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Preface

The Center on Disabilities at California State University, Northridge is proud to introduce the inaugural volume of the *Journal on Technology and Persons with Disabilities*. This is a published proceeding from the Annual International Technology and Persons with Disabilities Conference, representing submissions from the Science/Research Track presented at the 28th event held February 25 – March 3, 2013.

In 1985, Dr. Harry J. Murphy sought to support the study and practice of technologies and people with disabilities, with an initial emphasis on science and research, by founding the Annual International Technology and Persons with Disabilities Conference (CSUN Conference). In those days, information and communication technology and assistive technology were viewed as "handicraft" and experiments by dedicated researchers. The CSUN campus was the first conference meeting place which focused on supporting the development of a like-minded community representing the many associated fields. It became an integral stop for everyone who wanted to be involved with the best and the brightest. With each passing year, the CSUN Conference became further positioned as the premiere meeting venue for practitioners, educators, researchers, government officials, and assistive technology solution providers and recipients.

The Center on Disabilities at CSUN is proud of sponsoring an event, for almost three decades, that highlights the realities facing those living with disabilities and the many possibilities which facilitate the full inclusion of individuals with disabilities. Over the years it has become a major global platform for meeting and exchanging ideas, now attracting more than 4,000 participants annually.

Reflecting on the past, it is apparent that a vital component of Dr. Murphy's initial vision was missing from the CSUN Conference experience: a journal publication of the great work brought forth at the conference. For years we encouraged, welcomed, and respected the network of authors who made CSUN their destination for exchanging, discussing, and presenting their research and development. This journal provides a tangible medium to demonstrate these exciting and inventive ideas and proposals that we have come to expect from our stakeholders.

We were pleased and surprised at the overwhelming response to the first call for papers for the Science/Research Track introduced in 2013. A program committee consisting of a panel of more than 30 highly-qualified peers from around the world expertly and equitably reviewed the submission by more than 60 leading researchers and academics. Those submissions of the highest caliber were accepted for presentation and publication.

With a clear focus on scientific excellence, this new Science/Research Track at the conference illustrates how CSUN is committed to involve scientific researchers from around the world to fulfill its mission to be a platform of exchange with full cooperation and support of all stakeholders. The new *Journal on*

Technology and Persons with Disabilities allows these innovative contributions to live on beyond the confines of the conference.

We are grateful to those who advised and guided us to meet this publication goal. Thank you to each of the authors, the Science/Research Track review panel, the Center on Disabilities team at CSUN, and the editorial staff for their professional support in bringing the *Journal on Technology and Persons with Disabilities* to life. We are continually grateful to the many participants and partners who have contributed to the Annual International Technology and Persons with Disabilities Conference throughout the years.

Welcome to the inaugural volume of *The Journal on Technology and Persons with Disabilities*; we hope you enjoy our endeavor. Your continued support of the Center on Disabilities at CSUN and the annual conference moves us a step further in our pursuit of positively changing the world for people with disabilities.

Klaus Miesenberger
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Evaluation of Learning Systems for Blind Users

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Abstract

Academic institutions around the world are utilizing and investing in online learning management systems. While several research studies have examined the functionality of this type of technology, little attention has been paid to accessibility issues, in particular to the complex web-based interfaces for learners with disabilities--e.g., those with visual impairment. There is also no standardized method for evaluating accessibility features of a learning system. The approaches that are mostly used among practitioners and educators are based on accessibility guidelines or experts' judgments--without direct input from actual users. This results in a lack of user-subjective perspectives. In order to fill in the gap, this research investigated accessibility features of an online learning management system, based on the experiences of learners with visual impairment. Three data collection methods were employed: observation through usability tests, questionnaires, and focus groups. This study contributed to our better understanding of the interactions and experiences of visually impaired learners with online learning management systems. Furthermore, the research findings were applicable to issues of accessibility of a wider range of applications, particularly web-based information systems.

Keywords

Web accessibility; visual impairment; user experience; evaluation methods

Introductions

Education in the 21st century is heavily influenced by the emergence of new information and communication technologies and services. An online learning management system (LMS) is one type of information management tool that has been widely adopted in both distance education and on-site, traditional classrooms. Several research studies have examined the functionality of online learning management systems (Alonso et al, Asiri et al), but little attention has been paid to accessibility issues, in particular to the complex web-based interfaces for learners with disabilities. Consequently, instead of facilitating learning for this group of students, technology can become an obstacle to them. Students or learning system users with visual impairment are a population that is most disadvantaged in terms of accessing and utilizing educational technologies. Statistical data indicate that the number of blind students enrolled at the college/university level increases every year, but the technologies have not improved at the same pace. It is critical to ensure that educational materials, including those offered through online learning management systems, are accessible and usable by this growing group of learners.

This study was aimed at obtaining data that can be used to improve the accessibility of online learning management systems for students with visual impairment. Therefore, the researcher intended to test an online learning management system with learners who are end-users of the tool.

Research Goals and Methods

This research proposed evidence-based research into the design of accessible online learning management systems (LMS) for students with visual impairment. The main objective was to investigate the current functionalities and tools of such systems, in respect to accessibility issues, as well as the experiences of this group of learners. Based on this goal, the study involved four stages: evaluation, observation, exploration, and analysis. To carry out these stages of the investigation, a computer training course at an academic institution was used to facilitate the study. Eighteen subjects who had visual disabilities and were enrolled in the course were recruited and asked to use the designed online learning management system (Modular Object-Oriented Dynamic Learning Environment or MOODLE version 1.9) throughout a training course (Fig. 1). Subjects were required to be at least 18 years of age and needed to be experienced screen-reader users. The 18 participants were between 18 and 30 years of age, and there were an equal number of males and females. They were in different years of college and different fields of study. All participants were undergraduates, with the exception of one graduate student. All of them used the Job Access With Speech (JAWS) as screen reader technology with varying degrees of experience. Furthermore, 9 students had experience in using an online learning system. Among this group, 3 students had experience using MOODLE as the learning management platform in their universities.

Fig.1. Screen shot of the course page in the MOODLE.

Several methods were employed for data collection - i.e. observation through usability test, post-questionnaire and semi-structured group interviews. For the user testing sessions, subjects were paired to work collaboratively on the assigned tasks; they were encouraged to talk and discuss with each other when they encountered any problems. A walkthrough script was created to test only some typical features of the MOODLE standard package that were deemed appropriate to the course content. These selected modules/features were homepage, profile, messages, forums, chats, assignments, quizzes, and grades.

All user tests were conducted at the beginning of the training course in a computer room equipped with computers and screen reader technology. Acer Aspires with Intel Core 2 Duo CPU 2GB RAM, 500GB HDD, running Microsoft Windows 7 Professional 32-bit version and Job Access with speech (JAWS) v.13 were used throughout the testing sessions and the whole training course. Participants were allowed to modify the speech output speed to their liking to make it similar to how they typically interact with a computer. The browser used for the study was Internet Explorer 9.

The basic performance matrix was added to each task in order to investigate the relative effectiveness of each module. Task accuracy and task completion were used as the scheme of measurement. At the end of the testing sessions, participants were asked to fill in the questionnaire and participate in group interviews. These preference data were compiled and analyzed together with the notes from user testing observations to enhance understanding.

Results

Findings indicate that the majority of users could successfully complete the tasks, although with a different rate for each module/feature. Messages is the module where most tasks were completed (96%) while Discussion Forum received the lowest rate of task completion (81%). On the other hand, findings of the task accuracy or error counts revealed that the Discussion Forum was the module where users made the most errors (41%) while Messages was the feature where users made the fewest errors (4%) (Please refer to Fig. 2 for the summary of results). A Pearson product-moment correlation coefficient was computed to assess the relationship between the rate of task completion and total errors. There was a negative correlation between the two variables, r = 0.713, n = 8. Overall, increases in rate of completed tasks were correlated with decreases in rate of errors made.

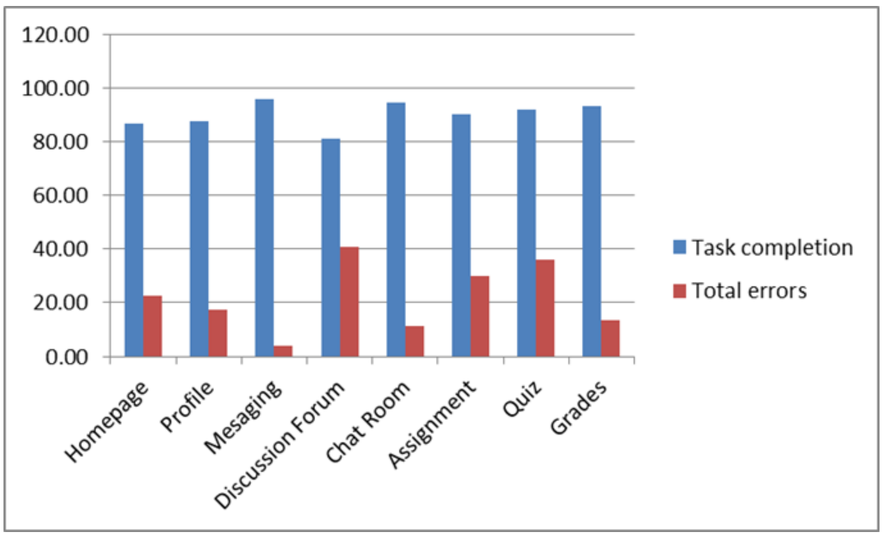

Fig. 2. The rate of task completion and error counts

Findings from the post-questionnaire and group interviews supported and clarified the results from user testing observation. They revealed that although users had a rather positive impression of overall features of the MOODLE system (4.1 on a scale of 1 to 5, with 5 being the most positive), they felt that some features were not easy to use. Clarity of the labeled sections and relevancy and conciseness of the page content received the highest ratings, 3.76 and 3.75, respectively. On the other hand, navigation of the application screen received 3.36, the lowest rating (see tables 1 and 2).

Table 1 Average rating of overall impression of each module/feature

	Homepage	Profile	Messages	Discussion Forum	Chat Room	Assignment	Quiz	Grades
Average Rating	4.22	4.13	4.11	4.25	3.80	4.25	3.80	3.89
Standard Deviation	0.548	0.641	0.928	0.463	0.789	0.463	0.789	0.601

Table 2 Average rating of each component

	Availability of menu function up to expectations	Ease of navigation of application screen	Clarity of button function	Clarity of menu function
Average Rating	3.62	3.36	3.64	3.53
Standard Deviation	0.152	0.090	0.178	0.250

Table 2 (continued) Average rating of each component

	Well-organized buttons	Well-organized menu items	Relevant and concise page content	Good page structure with logical sections	Clearly labeled sections with apparent functions
Average Rating	3.59	3.71	3.75	3.73	3.76
Standard Deviation	0.169	0.145	0.202	0.235	0.220

Major issues that influenced the use of MOODLE by blind users are summarized in the following paragraph.

Design problem

This includes general design issues that often result in participant confusion, such as the location of navigational items, save/submit buttons, form fields, and confusing layout/links. An example of this design problem was the final buttons on Quiz modules that were difficult to find.

Users had to spend a long time finding the last three buttons on a quiz page until they reached the bottom of the page.

Form control issues

This includes unlabeled form controls, binding between labels and form control, ambiguous text area and formatting toolbar, or losing cursor focus after pressing a certain key inside the text area (e.g. backspace and return keys). An example of these form control issues was the editor that is available in several modules (e.g. Forum, User profile, Assignment, etc.) The editor's formatting toolbar and the text area were unlabeled and inaccessible, and hard to control using a keyboard. Despite the provision of editor shortcut keys, none of the users were aware of this. They all had problems when trying to locate the text area at their first attempt and were unable to do any formatting with their content.

Mouse only/Flash/JavaScript issues

This includes mouse-overs for accessing any content, situations where JAWS cannot access certain form controls, inaccessible mouse-only flash content, alert dialog boxes, cascading or popping up windows, etc. An example of these issues was the popup window notifying users of new incoming messages. This notification window would automatically appear after a user logged in to the MOODLE; however, JAWS cannot access it and users failed to get the message immediately. Blind users had to intentionally access the specific page in order to check their messages.

Table issues

This refers to tables without headers and the ones that are poorly coded/labeled, making it difficult for participants to know what each cell in a row stands for. It also includes tables with unnecessary blank cells, mainly for a decorative purpose. An example of these table issues was the Homepage in which users had to locate their course. "List of categories" in the tabular format was difficult to understand by blind users. It contains a table with two columns: a category name and the number of courses in that category. There were no labels or column headings to help users understand what those columns represent.

JAWS issues

These are problems observed from the way JAWS reads form content. These include JAWS not reading page content or content in other languages, reading out of sync with cursor position, no confirmation of actions performed (e.g., file attached, new page ready, radio button checked, etc.). An example of these JAWS issues was an uploading feature in some of the modules (e.g. Assignment and Profile). Users submit their works by uploading their files to the system. However, after a certain file had already been browsed and was waiting to be uploaded, JAWS failed to read the name of the selected file that displayed in an edit field. Consequently, it was difficult for users to make sure that the file was the correct one. Moreover, there was no prompt signal when the file upload completed. Users had to arrow up and down to check the status of the uploading process.

External/cascading window issues

This refers to activities opened in multiple tabs or windows, which caused confusion to participants. An example of these issues was when entering the Messages page: a separate page was always open in the new window. Similarly, if someone wants to send a message, a new window would be opened when clicking on the name of the recipient. Most users were confused when working on several windows opening at the same time. They often got lost and did not know how to get back to the starting page. Or, sometimes users accidentally closed the original course page and had to login to the system again.

Complex ordering commands

This refers to activities that require participants to perform a number of steps in order to complete a task. An example of this problem was a tag block within the blogging feature. The blog page (categorized under User Profile) is basically comprised of 4 menu items: "Add a new entry," "View my entries," "Blog preferences," and "View site entries." Moreover, users can customize their page by adding other modules/features, one of which is "Tags" that allows a list of tags to become visible on this same page. As part of the customization, users had to click on "Turn editing on" to toggle between these settings. This button is in the center position of the page that is easy to see. However, blind users had no idea of this placement and did not quite understand its function. No one could make any additional setting changes and easily locate the assigned tags.

Labeling/instructional problem

This includes no instruction or title on certain pages or sections of a learning module, confusing instruction, confusing/misleading labels, unclear label or instructions, confusing positioning of instructions or guidelines for completing a task. An example of this problem was the "Edit my submission" label in the "online text" assignment. "Online text" is one type of assignment in the MOODLE that provides a single large text area for users to fill in and submit for grading. Before getting to the text area page, users were required to click on a button labeled "Edit my submission. " All users had problems understanding this button and couldn't relate this to the assignment. Users typically reacted by wondering why they had to click on "Edit my submission" even though they had not completed the task before.

Discussion and Conclusion

This study examined the accessibility of the MOODLE, an online learning system, to 18 blind students through usability testing observations, questionnaire, and group interviews. The findings revealed that the MOODLE system was rather accessible for users who are blind. However, some modules/features were still hard to use. Most of the problems, as listed in the previous section, can be improved with minor technical changes by following the Web Content Accessibility Guideline 2.0 (Web Accessibility Initiative). Transcoding is a general concept of transforming content or a program on the fly in an intermediary server, producing other formats (Harper and Yesilada). An application of transcoding techniques can also address some issues, particularly when implemented along with the Web Accessibility Initiative (Accessible Rich Internet Applications). For example, the technique of page rearrangement can be applied to solve the confusing button labels in the Quiz module. Despite this fact, there are also several items that are not covered by the guideline (e.g. an ambiguous label in the online text assignment). This is supported by the previous studies suggesting that accessibility guidelines are not the only component to promote access to web-based application system for users with disabilities (Power et al). Therefore, the usability testing of Web-based information systems should include individuals with disabilities in order to verify that an interface can be used by all individuals. Apart from the design specifications, it is worth noting that although subjects have the same type of disability-visual impairment, their methods of web navigation and interaction are somehow different, hence, resulting in their preferences.

This research is broader than a single study of accessibility evaluation of an online learning management system; rather, it is a contribution to a research stream that attempts to better understand the learner's experiences and interactions with the system. At the same time it aims to help clarify the difference between the rhetoric and the reality. Anecdotal information proclaims benefits of educational technology that can support all learners. For students with visual impairment, the topic of accessibility is still an issue that requires further empirical study. Moreover, future investigations of accessible learning systems could include the more general application domain. The implications of these research findings could be applicable to a wider range of applications, including most web-based information systems. In addition to application design, through multi-methodological approaches this study will enable the researcher to investigate user experiences that take place in an online learning management system in a more rigorous and empirical manner, which will positively contribute to the disciplines of accessible e-learning and information accessibility in general.

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Navigable, Customizable TTS for Algebra

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Abstract

To improve accessibility of math expressions for students with visual impairments, our project employs MathML and the products MathType and MathPlayer to provide an improved style of synthetic speech called ClearSpeak. This paper describes the project's background, the essential features of ClearSpeak, and results of the first feedback study with students that show for the tested notations, ClearSpeak was superior to the two pre-existing speech styles in MathPlayer (SimpleSpeak and MathSpeak).

Keywords

Math, MathML, Audio, Text-to-speech, Blind, Algebra

Introduction

Our IES funded development grant R324A100355, *Expanding Audio Access to Mathematics Expressions by Students with Visual Impairments via MathML,* addresses the math accessibility gap for students with visual impairments. We are developing improvements in text-to-speech assistive technology to make math expressions encountered in secondary school Algebra, as well as instructional material and assessments containing such expressions, accessible via synthetic speech and interactive navigation. This type of audio access can be used along with on-screen visual access to the document or with printed or brailled versions of the document, or it can provide previously-unavailable access for those who are using neither braille nor vision.

The IES development grant enhances the widely used MathType math authoring tool and the MathPlayer visual and audio rendering plug-in for Internet Explorer. The project has four main components:

1. Create a semantically rich speech style (ClearSpeak) for secondary-school algebra-level math expressions that uses language that is familiar to students to speak the expressions
2. Enhance authoring tools within MathType to allow customizable speech for math expressions
3. Enable speech of mathematical expressions from within Microsoft Word
4. Develop interactive within-expression navigation

The design of the ClearSpeak speech style and the way navigation works will be guided by several feedback studies and the final result will be the subject of a pilot study. This paper discusses the results of the first feedback study comparing ClearSpeak to the two pre-existing speech styles, SimpleSpeak and MathSpeak.

Background

Currently, math expressions are notoriously difficult to access using any form of audio (Bouck and Meyer 44). Among the reasons for this are their often-complex structure and lack of consistency in audio rendering. Moreover, math's non-linear two dimensional presentation in print provides important information about an expression’s structure that is more difficult to convey using linearly-presented speech. For example, $\frac{x}{3} + \frac{3}{x}$ shows the cancellation possibilities more clearly than do ${}^{x}\!/_{3} + {}^{3}\!/_{x}$ or the words “x over three, plus three over x.” Significant problems for audio math, including middle and high school algebra, include detecting boundaries (e.g., where fractions, exponents, roots, etc., begin or end) and tracking expressions involving nested parentheses.

Although teachers frequently develop electronic text-only documents for student use, mathematical material is usually inaccessible because math expressions and figures are typically represented by images. In addition, although over the last few years MathML has begun replacing images to represent math expressions in some documents, screen readers don’t currently know how to read MathML directly. They depend upon either pre-existing, custom written translations of math expressions to words (“alt text”) or Design Science's MathPlayer plug-in for Internet Explorer.

The first part of the project is aimed at developing a new, consistent, and familiar semantically rich speech style for MathPlayer that we call ClearSpeak. The development of ClearSpeak is informed by the results of earlier projects aimed at developing rules for human- or computer-spoken math. In the 1950s, Nemeth began developing a way of uniquely linearizing a mathematical expression for speech that mapped one-to-one to the Nemeth Braille Code he also developed. He initially developed this speech style for working with aides/readers so that he could write braille immediately as the reader spoke each part of the expression. Many years later, Nemeth worked with gh, LLC to formalize this into the MathSpeak™ speech style.

Another early set of human-speech rules was developed by Lawrence Chang. A practicing blind scientist, he developed the speech guidelines (“Larry’s SpeakEasy”) for his aides/readers. In the spirit of Chang’s rules, but enhanced for the requirements of high-stakes testing, ETS test developers developed a mathematical speech style for scripting tests and test preparation materials for recordings and for use with live test readers. This speech style uses pauses plus familiar language and syntax so that examinees are not forced to learn a new “language” at testing time. In the 1990s, development of computer generated math speech began with ASTER (Raman). ASTER uses prosodic cues (i.e., pauses plus changes to pitch, rate, volume, and voice) among other parameters to speak expressions in a more concise manner than MathSpeak. Design Science developed its MathPlayer plugin to speak with the user's choice of its simplified ("SimpleSpeak") style or a version of MathSpeak. It uses some prosodic speech cues, but screen reader support for these has been very limited to date. Others have also worked on computerized speech (MathTalk (Stevens, Edwards, and Harling 47-92), MathGenie (Karshmer Bledsoe, and Stanley 614-19) and auditory cues (Murphy, Bates, and Fitzpatrick 75-82)), but none of those systems were widely used.

