Understanding the Computer Skills of Adult Expert Users with Down Syndrome: An Exploratory Study

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ABSTRACT
Recent survey research suggests that individuals with Down syndrome use computers for a variety of educational, communication, and entertainment activities. However, there has been no analysis of the actual computer knowledge and skills of employment-aged computer users with Down syndrome. We conducted an ethnographic observation that aims at examining the workplace-related computer skills of expert users with Down syndrome. The results show that expert users with Down syndrome have the ability to use computers for basic workplace tasks such as word processing, data entry, and communication.

Author Keywords
Down syndrome, cognitive impairment, workplace technology, employment, assistive technology, human-computer interaction

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Design, Human Factors, Legal Aspects

INTRODUCTION
Over the last 3 decades, the model of developmental and educational growth for people with Down syndrome in the United States has changed. In the 1970s, many people with Down syndrome were locked in institutions, away from society. They had inadequate cognitive and language-based stimulation and adequate education was rarely provided [16]. Starting in the late 1970s and the 1980s, individuals with Down syndrome were offered the benefits of early intervention programs in speech and language, occupational and physical therapy, and mainstreamed education, where they could learn the academic and social skills necessary to interact with others in society. Change has occurred as a result of legislation, home rearing, and advocacy. However, as individuals with Down syndrome transition into adulthood, career options are limited. Very often, adults with Down syndrome are employed working in fast food cleaning tables, as a janitor, or in landscaping. The employment rate for people with cognitive disabilities in the US is estimated at 17-27%, depending on how you define a cognitive disability such as Down syndrome [23]. Computer skills potentially are useful as increasing numbers of individuals with Down syndrome lead longer lives and attempt to enter the workforce. In our previous research [8, 9], we examined how children and young adults with Down syndrome (age 4-21) learn how to use computers, and what challenges they face. In this study, we observed older, more experienced computer users with Down syndrome, to learn how they interact with computers, and to understand how they potentially could use computers in employment.

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BACKGROUND LITERATURE
There is very little research in the human-computer interaction literature related to people with Down syndrome. The first case study involving people with Down syndrome in computer interface design was published in 2007 [14]. The goal of that project was to build a web site, to help teach computer skills to people with Down syndrome. The project was run by the National Down Syndrome Society, and 6 young adults with Down syndrome (age 16-23) participated in the design. The only other work in the HCI literature that is exclusively about people with Down syndrome, is a survey that examined how children and young adults interact with interfaces [8]. There were 561 responses to the survey, which provides a baseline of information about human-computer interaction for younger users with Down syndrome. Results of the survey document that the majority of children and young adults with Down syndrome can use the mouse to interact with computers, which was previously believed to be challenging for individuals with Down syndrome, due to the spatial, cognitive, and fine motor skills needed. Of the survey respondents, they tended to start computer use very young, with 72% of the children having started using computers by the age of five and more than 80% having started by the age of six. However, text entry on keyboards appeared to be a problem. Only 10.8% of the respondents type using multiple fingers on both hands, and a majority type using only one index finger, or one index finger on both hands [8].

Further analysis took place on the open-ended responses to questions in the survey with 561 responses [9]. Cluttered screen designs, with many animations, seem to be overwhelming for children with DS. Time limits on application responses are often too short, since children with Down syndrome, who may be slow typists, need more time to complete a response. There is often a gap between the skills that children with DS need to learn in an application, and the style used to present the content. For instance, a ten-year old child with DS might need to learn simple mathematical skills that are typical for a six-year old. Most of the programs or games available for him for learning skills are designed with features that have appeal for typically developing, six-year old children (e.g., childish cartoon characteristics with

exaggerated tones and gestures). For a 10-year old child with DS, they will need to learn the skills in an application designed for a typical six-year old, but they still have the stylistic tastes and expectations of their chronological age, and therefore often view educational programs as "uncool." This creates a paradox: children with DS normally outgrow the programs or games that teach them the skills that they need to learn.

