ac.uk/research/DRC_Report.pdf.
- Dobransky, K. & Hargittai, E. (2006). The disability divide in Internet access and use. *Information, Communication & Society*, 9(3), 313-334.
- Elcessor, E. (2010). Bridging disability divides: A critical history of web content accessibility through 2001. *Information, Communication & Society*, 13(3), 289-308.
- Engelen, J. (2001). Guidelines for web accessibility. In J. Abascal & C. Nicolle (Eds.), *Inclusive design guidelines for HCI* (pp. 131-142). London and New York: Taylor & Francis.
- Engle, R., Sedek, G., Hecker, U., & McIntosh, D. (Eds.) (2005). *Cognitive limitations in aging and psychopathology*. New York: Cambridge University Press.
- Feng, J., Karat, C-M., & Sears, A. (2005). How productivity improves in hands-free continuous dictation tasks: lessons learned from a longitudinal study. *Interacting with Computers*, 17(3), 265-289.
- Feng, J., Lazar, J., Kumin, L., & Ozok, A. (2008). Computer usage by children with Down syndrome. *Proceedings of ASSETS Conference on Assistive Technologies* (pp. 35-42).

- Feng, J., Lazar, J., Kumin, L., & Ozok, A. (2010). Computer usage by children with Down syndrome: Challenges and future research. *ACM Transactions on Accessible Computing*, 2(3), 1-44.
- Federici, S., Micaangeli, A., Ruspantini, I., Borgianni, S., Corradi, F., Pasqualotto, E. et al. (2005). Checking an integrated model of web accessibility and usability evaluation for disabled people. *Disability and Rehabilitation*, 27(13), 781-790.
- Freeman, E., Clare, L., Savitch, N., Royan, L., Litherland, R., & Lindsay, M. (2005). Improving website accessibility for people with early-stage dementia: A preliminary investigation. *Aging and Mental Health* 9(5), 442-448.
- Friedman, M. & Bryen, D. (2007). Web accessibility design recommendations for people with cognitive disabilities. *Technology and Disability*, 19, 205-212.
- Fox, S. (2004). *Old Americans and the Internet*. Washington, DC: Pew Internet and American Life Project.
- Goggin, G. & Newell, C. (2003). *Digital disability: The social construction of disability in new media*. Lanham, MD: Rowman & Littlefield.
- Goodwin, M., Susar, D., Nietzio, A., Snaprud, M., & Jensen, C. (2011). Global web accessibility analysis of national government portals and ministry web sites. *Journal of Information Technology & Politics*, 8, 41-67.
- Gould, J. & Lewis, C. (March 1985). Designing for usability: Key principles and what designers think. *Communications of the ACM*, 28(3), 300-311.
- Harada, S., Landay, J., Malkin, J., Li, X., & Bilmes, J. (2006). The vocal joystick: evaluation of voice-based cursor control techniques. *Proceedings of ASSETS Conference*, 197-204.
- Harris, J. (2005). *Intellectual disability: Understanding its development, causes, classification, evaluation, and treatment*. New York: Oxford University Press.
- Harrysson, B. (2003). Internet enabling design for people with cognitive limitations. In B. Harrysson (Ed.), *Web design for cognitive accessibility*. Licentiate thesis, Division of Ergonomics and Aerosol Technology, Department of Design Sciences, Lund University, Sweden.
- Harrysson, B., Svensk, A., & Johansson, G. (2004). How people with developmental disabilities navigate the Internet. *British Journal of Special Education*, 31(3), 138-142.

- Henry, S. (2009). Government laws, regulations, policies, standards, and support. Retrieved April 10, 2010 from http://www.uiaccess.com/access_links.html#government_laws_regs_policies.
- Hitchcock, C. (2001). Bobby: A validation tool for disability access on the world wide web. In J. Abascal & C. Nicolle (Eds.), *Inclusive design guidelines for HCI* (pp. 107-122). New York: Taylor & Francis.
- Hogg, J. & Langa, A. (Eds.) (2005). *Assessing adults with intellectual disability: A service provider's guide*. Malden, MA: Blackwell Publishing.
- Holsapple, C., Pakath, R., & Sasidharan, S. (2005) A website interface design framework for the cognitively impaired: A study in the context of Alzheimer's disease. *Journal of Electronic Commerce Research*, 6(4), 291-303.
- Hochheiser, H. & Lazar, J. (2010). Revisiting breadth vs. depth in menu structures for blind users of screen readers. *Interacting with Computers*, 22(5), 289-298.
- Hu, R., Zhu, S., Feng, J., & Sears, A. (2011). Use of speech technology in real life environment. *Proceedings of Human-Computer Interaction Conference*.
- Jacko, J. & Salvendy, G. (1996). Hierarchical menu design: Breadth, depth, and task complexity. *Perceptual and Motor Skills*, 82, 1187-1201.
- Jacko, J., Salvendy, G., & Koubek, R. (1995). Modeling of menu design in computerized work. *Interacting with Computers*, 7(3), 304-330.
- Jaeger, P. (2004). Beyond Section 508: The spectrum of legal requirements for accessible e-government web sites in the United States. *Journal of Government Information*, 30(4), 518-513.
- Jaeger, P. (2006). Telecommunications policy and individuals with disabilities: Issues of accessibility and social inclusion in the policy and research agenda. *Telecommunications Policy*, 30, 112-124.
- Johnson, R. & Kent, S. (2007). Designing universal access: Web-applications for the elderly and disabled. *Cogn Tech Work*, 9, 209-218.
- Karreman, J., Geest, van der., & Buursink, E. (2006). Accessible website content for guidelines for users with intellectual disabilities. *Journal of Applied Research in Intellectual Disabilities*, 20, 510-518.
- Kennedy, H., Evans, S., & Thomas, S. (2011). Can the web be made accessible for people with intellectual disabilities? *Information Society*, 27(1), 29-39.