Speech Styles

A speech style governs computer-generation of speech. Design Science’s MathPlayer interprets MathML and, since it stores its rules and vocabulary externally as plain text files, it can work with any speech style that can be expressed using its rule-based pattern matching language. Prior to the current project, MathPlayer supported two speech styles:

- SimpleSpeak – common, simple expressions such as $\sqrt{x}$ are spoken simply; begin/end bracketing is used for disambiguating the start and end of more complicated expressions
- MathSpeak – maps 1-1 to Nemeth code with exceptions for some common expressions such as “x squared”

ClearSpeak is designed to improve on the existing speech styles by speaking math in a way that will be familiar to most students--the way teachers and other content providers speak math to them--but with adjustments to that customary speech to make sure the spoken math is unambiguous. Unfortunately, adding words to disambiguate expressions tends to increase the verbal and memory load and so tends to make spoken expressions harder to understand than the print versions of those expressions. ClearSpeak seeks to minimize this tendency by extensive use of pauses (which do not increase verbal load), by using language that integrates well with the expression, and by “translating” print conventions into their mathematical equivalents if a sighted reader of the print version would do so instantaneously (e.g., reading an exponent as “to the power” rather than as “superscript”)--thus removing an obstacle to understanding not encountered by sighted readers. For example, ClearSpeak refers by default to “power” rather than to “super,” “superscript” or “baseline.” Finally, since in different contexts or for different audiences it is desirable to have the same math structure speak differently, ClearSpeak provides three mechanisms for speaking them in a way that is appropriate for the intended purpose: default speech rules, author preferences, and exact speech.

Rules

Speech rules are the standard or default way for speaking math structures. The speech is based on information that can be parsed from the MathML representation of the expression/object. MathPlayer analyzes expressions based on types of structures present in the expression (fractions, exponents, parenthetical expressions, radicals, etc.), the level of complexity, the subject area, and the user's stated level of expertise. Based on that analysis, rules are invoked for speaking the expression, and the resulting speech information (including prosodic information) is supplied to the speech engine. In addition, rules include specifications of how various symbols (raised dot, set membership, etc.) are to be spoken. For expressions currently lacking a ClearSpeak specific implementation, the SimpleSpeak rules are applied.

Example: Simple fractions, defined as those with a single integer or variable in the numerator and in the denominator, fall into two cases:

1. Speak as a common fraction (e.g., "three quarters") if the numerator is a positive integer less than or equal to 19 and the denominator is a positive integer less than or equal to 10. E.g., $\frac{5}{7}$ is spoken as "five sevenths".
2. Otherwise, speak as '[numerator] over [denominator]'. E.g., $\frac{6}{21}$ is spoken as "six over twenty one," and $\frac{x}{8}$ as "x over eight."

Preferences

Sometimes, identical expressions may need to be spoken differently because of contextual differences, to resolve ambiguities, or for instructional or assessment purposes, so rules can and will not generate the appropriate speech in all cases. We provide a system of pre-defined preferences that authors of math documents can set to produce commonly encountered alternatives to the speech generated by the rules.

Example: The rules would speak $\frac{12}{15}$ as “twelve over fifteen,” but an author can invoke a preference to force it to speak as “twelve fifteenths,” as “the fraction twelve over fifteen (pause) end fraction,” or as “the fraction with numerator twelve and denominator fifteen.”

Exact Speech

For cases in which the developed rules and preferences do not produce the desired speech, authors can insert exact wording, plus additional pauses or changes to pitch, volume, or speech rate, if desired. Exact speech can be applied to the entire expressions or to parts of it.

Example: $\frac{x^2 + y}{3x} + 4$

The rules would speak this as “the fraction with numerator x squared plus y and denominator 3x (pause) plus 4.” If the teacher wants to lengthen the pause before “plus 4” to make it even clearer that the 4 is not part of the denominator of the fraction, exact speech could be used to lengthen the pause or else to insert “the integer” before “4”.

Initial ClearSpeak Evaluation

Setup

Our first feedback study, conducted in March 2012, compared the initial implementation of ClearSpeak with the two styles already built into MathPlayer (MathSpeak and SimpleSpeak). The 15 high school students who completed the study were blind (7) or had low vision (8), and were taking Algebra 1 or a subsequent math class. A questionnaire gathered background information such as how they accessed math (screen reader, human reader, etc.) and their proficiency with various mathematical concepts relevant to the study (fractions, exponents, parentheses). The study itself consisted of instructions and samples, plus seven math expressions. A slightly different version of each expression was created in each of the three speech styles (ClearSpeak, MathSpeak, and SimpleSpeak), and the expressions in each speech style were combined into a section, so that each student received one section for each speech style.

The math expressions were provided as pre-recorded text-to-speech (TTS) audio using Microsoft Anna. After each expression a set of math and behavioral/affective questions was developed to assess how clear, familiar, and helpful the speech was in understanding the math expression and whether the student was able to understand what the expression was, *not* whether the student was able to simplify the expression or solve a problem based on the expression. Additional feedback was requested asking for suggestions to improve the speech and how much the student liked or disliked each style. A sample expression and math question are below:

Sample Expression: $16x^9 + 12x^{13} + 5x^7 + 1$

Math Question for the Sample Expression: “What is the biggest exponent in the math statement?”

Quantitative Results

Table 1 summarizes average scores on four measures: students’ comfort with the speech (favorability), confidence that they understood what they heard (confidence) and that they answered the math question correctly (math confidence); and actual correct answers to math questions (correct math response). The averages shown are based on each student’s response to several questions related to each math statement.

Table 1: Results of speech style tests

	ClearSpeak			SimpleSpeak			MathSpeak		
Measure (range)	All	Blind	Low Vision	All	Blind	Low Vision	All	Blind	Low Vision
Favorability (0 to 6)	4.75	4.92	4.61	3.25	3.96	2.62	2.96	3.65	2.36
Confidence (0 to 3)	2.64	2.53	2.73	1.87	2.04	1.72	1.64	1.85	1.46
Math Confidence (0 to 5)	3.92	3.80	4.03	2.68	3.45	2.00	1.88	2.86	0.95
Correct Math Responses (0 to 1)	0.89	0.91	0.88	0.70	0.78	0.64	0.56	0.67	0.46

As Table 1 indicates, ClearSpeak outperformed the other styles on all measures. One-way ANOVA found significant differences among speech styles on each of the measures: favorability [$F(2, 312)=32.21$, $p<.01$], confidence [$F(2, 312)=20.51$, $p<.01$]; math confidence [$F(2,177)=19.36$, $p<.01$]; and correct math response [$F(2, 44)=9.17$, $p<.01$]. Post hoc Bonferroni comparisons indicated that ClearSpeak performed significantly higher ($p<.01$) than both MathSpeak and SimpleSpeak on all four measures. Additionally, it was found that achieving a higher number of correct answers is significantly associated ($p<.05$) with higher favorability, confidence, and math confidence scores.

After the audio was recorded and testing began, a bug that caused some extra words to be used in some MathSpeak expressions was discovered. This likely contributed to students' difficulty with MathSpeak: several students mentioned the faulty phrasing as being confusing. However, those complaints were also consistent with objections to several other aspects of MathSpeak, so it is unlikely that the bug had a significant effect on the results.

Qualitative Results

Although we have seen an overall preference for and better performance with ClearSpeak, students had varying opinions on pauses, speed, terminology, parentheses, and the verbalization of "times" in expressions where the "times" is implied by parentheses (e.g.,

$2(x+3)$). They seemed more united on a preference for the language of "powers" rather than that of "super," "superscript," or "baseline." Eight students explicitly objected to "super" or "superscript", and four objected to "baseline." Two mentioned "to the" and three mentioned "power" positively. Some did not know what these terms meant. Many did not care for the TTS voice used to record the speech: Microsoft Anna. Anna is tuned to speak regular text and has prosodic and pronunciation difficulties with math. Future studies will make use of the Eloquence voices that are commonly used by Window-Eyes and JAWS users. These do not try to be as natural sounding and do not make as many assumptions about word flow as does Anna and hence do a better job speaking math expressions. Screen reader users tend to prefer these voices because they can be used at high speech rates and still be understood.

Conclusions and Future Work

The first study showed that for the tested notations, ClearSpeak was an improvement over SimpleSpeak and the MathPlayer implementation of MathSpeak. As a side benefit, based on the results of the study, several features of ClearSpeak such as the use of "power" instead of "super" were added to SimpleSpeak after the first study, and the MathSpeak bug was corrected.

Having concluded that we were on the right track with ClearSpeak, our second study will focus on prosody and speaking nested parentheses. Initial work has narrowed our prosody changes to pausing and rate changes. These will be compared against the speech that uses words to indicate the start and end of fractions, roots, or other structures. For expressions with nested parentheses, we are experimenting with rate changes, pausing, and using different words for open and close parentheses to help students determine and remember which close parenthesis matches which opening parenthesis. GW Micro, a project partner, is integrating this work into their Window-Eyes product; many other companies have expressed interest in integrating their products with this work when the development is mature.

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Development and Study of AAC Application of Communication for Autistic Children

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Abstract

"Let's Talk!" is a new AAC (Augmentative and Alternative Communication) application for personal digital assistance for autistic children. This new and remarkable application has many particular advantages compared to existing AAC. We especially focus on an easy and simple manipulation. By tapping a symbol on a screen of a PDA with this application, a user can show his/her thoughts with pictures and sounds to others easily. There are 2 modes that can be switched depending on different situations of users. It has 120 symbols based on daily life and a user can also modify the original page with new icons made by pictures or sound. A user also can customize an original page by arranging icons she or he made or existing symbols. On the newest version of this application, we added Task Schedule System to stimulate motivations of children to do something on their own. In the last part of this study, we show some case studies. We introduced this application to students in a school for handicapped children.

Keywords

Autism, VOCA (Voice Output Communication Aid), PDA (Personal Digital Assistant), AAC (Augmentative and Alternative Communication)

Introduction

Many autistic children tend to have verbal communication disabilities, so they need some support tools to express their thoughts or needs. Some assistant applications for PDA (Personal Digital Assistant), such as Drop Talks, Voice4u, and Tap to Talk, aim to help autistic children who have communication disorders already diagnosed. Those communication assistant tools are called AAC (Augmentative and Alternative Communication) or VOCA (Voice Output Communication Aid). Although many studies about VOCA have been made and school educational fields have adopted these tools, they have not come into general use because of the high price and complicated operations. Therefore, we tried to develop a new communication assistant tool for PDA with simple and easy manipulation at a low price. We spent half a year to develop the application from October 2010 and finally released "Let's Talk!" in April 2011 on the iTunes Store. After we launched the app, we have modified and updated it 14 times within a year referring to data from schools for handicapped children or requests from users through ICT infrastructure.

Purpose of the study

There are some characteristics of autism as below:

1. Disorder in developing sociability
2. Disabilities in developing speech and communication ability
3. Repetition of same behavior and attachment to something

Because of these characteristics of disorders in developing sociability, it is very difficult for some autistic children to relate with others. Picture cards have been used to support communication for autistic children. But autistic children do not understand they need to show the card to someone who will fulfill their needs. In most cases, teachers show the cards and make the children choose one. The autistic children did not get enough successful experiences with this method, so their communication ability was not improved.

In 1985, Dr. Andy Bondy and Ms. Lori Frost developed PECS (Picture Exchange Communication System). They pointed out the problems of the existing picture indication system as, “The system does not teach children to be interested in people but pictures,” and “The system ignores the approach for people which is a part of communication.” But PECS also has some other problems. A user carries “a communication book,” which is a note with picture cards. The more new words a user is gaining, the more picture cards he/she needs to carry. It would take much time to find a card he/she needs or to make new cards.

If an autistic child uses PDA as a communication tool instead of those picture cards, he/she can reduce much time and effort to make or find cards. A user can create symbols by himself/herself that are suitable to his/her situation. It is a great advantage of the application in increasing new vocabularies.

Construction of the system

Usability of the application

We focused on a simple manipulation without complicated explanation to develop this application. The reaction area is wide and the volume of the voice and sound is very clear and loud enough to be able to hear outdoors or in a crowded place such as a classroom. These distinguishing characteristics will let handicapped children use those AAC more easily. They can communicate with others whenever and wherever by using pocket-able PDA without carrying a special piece of equipment. It is also expected that the unique contents of this application may create a chance to communicate with others. Autistic children will be accepted in the society by communication with the application, and it will increase the quality of life for them.

Two modes of the application

There are 2 modes on this application. First, on "Supportive Mode," a supporter who helps a person who has a disability starts communication. Second, on "Self-use Mode," a person who has a disability can show his/her request by voice with this application. By switching the modes depending on different situations of users, more effective communication will be expected.

Stamp Mode

On the newest version of “Let’s s Talk!”(iPhone / “Let's Talk!” AppVersionNumber 4.0 June 10, 2012), we added Stamp Mode. On this mode, you can make a chart with a goal. A child gets a stamp whenever he/she has done what they need to do. For an autistic child, it is easy to understand how many stamps they need to reach a goal. When a child achieves a goal, fireworks or fanfare will appear as a prize. It would be effective to give children the motivation to complete the chart to get these special prizes. Autistic children will get good influences through experiences of being able to do something by themselves repeatedly. It will help them to develop autonomy and independence and create motivations through trying anything on their own efforts.

Experiments at School for Handicapped Children

Introducing the application on an experimental basis was carried out at Miai Yogo School, a school for handicapped children. This application attracted the attention of most of the children, and they really enjoyed using it. They liked cartoon-like characters and were interested in the operation since it looked like a game for them. Some of the children who had never talked before started to communicate with teachers or parents with the application. It is obvious this application had great effect on those children with speech disorders. We collected data about the correlation between “Let’s Talk!” and the behavior of a child through observation.

Case study 1

The subject of investigation

8 year-old boy with autism who does not have the ability to speak.

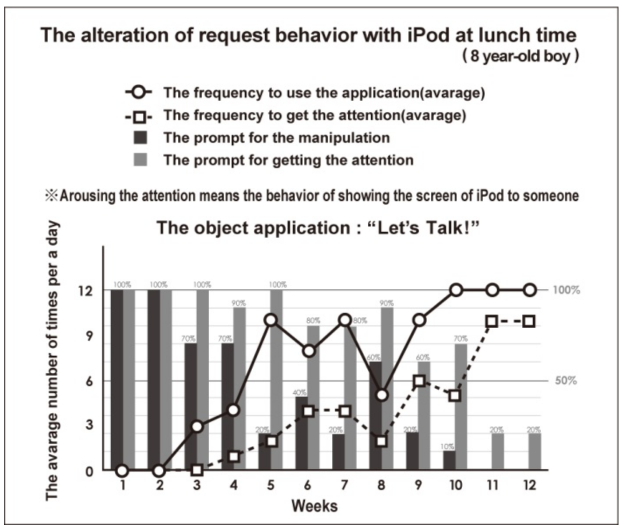

Fig. 1. The Alteration of Request Behavior with iPod at Lunch Time (8 year-old boy)

Table 1 The Alteration of Request Behavior with iPod at Lunch Time (8 year-old boy)

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
The frequency to use the application (average)	0	0	3	4	10	8
The frequency to get the attention (average)	0	0	0	1	2	4
The prompt for the manipulation	100%	100%	70%	70%	20%	40%
The prompt for getting the attention	100%	100%	100%	90%	100%	80%

Table 1 (continued) The Alteration of Request Behavior with iPod at Lunch Time (8 year-old boy)

	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12
The frequency to use the application (average)	10	5	9	12	12	12
The frequency to get the attention (average)	4	2	6	5	9	9
The prompt for the manipulation	20%	60%	20%	10%	0%	0%
The prompt for getting the attention	80%	90%	60%	70%	20%	20%

This student tried to tell his teacher he wanted to have another plate at lunch with the application. His teacher divided his lunch into 12 small portions and gave one of them at a time to urge him to ask for a refill as a training in communication. Figure 1 shows how his behavior changed when he started to use this application. The dark bar graph shows how many times the teacher taught him the manipulation of this application. The manipulation is divided into 5 levels.

1. To get the iPod
2. To release the lock of the iPod
3. To start “Let’s Talk!’
4. To choose an icon
5. To show it to someone

Autistic children will learn 1 to 4 quite easily, but they will not understand 5, which means that they need to show the screen to someone if they want their requests satisfied. The light bar graph shows how many times the teacher told him to get the attention of others. It is very difficult for the children to understand that they need to get the attention of other people if they want to communicate. So the teacher’s support was needed more than 50% until the 10th week for this boy. The solid line graph shows how many times he actually used this application. The dashed line graph shows how many times he tried to get the attention of his teacher.

It is clear that his motivation to communicate with the teacher had been increased by using the iPod with this application. His classroom teacher reported that he often had offensive movements, such as scratching or spitting at other students since he got in the school. But those behaviors decreased dramatically after he started to learn how to express his thoughts to others in a proper way with this application. Lately, he tries to start communication with PECS (Picture Exchange Communication System) and the iPod to let others to know his requests or needs.

In this case study, it is considered that the student is satisfied as his teachers understood what he needed, even if his requirements had not been fulfilled. It is important that he knows someone understands his requests and empathizes with him. Many teachers of the school said most of the children seemed to enjoy their life at school more after introducing this application.

Case Study 2

The subject of observation

11 year-old-boy (M in this report)

He was diagnosed with autism when he was 3 years old and has a severe mental disability. He did not speak. When he needs something, he will take another person’s hand and move it to the thing he wants to get. He eats only certain foods and did not eat school lunch almost at all when he was in 1st grade. He was able to eat something little by little, but still left about half of the portion when he was in 3rd grade. He sometimes attacked someone around him, for example kicked friends or teachers, when he was in 1st to 3rd grade. He cried out suddenly, ran around, stamped his foot or kicked someone around him when he became a 4th grader. He became interested in cell phones that his parents had when he was in 3rd grade.

Process of Development

In April, 2011, M touched the iPad for the first time. We gave it to him with “Let’s Talk!” on the screen. He understood that the screen would change when he touched it immediately. And he also got the idea that there were some screens that created sound when he touched them.

In May, 2011, he started to use the iPod, which he preferred for convenience to carry around, for lunch time. He began to show the words such as “Can I start?” “Reduce some of this, please.” “Can I have some more?” and so on with iPod that had some applications. He learned how to use those applications quickly when we taught him. In late May, we took pictures of the lunch menu and saved them in “Let’s Talk!” as original symbols. M showed what he did not like to eat when he saw the pictures. At this point, he did not try to arouse someone’s attention.

In June, 2011, he began to start the application quickly. He also became to be able to use other applications on the iPod. He erased the menu he ate with the To Do application and told us “Reduce some of this, please” with “Let’s Talk!” He started to arouse someone’s attention by tapping his/her shoulder or arm.

In September, 2011, he got used to the manipulation of the application. He even became able to create original symbols by himself. He added symbols of the way to go back home (a school bus or parents picking him up) by capturing images from the picture library.

In November, 2011, he began to be able to use some other applications besides “Let’s Talk!” He worked on his project, confirming the process with “Task Schedule.”

In February, 2012, M has been using “Let’s Talk!” less often lately. He uses his gestures to tell us simple requirements. If the person he tries to tell his request to cannot understand his gesture, he uses pictures in the iPod, which he always carries around or types limited words he knows on memo function. He seems to choose the suitable way for the situation to communicate. He sometimes makes voice sounds to get someone’s attention, which he had never done before this observation.

Summary of Observation

Before we started this project, M could do something only with someone’s indication and reply only yes or no if he was asked something. We tried to introduce PECS (Picture Exchange Communication System) to him, but we could not continue the training for supporters and his level stayed on Phase 2 (it is the phase a child can request even if he/she stays away from a supporter or picture cards).

He could understand how to use “Let’s Talk!” and what he can do with it by himself without any special training in a short period of time. He felt comfortable when someone sympathized with his emotion even if his request was not satisfied immediately while he learned the joy of communication with this application. He also became able to understand the situation when he needed to wait till someone finished what he/she was doing at that moment.

We believe that repeating the experiences of communicating with others stimulates the desire for communications and arouses initiative. It is obvious “Let’s Talk!” is useful in raising communication ability.

Conclusion

We developed a new communication assistant tool with PDA, “Let’s Talk!,” for autistic children. If autistic children feel the joy of communication by using this application, they will be strongly motivated to try to understand others’ thoughts.

On the report from the school for handicapped children introducing “Let’s Talk!” on an experimental basis, this application attracted the attention of most of the children and they really enjoyed using it. They liked the cartoon-like characters and were interested in the operation since it looked like a game for them. Some of the children who had never talked before started to communicate with teachers or parents with the application. Especially, it is very interesting that one of the children who had repeated self-injurious behavior, which some of the other children had made terrible fun of him for, tried to explain the problem with the application, then he stopped hurting himself. The most important thing is the application brought a lot of smiles to all the children. It is obvious “Let’s Talk!” had great effect on those children with speech disorders.

This application may have much possibility to be used by not only by autistic children but also people who have problems of communication because of some diseases, such as pharyngeal cancer, cerebral palsy from a stroke, or senile dementia. We believe this application will help all people with or without any disabilities to live a better life. And we also think if people can communicate with each other regardless of disabilities, it will provide new human resources and encourage developing a society where people support each other.