According to survey results, due to the typing and memory skills needed, passwords are often problematic for people with DS, especially when security policies require strong passwords (such as a combination of symbols, numbers, and upper and lower case). While there have generally not been attempts to design applications specifically for people with Down syndrome, if there were attempts, they might be challenging, as DS affects multiple channels of cognitive, motor, and perceptual abilities. Furthermore, DS impacts on each of these multiple channels at different levels of severity for each individual, so to make assumptions that everyone with Down syndrome can perform a certain skill is misleading. Even within the Trisomy 21 genotype (the most common form of Down syndrome, with over 95% [19]), there is diversity in cognition, communication, skills, and capability, for reasons that are still not understood [1] ; [4].

While the causes of such diversity within the group of people who have the same genotype is unknown, from the human-computer interaction point of view, the goal is to understand the diversity within the user group as it relates to interaction with computers. Another goal is to understand any potential factors influencing computer skills, which are not related to the genotype, and are instead caused by early exposure to technology, formal computer training, experience, education, personal encouragement, or public policies.

In addition, the skills of individuals with Down syndrome change greatly over time, and the previous survey data was reported by parents of children and young adults, but may not relate to individuals over age 21. Other studies in the HCI literature have included people with Down syndrome in the broader category of "people with cognitive impairments," without noting their specific strengths and challenges. For instance, Hoque (2008) examined computers for measuring speech challenges of people with Autism and Down Syndrome (which only included 1 participant with DS). [12]. Dawe interviewed families of people with cognitive impairment, to learn how and why they adopt assistive technology. This included a combination of 4 people with Autism, 5 people with Down syndrome, and 12 people with unspecified cognitive impairment. [6]. Other research has combined people with Down syndrome and people with other genetic syndromes [4,7]. The broad category of "users with cognitive challenges" or "users with disabilities" is not specific enough for research study, since each group of users with a specific disability has their own set of strengths and weaknesses. In addition, there is generally great diversity of computer skill within users with a certain disability, and of course this doesn't take into account the fact that many individuals have multiple challenges. Therefore, there is a need to consider the challenges faced by a group of people with the same disability label, as well as the need to identify the specific strengths and challenges for an individual with the condition.

Although there is little research literature on HCI issues for people with Down syndrome, there is a large body of literature on people with Down syndrome, as it relates to communication, cognition, fine motor, short-term memory and motor planning skills. While we know little about the computer skills of individuals with Down syndrome in childhood or adulthood, there has been research on the physical and behavioral characteristics of children with Down syndrome, that highlights factors that potentially could impact on computer skills. Research has documented difficulties in the sensory areas of hearing [21] and vision [22]. There are sensory and motor issues related to finger and hand movements including both hyper and hyposensitivity to touch (tactile) and difficulty with fine motor movements [2]. Low muscle tone and weak muscles are often a problem in the arms and fingers, which could impact on keyboarding skills. There also is a wide range of functional abilities in individuals with DS related to the extent of impairment in the various sensory and motor channels [2], memory [5], cognition [27], and communication skills [7]. Auditory memory and sequential recall are also difficult areas for children with Down syndrome [20]. There is evidence for a specific verbal auditory memory deficit, i.e., that it is harder to remember information that is heard rather than read [13].

The characteristics that might affect computer skills in a specific child are also related to coexisting conditions which may be present in that child, such as autism spectrum disorders [3], depression and obsessive-compulsive disorder [18]. These sensory, motor, and mental health issues would need to be taken into consideration when investigating computer usage needs in individuals with DS. The impact on perceptual channels could cause potential problems when the individual needs to use computers or computer-related output devices, such as text or menu items on a screen. The impact on fine motor skills and muscle tone may play a role when the individual uses a variety of input devices such as a mouse, keyboard, touch screen or a trackball. But, research has documented visual memory strength in people with Down syndrome and since computer usage is often still a primarily visual medium, it can be a good match for the strengths and challenges experienced by individuals with Down syndrome [17].

RESEARCH METHODS

Our research plan was to recruit 10 expert computer users with Down syndrome, and do ethnographic observations of their computer skills and usage, in their respective homes or workplaces.