- Kiger, J. (1984). The depth/breadth tradeoff in the design of menu-driven interfaces. *International Journal of Man-Machine Studies*, 20, 201-213.
- Kirijian, A. & Myers, M. (2007). Web fun central: Online learning tools for individuals with Down syndrome. In J. Lazar (Ed.), *Universal usability: Design computer interfaces for diverse users* (pp. 195-230). Chichester, UK: John Wiley and Sons.
- Koester, H. & Levine, S. (1994). Modeling the speed of text entry with a word prediction interface. *IEEE Transactions on Rehabilitation Engineering*, 2(3), 177-187.
- Koester, H. & Levine, S. (1996). Effect of a word prediction feature on user performance. *Augmentative and Alternative Communication*, 12(3), 155-168.
- Kumin, L. (1996). Speech and language skills in children with Down syndrome. *Mental Retardation and Developmental Disabilities Research Reviews*, 2, 109-116.
- Kuzma, J., Weisenborn, G., Philippe, T., Gabel, A., & Dolechek, R. (2009). Analysis of U.S. senate web sites for disability accessibility. *Review of Business Research*, 9(5), 121-127.
- Larson, K. & Czerwinski, M. (1998). Web page design: Implications of memory, structure and scent for information retrieval. *Proceedings of SIGCHI Conference on Human Factors in Computing Systems*.
- Lazar, J. (2007). Introduction to universal usability. In J. Lazar (Ed.), *Universal usability: Design computer interfaces for diverse users* (pp. 1-12). Chichester, UK: John Wiley and Sons.
- Lazar, J., Feng, J., & Hochheiser, H. (2010). *Research methods in human-computer interaction*. Chichester, UK: John Wiley and Sons.
- Lazar, J., Kumin, L., & Feng, J. (2011). Understanding the computer skills of adult expert users with Down syndrome: An exploratory study. *Proceedings of ASSETS Conference on Assistive Technologies* (pp. 51-58).
- Lazar, J. & Jaeger, P. (2011). Reducing barriers to online access for people with disabilities. *Issues in Science & Technology*, 27(2), 68-82.
- Lee, E. & MacGregor, J. (1985). Minimizing user search time in menu retrieval systems. *Human Factors*, 27, 157-162.
- Lejeune, J., Gautier, M., & Turpin, R. (1959). Etude des chromosomes somatiques de neuf enfants mongoliens. *Comptes Rendus de l'Académie de Sciences*, 248, 1721-1722.