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Adjusting Typographic Metrics to Improve Reading for People with Low Vision and Other Print Disabilities

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Abstract

A new software technique called typometrics is presented. This enables users to choose a wide range of typographic metrics to assist reading. A software implementation called TRx (Typometric Prescription) is described. TRx is a style authoring tool for web languages. Designed for use by assistive technology (AT) specialists and users with print disabilities, this software enables users to create personal reading environments with all the range of style available to authors of documents. The article concludes with a description of a three part study planned to collect baseline data for implementing typometric interventions to improve reading.

Keywords

Low Vision, CSS, Text Customization, User Centered, Reading, Assistive Technology

Introduction

People with print disabilities have limited employment opportunities because they cannot read professional literature in standard print effectively. When text is only available on paper, there is no way to alter the appearance of a printed document. By contrast, Web languages like Hypertext Markup Language (HTML) with Cascading Style Sheets (CSS) have created near total flexibility for digitally-rendered text (Shea). This means that the historical ecology that created standard print (Legge and Bigelow 14-18) can now be extended via digitally-rendered text to include non-normal readers. This can be achieved by giving this neglected group user-centered access to typographic metrics ("Text Customization"). This access should support user preferences and remain semantically faithful (Dick). Prior to this project, no comprehensive instrument existed to collect and record the preferred typographic metrics for people with low vision and other print disabilities. With the style authoring tool TRx, users and researchers can explore the value of adjusting typographic metrics to improve reading.

Discussion

Review of Literature

Typometric software techniques: 1) adjust the typographic metrics of text to create customized text for individuals with print disabilities, and 2) preserve the semantic cues provided by the typography of the original document format. Typographic metric adjustment provides access to text in formats that remove barriers that exclude people with print disabilities ("Text Customization"). Semantic preservation provides equal access to all information conveyed in the presentation of the document (Dick).

By definition, ophthalmology cannot treat, and optometry cannot correct low vision ("Low Vision"). While low vision optometrists can provide lens systems to improve how well a client sees print, these corrective devices are seldom robust enough to support the reading needs of working professionals who suffer from low vision. For effective intervention, one must change the text being read, not just how well one sees it.

Printed text on paper cannot be changed. While people with normal vision are served well by this medium, people with print disabilities are excluded entirely or at least effectively. Legge and Bigelow (14-18) show that the size of running text in publications converged to a value just above the critical print size (CPS) of normal readers. CPS is the smallest size one can read at maximum speed. Their study examined print size in publications since Gutenberg. Font size was driven by what the authors define as an ecology involving technology, reader preference and printing cost. When print was new, the text size was as close to the critical print size as technology permitted. As technology improved, the size of running text decreased, but it only dipped below the critical print size of normal readers when the nature of the content required smaller print (e.g. stock exchange reports).

One unspoken fact emerges from the Legge-Bigelow study. People with print disabilities were excluded. The present authors assert that other typographic metrics like font families and spacing were shaped by the same ecology. The inflexibility of print on paper forced rigid conformance to the reading preferences of normal readers in order to sell paper publications.

Document semantics are based on two dimensions, content and presentation ("Info and Relationships"). Content is the actual text and images created by the author. The presentation is the appearance of the document structures that contain content. Document structures include paragraphs, headings, lists, citations and many more. The visual rendering of these structures conveys their usage. The presentation of content reveals the author's organizational model to the reader. The content within document structures and the way structures are presented convey meaning. If one is looking for a particular citation in a document, one only needs to scan for text presented in citation format instead of reading the entire document. Without these presentational cues, professional articles are difficult to read. A typometric transcription of a document may change the typographic metrics, but it will create a visual presentation that is semantically equivalent to the original (Dick). The document will not look like the original, but visual differences between elements are preserved. This enables a reader who needs typographic transcription to customize a document to fit their reading needs, yet perceive the same organizational model the author intended (Dick).

Customizing typographic metrics would be impractical without the World Wide Web and its content markup language HTML, and presentation style language CSS. Since the style of a document is housed by one component, the CSS code, and content is housed by another, the HTML code, the view of a document can be customized to meet any individual's needs just by changing the CSS style and leaving the HTML content constant (Shea). This separation of content and presentation makes customization on a mass scale practical.

Using CSS, spatial metrics like spacing and border size can be customized to an accuracy of less than 1/3 millimeter. Colors can be chosen from a palette of 16 million, and virtually all major font families can be rendered ("Cascading"). The readers excluded from the ecology that produced standard print can now be included with web technology.

Enlargement of text has long been provided in numerous forms: lens magnification, closed circuit TV and screen magnification (Zimmerman, Zebehazy, and Moon 192-238). The first typometric tool was WebAdapt2Me by IBM ("IBM"). This was a comprehensive system, based on user testing, that identified font-size, font-family, line-spacing, letter-spacing, column format and color as typographic metrics that users could choose to adjust to improve reading (Hanson 4-6). WebAdapt2Me did not address semantic preservation, but it did provide the first significant user access to typographic metrics. Hanson’s user testing showed a strong preference for control over font size, spacing, margins size and font-family.

The user preferences observed by Hanson are supported by psychophysical data that show positive improvements in reading resulting from adjustments to typographic metrics (Legge). Moreover, Russell-Minda et al. (405-12), in their survey of research on legibility of text, confirm the strong relationship between typographic metric adjustments, reading performance and user preference. McLeish (35-40) demonstrated that small increases in letter spacing (+0.1 to +0.5 above normal spacing) improved reading speed.

The Typometric Prescription (Style Authoring Tool) —TRx

When optometrists use the phoropter to perform refraction testing, they make small changes in how the client sees a fixed sample of text by repeatedly switching lenses. They use client reports of how well the client sees the sample text to direct the refraction process until a lens prescription is reached. When assistive technology (AT) specialists use TRx to select a reading environment, they follow a similar process. This test begins with a client whose vision is corrected as much as possible. How well the client sees is the fixed point. Only the typography varies. Through a sequence of changing formats the AT specialist uses client reports to converge on a textual reading environment the client prefers. We call the result the client’s *reading profile*. For both optometrist and AT specialist the client’s declaration of satisfaction is the end point of the process.

The TRx instrument presents each user's style choice visually on the computer screen. The user adjusts the style parameter like font or border size by clicking on buttons labeled *more* and *less*. Each change appears immediately on the screen in a sample area. The user is never asked to supply a numeric value for a typographic metric. Instead, users only respond to what looks right to them. A sequence of choices (*more* or *less*) gradually converges to a profile. The process is like the choices an optometrist relies on for refraction testing.

The TRx instrument allows full access to all of the styling parameters available to a document author: font (family, size and boldness), spacing (letter, line and word), color (background and foreground) and box model (margins, padding and borders). One can continue changing parameters until maximum readability is reached. Since TRx is accessible to users with print disabilities, the user can change the reading profile or make new profiles with TRx after the initial session with an AT specialist.

TRx includes a collection of document formats to help users start the process. Additionally, TRx provides a full book sample, so that users can test their reading profile in a realistic reading environment. TRx reading profiles can be produced in a variety of electronic formats depending on need. A CSS coded version of the reading profile can be applied to HTML content code in order to create a presentation in the user’s preferred format.

An Initial Study

Our initial study of the TRx software will gather baseline data on how to use typometric modifications to aid reading. It will consist of three parts: 1) collection of demographic data, 2) evaluation of individual adaptations to reading, and 3) observation and support for using typographic metric adjustment to improve reading.

We will initially study college students with low vision (visual acuity: 20/60 to 20/400). Enrollment in college implies that reading is an essential life function. Only students registered with the Disabled Students Services Office (DSS) at California State University, Long Beach (CSULB) will be selected. Enrollment in DSS indicates willingness to seek help.

The demographics that interest us are medical and academic. We will collect the following data: medical diagnosis, visual acuity, visual field, color perception, and whether low vision is congenital or acquired. We will also collect academic data: major, scores on standardized exam, entering GPA, university GPA, matriculation institution, and the services the student requests from DSS. An initial contact with CSULB DSS office provided an estimate of twenty-five students that fit the target population.

In the second study, we will collect quantitative visual reading functionality data using measurement instruments like the MNREAD (Legge 167-85). We also will collect qualitative data obtained from interviews. Our qualitative data will focus on the accommodation strategies that allowed these students to succeed in their academic studies.

The data from the second study will help us implement the third study, the typometric intervention, in a way that disrupts the students' lives as little as possible. All of these students have developed personal strategies to survive with a disability in a difficult academic environment. We will be asking them to modify their survival strategy, and that can be disruptive even if it provides improvement. Based on individual information we have gathered, we will customize an intervention strategy that minimizes disruption. We will provide students with weekly support sessions. While these are primarily for support, we will collect qualitative data based on our interactions.

The goal of our three part study is to assess who is helped, how typometric intervention fits into a general student success strategy, and how the negative side effects of changing reading strategy can be minimized.

Conclusion

Our study will not address the ultimate question: does typographic metric adjustment improve professional reading for people with low vision and other print disabilities? This question has many facets, but one central question is this: does typometric adjustment improve reading stamina? Stamina is a critical barrier to most readers with print disabilities. Comfort level while reading has a significant impact on reading stamina. Can typometric adjustment reduce headaches, nausea and posture difficulties associated with reading with print disabilities? Our baseline studies should give us guidelines so that we can identify some of the essential variables.

A complete answer to the ultimate question may take years. Our team invites researchers to use TRx to improve reading for people with print disabilities. At present, assistive technology for low vision appears to be stalled at screen magnification. Hopefully this research will expand the choices of assistive technologies for many people with low vision and others with print disabilities.

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ATLab: An App-Framework for Physical Disabilities

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Abstract

New touchpad- or tablet-devices are available at a reasonable price and have the potential to grant access to digital learning contents for training and therapy also for disabled people. In particular, these new technologies and interaction concepts offer possibilities to realize a better and more efficient access to digital teaching contents for people with learning disabilities, limited motor skills and speech impediment. In this paper we describe the ATLab Project which is funded by Research Studios Austria. The main goal of this project is the development of a flexible and easy system for the specific production of applications on current available tablets (ePads) for disabled people.

Keywords

Physical Disability, Graphical User Interface, Alternative Input devices

Introduction

The WHO estimates that about 15% of the human population suffers from disabilities. Most of these disabilities are limiting a person's effectiveness and/or efficiency of interacting with objects in general. Nowadays, the majority of inhabitants in developed countries use electronic devices such as cell phones or computers in their everyday lives to achieve their tasks easier and faster. Therefore, these days effective interaction with this type of device is an obligatory requirement in working life as well as in private life.

Applications running on tablets show considerable potential to support the needs for this group:

- Natural input: new learning content through multi-touch, advantage of gross motor activity
- Mobility: not fixed, low battery consumption
- Application domains: Learning, communication, games, controlling of environmental systems
- Variety of hardware: hardware suiting the person's special needs, easy inclusion of alternative input devices like external switches, eye-tracking, gesture recognition, etc.
- Costs: Low price and purchase costs

Touch-based interaction in many aspects and situations can also simulate AT devices or provide flexible and affordable alternatives to AT devices mentioned above. Furthermore, a huge amount of various tablets are available and even more with an increased level of features will come on the market in the near future. According to *The Guardian*, tablet computers will see an explosion in sales over the next years, selling 60% as many units as PCs by 2015 (Platus Learning System).

Today's common mobile devices offer built-in accessibility features like multi-touch screens, screen magnification and speech output functions, which are intended first to support people with disabilities but also support all users in varying contexts and situations on the move. However, often the built-in accessibility functions are not sufficient. Especially people with motor disabilities are often incapable of operating applications on mobile device with the built-in touch functionality.

This is the point where the research project Assistive Technology Laboratory-short ATLab-comes in. The main goals of this project are a) the inclusion of AT pointing devices in tablet interaction by motor and/or cognitive disabled people and b) the development of a flexible and easy-to-use framework for the design of specific applications for disabled people on currently available tablets.

State of the Art

Today, we can find only a rather limited offer of applications on mobile devices like tablets which are accessible and provide support for alternative input methods. Back in 2002, Myers et al. used the Palm handheld as input devices for motor impaired people. They modified some hardware (e.g. stylus) and software (e.g. onscreen keyboard) and collected data in a user study. As time has gone by, other applications have enabled users to access small onscreen keyboards available on smart-phone technology by allowing touch to pass through the letters of a target word. Many smart phones incorporate voice control and screen reading programs to increase accessibility for those with fine-motor and/or visual and literacy deficits (Jackson and Mappus).

For people with severe physical disabilities, switch scanning access for mobile applications is beginning to emerge. Switch scanning is a special method of Human-Computer

Interaction (HCI) where the focus of the application moves automatically in a predefined order and predefined or user defined time span (e.g. using a hardware-switch) from one control to the next. Pressing another switch triggers an action on the currently focused control. On the iPad some applications like Sounding Board support switch scanning already (AbleNet Inc.).

Other popular alternative input methods for people with motor disabilities like head- and eye-tracking or a brain-computer interface are not yet possible on these devices (Jackson and Mappus; Myers). If all the above mentioned input methods were supported in these applications, complexity and effort would increase accordingly (Farrall). Due to the lack of a framework supporting the process of development of these kinds of applications, standard apps need to be enhanced or rewritten.

ATLab-Framework Overview

ATLab implements a software framework for an easier and quicker development of accessible applications for people with disabilities on the most common mobile platforms: iOS, Android and Windows 8.

The framework expands the normal way of touch interaction and allows building applications that offer the user a wide range of different and adjustable input methods:

- Natural input: Multi-touch gestures in touch-up or touch-down mode
- Switch Scanning: External input device with one or two buttons connected via Bluetooth or USB
- Touch Scanning: Divides the touch screen into one or two parts that are used as switches

This enables the user to select the best way of interaction with the application. As an example, normally when the user touches the screen, an application instantly triggers an action, which makes it hard to operate for people that suffer from a disability that causes unintended movements of the hand like tremors. To deal with this issue the framework also allows configuring a hold-timer and blocking-timer. The hold-timer triggers the action only when the finger touches the screen for a user-defined period of time. User interactions which might be caused by unintended touches are filtered out. The additional blocking-timer defines a period of time where any user input is blocked.

The framework also defines a scan-matrix, which enables the user to control the application by scanning controlled with Bluetooth-or USB-Switches. At the moment the framework supports 1-and 2-Button scanning. There are plans to extend to more buttons. Besides the standard way of scanning, the framework also introduces a new way of switch scanning called “touch scanning.” This concept uses the whole screen of the mobile device as a switch. A touch on the right-side of the screen moves the current focus to the next scan-object whereas a touch on the left-side of the screen triggers an action on the currently focused object. This allows switch scanning without the need of extra hardware.

Due to the component-based design of the framework, new methods and tools of Human-Computer Interaction (HCI) employing other input devices like the Microsoft Kinect and the upcoming LEAP can easily be integrated in the Microsoft Windows version of the framework (LeapMotion Inc.; Fager et al.).

Another component of the framework is the ScreenNavigator, which is in charge of the construction and deconstruction of the screens and handles the flow through the application. Therefore it uses a predefined XML document which describes all available screens and offers logical statements as sequences and switch-by conditions. It is also possible to modify the screen list on the fly.

The framework also hosts an editor that allows an easy creation of new game content with a user friendly interface. With this, persons without experience in programming are also able to create game content for everybody.

Cloud services integrated in the framework provide user account management which allows users to create a cross-application user account. A user profile which contains input device settings and other configurations is bound to that account. Once the user profile is created, it is available on all applications and all devices, which makes life easier for care attendants. In addition, the cloud services provide data exchange and storage consumption management to keep track of cloud user data storage and multimedia data sharing. The services also allow controlling data access by means of different roles to map a teacher-pupil relationship.

First Application and User Study

The goal of one framework-based application, SwitchTrainer, is to learn handling the one- or two-button switches. It supports switch scanning and touch scanning as implemented in the framework. Furthermore, it provides a game-like learning application supporting the development of skills in touch up/down mode with the touch screen.

Fig. 1. Some Screenshots of Switch Trainer

The target group of the game is children with motor disabilities and perhaps also cognitive disabilities. The screen-by-screen game without opponents and time restrictions contains multiple mini games inviting the user to get to know the input devices by one own's initiative using a trial and error approach.

We used this application as the basis for the first user study of our framework. A group of 9-16 year olds with certain disabilities were selected as test participants. The tests in this user study were based on the methods of the qualitative content analysis by Philipp Mayring, and the description for data analysis described by Sharp et.al. should prove the usefulness of the different input methods which are currently implemented in our framework. Depending on the user's disability a consultant helped the user to find his or her preferred input method.

A first conclusion of the study was that all input methods are suitable for the respective group of people with disabilities. Depending on the user’s disability some input methods are more suitable. Users that were able to touch the screen but did not possess the accuracy to hit a button exactly favored touch scanning as it is a more intuitive and direct approach than scanning with external hardware-switches.

Another result of the user studies was that some users preferred different input methods depending on the task they had to fulfill within the application. For tasks where less touch precision was needed some users preferred to operate the application with touch input. For tasks where a high level of precision was required, users preferred scanning to control the input. A further research question would then be whether the framework could automatically detect the user’s abilities with respect to the precision needed for a specific task and would then automatically switch to the preferred input method and settings.

The overall feedback of the participants in the user test about the framework and the application based upon it was quite promising and encourages us for our future work.

Conclusion and Outlook

The proposed framework focuses on integrating different input devices including Assistive Technologies (AT) and intense developer support for tablet games for people with disabilities. ATLab supports i) an easy integration of various input devices, and ii) game and content design.

In the next steps, more features will be added to the framework and another game will be implemented. Those features include a user management system containing roles and access control e.g. for teacher-pupil or advisor-client constellations. The management features are part of the cloud implementation which stores the application data together with the user and device profiles/configurations. This enables the user to employ the same settings and profiles for different games and applications. The cloud service also supports sharing and distributing content, images and videos between users, teacher and pupils, or advisor and clients. As a long-term goal, we intend to implement multi-player functionalities allowing competition and cooperation amongst users.

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Developing the Capabilities of Blind and Visually Impaired Youth to Build and Program Robots

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Abstract

In this paper, we discuss the use of accessible technologies for exposing visually impaired students to the science of robotics using real world, hands-on activities. The purpose of the initiative stemmed from the current lack of engineering and robotics related extracurricular programs, activities, and resources offered to blind and visually impaired youth. Discussion of the technologies and our approach is presented in this paper and validated through a national outreach effort with visually impaired student populations.

Keywords

Visually Impaired Youth, Robotics, Accessibility

Introduction

Students living with various disabilities need exposure to real world situations and should be given such opportunities early in their education to stay competitive in the world arena of science, technology, engineering, and math (STEM). Educators that work with students with disabilities need new and exciting, accessible learning models that bring these students closer to real world learning scenarios to expose students with disabilities to careers in science and technology. Despite a student's particular disability, all students should have exposure to hands-on science and technology environments that prepare them for real world applications.

Currently, there are only a small number of efforts that are deployed to engage students with disabilities in the fields of computing and robotics, including the National Center for Blind Youth in Science, the AccessComputing Alliance and Project ACE which provides resources to prepare youth with visual impairments for higher-education and computing career opportunities (Bech-Winchatz and Riccobono; Access Computing; Ludi and Reichlmayr). In addition, there are a few individual efforts that have utilized robots to facilitate learning for students with physical impairments (Howell, Chipman, and Stanger; Cook et al.). Our efforts differ from other related projects in its attempt to engage students with disabilities by focusing on accessible interfaces for robot programming. We aim to deliver computing and engineering content via robotics as a delivery mechanism while providing infrastructure to engage pre-college level students in the classroom environment.

This approach requires several subprojects. The first subproject is to provide hands-on robot building activities that engage youth in the engineering design necessary to accomplish a given objective. The second subproject is the investigation and augmentation of current interfaces that will enable access to robot programming activities for the students. Accessibility is a strong requirement for these interfaces to be effective. The last subproject is the planning, execution, evaluation, and refinement of robotics institutes in conjunction with the Center for the Visually Impaired, the National Federation of the Blind of Georgia, Cleveland Sight Center, and the Colorado School for the Blind. In this paper, we discuss these subprojects for developing the capabilities of blind and visually impaired youth to build and program robots, which has been validated through a number of workshops and summer camps over a 5 year period.

Subproject 1: Hands-On Building of Robotic Platforms

Evaluation of Robot Platforms for Building

In 2007, we began hosting summer robotic workshops for the Center for the Visually Impaired STARS Program (Figure 1). These first workshop series were designed to understand what robot kits could be utilized to help develop skills in building and design for visually impaired students. The students, whose ages ranged from 9 to 17, were exposed to real-world situations using various robotic platforms. Our goal was to evaluate which robot building kits were better suited for engaging this target demographic. Using a team of mentors from the Center for the Visually Impaired, each student was paired with a sighted buddy who helped the blind student by reading directions, handing the student parts, and assisting with putting together the different parts of the system.