Unlike previous research, which was based on data collected from a survey filled out by parents, this research was based on ethnographic observation of adults with Down syndrome, using computers in their natural settings. We had heard many reports of "expert" computer users with Down syndrome, and had informally observed some of these experienced users. This is a typical progression of research, where exploratory surveys and ethnographic observations take place to gain an understanding of a previously unexplored area of interest, and more structured research, such as experimental design, will take place at a later time once there is a foundation of understanding [15]. Our goal was to observe expert users, and we do not claim that these users are typical individuals with Down syndrome. Rather, we were interested in observing the scope, given the best circumstances, of what was possible for adults with Down syndrome as it related to computer usage.

To start with, we needed to define what qualifies an individual 18 years or older with Down syndrome as an "expert computer user." We used the following qualifications in this study:

1. Has used computers for at least 5 years

2. Uses computers at least 5 days each week

3. Uses the computer at least 10 hours per week

4. Is familiar with email or a social networking site such as Facebook. Uses those approaches to communicate with relatives or friends at least 3 days a week.

5. Is familiar with word processing software.

6. Is familiar with the internet. Uses the web for information retrieval and entertainment purpose on a daily basis.

Note that three categories of applications are included: communication (such as e-mail and facebook), information retrieval (web browsing and searching), and office automation (word processing, spreadsheeting, and presentation software). We believe that these are the core computer skills required for office work.

To recruit participants, we sent out recruitment e-mails to Down syndrome community listservers in Maryland and Virginia. We noted the basic requirements, but asked anyone who was interested to fill out a survey documenting their habits and usage skills. Using the survey, we determined that a number of them would not meet the requirements for this phase of the research, because they did not have the minimum amount of computer experience. For those who did qualify for the research, we observed them using computers, for a minimum of two hours, in their respective homes or workplaces. Many of the observations lasted longer than 3 hours. The study received approval from the Institutional Review Board, and all participants signed an informed consent form before they began participation in the study.

These observations were not strictly passive. We specifically asked participants to show us their skills for web searching, communication (e-mail and social networking), and office productivity applications. We observed skill level with keyboard and mouse, as well as usage of any portable electronic devices. We also interviewed the participants beforehand, about their formal and informal training and education related to technology, as well as their usage of technology in any paid or volunteer employment situations. We did not present specific task lists of steps. We just gave a general category of software application, and asked them if they could show us how they typically used it.

The demographic information of the participants is listed in table 1. The hours per week using a computer listed are inclusive of home, workplace, and public places such as libraries. Of the 10 participants, 7 are female. All 10 participants have outside paid or voluntary employment and use computers everyday. All participants were observed at home except P2, who was observed at her workplace. In all 10 observations, we only took written notes, to be analyzed after the session.

All 10 participants have previously taken formal computer training classes, in either keyboarding, internet searching, e-mail, PowerPoint presentations, MS-Word and Excel, web design, video editing, or a combination of these skills. Some of these training classes began as early as elementary school, and many of these participants took training classes in high school and community college. For example, P6 took keyboarding and MS-Office classes in middle school, and has taken advanced MS-Office application training in college. P9 took keyboarding courses in elementary school, e-mail, keyboarding, and MS-Office in high school, and took additional keyboarding classes at the community college. P10 took keyboarding classes in middle school, PowerPoint classes in high school, and is currently taking college classes to learn how to do video editing.