- Lopes, R. & Carrico, L. (2010). Macroscopic characterizations of web accessibility. *New Review of Hypermedia & Multimedia*, 16(3), 221-243.
- Loy, B. & Batiste, L. (1998). Surfing the net: The three keys to universal access. *Proceedings of Technology and Persons with Disabilities Conference*. Retrieved on October 10, 2010 from http://www.csun.edu/cod/conf/1998/proceedings/csun98_011.htm.
- Lund, A. (1997). Expert ratings of usability maxims. *Ergonomics in Design*, 5(3), 15-20.
- Marcell, M. & Falls, A. (2001). Online data collection with special populations over the World Wide Web. *Down Syndrome Research and Practice*, 7(3), 106-123.
- MacArthur, C. (1999). Overcoming barriers to writing: Computer support for basic writing skills. *Reading & Writing Quarterly*, 15, 169-192.
- McGuire, L., Ford, E., & Ajani, U. (2006). Cognitive functioning as a predictor of functional disability in later life. *American Journal of Geriatric Psychiatry*, 14(1), 36-42.
- Miller, D. (1981). The depth/breath tradeoff in hierarchical computer menus. *Proceedings of the Human Factors Society Conference* (pp. 296-300). Santa Monica: Human Factors Society.
- Mulhern, R. (2009). How can I design a recovery-oriented e-learning website for people with mental health difficulties? *Educational Journal of Living Theories*, 2(3), 399-431.
- Myhill, W., Cogburn, D., Samant, D., Addom, B., & Blanck, P. (2008). Developing accessible cyberinfrastructure-enabled knowledge communities in the national disability community: Theory, practice, and policy. *Assistive Technology*, 20(3), 157-174.
- National Association for Down Syndrome. (2008). Facts about Down syndrome. Retrieved on August 25, 2009 from http://www.nads.org/pages_new/facts.html.
- Newell, A., Booth, L., Arnott, J., & Beattie, W. (1992). Increasing literacy levels by the use of linguistic prediction. *Child Language Teaching and Therapy*, 8(2), 138-187.
- Newell, A., Arnott, J., Booth, L., Beattie, W., Brophy, B., & Ricketts, I. (1992). Effect of "PAL" word prediction system on the quality and quantity of text generation. *Augmentative and Alternative Communication*, 8, 304-311.
- Nielsen, J. (1999). *Design web usability: The practice of simplicity*. New York: Peachpit Press.

- Norman, K. & Chin, J. (1988). The effect of tree structures on search in a hierarchical menu selection system. *Behavior and Information Technology*, 7, 51-65.
- Norris, P. (2001). *Digital divide: Civic engagement, information poverty, and the Internet in democratic societies*. New York: Cambridge University Press.
- Paap, K. & Roske-Hofstrand, R. (1986). The optimal number of menu options per panel. *Human Factors*, 28, 377-385.
- Pirolli, P. & Card, S., (1995). Information foraging in information access environments. *Proceedings of Human Factors in Computing Systems Conference* (pp. 51-58).
- Raskind, M. & Higgins, L. (1999). Speaking to read: The effects of speech recognition technology on the reading and spelling performance of children with learning disabilities. *Annals of Dyslexia*, 49(1), 251-281.
- Rehabilitation Act Amendments of 1998, 29 U.S.C. § 794 (1998).
- Roizen, N. (1996). Down Syndrome and an associated medical disorders. *Mental Retardation and Developmental Disabilities Research Reviews*, 2, 85-89.
- Roizen, N. (2005). Down Syndrome. In M. Batshaw (Ed.), *Children with disabilities* (5th ed., pp. 307-314). Baltimore, MD: Paul H Brookes Publishing.
- Rowland, C. (2004). Cognitive Disabilities Part 2: Conceptualizing Design Considerations. Retrieved on October 30, 2010 from <http://webaim.org/articles/cognitive/conceptualize/>
- Rotondi, A., Sinkule, J., & Haas, L. (2007). Designing websites for persons with cognitive deficits: Design and usability of a psychoeducational intervention for persons with severe mental illness. *Psychological Services*, 4(3), 202-224.
- Sears, A., Feng, J., Oseitutu, K., & Karat, C. (2003). Hands-free, speech-based navigation during dictation: Difficulties, consequences, and solutions. *Human-Computer Interaction*, 18(3), 229-257.
- Sevilla, J., Herrera, G., Martinez, B., & Alcantud, F. (2007). Web accessibility for individuals with cognitive deficits: A comparative study between an existing commercial web and its cognitively accessible equivalent. *ACM Transactions on Computer-Human Interaction*, 14(3), 1-15.
- Shinohara, K. & Tenenberg, J. (2009). A blind person's interactions with technology. *Communication of the ACM*, 52(8), 58-66.
- Strover, S. (2003). Remapping the digital divide. *The Information Society*, 19, 275-277.