Fig. 1. Pictures of Robot-Building Activities

Taken from Computing and Robotics Workshops 2008-2012

Various robotic platforms were tested including Parallax, Tamiya, LEGO Mindstorm NXT, and LEGO Mindstorm RCX. We found that with the help of the sighted buddy, the students were able to successfully complete the build out of all the various robot kits, however, with great difficulty. Many of the students using the Parallax and the Tamiya kits had difficulty and complained the parts were too small and difficult to handle. Student teams also designed, built, and programmed robotic structures using the LEGO Mindstorm NXT and RCX Robotic Platforms. We found that the students using the LEGO kits needed less intervention from their sighted buddy and found the LEGO parts easier to handle, identify, and place in their proper location to complete their robot. Out of the two LEGO Robotic kits used, the RCX provided an easier interface for the students to locate and identify the parts. The LEGO RCX building components consist of classic LEGO pieces with raised studs. We found that this feature, in conjunction with the odd shapes, made it easier for the students to identify the part and complete his/her robot design (Figure 2). Based on our observation through these student interactions, we determined that the LEGO Mindstorm platforms were the most suited for designing interactive robot building activities for blind and visually impaired students.

Fig. 2. The LEGO RCX kits Showing Classic LEGO pieces with Raised Studs

Objective of the Robot Building Activity--Sumo Challenges

To provide a focused objective for the robot building activity, we initiated a curriculum that centered on competition through a Sumo-Bot Challenge, which featured two LEGO robots trying to push each other out of a ring. The challenges were non-destructive, kid-friendly, and a great learning experience for the students. Students were instructed to build a basic two-motor vehicle using the LEGO RCX or NXT robotic system. Once completed, the students were encouraged to build and add attachments that would give each robot a winning advantage. The two self-controlled robots were then placed in a challenge ring where the robots tried to push the opposing robot out of the ring. The first robot that touched the outside of the ring lost the round. The first robot to win two rounds won the match. Each of the LEGO Sumo-Bots was pre-programmed to move in a forward direction at a constant speed. After positioning and starting the robot, no remote control, power, positioning, or other external help could be provided. The robot had to autonomously push forward by itself until the round ended. A typical build session ranged from 30 minutes to 1 hour, depending on the complexity of the platform desired. Figure 3 shows highlights of two Sumo-Bot Challenges in 2009 and 2011.

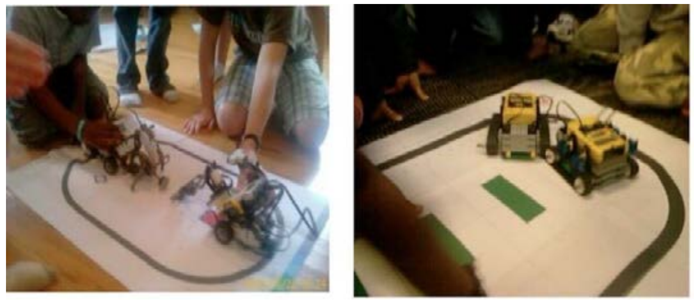

Fig. 3. Snapshots of the Sumo-Robot Challenge in which Students Competed Using Their Individually Built Robot Platforms

The excitement of the Sumo-Robot Challenge had a direct computing influence in that students began to express a desire to not only build the best robot platform, but program their robot to perform different functions in order to give their platform a competitive advantage. This naturally led to the next subproject in which we taught students how to program their robot platforms using various accessible programming interfaces.

Subproject 2: Robot Programming Activities

One of the major technical innovations found in the next subproject was the utilization of accessible interfaces to enable the programming of robots by blind and visually impaired youth. Accessible interfaces consist of a collection of multi-modal interfaces that rely on the integration of text-to-speech translators, audio feedback, and haptic interfaces to engage students with visual impairments in robot-educational activities (Howard et al.). Although there were a number of available programming interfaces available for the LEGO Mindstorms, we selected the Bricx Command Center (BricxCC) as a programming interface due to its accessibility attributes. We then integrated the JAWS screen reader and MAGIC screen magnification software to provide access to the programming environment (Freedom). The screen reader enables a direct text-to-voice conversion of the text within the programming console whereas the magnifier provides expansion of the text for those designated as legally blind (i.e. a central visual acuity of 20/200 or less). Using this platform, a teaching protocol was developed that utilized screen readers to relay visually displayed information on the computer console and a lesson plan that provided step-by-step instruction on the basic programming environment and syntax, such as compiling and downloading robot instructions, introduction of the robot command library, calling a function from the provided library, and figuring out how to call functions with input parameters. This self-explanatory teaching protocol was used to teach basic knowledge for programming the robot.

To provide sufficient feedback so that students could "see" what their robot accomplishes after it was programmed, we utilized two types of feedback--vibration-based haptic feedback and auditory feedback (Park et al.). For haptic feedback, a Wii remote controller (Wiimote) was used as the primary interface between the robot and the user. In this instance, combinations of differences in timing and forces of the Wiimote vibrations reflected different actions of the robot. In the case of auditory feedback, various sounds associated with different piano notes were recorded, and the saved sound file was associated with different robot behaviors. A full suite of auditory and haptic feedback was created to provide the student:

1. Sense of distance for how far the robot had traveled or in which direction the robot was turning
2. Sense of distance to an object located in front of the robot
3. Sense of whether the robot had reached a goal or not
4. Sense of whether the robot had bumped into a wall or an obstacle

As an example, Figure 4 depicts the auditory notes used to provide information about robot actions.

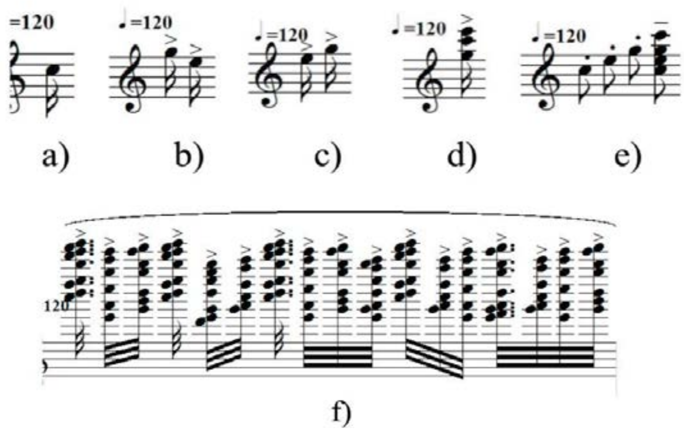

Fig. 4. Piano notes for auditory feedback: a) travel forward, b) turn left, c) turn right, d) object detected, e) goal achieved, and f) bump (crash).

Objective of the Robot Programming Activity--Maze Challenges

To provide a focused objective for the robot programming activity, the students were given a task to program their robots to navigate through a maze. For this task, we first provided students with a preprogrammed robot that was capable of successfully navigating the maze. While the robot navigated though the environment, the students were provided haptic/audio feedback. During each run, each student would report what they felt their robot was doing (i.e. moving forward 10cm, turning 45 degrees, etc.). This information was recorded and then provided to the students in order to enable them to program their robot to solve the maze (Figure 5).

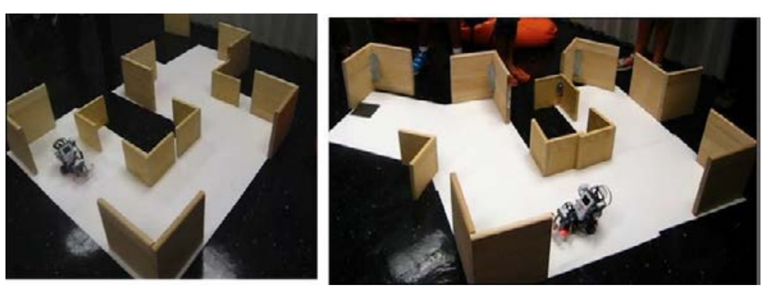

Fig. 5. Different configurations for the robot maze challenge.

Subproject 3: National Robotic Institutes

Over the past five years, we have run a number of robotic institutes nationally in the US, in conjunction with the Cleveland Sight Center, Center for the Visually Impaired, the National Federation of the Blind of Georgia, and Colorado School for the Blind. The institutes were targeted at middle and high school students with visual impairments and have had over 60 student participants. For assessment, we evaluated both the robot building activities and the robot programming activities. This was accomplished through pre- and post-surveys (Figure 6) as well as evaluation of the learning curve associated with how well students achieved their programming objectives.

Robotics Workshop

1. How helpful were the Wiimote vibrations in letting you know what the robot was doing?
a. very helpful b. helpful c. slightly helpful d. not helpful

2. How helpful were the sounds in letting you know what the robot was doing?
a. very helpful b. helpful c. slightly helpful d. not helpful

3. Which do you think was most helpful?
a. Vibrations b. Sounds c. both d. none

4. Which do you think was most confusing?
a. Vibrations b. Sounds c. both d. none

5. How much do you think this workshop helped show you that you are capable of working with computers or robotics?
a. a lot b. some c. a little d. none

6. How much has this workshop encouraged you to consider working with computers or robotics when you grow up?
a. a lot b. some c. a little d. none

Fig. 6. Partial Survey Used to Evaluate Robotics Activities with Blind and Visually Impaired Youth

The learning assessment showed that, by providing sufficient haptic and auditory feedback, students could learn how to perform even highly visual tasks, such as programming a robot to solve a maze. In addition, based on the subjective assessment metrics we have validated after participating in the robot sessions, students have a stronger desire to consider working with computers/robotics as a career possibility.

Discussion and Future Work

Future work focuses on the development and dissemination of training kits based on learned practices using the accessible robot building and programming interface tools. A strong benefit of this effort is the investigation and augmentation of alternative interfaces that can be shared with others such that educators can engage students with visual impairments in the classroom environment. Teachers should be able to utilize the training kits and the associated robotic institute infrastructure to encourage participation of students with visual impairments in computer-related activities. Students themselves should also be able to use the provided infrastructure to enable independent exploration of other programming activities. To support this effort, we are currently creating a website that will allow easy access to documentation, learned practices, and modules. The website will be self-contained and conform to accessible design. We are also working on augmenting the curriculum to engage students with motor impairments in educational robotic activities.

Acknowledgements

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Wireless Technology Use and Disability: Results from a National Survey

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Abstract

Access to and use of wireless consumer technology (e.g., mobile devices like cellphones and tablets, software and services) has become critical to social and economic participation. This is especially true for people with disabilities. This article presents data from the Survey of User Needs (SUN) conducted by the Rehabilitation Engineering Research Center for Wireless Technologies (Wireless RERC) from September 2012 through April 2013. The SUN focuses on wireless use among people with disabilities to identify patterns of use and the needs of this population. Key questions related to comparative trends among people with disabilities and the general population are addressed, including wireless adoption rates, preferred platforms (cellphone, smartphone, tablet), wireline (landline) use, and wireless use by disability type. Data show that as a group, people with disabilities own and use wireless technology at rates similar to the general population, but substantial variation exists in ownership of different types of wireless devices between disability types.

Keywords

Wireless, use, accessibility, cellphone, smartphone, tablet

Introduction

Access to and use of mainstream wireless technology is increasingly essential to full social and economic participation. The digital divide can be a social divide--if you do not have access to mainstream consumer information and communication technology, you are literally not part of the conversation. For people with disabilities, who already face considerable obstacles to social and economic participation, access to wireless technologies is especially critical. Data from the CTIA-The Wireless Association show over 331 million wireless service subscriptions in the United States (CTIA 2). The Pew Internet and American Life Project reports survey data that show a steadily rising rate of cellphone ownership among American adults in recent years, from 73% in 2006 to 87% in 2012 ("Trend"), with current smartphone ownership at 46%, and tablet computer ownership at 31% of American adults.

At the same time, advances in consumer technology have created new opportunities to empower people with disabilities: to augment or assist communication, aid vision, aid memory, guide navigation outside the home, automate and monitor events inside of the home, monitor health, provide emergency communications and location finding, provide information on the go, socialize, and more. Despite these new opportunities for greater accessibility and utility, the rapid rate of technological innovation poses risks that hard-won advances in accessibility could be undone by new generations of mobile wireless technology (Schroeder and Burton).

This article presents findings from the Survey of User Needs (SUN), a national survey on use and usability of consumer wireless technology by people with disabilities, conducted by the Rehabilitation Engineering Research Center for Wireless Technologies (Wireless RERC). These findings address several core questions related to disability and technology access:

- Disability divide--Do people with disabilities use wireless technologies at rates similar to the general population?
- Income divide--Does income effect adoption rates and use of wireless technology by people with disabilities? (Wireless RERC 1-2)
- Age divide--Do younger adults with disabilities use more advanced wireless technology than older users? (Morris, Mueller, and Jones)
- Wireless substitution--Do income and age of people with disabilities affect the use of wireline technology in the home? (Blumberg and Luke 2)
- Functional divide--Do people with specific disabilities own or use more sophisticated types of wireless devices more than other groups?

Originally launched in 2002, the SUN has been updated over the years to keep up with the rapid pace of technological change. Now in its fourth version (SUN 4) this unique, nationwide survey on wireless technology use by people with all types of disabilities has come to be an important reference for the wireless industry, regulators, people with disabilities and advocates, and other researchers. The results presented in this paper focus on the most recent version of the SUN launched in the fall of 2012. Participants were recruited across the eight general disability categories listed in Table 1. These are based on the categories used by the American Community Survey (ACS), augmented with categories adapted from the National Health Interview Survey (NHIS). The SUN questionnaire permits finer segmentation of respondents by disability sub-types (e.g., blindness as a subtype of difficulty seeing, using a wheelchair as a subtype of difficulty walking). A total of 780 people responded to the survey, with 659 reporting having at least one of the disability types. Females constitute 57% of the respondents. The mean age of 50 years is partially attributable to excluding minors under the age of 18, due to concerns with conducting research with vulnerable populations.

Table 1 Survey of User Needs Sample by Disability Type

Disability Type	Respondents (%)*
Difficulty walking or climbing stairs	39%
Difficulty hearing	36%
- Hard of hearing	26%
- Deaf	10%
Difficulty seeing	29%
- Low vision	15%
- Blind	11%
Difficulty using hands or fingers	26%
Difficulty concentrating, remembering, deciding	24%
Frequent worry, nervousness, or anxiety	20%
Difficulty using arms	17%
Difficulty speaking so people can understand me	14%

*Many respondents noted more than one disability type.

Source: Wireless RERC, Survey of User Needs, 2012-2013.

Discussion

The paper comprises two main areas of analysis: 1) analysis of responses for all eight disability categories together; and 2) analysis of responses for individual disability categories. General trends related to overall ownership rates and ownership of specific types of device (basic or “feature” phone, smartphone, tablet) are examined. Additionally, response data on wireless substitution (“cutting the cord”) are examined as another way of understanding the degree to which people with disabilities rely on wireless technology.

Table 2 also shows the details of ownership of three general types of devices: basic cellphone, smartphone, and tablet. Overall, SUN respondents with disabilities own basic cellphones and/or smartphones at a slightly lower rate (84%) than the general population (91%)

as measured by the Pew Internet and American Life Project ("Trend"). Some SUN respondents reported owning only a tablet, but not a cellphone or smartphone. Adding these respondents to the basic cellphone and smartphone owners raises the wireless ownership rate to 91%. The SUN sample of people with disabilities shows a rate of smartphone ownership that is similar to the Pew sample for the general population. Tablet ownership rates also are comparable in both samples.

Table 2 Wireless Use and Device Type (All respondents with a disability)

Do you own or use a cellphone, smartphone or tablet?	SUN	Pew
Cellphone or smartphone	84%	91%
Cellphone, smartphone or tablet	91%	--
If you own or use a cell phone or tablet, what kind do you use? (Check all that apply)		
Basic cellphone (e.g., Motorola Razr, Pantech Breeze, Nokia 6350)	31%	35%
Smartphone (e.g., iPhone, Android phone, BlackBerry, Windows phone)	54%	56%
Tablet (e.g., iPad, Kindle Fire, Galaxy Tab, Google Nexus)	31%	34%
Other (iPod Touch, Nook, Kindle, netbook, laptop)	6%	--

Sources: Wireless RERC, *Survey of User Needs*, 2012-2013. *Pew Internet Surveys*, 2006-2013.

Findings are mixed regarding a possible income divide in wireless device ownership among people with disabilities. It is generally expected that people with higher incomes are more likely to own more expensive devices, which in turn are used with more expensive plans (for cellphones and smartphones, but not necessarily tablets).

Table 3 Wireless and Wireline Use by Income (All respondents with a disability)

	No wireless device	Basic phone	Smart phone	Tablet	Wireline
Less than $10,000	13%	34%	47%	24%	60%
$10,000-$14,999	6%	42%	44%	21%	66%
$15,000-$24,999	17%	29%	43%	19%	74%
$25,000-$34,999	11%	40%	45%	27%	68%
$35,000-$49,999	5%	40%	52%	27%	76%
$50,000-$74,999	10%	32%	55%	36%	77%
$75,000 or more	4%	19%	74%	46%	81%

Source: Wireless RERC, *Survey of User Needs*, 2012-2013.

Table 3 shows that there is no discernible income-based pattern to either not owning a wireless device or owning a basic cellphone. On the other hand, the data show clear patterns by which respondents with higher incomes are also more likely to own smartphones and tablets.

Table 4 shows the same wireless options as Table 3, but here the 6 row headers contain age ranges beginning with 18-30 and ending with over 70 years old. It is expected that there would be an age divide whereby younger respondents with disabilities would be less likely not to have a wireless device or to have a basic cellphone than older respondents. Conversely, younger respondents should be more likely to own more sophisticated devices like smartphones and tablets. The percentages of respondents shown in Table 4 support these aspects of an age divide, with the exception of not owning a wireless device. Unexpectedly, the data show that younger respondents are more likely not to own a wireless device than older respondents. Here, too, there is an exception: the oldest age group (over 70) has a higher rate of non-ownership (11%) than all but the youngest age group (18-30), 16% of whom do not own a wireless device.

Table 4 Wireless and Wireline Use by Age (All respondents with a disability)

	No wireless device	Basic phone	Smart phone	Tablet	Wireline
18-30	16%	26%	57%	35%	60%
31-40	10%	25%	67%	37%	55%
41-50	9%	26%	60%	36%	72%
51-60	7%	34%	52%	24%	79%
61-70	7%	40%	48%	25%	85%
Over 70 years old	11%	53%	26%	32%	87%

Source: Wireless RERC, *Survey of User Needs*, 2012-2013.

Tables 3 and 4 also show wireline use as a percentage of respondents. According to the CDC's semi-annual report on "wireless substitution," individuals with lower income and of lower age are more likely to live in households without wireline phone service, often due to economic pressures (Blumberg and Luke 2-3). Tables 3 and 4 show that younger respondents and those with lower household income are more likely to live in a household without a wireline telephone.

Analyzing data for all respondents with disabilities as a single group has revealed some important trends. However, a more complete understanding requires analysis of wireless device ownership by disability. Table 5 shows wireless device and wireline ownership for the eight disability types listed in Table 1. Table 6 shows the same technology options, but with the respondents who reported having visual or hearing loss disaggregated by level of functional loss: low vision and blind, and hard or hearing and deaf.

Table 5 Wireless and Wireline Use by Disability Type (All respondents with a disability)

	No wireless device	Basic phone	Smart phone	Tablet	Wireline
Cognitive	12%	33%	52%	23%	70%
Anxiety	11%	34%	51%	28%	71%
Seeing	11%	36%	50%	26%	78%
Hearing	10%	25%	58%	33%	73%
Speaking	17%	28%	52%	43%	69%
Using arms	11%	41%	40%	33%	83%
Using hands/fingers	12%	37%	48%	32%	80%
Walking, climbing stairs	9%	39%	48%	34%	76%

Source: Wireless RERC, *Survey of User Needs*, 2012-2013.

Disability type differs from income and age as a variable in that there is no natural order or progression of the values, except perhaps low vision and blind, and separately hard of hearing and deaf. Consequently, it is not possible to analyze trends across the eight general disability categories as in previous tables. Nonetheless, some specific values stand out. First, those who reported having difficulty speaking have the highest rate for not having a wireless device (17%), and the lowest rate for having a wireline in the home (69%). These results suggest low levels of voice connectedness, relative to the other disability categories (with exception perhaps of people with profound hearing loss), which makes sense given the difficulty with speech. Conversely, this group shows by far the highest rates of tablet ownership (43%), perhaps reflecting use of storyboard-based speech generating apps on tablets, as well as possible use of the larger keyboard interface for text-based communications (text messaging, email, social media).

It is also notable that the three physical disability categories (using arms, using hands and fingers, and walking and climbing stairs) reported the highest rates of ownership of simple phones (41%, 37% and 39%, respectively). These results might reflect interactions with age, but they may also reflect the possible greater accessibility of simple phones with physical buttons by people with limited physical abilities. These interfaces may produce less slippage of fingers or styluses and physical feedback of key activation. Simple cellphones also may provide greater durability when dropped. There are also notable distinctions between the two vision loss groups and the two hearing loss groups (Table 6). Deaf respondents show much higher rates of smartphone (66%) and tablet ownership (48%) and much lower rates of basic phone (19%) and wireline ownership (46%) than hard of hearing respondents.

Table 6 Wireless and Wireline Use by Disability Type (All respondents with a disability)

	No wireless device	Basic phone	Smart phone	Tablet	Wireline
Low vision	11%	38%	47%	33%	74%
Blind	9%	32%	51%	15%	84%
Hard of hearing	12%	30%	54%	27%	81%
Deaf	8%	19%	66%	48%	46%

Source: Wireless RERC, *Survey of User Needs*, 2012-2013.