	Gender	Age	Number of years using computer	Hours/week using computer
P1	F	28	9-10	30
P2	F	38	> 10	30
P3	M	20	> 10	35
P4	F	28	6-8	14
P5	F	28	> 10	35
P6	F	25	> 10	10
P7	F	27	6-8	15
P8	F	23	> 10	25
P9	M	27	> 10	30
P10	M	22	> 10	12

Table 1. Background demographic information for the 10 participants

RESULTS

The participants' everyday usage of computer applications is summarized in table 2. We grouped the applications into three categories: specialized applications (including word processing, Excel, PowerPoint, Database, and calendar); communication tools (including email, instant messaging, Facebook), and security applications (including password and CAPTCHAs). We observed that many of the participants not only are able to use multiple systems, but they jump back and forth between multiple operating systems, computers, and/or devices. For instance, P3 uses three different PCs in the same room (a laptop, and two desktops). P4 uses a Mac, a PC, and a cell phone to text message, and P6 uses both a laptop running Windows 7,and a desktop computer using Windows XP. P9 uses both a Mac laptop and Windows XP desktop at home, and a Windows (unknown version) at work.

Specialized applications

	Word processing	Excel	Power-Point	Data-base	Calendar
P1	√	√	√		√
P2	√			√	
P3	√	√			√
P4	√				√
P5	√		√	√	√
P6	√	√		√	√
P7	√		√		
P8	√	√	√	√	
P9	√				
P10	√	√	√		

Table 2. Use of specialized applications by participants

Word processing

All participants use word processing software very often. All of our participants use multiple fingers on both hands, however, there

is great variability in the speed of typing. All of our participants are familiar with the formatting functions such as bold, italic, and underline. They could insert images and tables into the word document. They understand the 'spell check' function and use it to track spelling errors. For instance, P8 is a very accurate typist. According to an assessment she completed in August, 2010, she types at 29 words per minute with 98% accuracy. P8 commented that the Mavis Beacon typing application helped her improve her typing skills, as did two additional participants. She spent a lot of time on computers in high school and wrote class reports on the computer in middle school. Interestingly enough, both P2 and P9 are very detailed-oriented, and type out entire book and movie manuscripts using word processing. None of the participants were observed using the "track changes" feature in word processing, and in the follow-up interviews, no one indicated using it.

Excel

Five participants use Excel spreadsheets for making check lists, tracking prices, etc. These participants essentially use Excel for the layout features. None of the participants have learned or used any of the mathematical, sorting, or other comparatively advanced functions in Excel. Interestingly, many participants and their parents commented that they haven't used Excel because there has not been a need for it, but they do want to learn it. They believe they can pick up the mathematical or other advanced functions if they need them for work-related purposes.

PowerPoint

Five participants have used PowerPoint for presentations. They understood the basic functions of PowerPoint, such as insert a slide, apply a design template, insert a picture to a slide, create a transition, edit text, etc. P7 is a very frequent user of PowerPoint. She and her friends give PowerPoint presentations to groups about their experiences as young adults with DS. In order to improve her skills, P7 took courses on PowerPoint at a local community college. P10 learned how to make PowerPoint presentations in a high school class.

Database

Four participants have used databases as a part of work. Their interaction with databases is generally limited to searching for, adding, editing, and removing records. For instance, P2 adds and deletes and updates records in the work databases that are used for customer mailing. Their interaction with Database applications only involves data entry or simple search and sorting. P5 will receive piles of papers from her supervisor, with individuals to find in the database. She needs to find a certain e-mail address, then either remove it, or transfer it to another database file. None of them has ever received any formal training in database applications. Their existing skills related to database were acquired through hands-on demonstrations from their family and work colleagues.

Calendar

Five participants use an electronic calendar on their computer to schedule and track their activities. Some participants use a shared calendar with their family, the others keep a calendar of their own. Some forwarded email messages for events that needed to be on the calendar to their parents to coordinate schedules.

Communication tools

Table 3 summarizes the communication and security tools used by participants. All participants state that computers are an important tool for them to communicate with their employers, relatives, and friends. All participants use one or more applications or websites for communication purposes.

Emails

All participants use email as an important communication tool and have multiple email accounts, often on different providers, using different interfaces. For instance, P10 has a Yahoo Mail account, as well as a university e-mail account using iPlanet messenger express. P9 has an AOL e-mail account, as well as an Outlook e-mail account at work. P8 has 3 different e-mail accounts; one is at the university (using iPlanet messenger express), and P8 has two different Gmail accounts (one Gmail account is for work, and one is for friends). P6 uses both a Windows Live e-mail account, as well as a Comcast e-mail account.