- Svensk, H. & Johansson, G. (2004). How people with developmental disabilities navigate the Internet. *British Journal of Special Education*, 30(3), 138-142.
- Tam, C., Reid, D., Naumann, S., & O'Keefe, B. (2002). Perceived benefits of word prediction intervention on written productivity in children with spina bifida and hydrocephalus. *Occupational Therapy International*, 9, 237-255.
- Telecommunications Act of 1996, 47 U.S.C. §§ 153, 255 (1996).
- Trnka, K., McCaw, J., Yarrington, D., & McCoy, K. (2009). User interaction with Word Prediction: The effects of prediction quality. *ACM Transactions on Accessible Computing*, 1(3), 1-34.
- U.S Department of Education. (2007). *A Guide to the individualized education program*. Retrieved on April 7, 2010 from <http://ed.gov/parents/needs/speced/iepguide/index.html>.
- Vandenbark, T. (March, 2010). Tending a wild garden: Library web design for person with disabilities. *Information Technology and Libraries*, 22-29.
- Venkatagiri, H. (1993). Efficiency of lexical prediction as a communication acceleration technique. *Augmentative and Alternative Communication*, 9, 161-167.
- Vicente, M. & Lopez, A. (2010). A multidimensional analysis of the disability digital divide: Some evidence for Internet use. *The Information Society*, 26, 48-64.
- Waddell, C. (2006). Overview of law and guidelines. In J. Thatcher et al. (Eds.), *Web accessibility: Web standards and regulatory compliance* (pp. 53-67). Berkeley, CA: Friends of ED.
- Wang, P. (1996). A neuropsychological profile of Down syndrome: Cognitive skills and brain morphology. *Mental Retardation and Developmental Disabilities Research Review*, 2, 102-108.
- Wentz, B., Jaeger, P., & Lazar, J. (2011). Retrofitting accessibility: The inequality of after-the-fact access for persons with disabilities in the United States. *First Monday* [Online], 16(11).
- Wishart, J. (1996). Learning in young children with Down's syndrome: Developmental trends. In J. Rondal, J. Perera, L. Nade, & A. Comblain. (Eds.), *Down's syndrome psychological psychobiological and socio-educational perspectives* (pp. 81-96). London: Whurr Book Publishers.
- Wobbrock, J. & Myers, B. (2006). From letters to words: Efficient stroke-based word completion for trackball text entry. *Proceedings of ACM Conference on Computers and Accessibility*, 2-9.

- World Health Organization. (2011). *World Report on Disability*. Retrieved on July 8, 2012 from http://whqlibdoc.who.int/publications/2011/9789240685215_eng.pdf.
- World Wide Web Consortium. (1999). Web content accessibility guidelines 1.0. Retrieved on August 1, 2010 from <http://www.w3.org/TR/WAI-WEBCONTENT>.
- World Wide Web Consortium. (2008). Web content accessibility guidelines 2.0. Retrieved August 1, 2010 from <http://www.w3.org/TR/WCAG20>.
- Wallace, D., Anderson, N., & Shneiderman, B. (1987). Time stress effects on two menu selection systems. *Proceedings of Human Factors and Ergonomics Society Conference* (pp. 727-731).
- Wheaton, J. & Patrizia, B. (2007). Web accessibility in Europe and the United States: What we are doing to increase inclusion. *Rehabilitation Education*, 21(4), 259-268.
- Zaphiris, P. & Mtei, L. (2000). Depth vs. breadth in the arrangement of web links. *Proceedings of the Human Factors and Ergonomics Society Conference* (pp.139-144).
- Zordell, J. (1990). The use of word prediction and spelling correction software with mildly handicapped students. *Closing The Gap*, 9(1), 10-11.

CURRICULUM VITA

Ruimin Hu
2644 Valley View Drive
Lancaster, PA 17601

Information Technology
Doctor of Science, 2012

Education:

Towson University	2006-2012	D.Sc.
Purdue University	1997-2000	M.S.
Jiangxi University	1987-1990	M.A.
Fujian Teachers University	1978-1982	B.A.

Professional Publications:

Hu, R., Feng, J., Lazar, J., & Kumin, L. (2011). Investigating Input Technologies for Individuals with Down Syndrome. *Universal Access in the Information Society*. November 2011.

Hu, R., Zhu, S., Feng, J., & Sears, A. (2011). Evolving Requirements for Speech Applications: Lessons Learned from Field Studies. *Proceedings of the Human-Computer Interaction International 2011*. Orlando, Florida, USA.

Feng, J., Zhu, S., Hu, R., & Sears, A. (2010). Speech-Based Navigation and Error Correction: A Comprehensive Comparison of Two Solutions. *Universal Access in the Information Society*. May 2010.

Feng, J., Zhu, S., Hu, R., & Sears, A. (2008). Speech Technology in Real World Environment: Early Results from a Long Term Study. *Proceedings of the 10th International ACM SIGACCESS Conference on Computers and Accessibility*. Halifax, Nova Scotia, Canada.

Professional Experience:

Assistant professor 8/2011–Present Anne Arundel Community College, Arnold, MD
Research assistant 8/2006–8/2011 Towson University, Towson, MD
Adjunct faculty 8/2007–5/2008 Elizabethtown College, Elizabethtown, PA
Instructor 6/2001–6/2006 ITT Technical Institute, Mechanicsburg, PA
Research assistant 10/1997–5/2000 Purdue University, West Lafayette, IN
Editor 9/1990–10/1995 Haixia Literary and Art Publishing House, Fuzhou, Fujian, China
Teaching assistant 9/1988–6/1989 Jiangxi University, Nanchang, China
Teacher 8/1982–6/1987 No. 1 High School, Zhangping, Fujian, China