These results make sense since people who are deaf have more complex communication needs that often cannot be satisfied by basic cellphones or wireline phones. For the vision loss groups, the largest differences are in use of tablets and wireline service in the home. Low vision respondents own tablets at a much higher rate (33%) than blind respondents (15%); and they are substantially less likely to have a wireline phone in the home (74% versus 84% for blind respondents). Because tablets offer visual interactions that other devices cannot match, it makes sense that people with low vision would be very attracted to them, while those who are blind would not. Wireline phones, often more readily accessible than wireless devices to people who are blind, are likely to attract high percentages of blind users.

Conclusions

The survey results presented here lead to two general conclusions. First, people with all types of disabilities taken as a single group use basic cellphones and smartphones at a slightly lower rate than the general population, but smartphones at a higher rate. These results chip away at the notion of a disability divide between people with disabilities and the general population regarding technology use. Additionally, among people with disabilities there is evidence of an income divide (higher incomes lead to use of more sophisticated technology) and an age divide (lower age leads to use of more sophisticated technology). These divides are also believed to characterize the general population.

The second conclusion is that substantial differences in technology ownership and use can be found between and among people with different disabilities. Basic cellphones, smartphones, tablets, and even wireline phones all offer different capabilities that make them more usable for those with a certain limitation, and less so for those with a different limitation. Enabling customers with disabilities to understand and select wireless devices and services that best fit their own needs and abilities should be a primary mission of manufacturers and carriers that value this large and growing customer market.

Note

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Robotics Programming Tools for Blind Students

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Abstract

Despite advances in assistive technology, relatively few visually impaired students participate in computer science courses. Significant factors in this underrepresentation include lack of precollege preparation, access to resources, and the highly visual nature of computing. This paper describes the development of software that provides an accessible Lego Mindstorms NXT programming environment for teenage students who are visually impaired. With the popularity of robotics in both pre-college and introductory programming classes, such an environment has the potential to accommodate students who are visually impaired in classroom and outreach activities. Pilot testing results will be presented in addition to the design of the system.

Keywords

Visually impaired, outreach, teens, robotics

Introduction

In the US as the numbers of students pursuing computer science and related degrees has declined in recent years, efforts by the National Federation of the Blind (*Youth Slam*); Cannon, Panciera, and Papanikolopoulos; and Doerschuk, Liu, and Mann have been undertaken to increase interest and participation in computing degrees. Like other underrepresented groups, students who are visually impaired do not participate in computing careers to their full potential. Factors include inadequate preparation and awareness of potential career paths. Students who are visually impaired continue to encounter barriers in computing courses in terms of access to course tools and participation in activities in part due to highly graphical depictions within user interfaces.

As robotics has become popular as a means for engaging pre-college students in computing and engineering (including efforts by the National Federation of the Blind and Cannon, Panciera, and Papanikolopoulos), the need for accessibility persists. Work by Ludi and Reichlmayr has demonstrated how Robotics, such as Lego Mindstorms, are as appealing to students who are visually impaired as they are to sighted students. The default programming software available from Lego uses icons to represent commands. This software is not accessible, most notably in terms of screen reader compatibility. Whether for in-class activities or extracurricular outreach, the software needs to maximize accessibility in order to promote interest in computer science and related disciplines.

The underrepresented students of concern are those who are visually impaired, where the threshold is legally blind. The American Federation of the Blind defines the term “legally blind” as defined through federal law, with “central visual acuity of 20/200 or less in the better eye with the best possible correction, as measured on a Snellen vision chart, or a visual field of 20 degrees or less” (*Statistics*).

The goal of the JBrick project is to devise accessible Lego Mindstorms programming software that can be used by those with or without sight. In the case of the ImagineIT workshops and future outreach, the target users are teens who are visually impaired. These teens are often novice programmers, as the focus of the outreach is to enable the participants to explore Computer Science via robotics.

Evaluating Mainstream Tools

This goal was derived over time, in part due to evaluating other environments that meet accessibility and other criteria. Research was conducted to find the best alternative programming software and language in terms of accessibility and cost. BricxCC, developed by Hansen, and the NXC (Not eXactly C) language were the initial choices for use in our student outreach workshops but the BricxCC software, developed in Delphi, is not entirely compatible with JAWS and thus requires the help of a sighted person at times. For example, code navigation can require help by a sighted person when the program is large since displayed code line numbers are not read. The alternative is for the user to count the lines, which can be frustrating and time consuming in a large program. A summary of the alternatives are as follows:

Table 1 Overview of the Pros and Cons of Using RobotC, Microsoft Robotics Developer Studio, and LejOS platform

Robotics Platform	Advantages	Disadvantages
Robot C	• Used in FIRST high school robotics programs • Has a simulator • Is relatively low cost • An entry point for beginners but good for advanced • Mac or PC	• Has many issues with JAWS • Simulator and help are not accessible
Microsoft Robotics Developer Studio	• Free • Can be used with many different robotics systems • Can work with the Kinect • Use of C# is nice for those who already know how to program	• PC only • Visual programming language is not accessible • Use of C# is not novice-friendly • Simulator not accessible
LejOS (for Java) uses NetBeans or Eclipse	• Free • Used in some universities • Use of industry tools	• Requires changing the NXT firmware • Not novice friendly • Buggy

The NXC language was chosen over Java, another popular alternative. The NXC language is easier to learn, and in order for the robot to work with Java programs, the robot's firmware needs to be changed. These factors will promote replication of developed materials in schools or at home. Each BricxCC feature was assessed with the JAWS screen reader and Zoomtext screen reader and magnifier, as described in work by Ludi and Reichlmayr. Persistent issues had some impact on participant satisfaction. The decision was made to migrate from BricxCC to a new system--JBrick.

JBrick Features

The desire to have an accessible Lego Mindstorms programming environment has been the main driver for JBrick. The accessibility assessment of BricxCC, combined with notes taken during workshops when BricxCC was used with teens, provided a set of accessibility and features needs that in turn were the foundation for JBrick's requirements. The primary assistive technology is assumed to be screen readers and magnification software programs, though Braille displays are also significant.

The core concerns are:

- Accurate reading of the source code
- Ability to recognize the NXT brick, compile code and download programs to the brick and indicate status of process with audio
- Ability to open and save source code files
- Ability to read errors from the compiler
- Ability to navigate to the line of code that the compiler error is referring to quickly

Some of the more refined requirements include the following:

- The user shall read/hear the source code, including keyword highlighting and line numbers
- The user shall view/hear errors from the compiler, where each has an associated line number
- The system's interface and code files are compatible with JAWS and Zoomtext
- The system shall be usable by sighted and visually impaired users alike, either working separately or collaboratively
- The system shall provide audio cues for status such as compiling, downloading to the brick, or finding the brick
- The system must be multiplatform
- The system must be compatible with the NXC compiler and not require firmware changes to the brick
- The user shall be able to change font size and font/background colors

The sample of the system features and quality attributes presents the fine-grained approach to requirements that include customizability of the user interface.

Design of JBrick

In order to ultimately deliver JBrick on multiple platforms, Java was selected as the development language. The NXC compiler is being reused, so programs coded in JBrick and BricxCC are interoperable. Here is a sample of an NXC program:

```
// sound THRESHOLD in decibels to trigger movement
#define THRESHOLD 10
// name for SENSOR_2 (sound sensor)
#define SOUND SENSOR_2

task main()
{
  SetSensorSound(IN_2);
   // loop forever
  while(true)
        {
  // keep sampling until threshold is exceeded
              until(SOUND > THRESHOLD);
        OnFwd(OUT_AC, 75);
        Wait(300);
  // resume sampling for same threshold
        until(SOUND > THRESHOLD);
  OnRev(OUT_AC, 75);
        Wait(300);
   }  }
```

Standard Java libraries have been used, including the Java Accessibility libraries.

The JBrick user interface is simplified, as shown in Figure 1. The drop down menu structure has been streamlined from 8 menus in BricxCC to 5 menus in JBrick. This streamlining can help with recall when the menus are read. JBrick has fewer icons, each larger in size and omitting superfluous aesthetic detail and tooltips. Navigation can now be accomplished with the keyboard as the sole input device. Common commands such as compile and download can be accessed through keyboard shortcuts.

Line numbering is visible to the left of each line of source code. The numbering is managed separately in order to be displayed on the screen, read by the screen reader, and displayed on a printout. Such features help both new programmers and experienced programmers work with code regardless of visual acuity.

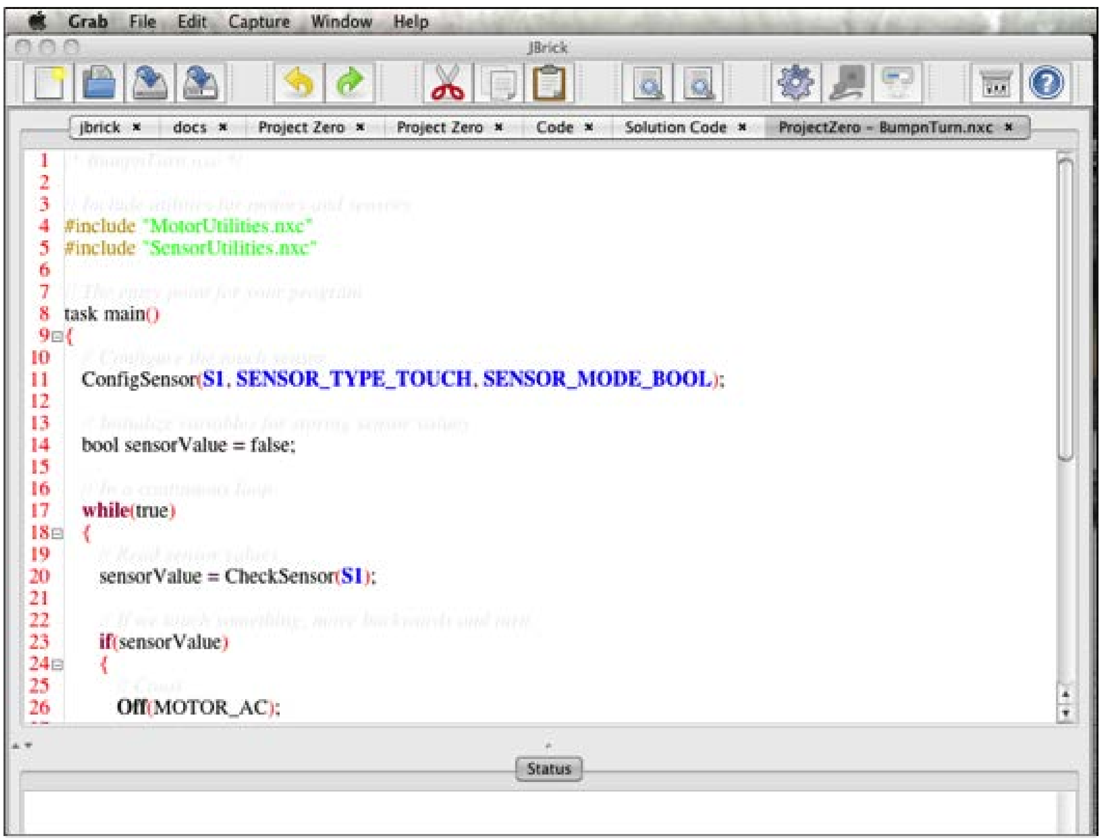

Fig. 1. Screenshot of JBrick Software-Depicting a Sample Code File List.

The large icons and streamlined menu are displayed.

Font legibility is also critical as default font sizes are often small. In JBrick, the default format for the font is Ariel Bold 12. The size can be increased. The color of the text, keywords, and the background can also be changed in order to accommodate the needs of the user. The default coloration is high contrast. The menu options and key sequences to compile and download files onto the brick can be accessed as a menu item, icon, or key sequence. The improvement has been in the form of a beep and dialog box to inform the user as to the status of the process rather than silence (as is the case with BricxCC). JBrick is also usable on Mac OSX and is compatible with VoiceOver. These features increase accessibility for users with visual impairments in addition to increasing usability for sighted users. For example, adjusting font sizing and screen coloring helps with legibility. Streamlined menus minimizes short-term memory overload for all users.

User Testing

After the technical and initial accessibility evaluations were complete, JBrick was pilot tested with a group of 5 undergraduate students with varying visual acuity, including 2 students who are blind. The students had no experience in programming Lego Mindstorms robots (or programming at all). Using a pre-designed NXC programming tutorial, each student worked through a set of tasks to learn how to use JBrick in addition to completing a simple programming activity using a stationary robot. The workflow tested consisted of the following tasks:

1. Open the program, and change the view to include the file tree and change the proportions of the other pane
2. With the program already open, open a new file and enter code
3. Save the file as test.nxc

4. Compile the file and download to robot
5. Open the Preferences pane and change the colors of text highlighting and any other preferences, except for the location of the compile
6. Open a new file then navigate back to test.nxc
7. In test.nxc, force an error by deleting a semicolon and try to compile. Use the error messages to fix the problem
8. Copy and paste part of the body of main in test.nxc
9. Fold the body of main in test.nxc
10. Close all open files, then close the program

Due to the small sample size, observational data included the number of errors made. Time to complete tasks was not as important since students work at their own pace.

Discussion

While all of the students ran into some issues with getting the test program to work, the issues were mostly in the area of text entry rather than JBrick itself. While the NXC language cannot be revised at this stage, the Future Work section discusses an approach to mitigate program entry (typing) issues. Excluding text entry issues, tasks 1 through 8 and task 10 were completed with 0 errors. Task 9 was thrown out due to a technical defect. However, in the course of the tasks' execution some minor defects were discovered. In Task 5 (Preferences), the tab order was incorrect, though users were able to complete the task. During Task 7 (Fixing the Defect), 1 student was a little frustrated by having to listen to multiple errors that were generated. This issue goes back to text entry/typing skills, given that text-based programming can generate numerous errors from typos. In addition, small technical (user interface) defects were found with the GoTo command (misreading the ENTER key) as well as being able to fold the MAIN method in order to minimize the reading of some code (Task 9). The issue with the GoTo command did not prevent the user from completing the task, and most users did not notice the defect during the test. The defect in Task 9 caused issues and was thus thrown out of the user study. The results showed that the line numbering helps students find parts of their code when editing, though a change in voice for the number would give the features more value. In addition, no screen reader or magnification issues occurred with JAWS or ZoomText.

Conclusions and Future Work

JBrick has been successful in terms of providing an accessible foundation in Lego Mindstorms NXT programming for pre-college students with varying degrees of visual impairment. As such, students can collaborate with sighted peers or other students who are visually impaired during robotics activities that build technology skills. Moving forward, additional features will be added in order to provide students the ability to navigate code using audio cues, as well as debugging (a tool to help work through coding and logic defects). JBrick will be tested with high school students participating in the Computer Science Academy, starting in Summer 2013. In addition, Versions of JBrick for iOS and tablet PCs are underway that will provide new means of interaction. For example, JBrick for the tablet PC uses physical blocks as a way to help enter commands and edit programs. This user interface may help younger students and those who either lack keyboarding skills or who have some dexterity issues.

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Non-visual Drawing with the HIPP Application

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Abstract

An audio-haptic drawing application prototype has been developed in a project and iteratively been tested by five pupils who are 8-13 years. The application has been used by pupils, assistants and teachers to access graphics and create graphics that are accessible for pupils with severe visual impairment or blindness. We have observed a spread in the actual use of the system that seems to depend on the special pedagogical knowledge of teachers and assistants, their learning focus, and the age of the pupil when they start using the system.

Keywords

Drawing, audio-haptic, learning, multimodal, visual impairment, graphic.

Introduction

Persons who have visual impairments are excluded from accessing certain types of information that are accessible to the general public. Screen reading software and Braille displays or text-to-speech systems are used for enabling access to text, but for accessing graphics, especially digital graphics, no standardized technology is in widespread use. In education, preprinted material is often used, which forces teachers to plan well ahead of time to be able to produce or borrow the material they need. This makes the learning situation less dynamic, and it is hard to produce tactile material on-the-fly. Because of this, pupils with severe visual impairments also get less exercise in the reading and understanding of graphical material, which will exclude them from certain information in their grown-up lives.

Related Work

As described in *Drawing and the Blind* (Kennedy) and *Art Beyond Sight* (Axel and Levent), people with visual impairment can find an interest in drawing by hand. Several tools exist to enable this activity.

An existing supportive technology for creating graphics is a CAD application which has been developed to enable users to create drawings with the help of audio and keyboard. This is accomplished by a structured approach of dividing a drawing into small parts which thus enables the user to draw segments of a drawing (Kamel; Kamel, Roth, and Sinha.). In 1996, Kurze presented a tactile digital drawing application that combined a digitizer pen with a thermo pen. The thermo part of the pen raised lines on swell paper, and the digitizer recorded the movements to save them digitally. An idea for a voice recognition system for vocal tagging of the drawings was also presented (Kurze). The greatest drawback of that particular application was that the drawings could not be dynamically edited. The possibility to use the PHANToM for drawing and exploring drawings has previously been investigated. Two different applications were developed, with a few years in between. The first application ("Paint with your fingers") was created by Niclas Melin in 1995 (Sjöström and Rassmus-Gröhn), and the target users were children with blindness. This application focused on the possibility to paint colors, and to give them different haptic textures to make it possible to distinguish them from one another. The second application took the results from the user trials of the first application, and improved the functionality (Hansson). The resulting application prototype provided the user with the possibilities to choose colors from a palette and draw with them. Like the previous application, different textures were applied to the colors. Also, a dividing line between drawn segments of different color was added.

HIPP builds on a system called AHEAD and presented extensively in Rassmus-Gröhn. During the time of the development of the AHEAD application, a couple of other non-visual drawing applications were developed. One, created by Crossan and Brewster, is evaluated primarily as a tool for teaching handwriting to blind pupils (Plimmer, Crossan and Brewster). The application can be used in collaborative mode, where a teacher can guide the trajectory of the pupil's pen. Thus, that application focuses on the guiding and the learning of shaping letters correctly. Another application created by Gutierrez is primarily for single-user drawing, and it features tools for zooming and different modes of exploration, e.g. free exploration, guided exploration or constrained exploration (Gutierrez). T. Watanabe et al. have also presented a compound technology solution using a tactile display device, a 3D digitizer and a tablet PC to enable blind pupils to draw and feel their drawings (Watanabe et al.), and to access general graphic material. This system has been evaluated in school with a Kanji (Chinese characters) learning system and tactile games, as well as in geography and history lessons.

More recently, Lévesque et al. have presented a different solution for exploring schoolbook illustrations via laterotactile deformations of the finger skin combined with a 2D exploration (Petit et al.). Like the HIPP program, it envisions the support of vector graphics (Lévesque and Hayward) and supports multimodal drawings through the MaskGen software. Compared to HIPP, it enables more different types of tactile rendering, but although the more recent version is more dynamic and supports zoom functionality (Lévesque et al.), it does not enable drawing.

Another type of hardware called Hyperbraille enables bimanual graphical exploration (Prescher, Weber, and Spindler). The device consists of a 2D pin array much like braille displays and is made primarily for rendering the window-based GUI of a computer, including the possibility to zoom. Some drawing is possible, but not in a direct free-form way as shown in hyperbraille.

A handbook has been published with more details on the pedagogical perspectives behind the use of HIPP (Fahlström and Björk). One important concept is the intersubjectivity between the teachers or pedagogues and the child, through the drawing. As stated in Fleer, it is important to create an intersubjectivity where the adult and the child can meet and agree on the object and focus of their activity (the drawing). This should enable the child to link the activity back to their own life and the adult to bring in specific concepts. More details about intersubjectivity in HIPP can be found in Björk.

Method and System Design

We have used a participatory design process in a school context to develop an audio-haptic non-visual image editor and explorer (Rassmus-Gröhn, Magnusson, and Eftring; Rassmus-Gröhn). The system, called HIPP (for Haptics In Pedagogical Practice) and the methods around it, while undergoing continuous improvement, were evaluated in four schools by five pupils who are partially sighted or blind, their teachers and assistants.

The drawing application is written C++ and Python on top of the H3D API (Sensegraphics AB) and Cairo graphics (Cairo graphics), and is available as open source code (Rassmus-Gröhn and Szymczak). It uses a combination of haptic and sound feedback to display information to the visually impaired user. The haptic feedback is displayed via the PHANToM OMNI device, and drawn objects are tagged with a number and text string which is spoken by the application each time a user selects it.

Fig. 1. HIPP Concept Picture. The pen for haptic feedback of the drawing on screen, the speaker for spoken feedback or sound effects related to the point the pen is touching.

Objects can be manipulated in different ways: moving, resizing, copying, pasting and deleting. Additionally, shapes can be transformed into straight lines, rectangles or circles. The manipulation tools are fitted with auditory icons, which are feedback sounds designed to resemble a real world manipulation of similar nature (Gaver). E.g. the copy function sound effect is a camera click.

Results

The extent and mode of use of the HIPP system has varied for the different pupils. It has been used both for the own creation of drawings (made by the pupils) and exploring of school material, such as diagrams, maps or other illustrations. To begin with, the teachers were very focused on teaching--transferring knowledge in pictures to the pupils--and would generally start talking about maps and mathematics figures as being the biggest problem in school. This seemed to get more prominent the older the pupils got, and the playful experimentation with the digital material (in the form of the HIPP system) was not pursued as much, and this seemed to lessen the number of uses of the HIPP system in the classroom.