They check and answer their emails on a daily basis. Interestingly, the majority of the participants prefer to delete their emails as soon as they read and answer them. Therefore, unlike the inbox of a typical computer user that usually contains hundreds of emails, they only have a dozen emails in their inbox, and some have no e-mails in the inbox. P2 deletes e-mails so quickly, that there's a sign next to her desk at work, reminding her to "read e-mail, but DO NOT delete it." We asked why the participants prefer to delete messages from their inbox. There isn't a unanimous explanation. P9 said that he thought hardcopies are safer than electronic messages. So he prints useful emails and then deletes the emails from the inbox. P6 writes down the content of important emails before deleting them. Some participants delete mail from both their inbox and their sent mail box. P6 immediately goes to the sent-mail folder, and deletes those copies of e-mails, as does P2.

	Communication			Security	
	Email	IM	Facebook	Password	CAPTCHA
P1	√		√	Easy	100%
P2	√	√	√	Easy	100%
P3	√			Hard	100%
P4	√	√	√	Easy	100%
P5	√			Easy	100%
P6	√		√	Easy	66%
P7	√			Easy	100%
P8	√	√	√	Hard	100%
P9	√	√		Easy	66%
P10	√		√	Easy	100%

Table 3. Use of communication and security applications

P7 is another example of a frequent email remover. As soon as she responds to an e-mail, she deletes it, as she doesn't want to have a lot of messages in her inbox. She says she doesn't need to keep old e-mails, because she remembers who she e-mailed. All participants take their e-mail responsibilities seriously, as P7 noted, "When at the ARC, I spend a few hours checking my e-mail, because the more e-mail I can do at the ARC, the less I need to do when I get home."

Usage of mail folders by participants varies. For instance, P8 has 30 different mail folders, but P10 has no mail folders. Some participants created different folders in their email account, but there are very few messages in those folders. It seems that the

participants have not taken advantage of the message organization functions.

It was also mentioned that some of the participants use the telephone more than email because most of their friends prefer using the phone. Many of their friends do not have email access at home. P10 began using email more last summer because he was enrolled in a post-secondary school program at a local university, and most of his friends there used email to communicate with each other when they were not at school.

Instant messaging

Four participants use instant messaging (IM) to communicate with friends and relatives. All of them have a camera so that they can see their friends when using IM. Some participants also use Skype. While we observed, P9 opened Skype, checked who was available to talk with him (an uncle from Brazil was available), and was able to connect, use Skype and converse with his uncle in Portuguese.

Facebook

Six participants have Facebook accounts. Some of them are active Facebook users. They keep in touch with relatives and friends via Facebook. They also like to use the video IM function on Facebook. For example, P1 has 233 friends on Facebook. She sends e-mail, posts status updates, uses the chat facility, uploads photos, and uses games such as Farmville and yoville. She also uses Facebook mobile on her iPhone. Her parents are also on Facebook, and while they read her status updates, they do not know all of her friends and are unaware of the games that she plays. The parents tend to tag and label the pictures posted on Facebook, and P1 then provides comments on them. P4 has two Facebook accounts, one for old friends, the other for newly developed friends, and she spends several hours a night on Facebook. It is a part of her daily social life, and for communicating with family members and friends who are living at a distance, it replaces face-to-face communication. P6 makes sure to login to Facebook every day. P8 is on Facebook, but her mother must personally approve all of her Facebook friends. The mother of P10 indicated that he used to not be interested in Facebook, but this summer, he was more interested because friends in his college program were on Facebook a lot.

The reason for not using Facebook varies, but the primary reason is security and privacy concerns. Multiple parents stated that they don't think Facebook is a good idea for the participant and have instructed them not to use it. For instance, P2 used to use Facebook, but stopped, because her family did not want her to use it anymore. One participant does not use Facebook because of the privacy requirements of her job.

Security-related applications

Passwords

Eight out of ten participants commented that user authentication using user name and passwords is an easy task. All of them have more than one user name and password. To our surprise, unlike many neurotypical users who write down their passwords or save their passwords in an electronic file, the participants we observed typically just remember the passwords without writing them down. For example, P4 used all different user name and passwords for her five accounts (2 email accounts, 1 IM account, 2 Facebook accounts). One of her user names is 14 digits, including both letters and numbers. Two of her passwords are 12 and 14 digits long, respectively. Four of the participants, (P2, P5, P7, and P9) have passwords that they use to access workplace servers and databases at their respective workplaces, in addition to their personal accounts. Two participants commented that they have substantial problems remembering the password. For example, both P3 and P8 save the user name and passwords on their computers so that they do not need to enter them when they log in.

CAPTCHAs

The observation for CAPTCHAs is encouraging. While we were primarily asking participants to show us what they typically do (what tasks, web sites, and e-mail programs), for CAPTCHAs, we specifically asked them to complete a task of the researchers' choosing. We asked participants to answer three visual CAPTCHA tests (available at http://www.google.com/recaptcha/learnmore), although due to the various tasks that the users were showing us at the time, not all of the participants attempted three CAPTCHA tests. We therefore reported in percentage of success in CAPTCHA tests attempted. In order to solve this specific type of visual CAPTCHA test, the user needs to recognize and enter two separate words. Eight participants had a 100% CAPTCHA test success rate. Two participants did have one failed attempt each, when they first tried to figure out how the CAPTCHA works (the participants were not offered the opportunity to train or play around with a CAPTCHA first). For example, P6 had a spelling error on the first CAPTCHA test, but answered the next two correctly. P9 hit enter accidently after only typing one word (two words are needed). On the next attempts, both P6 and P9 were able to successfully complete the CAPTCHA tests.

Use of input techniques

	Key-board	Mouse	Phone keypad	Touch screen	Touch pad	Speech input
P1	√	√	√	√		
P2	√	√	√			
P3	√	√	√	√		√
P4	√	√	√	√		
P5	√	√	√			
P6	√	√			√	
P7	√	√				
P8	√	√				
P9	√	√				
P10	√	√	√	√		

Table 4. Use of input techniques

Keyboard and mouse is the primary input solution for all participants (See table 4 for more data on the use of input techniques). Six participants use a phone keypad for text messaging. Five participants use touchscreen or touchpad. P4 demonstrated how she uses the touch screen of iPhone to text message. She texted using both thumbs quite fast and accurately. One participant has tried speech-based input at some point but is not using it currently. It is very interesting to note that none of the participants are currently using any form of assistive or adaptive technology, such as those often used by people with disabilities.

Use of mobile devices

We also interviewed the participants as to their usage of mobile devices such as cell phones (see table 5 for more data on usage of mobile devices). Three participants access emails via their cellphone. Seven participants communicate with their relatives and friends through text messaging. Four participants use iTunes to download and listen to music.

	Communication		Entertainment	
	Email	Text messaging	iTunes	iTouch
P1	√	√	√	
P2		√		
P3		√		
P4	√			√
P5		√		
P6	√	√		
P7			√	
P8		√	√	
P9				
P10		√	√	

Table 5. Use of mobile devices

Information Searching

All 10 of the participants were frequent users of Google and were comfortable doing keyword searches (see table 6). For most participants, using Google was preferred to typing in a URL or using bookmarks (although P1 indicated her preference for bookmarks, and P6 indicated her preference for typing in the URL). We asked the participants to show us some web sites that they typically visit.

	Google	Facebook	weather/map	youTube
P1	√	√	√	√
P2	√	√	√	
P3	√		√	√
P4	√		√	
P5	√	√	√	√
P6	√	√		√
P7	√			√
P8	√	√	√	√
P9	√			
P10	√	√		√

Table 6. Websites frequently used for information searching

The participants liked video web sites (such as YouTube and Disney Channel), sports web sites (such as the Baltimore Ravens and Washington Redskins), weather web sites (such as weather.com), movie web sites (such as Netflix and local movie times) music web sites (such as iTunes and American Idol) and shopping web sites for pricing comparisons (such as Best Buy, Barnes and Noble, Amazon, Walmart, and Target). A number of the participants also described web sites that they visit in the context of their employment (such as office supply stores and package shipping). The participants adopt various searching strategies when searching within a web site. For example, when searching books in a library catalog, P4 demonstrated four different strategies: search by authors, search by book titles, search by topics, and search by subjects.