How to teach pupils with blindness to draw is not self-evident, but one approach that showed to be fruitful was to let the pupils do doodle-drawings with the HIPP system, much as younger sighted children do when learning to hold a pen at 1-3 years of age. These doodles were then interpreted by an assistant who would say things like, “Oh, what you are drawing there looks like a rose, would you care to bring it home to give to your Mom?” And then they would print the drawing on swell paper (which raises the black lines on the paper) and explore it as well. When the pupils later took the initiative to draw something, visual interpretation and communication around 2D drawing conventions were discussed.

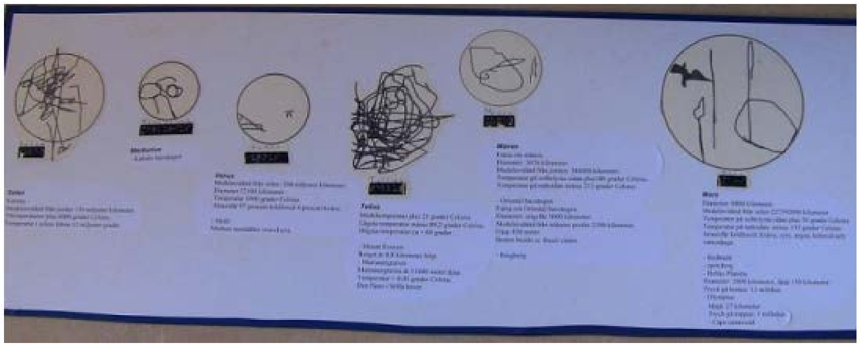

Fig. 2. Solar System Printed on Swell Paper

For example, one pupil would like to draw a planet from the solar system. Therefore, the pupil started to ask questions like: “How do you draw a planet? And how do you know that the planet you draw as a circle, is in fact a sphere? And how do you draw the craters on the moon? How about the mountains?” From the pupil’s initiative, a whole wealth of discussion topics around 2D drawings, scaling and perspective came naturally from working with the system in a real life activity. The fact that the drawings were not only kept in the digital format, but also printed on swell paper and examined appeared to help convey the meaning and importance of graphical images.

Fig. 3. A Part of an Ocean Collage in the Classroom. The shell and the bird above it are created with the HIPP application, and colored with crayons inside the swelled lines.

In Sweden, most pupils with visual impairment are integrated in regular classes. Since pupils with visual impairment have different learning materials it can be difficult to take part in the creation and exchange of graphics, which is important as a learning tool especially for the younger children. HIPP can also be part of those activities, which is shown in Figure 3.

Discussion and Conclusions

As can be seen from the examples above, the HIPP application has sufficient functionalities to be of use in the classroom. However, it puts some demand on the pedagogical personnel surrounding the child, and we have seen how the computer skill and the knowledge of special pedagogy have an impact on how often the tool is used and in what situations. It should be recognized that such skills are important also with other material and pedagogical situations.

Learning to draw, and also being inspired to draw, is indeed possible with the help of HIPP. Printing swell paper copies of the drawn pictures, sometimes in several stages before the picture is finished, helps making the build-up of pictures clearer to the pupil. We have also seen how the task of drawing something triggers questions about 3D-2D projections, and about certain conventions in drawing, for example how you usually draw a car from the side, and not from the top.

With the younger children, a playful approach has been more pronounced, and we believe that this is one reason that it has worked better. The root cause for the playful approach can be the pedagogy for smaller children as such, but it may also have to do with the escalating demands on the pupils as they grow older. They simply have no time to learn a new tool in a playful manner. This indicates that introducing a new tool like HIPP should be scheduled in the lower classes, although care needs to be taken since we have also experienced clashes with other new tools being learned such as Braille displays or new keyboards.

We have seen that in the schools where HIPP has been used primarily as a transmitter or conveyor of school material such as maps, drawings and diagrams, the HIPP drawing application has been used less. Our analysis is that without the knowledge of what a picture is and how you create it, the decoding and understanding of pictures is harder for the pupils. It also puts a greater demand on the assistants or teachers actually creating the material and spending preparation time working with HIPP. The time needed to spend on a new tool, even if it is seen as useful, is hard to add on top of the other work that is already done in school.

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Using Kurzweil 3000 as a Reading Intervention for High School Struggling Readers: Results of a Research Study

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Abstract

Despite increased use of assistive technology by struggling readers, scientific research on the effect of using assistive technology is limited. An experimental study was conducted to examine the effects of using text-to-speech software (i.e., Kurzweil 3000) upon the reading performance of ninth grade struggling readers when not using the software (i.e., unaided). After using the software for one semester, the intervention group students had significantly greater increases in vocabulary and comprehension when compared to the control group students. These findings contribute to increasing the scientific evidence-based research on the use of text-to-speech software as a reading intervention for secondary struggling readers.

Keywords

Assistive technology for reading, text-to-speech software, high school struggling readers

Introduction

The US No Child Left Behind Act (NCLB) of 2001 (P.L. 107-110) Title I, Part B, promotes *Reading First* and *Early Reading First* initiatives to ensure all students, including students with disabilities and at risk, read by the end of the third grade. In addition, the Assistive Technology Act of 2004 (PL 108-364) and the New Freedom Initiative of 2001 mandate the use of assistive technology (AT) as mainstream culture to support students with disabilities, and at risk, and address their learning needs (White House). Text-to-speech (TTS) software is one example of AT that has become more widely used by struggling readers in high schools (Engstrom; Silver-Pacuilla and Fleischman). However, scientific research on the effect of such TTS software use on high school students' reading is very limited (Deshler).

Kurzweil 3000 version 12 (2010) is one of the TTS software programs used frequently in schools. This TTS software utilizes optical character recognition (OCR) to convert print materials into electronic format. The software presents a steady pace of auditory and visual input of text and includes embedded reading supports. It supports reading by (1) highlighting segments of text to focus readers' attention on chunks of words; (2) increasing font size or decreasing the number of words on the screen to improve focus and accuracy; (3) gradually increasing reading speed to train the eyes to move more quickly across the page; (4) allowing students to listen to a passage multiple times to reinforce the flow and cadence of the words; and (5) allowing readers to instantaneously look up words and have the word meaning read back to them from the built in dictionary.

The purpose of this study was to determine the effectiveness of TTS software (i.e., Kurzweil 3000 version 12) as a reading intervention for 9th grade struggling readers. For the purpose of this study, a struggling reader was defined as a student in Grade 9 who read at or between a 1.0 and 6.9 grade level equivalency (GLE) on the Gates-MacGinitie Reading Test (GMRT; MacGinitie, MacGinitie, Maria, and Dreyer) at baseline.

The following research questions were investigated:

1. To what extent does the use of TTS software affect reading vocabulary outcome of 9th grade struggling readers?
2. To what extent does the use of TTS software affect reading comprehension outcome of 9th grade struggling readers?
3. To what extent does the use of TTS software affect reading rate outcome of 9th grade struggling readers?

Methods

To investigate the research questions, an experimental design was used. The duration of the intervention was one semester (approximately 10 weeks). Data were collected from Spring 2011 to Spring 2012. For analysis, the combined data set was used.

Teachers were recruited and randomly assigned into the intervention group or control group. Then, students were recruited and assigned based on their teachers' group assignment. To maximize the number of students who benefit from the intervention, more teachers were assigned to the intervention group than to the control group.

After group assignment, project staff provided one hour of training on the use of the software to the intervention group teachers and students using a researcher-developed TTS guide. The proficiency of teachers and students in using the software was assessed both immediately and two weeks after the training, using a fidelity checklist.

After the training and fidelity check, students in the intervention group were encouraged by the teacher to use the TTS software to read scanned grade level reading materials during participating teachers' content area classes for at least 400 minutes during the semester. The use of the software by the intervention group was tracked with an automated TTS software log. The control group received neither training in nor access to the TTS software; these students received typical instruction in content area classes.

Students' reading vocabulary and comprehension were measured using the Gates MacGinitie Reading Tests (GMRT) (MacGinitie, MacGinitie, Maria, and Dreyer). The GMRT 7/9 was administered to all participants, in both the control and intervention groups, once at the beginning of their participation semester and once at the end. At each testing occasion, a different parallel form of the GMRT was administered to reduce the effects of the test-retest bias. In addition, to measure reading rate, students were instructed to read the first passage in the GMRT for 30 seconds and mark the last three words that they read. The number of words read per minute was then calculated by multiplying the number of words read in 30 seconds times two.

The data on a total of 164 students were used for the analysis. Of the 164 participating students, 32 students participated in the control condition, and 132 students participated in the intervention condition.

Results

On average, students in the intervention group used the TTS software for 582 minutes during one semester. To examine the effects of the TTS reading intervention upon the unaided reading outcomes (i.e., reading vocabulary, reading comprehension, and reading rate) of struggling readers in Grade 9 (i.e., tested without the TTS software) the data were analyzed using Analysis of Covariance (ANCOVA).

Table 1 Results of Analysis of Covariance for reading vocabulary, comprehension, and rate.

Source	*df*	Type III SS	*MS*	*F*	Partial η^2
Reading Vocabulary					
Pre-score	1	212.772	212.772	113.282**	.434
Group	1	9.052	9.052	4.819*	.032
Error	148	277.982	1.878		
Reading Comprehension					
Pre-score	1	68.121	68.121	64.675**	.303
Group	1	5.055	5.055	4.799*	.031
Error	149	156.938	1.053		
Reading Rate					
Pre-score	1	53868.228	53868.228	14.186	.107
Group	1	5488.575	5488.575	1.445	.012
Error	119	451860.762	3797.149		

*p < 0.05, **p < 0.001

Effect of TTS Software Use on Vocabulary

There was a significant positive effect of the TTS intervention upon reading vocabulary, after statistically controlling for students' baseline performance on the vocabulary measure, F (1, 148) = 4.819, $p < .05$, partial $\eta^2 = .032$. The mean, of the intervention group, when adjusted for initial differences (M = 4.964 GLE), was significantly higher than the adjusted mean of the control group (M = 4.322 GLE).

Effect of TTS Software Use on Reading Comprehension

After statistically controlling for pre-reading comprehension GLE scores, a significant effect of the TTS intervention upon reading comprehension was found, F (1,149) = 4.799, $p <$ .05, partial $\eta^2 = .031$. The mean of the intervention group when adjusted for initial differences (M=4.981 GLE) was significantly higher than the adjusted mean of the control group (M=4.493 GLE).

Effect of TTS Software Use on Reading Rate

After controlling for students' baseline performance on the measure of reading rate, a statistically significant difference in post-reading rate was not found, F (1,119) = 1.445, $p > .05$. The mean of the control group adjusted for initial differences (M = 198.92) was higher than the adjusted mean of the intervention group (M = 181.41), but this difference was not statistically significant.

Discussion

The research addressed the effects of using TTS software on the reading performance of 9th grade struggling readers (measured while not using the software). The positive findings included significant improvements in vocabulary and comprehension, but not in reading rate.

Specifically, the vocabulary gains of students in the intervention group exceeded the vocabulary gains of the control group by a GLE of six months. The reading comprehension gains of students in the intervention group surpassed the reading comprehension gains of the control group by a GLE of five months. This finding implies a correlation between reading comprehension and knowledge of word meanings (Stahl and Nagy). In fact, Cromley and Azevedo found, through a path analysis conducted with data on struggling readers, that vocabulary makes the largest contribution to reading comprehension.

In addition, previous studies investigated the effects of TTS use by measuring students' reading comprehension while using the TTS software. Thus, this study makes a unique contribution to the reading intervention literature. It also supports McKenna and Walpole's hypothesis that struggling readers' unaided levels of reading competency will gradually improve as a result of the use of AT.

This study did not find a significant effect of TTS software use upon student reading rate. For this study, reading rate was defined as a running record of the number of words read silently per minute. Students' word reading accuracy was not examined. A future study is necessary to investigate the TTS effect on unaided reading accuracy.

Conclusion

While students' access to AT for reading is increasing, scientific research on the effects of AT on reading performance is limited. This experimental study investigated the effects of TTS software use on reading vocabulary, reading comprehension, and reading rate of high school struggling readers. The results indicate the significant effect of TTS software use for increasing vocabulary and reading comprehension of high school struggling readers, but not for increasing reading rate. This study contributes to increasing the scientific evidence-based research on the use of a computer-based AT for improving the unaided reading of high school struggling readers.

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Project CAPKOM: Fostering Web Literacy of People with Cognitive Disabilities

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Abstract

People with physical or sensory disabilities are a well-researched user group considering or with considerations to their needs and prerequisites to use the web, while potential users with cognitive disabilities lack adequate solutions to overcome barriers resulting from their disability. An innovative graphical user interface developed within the project CAPKOM intends to improve the web experience of people with cognitive disabilities by a twofold approach: the user interface will be instantly adaptable to the very different demands of people with cognitive disabilities and iterative user tests will feed results into software development activities, first exemplified by a community art portal for people with cognitive disabilities.

Keywords

Cognitive Disability, eAccessibility, Webdesign, Graphical User Interface

Background / State of the Art

An extensive set of rules and guidelines for designing, implementing and publishing barrier free websites and software focuses on general, technical accessibility from the perspective of different groups involved in providing content and information via the internet (WCAG; Nietzio, Scheer, and Buhler). Those rules guarantee accessibility and to some extent also usability for a broad scope of users with and without disabilities, including older adults.

People with cognitive disabilities face a different (if not even a reverse) situation as conventional navigation and “pure” textual description build profound obstacles (in getting information or using mainstream ICT) (Bohman). An example of a contradictory situation might be a flash-video explaining a website before use. This can be both annoying for mainstream users as well as very helpful for the target group. In recent years, a number of experts raised awareness of challenges in making the internet accessible for people with cognitive disabilities (Poulson and Nicolle; Pouncey). Most experts judge that accessibility for users with cognitive disabilities can be a far greater challenge than for those with other types of disabilities (Gregg). The individual needs of people with cognitive disabilities vary widely depending on grade and form of the disability.

Following studies and experience, translating websites word by word (e.g. into Easy to Read) or reading websites aloud leads to inefficient or inappropriate solutions. In order to find ways to comfort our most diverse target group in surfing the web on their own, CAPKOM aims at developing an innovative graphical user interface (independent technological platform and also available on mobile platforms) instantly adaptable to the needs of people with different types of cognitive disabilities.

The adaptability of the planned graphical user interface in the context of the CAPKOM project clearly targets users with cognitive disabilities. As part of the user testing, we monitor to what extent people with cognitive disabilities are able to act independently in using information and communication technologies to identify the necessary prerequisites.

Methodology

With the incentive of being part of an online art portal, initially adapted to the needs of people with cognitive disabilities (to display and discuss pieces of art by both artists with and without cognitive disability), we involved our target group and their caregivers from the beginning ("The Art Platform"). Following the results of user tests and rapid prototyping sessions, we paid special attention to text complexity and added symbols to support navigation and content. Following Bernasconi, the use of well introduced and known icons and symbols facilitates navigation, understanding, and use of a website. A follow up evaluation of the current situation with regard to barriers and difficulties, browsing behavior and IT skills of our target group shows the following most important categories and prerequisites to be kept in mind:

- Group description, "cross section"

  Which disabilities does the target group have?; Which restrictions do they have through their disability; What are they good at?
- Physical description, "individual persona"

  Name; age; living conditions (How and where do they live?); Description of the forms of their disability; Description of their personal skills; Description of their use of technologies (Which kind of electronic devices does he/she use?, For what and how?);

- Scenarios / use cases

  Typical use environment (Where and how does the person surf the Internet?; At home, at work or in school? To play, to network, to learn?);

- use and user interaction paradigms

R & D Idea

From a technical perspective, our targets were:

- Design and development of a software-framework for the creation of user interfaces for people with cognitive disabilities
- Implementation of this framework using the example of:
  - A community art portal ("The Art Platform")
  - An application for smartphones
  - A communication software suite (already sketched and in development by PLATUS, a project partner and company working in the area of Augmented and Alternative communication (AAC)) (Platus Learning Systems)
- Based on the findings and results from intensive user testing (our panel comprises around 400 individuals with a very diverse set of abilities and competences), we will develop mobile applications for smartphones and software solutions for Augmented and Alternative Communication (AAC).
- Last but not least we plan to develop a wizard to easily adapt the user interface to the needs of the respective user with cognitive disabilities.

This required a special methodology:

- Research and development of a knowledge model adapted to people with cognitive disabilities,
- Development of a symbol based communication system adapted for the specific needs of people with cognitive disabilities,
- Provision of an adequate user interface adapted to the project framework,
- Experience-prototyping for iterative software development and evaluation routines

First Results

We designed and used different mock ups with symbols and navigation structure and implemented them within a user interface and a website (a community art portal) for people with cognitive disabilities, containing some pages for uploading, showing and discussing self-made pieces of art with:

- An easy to use, color indicated navigation scheme
- Symbols added to textual indicators
- Simplified text

We additionally gained useful information on the preparation of an action plan following focused discussions with experts and caregivers for people with cognitive disabilities:

- A separate database should give the opportunity to upload a user’s own icons or pictures.
- The portal should provide the possibility to learn a certain structure of websites, which supports the target group by giving them tools, methods, community experiences and training actions for other internet sites and platforms.
- Possibility to easily implement, own (known), and restore default symbols.

- Undo-function, acting as safety net mechanism.
- AAC: icons with text, speech output, mouse-over-function.
- Clear distinction between website content and navigation area.
- Search-function placed in the upper right part of the site.
- Navigation placed on the left side, with pointed out buttons and control elements enriched by big icons, leading to a better overview and orientation.
- A short introduction of the platform is necessary, especially in making settings and adjustments.

As displayed in Figure 1, we refrained from using color based navigation as it turned out to be more distracting than helpful. Additionally, we took all texts on this portal and translated them into an easier language version following the “European standards in easy to read and use information” (Inclusion Europe; WAI W3C). Last but not least, we adapted the whole structure of the page to a better overview and usability.

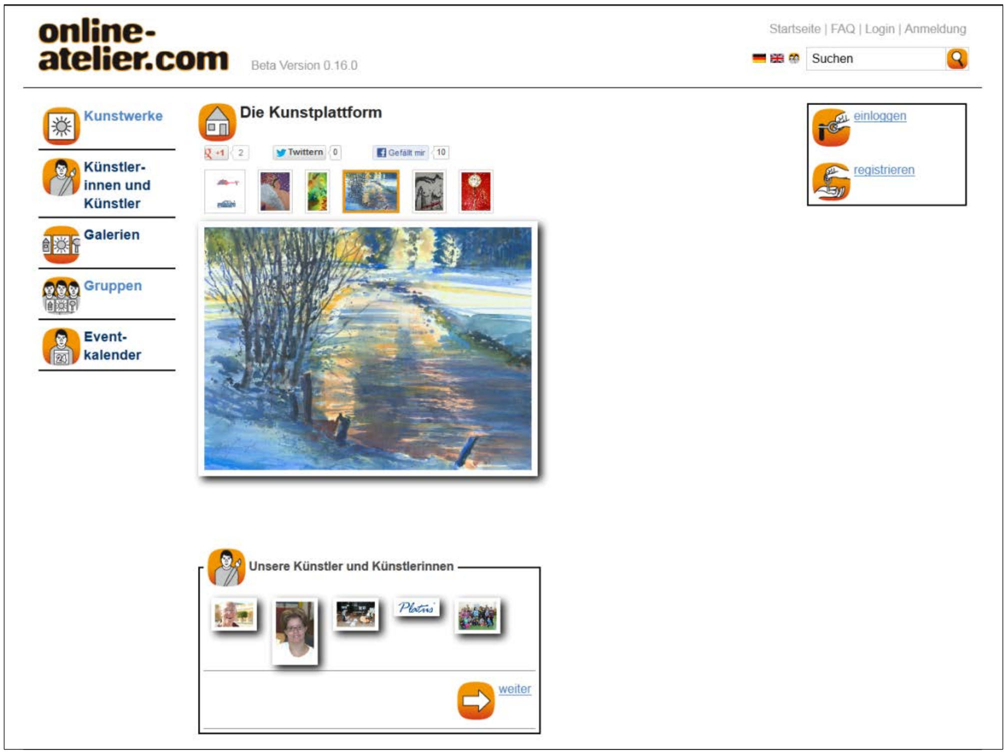

Fig. 1. The CAPKOM Art Portal in Version 2, After User Testing and Expert Discussions

Conclusions

With the CAPKOM project and all related applications, we aim at two primary goals:

- Ethical goal: To include as many people as possible in innovative applications of information and communication technologies and bring them together (e.g. in a community art portal where they can express themselves and discuss their works) without barriers. In this context, the community art portal can be regarded as an easy and reliable starting point, which gives users the opportunity to learn how to realize the different possibilities provided by the internet.
- Practical goal: By using our example applications, we show how modern ICT and AT is best implemented and adapted to the needs of a very diverse user group and how this knowledge can also provide commercial benefit. There is a great demand for ICT for

people with disabilities but still, the supply is very limited. Concerning the commercial benefit, ever more people are getting access to the internet and the wired disability community continues to grow at incredible rates. Ultimately, there is a new market to be opened up (Paciello).

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- UTILO KG, Austria: http://www.utilo.eu
- Platus Learning Systems GmbH, Austria: http://www.platus.at
- Lebenshilfe Salzburg, Austria: http://www.lebenshilfe-salzburg.at

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Necessities for Math-Access Tools with Speech

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Abstract

Some new points that should be required in assistive tools for print disabled people to access math/science with speech output are discussed. The manner of "aloud reading" should be switched to the appropriate one according to the characteristics of a reader's disability; blind users need a different manner than dyslexic users. Furthermore, the ambiguity of math expressions requires assistive tools to offer a method to assign an appropriate reading flexibly to those expressions according to context. In our accessible math-document editor, those features are really implemented. Combining it with our math OCR software, one can easily convert a math/scientific document in print or PDF into accessible e-books in DAISY or EPUB.

Keywords

MathML, Print Disability, Dyslexia, DAISY, Speech, Math

Introduction

"Knowledge" forms the foundation of contemporary society. In particular, abilities to make full use of scientific information including math expressions must be an essential skill for people to play active roles in society. However, such information was not necessarily accessible for print disabled people until recently. Fortunately, the situation has become remarkably improved these days. For instance, since MathML has been officially adopted in the current version of "the Digital Accessible Information System (DAISY)," we have become able to produce text-based/multi-media DAISY math content, in which one could access a math formula character by character, symbol by symbol with speech synthesis (DAISY Consortium). The International Digital Publishing Forum (IDPF) decided to adopt DAISY XML as a part of EPUB3 standards in 2011 (International Digital Publishing Forum).

However, there still remain several unsatisfactory points even in the current assistive tools to access math with speech. First, the fact that there is certain ambiguity in reading out math expressions is not necessarily taken account of in those tools. Many mathematical symbols or formulas have various names. For instance, "x with a raised 2, x^2" is usually used for x squared; however, it sometimes represents another quantity such as the second component of a vector. Such formulas have to be read in an appropriate manner according to their context. We need a method to define how to read those symbols or formulas with speech synthesis; however, it is difficult to change the manner of “aloud reading” in many math-access tools. Furthermore, “how a math formula should be read aloud” depends on the characteristics of the reader’s disability. We cannot provide such choices in most cases, either.

Math-Access tools

Math-Access tools with Speech

In the last two decades, various approaches have been tried to improve math accessibility. In 1994, T. V. Raman reported on his "Audio System for Technical Readings" which could read out math documents in LaTeX format with DEC Talk synthesizer, which might be the very first trial in this field (Raman). While LaTeX still plays an important role in math accessibility, recently MathML has become a key technology in assistive tools for print-disabled people to access "science, technology, engineering and math" (STEM) with speech. For instance, "MathPlayer" is a plug-in for a web browser such as Internet Explorer (Design Science). With this plug-in, the browser not only can display but also read out math expressions described in MathML embedded in a web page. "ReadHear" is one type of DAISY playback software, which can read aloud math expressions described in MathML, while highlighting each character/symbol as it is read aloud (gh, LLC.). There have been several other challenging activities based on MathML such as "Math Genie" (Gillan, Barraza, Karshmer, and Pazuchanics).

MathML

MathML is one of the XML (extended markup language) family, which was originally used for embedding math expressions in a web page; however, now it is used in various e-book formats such as EPUB3.

Although it is not well known, since the very beginning of its history, MathML has 2 types of notation for describing math expressions: "Presentation Markup" and "Content Markup." Presentation Markup aims only at formulating each symbol in a print math style. For instance, x with a raised 2, x^2, is always described as follows:

<msup>

<mi>x</mi> <mn>2</mn>

</msup>

regardless of its meaning, "x squared" or "the second component of a vector **x**."

On the other hand, Content Markup focuses on the semantics or meaning of math expressions. For instance, when x with a raised 2 means "x squared," it is described as follows:

<apply>

<power/> <ci>x</ci> <cn>2</cn>

</apply>.

When it means "the second component of a vector **x**", it is described as follows:

<apply>

<selector/> <ci type=”vector”>x</ci> <cn>2</cn>

</apply>.

That is, a description of Content Markup for a math expression depends on its semantic meaning. Using it, we can distinguish different math expressions having the same print style from each other. However, since this notation is rather complicated, there are practically no used web browsers that can support Content Markup.

Infty Software

Our group, the Infty Project and the not-for-profit organization, the Science Accessibility Net, have been developing math-access tools for more-than-15 years (Infty Project, sAccessNet). Our math-OCR system, "InftyReader," can recognize STEM documents in print or PDF and convert them into various accessible format such as LaTeX, MathML and Microsoft Word XML. "ChattyInfty" is an accessible math-document editor with speech. Using it, blind users not only can read but also author a STEM document for themselves.

We worked on upgrading ChattyInfty thoroughly so that a recognized result with InftyReader or an edited file with ChattyInfty can be converted into DAISY XML format. Thus, the new version of ChattyInfty, "ChattyInfty3," becomes an accessible authoring tool for text-based/multi-media DAISY (Yamaguchi and Suzuki, “Accessible;” “On Necessity”). It is also useful for people with low vision or dyslexia as well as blind users. In the software, both the technical and non-technical content can be read aloud. Furthermore, since a result recognized by InftyReader can be imported directly, both sighted and print-disabled people can produce a DAISY book easily from printed or PDF material by making use of Infty software only.

In terms of multilingual support in ChattyInfty3, users can author/change not only how to read mathematical content but also captions in menu items and dialogs as they like since those things are all stored in independent files on a main program. Users, therefore, could customize ChattyInfty3 for each local language if necessary. For the present, although only Japanese and English versions are available, we are working on developing French and some other-language versions. Incidentally, the foreign-language versions other than Japanese use Microsoft Speech API, Ver.5 as a speech engine. Users can produce Text-based/multimedia DAISY content (DAISY3) in which all the math expressions are represented in MathML. In addition, output capability to EPUB3 is also implemented.

ABBYY "FineReader" is known as one of most powerful OCR software applications in the world (ABBYY). Recently, we released FineReader plug-in for InftyReader. By combining it with InftyReader, recognition rate for European languages including extended Latin characters becomes remarkably improved.

What Is Required of Math-Access Tools

Three Kinds of Aloud-Reading for Math Expressions

By making use of Infty software, we started a collaborative project with the Japan Braille Library two years ago to provide DAISY math/science textbooks to various print-disabled students. Through this activity, we noticed that "how a math formula should be read aloud" does depend on the characteristics of the reader's disability. For blind users, extra messages for which there are no corresponding print symbols explicitly in a math formula should be provided to show the structure of that formula exactly. For instance, they do need messages such as "Begin Fraction" and "End Fraction." The manner of “aloud reading” originally defined in ChattyInfty was essentially of this style. However, for other print-disabled people who can "see" the math expression up to a certain level, dyslexic users for instance, those extra messages actually disturb their understanding. They are often confused with the messages that do not have corresponding print symbols. Furthermore, even for blind users, when reading material repeatedly, they tend to want to skip those messages as well.

Thus, we implemented a new function in ChattyInfty3 so that three different types of “aloud reading” for math formulas can be selected. "Plain-Reading mode" is based on one which may be most widely used in English-speaking countries. It is natural; however, a spoken math expression is often ambiguous. We assume that people with low vision and dyslexia use it. In "Smooth-Reading mode," minimum-necessary speech guides for blind users to grasp the structure of a math formula correctly are added. "Detailed-Reading mode" is assumed to be used when a blind user wants to know the math-formula structure in the most detail.

"Yomi" Function in ChattyInfty3

As was mentioned previously, there are many ambiguities in reading math expressions. However, most math-access tools with speech do not seem to take this point into account. A fact that they are based on MathML in the presentation-markup notation may be one reason for that. As far as blind users are concerned, they could take down spoken math contents once in Braille and read it (a Braille document) over again. In this case, "presentation-based aloud-reading" is probably enough for their demands. Actually, "MathSpeak," that is a system of “aloud reading” for blind users given by A. Nemeth, seems to be of this type (MathMonkeys, LLC.).

However, people with other print disabilities such as those with severe low vision or dyslexia do need to directly understand the spoken math content, itself. If MathML in the content-markup notation could be used, it might be possible for us to assign appropriate “aloud-reading” automatically to each math expression. However, since it is impossible now, we need a new way to handle how to read out each symbol or math formula locally according to their context. We refer to this new concept of assigning a pronunciation as "Yomi" (a Japanese word that means "a manner of aloud reading"). We actually give a concrete method to assign Yomi to math expressions in DAISY3/EPUB3, which is implemented in ChattyInfty3.

Discussion

Here, at first, we list some samples to show the difference among three modes of “aloud reading”: Detailed Reading, Smooth Reading and Plain Reading in ChattyInfty3. The 10th terms of a sequence, c_{10} is represented in each of them as follows:

Detailed Reading: "c sub ten sub-end,"

Smooth Reading: "c sub ten (a short pose),"

Plain Reading: "c ten."

A fraction, two over three, 2/3 is read as:

Detailed Reading: "Frac two over three frac-end,"

Smooth Reading: "Frac two over three (a short pose),"

Plain Reading: "two over three."

Incidentally, we could assign "two thirds" to it with the Yomi function. Contrary to our expectation, we realized that, except for complicated math expressions, blind users seem to prefer Smooth Reading to Detailed Reading. Although most people with severe low-vision and dyslexia like Plain Reading, some of them tend to choose Smooth Reading since they do not look at a display when reading a DAISY book. Thus, we now assume Smooth Reading as a default in ChattyInfty. These three modes of "aloud reading" could be switched to another at each line if necessary. Unfortunately, since most of the other math-access tools with speech do not have such a feature, they are not necessarily useful for print-disabled people other than blind users.

We made a brief survey on the ambiguity in "aloud reading" of math formulas in several math textbooks. Although it is difficult to evaluate our result quantitatively, if we may say so, we confirmed that such ambiguity often appears in those books. Here are some examples we listed.

In fraction-type formulas:

A mixed fraction, 2 1/3: "two and a third" can be read as "two times a third."

A derivative, dy/dx: "(derivative) dy by dx" can be read as "(fraction) dy over dx."

In Super/Subscript type Formulas (in addition to the sample listed before):

f with a raised -1, f^{1}: "f inverse" can be read as "f to the -1 power."

In math formulas with enclosing symbols:

A function A of an argument -x, A(-x): "A of -x" can be read as "A times a quantity, -x."

A combination, C(5, 3): "combination of 5 things taken 3 at a time" can be read as "a point C of coordinates 5 and 3."

Since each of them has the same form in print, access tools with speech cannot choose a proper “aloud-reading” automatically. In ChattyInfty3, one can assign appropriate manners to them with the Yomi function. Furthermore, although it is not an ambiguity issue, as situations require, we often have to choose the suitable manner of “aloud reading” for a math expression such as "2 and 3" in arithmetic and "a plus b" in algebra. The Yomi function is also useful in handling those cases.

Conclusion

Persons who verse themselves in mathematics probably could understand content of a STEM document according to its context even if some math formulas were read out in a wrong manner. However, for low-skilled students, it is clear that a textbook should be read aloud as correctly as possible. Three types of “aloud reading” and the Yomi function could give a certain contribution for those cases. We believe the other math-access tools with speech should take into account these points as well to support various types of print-disabled people.

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Innovative Haptic Interface for Navigation

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Abstract

This paper presents the development of an innovative navigation interface with haptic support for people with visual impairment. Based on the idea of adaptive control elements, interaction with the interface is facilitated and haptic distinction between different menus is made possible. By integrating haptic feedback, a safer and more user-centered approach for navigation systems is introduced, which leads to a more immersive way of interaction.

Keywords

Adaptive control elements, multimodal interaction, navigation interface, visually impaired people, user centered interface design

Introduction

Mobility is one of the most important human basic needs. Due to high risk of injury, people with visual impairment often reduce their traveling activity to a minimum, which in the worst case can lead to isolation of the person. Therefore, continuous development of assistive technology that increases the safety level during navigation is essential. Since most navigation systems only use auditory output, there is a high chance that information is not being perceived properly, e.g., because of ambient noise. By adding an additional haptic output an efficient interaction can be ensured.

This paper presents the development of a navigation interface with additional haptic support. The idea was realized during the research project "Hard- and Software Interface development of map-based haptic orientation and navigation systems for people with visual impairment." The project was carried out by the University of Stuttgart in cooperation with the industrial partner, Handy Tech Elektronik GmbH. The University of Stuttgart is represented by the Institute for Visualization and Interactive Systems (VIS) and the Institute for Engineering Design and Industrial Design (IKTD), Research and Teaching Department Industrial Design Engineering. IKTD was mainly in charge of the interface focuses on the development of ergonomic devices. VIS realized the software of the system.

State of Technology and Research

Navigation systems which help people with visual impairment have been commercialized for about four years. At this point nearly all commercialized stand-alone GPS navigation systems just use acoustic output. On the research and development level, there are projects going on trying to use other modes of feedback like HaptiMap, Tacit, vibro-tactile belts or vibrating compasses. To improve navigation for people with visual impairment, a holistic approach considering all channels of human machine interaction is recommended.

Human-Product-Relation and Multimodality

The cognition of and the behavior in response to a product depend on the perception of a person. The product interacts with the user through the product gestalt, which consists of its assembly, shape, color and graphics (see Figure 1).

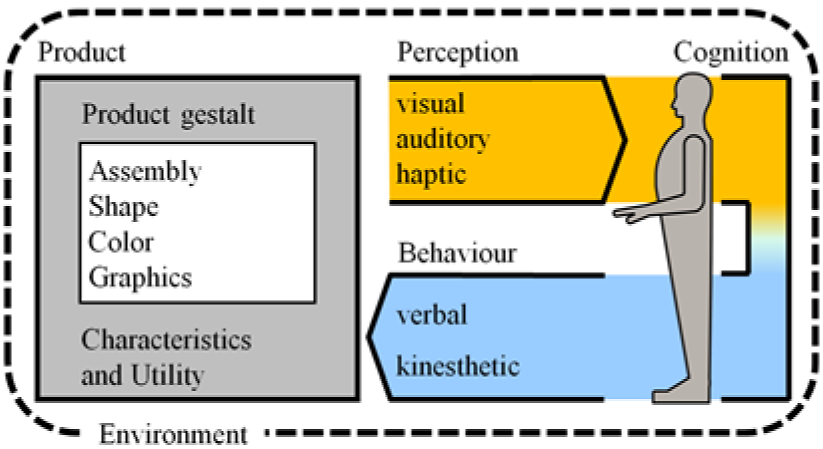

Fig. 1. Basic Model of Human-Product-Interaction

The concept of multimodal interaction can be chosen as a basic approach to improve the usability of navigation systems. Schomaker et al. define an interaction as multimodal if it is "restricted to those interactions which comprise more than one modality on either the input (perception) or the output (reaction) side." According to Schmid, Petrov, and Maier, the user's capacity of perception is enhanced through the distribution of data via multiple modalities. People with visual impairment can use two modalities (auditory and haptic). Since auditory information, like a sound, can be easily disturbed by ambient noise during navigation, there is a high chance that information is not being perceived properly by the user. By using the somatosensory modality as an additional source of input, a safe and efficient transmission of information is ensured.

Adaptive Control Elements

An additional haptic user input for the interface of a navigation system can be made possible by the basic approach of adaptive control elements. Adaptive control elements are characterized by their ability to vary and adapt their gestalt (structure, shape) depending on the context of the human machine interaction (Petrov). As a consequence, the user is being relieved in situations of complex information input.

Haptic Specifications

To develop an ergonomic device, the German guideline VDI 2424 suggests a centripetal user-centered design approach. In this case the design is based on the haptic requirements of the human hand, so that the tangible feedback is well received. Especially important for proper haptic perception is the tangible height of elements which leads to deflection of the human skin during contact. According to Kaczmarek and Bach-Y-Rita, the absolute threshold of haptic perception due to deflection of human skin of the fingertip is 10 µm (3.93×10^{-4} in). For the design of haptic devices Kern suggests a maximum height of 1 mm (3.93×10^{-2} in). Apart from requirements concerning the haptic perception of the human skin, a basic understanding of the exerted finger forces is essential for the choice of adequate drive elements that enable the variation of the interface gestalt. In this context, measurements published in the German standard DIN 33411 state axial forces being exerted from the index finger of 7 N maximum. Those key specifications provide a basis for the dimensions of the tangible elements.

Arrangement of Control Elements

Schmidtke states that control elements should be arranged according to their rate of use with the most frequently used ones being located in the most comfortable area of operation. Since the system should be used easily during navigation and a visually impaired user is expected, in addition, to carry a white cane for people with visual impairment, there is only one hand left to operate the device. Thus, single-handed use is required. To enable a sinistral and dextral operation, symmetric assembly is necessary. Therefore the interface is divided into three control element areas. Figure 2b shows the natural position of rest of the operating thumb which represents its most comfortable position, with the inclination angle of the thumb joint being minimal.

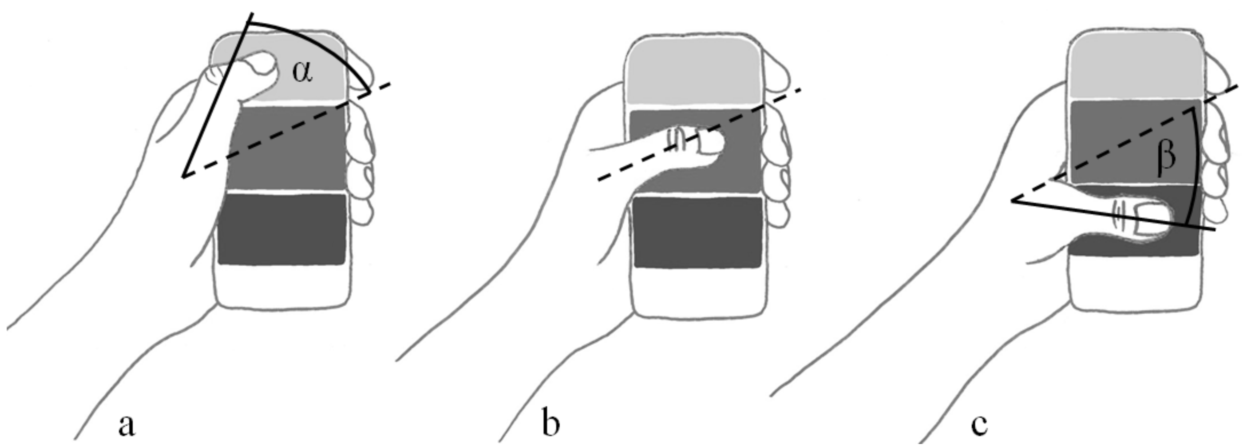

Fig. 2. Determination of Comfortable Thumb Reaching Areas for a Single-Hand Control Device

As a consequence the central area of the interface is supposed to contain the most frequently used control elements. To reach the upper area a positive inclination (α) of the thumb is implied (see Figure 2a). Speaking of comfort, this thumb movement is clearly to be preferred over the negative inclination (β) to reach the lower area (see Figure 2c). As a result, the upper area is defined to contain frequently used control elements while the lower area should only contain least frequently used elements.

Design of the Apparatus

Conceptual Design

To develop the conceptual interface design, a set of essential menu functions were derived from different user questionings. Twelve control elements were defined for an ergonomic handling of the device. Based on the anticipated rate of use, those control elements were divided into a key field with three main areas: a primary, secondary and tertiary area. The nine keys of the primary area are expected to be used frequently and situated in direct space of reach. Accordingly the keys of the secondary and the tertiary area will be used less and therefore are placed in less comfortable areas above and under the primary one. Figure 3 illustrates the final arrangement of the eleven control elements according to their absolute rate of use.

The idea of adaptive control elements was realized by two types of additional retractable and liftable tangible elements, bridge and navigation elements, permitting additional haptic information encoding.

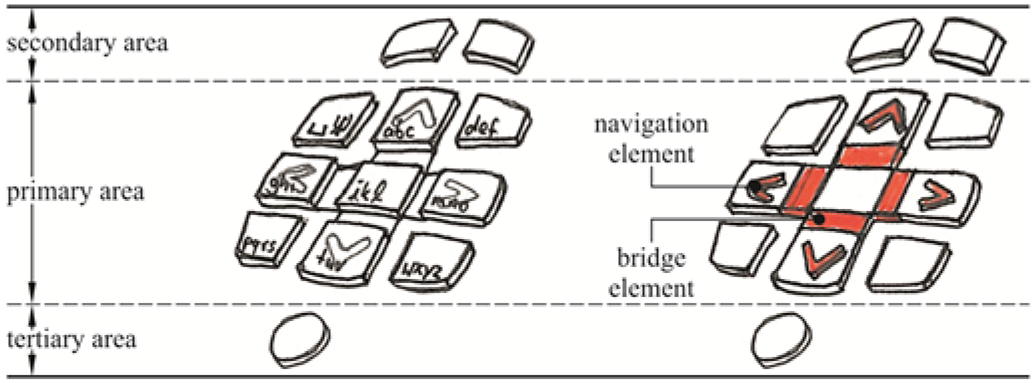

Fig. 3. Conceptual Design of the Interface with Bridge and Navigation Elements in Retracted (left side) and Lifted (right side) Position

Four movable bridge elements vary the interface gestalt of the key field and thus facilitate haptic distinction between different menus such as input / setup mode or navigation mode. By lifting all four bridge elements, the key field transforms into a cross gestalt intuitively being associated with the four cardinal directions. At the same time it indicates to the user that s/he is in navigation mode. While entering a particular destination, a homogenous key field is desirable, which is achieved by lowering the bridge elements.