DISCUSSION

The results of the current study document the successful use of a variety of applications, communication tools and security applications by adults with Down syndrome. Our findings support that the physical, sensory and behavioral characteristics of adults with Down syndrome can be identified in their patterns of computer usage, e.g. research has shown that individuals with Down syndrome are stronger in visual processing than they are in auditory processing [20]. Although security features such as CAPTCHAs are cognitively abstract, they presented no problems for the participants, who were all able to successfully complete a visual CAPTCHA input task. Research also suggests the obsessive compulsive tendencies of some individuals with Down syndrome [18] and our findings related to deleting emails from the inbox support that characteristic. There is a clear relationship between the characteristics of people with Down syndrome and their specific patterns of usage.

Common Themes Observed

During the study, we observed some common themes among the participants that helped us understand the potential computer related skills that people with DS could achieve, the factors that may contribute to the acquisition of those skills, and how those computer skills could be used in a workplace setting. Obviously, the overall skill level was higher than the average computer users with DS, since we specifically recruited people with a high level of computer skills to explore the potential employment opportunities. Some of the common themes that emerged from the participants included:

- Of the 10 expert users with Down syndrome, all of them used multiple fingers on both hands for keyboard entry, as well as the mouse, with no modifications needed.

- None of the 10 users had any forms of assistive technology or modifications, which is very different from the common expectations that people with cognitive impairments need it.

-Related to security, the 10 users were highly successful when attempting visual CAPTCHAs, which was not expected. The users tended to manage multiple accounts, as well as multiple passwords. However, the strength of password, such as requiring CAPS, numbers, and symbols, may increase the complexity.

- The participants we observed were themselves very observant of the various visual cues in their screen layout, immediately noticing when the laptop battery icon was showing low strength, or when the wi-fi icon was showing a weak Internet connection. Often, the users pointed things out to the observers that we ourselves did not notice.

- Most of the 10 users deleted e-mails very quickly, and kept empty inboxes in their e-mail accounts. Some went as far as to immediately delete e-mail messages as soon as they read them, as

well as delete messages in sent-mail right after they were sent. We have been investigating the research literature on behavioral issues in people with Down syndrome, and the findings from others point to people with DS having a high occurrence of obsessive-compulsive disorder and related conditions.

- Most of the 10 users utilized computer skills in employment settings, although it was sometimes in unpaid employment rather than paid employment.

- All 10 participants had taken formal computer classes, at some point in their lives, and most participants had taken multiple computer classes at various stages of their education. Even when formal education was complete, many participants continued to sign up for computer skills classes at a local community college.

Implications

Implications for computer users with Down Syndrome: One of the mantras that we heard from these expert users with Down syndrome was that formal training and practice were important. All of these expert users had taken formal computer training classes in their lives, and most continue to take computer classes on an ongoing basis. Social support may also be important. For instance, some of the expert users had other friends with Down syndrome who were online, and that encouraged them to improve their computer skills. There was one example where a participant wasn't using email and facebook, but once the participant made friends who were online more often, it encouraged them to spend more time online.

Implications for policymakers: Implications for policymakers can generally be separated into implications for design policy and implications for education and employment policy. For design policy, the topic of users with Down syndrome needs to become a part of discussions on accessibility design. The general category of cognitive impairment in design is a tricky one. While the new 2.0 version of the Web Content Accessibility Guidelines does briefly mention cognitive impairment, there aren't many descriptions of how to design for it, and certainly, there are no mentions of Down syndrome [26]. While the advisory board (TEITAC) that provided suggestions for how to redesign the United States Section 508 guidelines actively discussed cognitive impairment in development of the draft version of the new Section 508 design guidelines, there was concern about whether design rules for cognitive impairment should be included at all, since they were "too broad, not measurable, and thus impossible to achieve" and therefore, suggestions for design for cognitive impairment did not make their way into the draft version of the new section 508 [24].

In terms of education and employment policy, there need to be policy changes that encourage formal computer skills education for individuals with Down syndrome, as well as evaluation of and job training for employment that utilizes computer skills. There are often unwritten or not well-publicized policies that limit participation of people with cognitive impairment in information technology employment. For example, some state rehabilitation agencies have policies stating that people who do not have a documented IQ of 90 or above cannot participate in computer skills training, regardless of their existing computer skill level. And in the K-12 environment, students with cognitive impairments are often not given the opportunity to take computer classes which they would benefit from [10].

Implications for researchers: More research needs to be done to understand the diversity within user groups who have the same disability label. "Cognitive impairment" itself is a very broad label, but even within people who have the same genetic syndrome (e.g. Down syndrome or Fragile X syndrome) there may be great diversity in computer skill. The story told from this research on computer usage by adults with Down syndrome is very different from the 2008 survey of children with Down syndrome [8]. Challenges that were prevalent in the 2008 survey (such as problems with typing and security features) were not an issue with these expert users. More research needs to continue, on understanding how people with Down syndrome interact with computers and web sites, and how their patterns of usage (and specific strengths and weaknesses) change as they age. Furthermore, between the large survey and the ethnographic observations, there may now be enough existing research to create experimental design research involving people with Down syndrome.

Implications for designers: For expert users with Down syndrome, it does not appear that there need to be any modifications of interface features, for most of the software applications observed in the study. These expert users were generally fine using the same design as users without any impairments. However, this finding should be interpreted with caution for two reasons. First, the participants had to go with the current design because there was no 'cognitive impairment friendly version' of any of the applications that we investigated. If an application with accommodation were available, it is possible that the participants might be able to spend less time learning the application or might achieve even higher performance. Second, we did observe tasks and applications that some participants did not accomplish or master, such as formulas in spreadsheets, and many functions in database applications. With potential training in these areas, and the opportunities to use these skills in employment, it is very possible that the expert users with DS would be able to learn these skills [10].

Although all of the expert users were generally effective typists, the typing speed might be slower than expert users without any impairments, therefore, existing design rules (such as paragraph p of section 508 web design rules—"When a timed response is required, the user shall be alerted and given sufficient time to indicate more time is required") [25] for accessibility, while not specifically addressing Down syndrome, might also be helpful for expert users with Down syndrome.

Designing for accessibility generally means designing for flexibility, but that doesn't necessarily mean design that provides specific features for a specific disability. For instance, while a number of authors had postulated that blind users, since they use primarily audio output instead of visual output, would prefer narrow, deep menu hierarchies to broad, shallow menu hierarchies, data collection found that blind users, like most users, prefer broad, shallow hierarchies [11]. While the younger users with Down syndrome in our previous survey had trouble with passwords and the gap between the cognitive skill level and the presentation style, neither one of those seemed to be a problem with our older expert users.

CONCLUSIONS

This study shows that some individuals with Down syndrome are capable of acquiring the basic computer knowledge and skills that would be appropriate for office work. This finding is important in that it substantially broadens the potential career opportunities for individuals with DS. Designers, researchers, policymakers, and people with Down syndrome should investigate the impact of this research on their work. For instance, users with Down syndrome should attempt to get more formal training with computers, and

policymakers should support this. Researchers must investigate the diversity of computer users with Down syndrome, and in the future, experimental empirical data would be helpful. Rehabilitation specialists should consider and assess computer skills when assisting individuals with DS in searching for jobs. Future research will need to move towards a more detailed understanding of the diversity of computer skills among people with Down syndrome, examine the workplaces, and how workplace tasks can match the specific skills and strengths of people with Down syndrome.

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