Four movable tangible navigation elements provide a haptic support during navigation mode. Depending on the element being lifted the aspired direction is indicated. By varying the frequency with which the elements are lifted and retracted, the distance toward the next change of direction is encoded continuously. The higher the frequency the closer the user is to the aspired waypoint.

Assembly

To enable both the bridge and navigation elements to be lifted and retracted, drive elements are necessary. While all four bridge elements must be connected in parallel since they all lift or retract together, the drive unit must enable the navigation elements to lift and retract individually. A set of electrical drives was chosen with consideration to the necessary holding forces and lifting range. The drives must have sufficient power so that the adaptive elements remain lifted during haptic exploration by the user.

Figure 4 shows the CAD model with the adaptively variable key field and the main drive unit. The key field consisting of button caps and switches is placed on a circuit board. To support the circuit board, a support frame was designed. Below the key field, four electrical drives are arranged ring-like to enable the individual movements of the navigation elements. Those navigation elements form the tips of spring elements. They are necessary to allow the navigation elements to be pushed down with the affected keys they are integrated into. This mechanism prevents the navigation element from causing excessive deflection of the human skin while the adaptive control element is pushed down. A fifth electrical drive below the other four drives is connected to an upstroke mechanism. This mechanism enables the bridge elements to lift and retract. All drives are integrated into the support frame, which also serves as guidance for the upstroke mechanism.

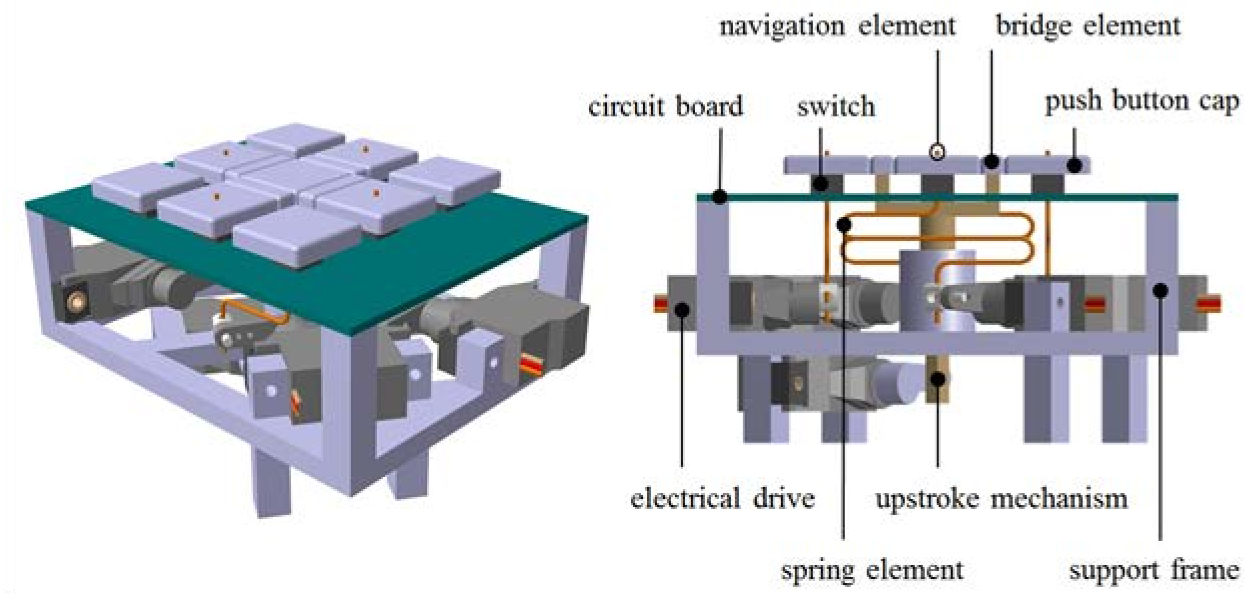

Fig. 4. Functional Components of the CAD Prototype

Housing and Overall Shape

Based on the CAD model, a hardware prototype was manufactured and assembled (see Figure 5). To house all functional components and facilitate single-handed use, the device has a curved shape with anthropomorphic areas. This allows the user to carry and operate the device at the same time with one hand only.

Fig. 5. Manufactured Prototype with Housing

Conclusion

An innovative navigation interface with haptic support is developed, based on the idea of multimodal interaction and adaptive control elements. Thereby, for people with visual impairment, interaction with the interface is facilitated, and haptic distinction between different menus is made possible. Due to the additional haptic feedback, a safe and efficient transmission of information can be ensured during use. Apart from that, the use of adaptive control elements partly compensates for the lack of information based on the impaired visual channel. This leads to an enormous improvement of the device's usability and introduces a new kind of haptic esthetics in assistive technology. This navigation interface can be used both for outdoor and indoor navigation. The basic approach of adaptive control elements is not restricted to navigation systems. It can also be adapted to other types of assistive technology.

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Accessible Voting Systems Usability Measures

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Abstract

It is critical that all adults be able to successfully and independently engage in the voting process. In order to ensure that this is possible, individuals with disabilities must be included in usability evaluations of accessible voting systems, and the present paper defines standardized evaluation criteria and benchmarks for including blind, visually impaired, and dexterity limited individuals in testing. While voting accuracy is always the most important measure of any voting system, additional factors disproportionately impact individuals with disabilities, which can make the voting process difficult and painful if not properly controlled. As a result, the authors propose the use of revised Voluntary Voting System Guidelines and Voting Performance Protocol measures for total completion score, voter inclusion index, and perfect ballot index, as well as two new measures, voting time and interactions, to determine whether a system should be considered acceptable for people with disabilities. These new measures are necessary to ensure that the voting process can be successfully and reasonably completed by individuals with disabilities.

Keywords

Voting; accessibility; voting metrics; accessible voting systems; usability

Introduction

Usable voting systems are essential to the democratic process for all people, but are especially important for persons with disabilities. Electronic voting systems, which are used in local, state, and federal elections in the United States and other countries, need to be designed so that all users can independently and effectively interact with them in a reasonable amount of time and without discomfort.

The Voluntary Voting System Guidelines, or VVSG (U.S. Election Assistance Commission), has standards for voting system accessibility and usability as mandated in the Help America Vote Act, or HAVA. While there are extensive design requirements and associated tests for conformance to these requirements in the VVSG for both accessibility and usability, usability testing requirements for both the general population and people with disabilities are still under development. Human performance tests that include consideration for accessibility requirements (i.e., testing the usability of these systems for people with disabilities) are crucial to ensuring a satisfactory and successful voting process.

There is very little published research on accessible voting metrics; however, the present work builds on prior research for developing a methodology for conducting usability test for accessible voting systems, including Laskowski, et al. and the U.S. National Institute of Standards and Technology (NIST).

Discussion

Usability and accessibility experts at Michigan State University (MSU) were tasked by NIST with developing a suitable, rigorous test protocol that a Voting System Test Laboratory could follow to conduct usability conformance testing of accessible voting systems with persons who are blind, have low vision, or have dexterity impairments, in order to ensure that they can vote accurately and independently with a particular voting system. The MSU researchers developed a testing methodology for determining whether voting systems are usable and accessible for persons with disabilities, including consideration for whether they are able to cast ballots as they intend without causing serious discomfort (Swierenga and Pierce). The test recommendations are aimed at making pass/fail judgments for voting system certification to the VVSG.

After developing and refining the tests and protocols to make them appropriate for the selected demographic groups, dry runs of the test protocol were conducted using multiple voting systems to obtain expert timings and performance benchmarks to refine pass/fail metrics (user testing was outside the scope of the project). Dry run data were collected by having usability researchers go through the voting protocol with each system while using specific accessibility features, while a second researcher recorded the time required and counted the number of button-presses/interactions. Unfortunately, most systems required too much time and too many interactions (e.g., button presses, screen-touches, sips/puffs, etc.) when assistive technologies were used to be reasonably completed under our constraints (limitations imposed by disabilities or the use of assistive technologies). Individuals with disabilities and experts confirmed our findings when given the opportunity to interact with the systems and evaluate the protocol. One outcome of this research was to recommend two additional pass/fail measures to determine system conformance and to help ensure an equitable experience for all voters (Swierenga et al.).

Draft Measures

The most important measure of the success of a voting system is the accuracy of a voter's selections. As a result, the use of revised Voting Performance Protocol measures for effectiveness (total completion score, voter inclusion index, and perfect ballot index) is recommended to determine whether a system is acceptable for people with disabilities (Swierenga and Pierce 36-37). For Total Completion Index and Perfect Ballot Index, it is recommended that a system's uncorrected mean score must exceed a benchmark value in order to pass. The recommended benchmark is 92.5% for Total Completion Score and 2.00 for Perfect Ballot Index. Voter Inclusion Index should be calculated across all groups, and a 95% confidence interval should exceed a benchmark of 0.35 to pass. Additionally, two new metrics, voting time and interaction counts, should also be used as criteria for system acceptability for individuals with disabilities (Swierenga and Pierce 37-39).

Voting Time

Voting time, while not considered for conformance in the standard Voting Performance Protocol, becomes more critical for individuals with disabilities for a number of reasons. First, the time required is significantly longer; Swierenga et al. ("Impact of visual impairments") found that, as a rule of thumb, users who are blind or have low vision typically take up to 4 times as long as users with normal vision in usability studies with computers. While variation between 5 and 20 minutes may not be considered problematic in voting session duration, for users who are blind or have low vision, that would translate to variation between 15 and 80 minutes.

Sitting and concentrating for an hour or more to complete a ballot at the polls is not reasonable, and individuals with disabilities are more likely to suffer from physical and mental strain and discomfort in a voting session lasting that long. Furthermore, with a limited number of accessible voting systems at any given polling station, long voting times severely limit the number of people who can vote, and make it extremely inconvenient to find enough time to vote (especially for individuals who come as a group).

Calculating the average number of minutes needed to successfully complete the NIST Test Ballot for each user group (i.e., users who are blind, users with low vision, and users with dexterity impairments) is recommended. For each group, the maximum allowable average time should not exceed 40 minutes. Mean time for a single-group greater than this benchmark would constitute a failure for the voting system. This value was calculated after expert review and benchmarking of multiple voting systems with and without assistive technologies; however, it was primarily based on reasonable expectations for individuals with disabilities to be engaged in a single task of this type, regardless of current system abilities.

The researchers completed the NIST Test Ballot according to the instructions that would be followed by individuals in the usability tests to determine best-case times, i.e., no deviation from the instructions or confusion about how to use the machine, with three existing systems (see Table 1).

Table 1 Best case times for completing the standard NIST ballot using various alternative input devices.

		Silent	Audio
System 1	Touchscreen	10:00	
	Button Panel	11:00	17:00
	Jelly Switch	23:00	
System 2	Touchscreen	7:00	
	Button Box	18:00	37:00
	Jelly Switch	24:00	52:00
System 3	Buttons	6:00	32:00

Interactions

"Interactions" are button-presses, screen-touches, sips/puffs, and any other physical actions taken by a user to interact with the voting system. Individuals with dexterity limitations are significantly impacted by the number of interactions that they must initiate. For a button-press, the amount of strain depends on the amount of pressure applied, the size of the button, and the number of presses required. While pressure and size can be easily controlled by appropriate physical specifications in the VVSG, user data are needed in order to determine the average number of interactions that are made by users when using the NIST Test Ballot on the system.

We recommend calculating the average number of interactions needed to successfully vote for each user group and for each input device across groups. For individuals using a one- or two-button device (such as a dual rocker switch) or using a touchscreen or full keyboard, the average should not exceed 400 interactions. For individuals who use multi-button inputs (more than two buttons/options, but less than a full keyboard), the number should not exceed 600 interactions. User groups with dexterity limitations should never exceed 400 interactions. Exceeding these limits would constitute a failure for the voting system. These values were calculated based on the number of interactions required to complete the NIST Test Ballot according to the instructions used in this study; they include a significant margin for error and allow for variation due to user interface and interaction differences between systems. The observed values for the voting systems tested often greatly exceeded this benchmark, but most could be reduced and therefore comply with only minor software or hardware revisions.

When the instructions were piloted using the NIST Test Ballot on actual voting systems to determine best-case counts (i.e., no deviation from the instructions or confusion about how to use the machine), it was found that all of the systems required a large number of button presses to complete the ballot voting task.

- System 1 touchscreen, silent: 142 button presses
- System 1 button panel, silent: 597 button presses
- System 1 dual-rocker switch, silent: 872 button presses
- System 2 dual-rocker switch, audio: 1200 button presses

Conclusion

Usability performance tests for accessible voting systems require additional and revised measures in order to successfully determine whether they can be successfully and reasonably used by individuals with disabilities. The present study proposes two new measures, voting time and interactions, as well as modifications to existing measures (total completion score, voter inclusion index, and perfect ballot index).

Future work is needed to determine the proposed benchmarks are adequate, based on usability tests with persons with disabilities using the pilot testing protocol developed by Swierenga and Pierce. Critically, they must also take into account reasonable expectations for individuals with disabilities to be engaged in a ballot voting session, regardless of current system abilities. It is important to note that the voting time and interaction benchmarks must be set as low as possible to avoid causing injury or pain to voters, and to try to ensure that they can successfully complete the voting task in one sitting. The ultimate goal is to significantly enhance the usability of voting systems for all users, including those with disabilities, so that voters can vote independently in elections.

It is clear that voting system designers and manufacturers will need to modify their products in order to make them usable for individuals with disabilities, once subjected to more stringent user-testing protocols. Consideration given to the number of interactions and amount of time required to vote under a variety of conditions will likely result in broad changes to interaction designs which will improve the systems for all users.

Acknowledgement

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Accessible Cyberlearning in Practice

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Abstract

The Institute on Disability and Public Policy (IDPP) for the Association of Southeast Asian Nations (ASEAN) Region was formally established in 2011 to partner with governments in the ASEAN region to foster public policies that promote persons with disabilities entering society to compete on a par with their non-disabled peers and prepare disabled leaders in the field of public policy. To address this mission, the world's first virtual master's degree program focused on the complex intersection of disability and public policy in the ASEAN Region using advanced cyberlearning techniques was created and specifically marketed to persons with disabilities in the ASEAN region. The infrastructure needed to deliver this type of program to learners in the ASEAN region and instructors all over the world required an accessible cyberlearning environment. This paper will explore the practical application of designing, developing and implementing an accessible cyberlearning environment.

Keywords

Accessible Cyberlearning, Cyberinfrastructure, Distance Learning, eLearning

Introduction

The Institute on Disability and Public Policy (IDPP) for the Association of Southeast Asian Nations (ASEAN) Region was formally established in 2011 with major funding from the Nippon Foundation. Its main task is to partner with governments in the ASEAN region to foster public policies that promote persons with disabilities entering society to compete on a par with their non-disabled peers and to prepare leaders with disabilities in the field of public policy. One of the initiatives to address this charge was the establishment of the world’s first virtual master’s degree program focused on the complex intersection of disability and public policy, the Master of Arts in Comparative and International Disability Policy (CIDP) degree, offered by the School of International Service at American University. In an effort to address the lack of access of persons with disabilities to postsecondary education in the ASEAN region, particularly in the field of public policy, The Nippon Foundation offered full fellowships for select CIDP students, with preference given to students from the ASEAN region who are blind or visually impaired, deaf or hard of hearing, and/or mobility impaired.

To best support the IDPP’s mission of providing unparalleled opportunities for advanced academic studies for students, faculty, and staff (with and without disabilities), creating an accessible cyberlearning environment was imperative to the CIDP’s effectiveness at achieving its mission of delivering an innovative curriculum not limited by physical constraints and geographic location of knowledge resources. This paper will explore the practical application of designing, developing, and implementing an accessible cyberlearning environment.

Cyberlearning

Cyberlearning is a broad term that many equate to online learning and distance education. For the purposes of the IDPP program, the definition that most accurately reflects the learning environment is provided by the NSF Task Force:

> Cyberlearning offers new learning and educational approaches via networked computing and communication technologies, and the possibility of redistributing learning experiences over time and space. Our scope incorporates the entire range of learning experiences over the course of a lifetime--not only formal education, not only in classes, but throughout the waking hours. (NSF Task Force on Cyberlearning 10)

To address the objective of the CIDP, NSF's definition best captures the learning environment required to support the transfer of knowledge and skills needed to develop change agents and foster learning in disability public policy.

The shape of cyberlearning is changing daily as more and more institutions embrace the technologies now available to deliver instruction synchronously and asynchronously (Yearwood and Nichols 1532). To establish a solid cyberlearning environment, it is imperative to allow the educational and pedagogical needs of ALL to drive the customization of the cyberlearning environment and not the technology. One of the essential tools needed to manage the delivery of content asynchronously was a Learning Management System (LMS) which provides an integrated set of web-based tools for teaching and learning: "Some tools are static and allow instructors to transmit information to students, such as a syllabus, assignments, reading materials, and announcements. Other tools are interactive…and allow students to communicate, synchronously and asynchronously" (Malikowski, Thompson, and Theis 150).

To provide synchronous teaching and learning, a virtual classroom (VC) is required to support and facilitate this engagement. Synchronous learning most mimics the traditional classroom where instructor and student can actively engage in lecture and discussion real-time:

> Advantages of using a synchronous learning environment include real time sharing of knowledge and learning and immediate access to the instructor to ask questions and receive answers. However, this type of environment requires a set date and time for meeting, and this contradicts the promise of "anytime, anywhere" learning that online courses have traditionally promoted. (Skylar 71)

VC software typically provides a platform for sharing real-time audio and visual presentations, similarly to a narrated PowerPoint slide presentation; to engage the participants during the lecture, instructors can utilize polling/quiz features to receive real-time feedback. While in the VC the instructor can integrate Internet browsers into the platform and application sharing, as well as send small groups of students to breakout rooms to collaborate using the audio, whiteboard, chat, application sharing and web browsing tools. In addition to the real-time offerings, each class session can be recorded and shared via a web link, audio, video and/or transcription to those who were absent or who want to review a previous class session.

The final component to establishing a cyberlearning environment is identifying strengths and limitations of the Internet networks available to students and instructors in the ASEAN region as well as faculty members in the United States to transmit and support teaching and learning. As described by Rao, an Integrated Communication Network (ICN) is needed to support the acquiring of information in various signal formats (e.g. video, image, text, audio, voice, data, Internet, email, etc.). The ICN helps to seamlessly integrate and disseminate information by using efficient and cost effective communication modes to various destinations for public use (Rao 226). A modified version of Rao's concept of ICN can be seen in Figure 1, which helps illustrate all of the variables that need to be considered for the CIDP program.

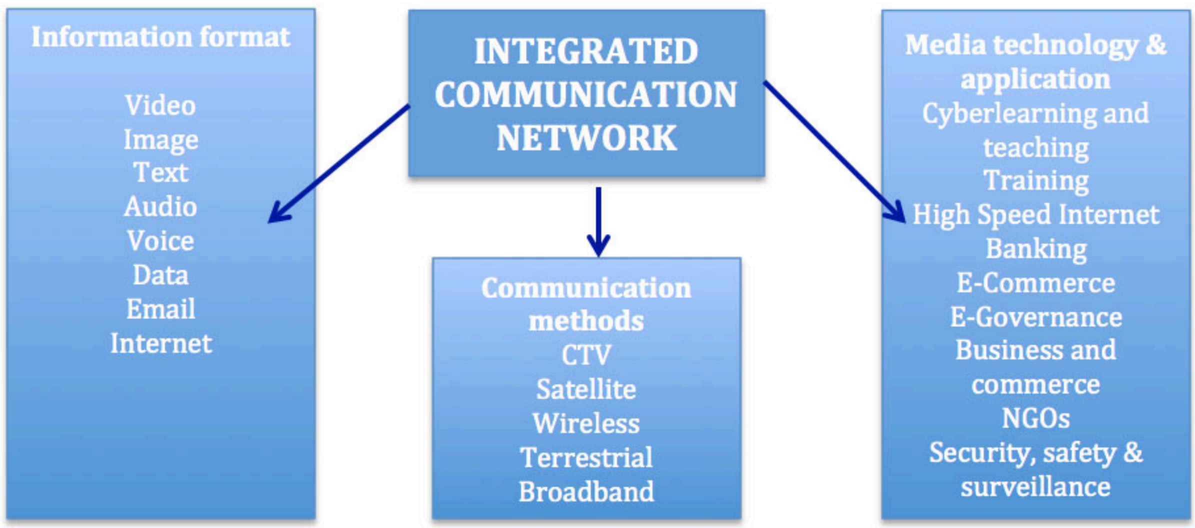

Fig. 1. Modified Version of the ICN Concept

Approximately 33% of households in the ASEAN region have Internet access, according to the International Telecommunication Union (ITU)'s 2013 report, which features 2013 estimates for ITU's key telecommunication/ICT indicators (Sanou 3). Many of these residents live in rural areas where their Internet signals are not consistent and/or not existent. The digital divide is not restricted to developed and developing countries but is also apparent between urban and rural regions within every country (Johnson et al 143). When designing for this type of disparity, it is imperative that the LMS and VC can function effectively in low-bandwidth to support the respective ICN for a particular ASEAN region.

Accessible Cyberlearning

To create a cyberlearning environment that was accessible to ALL, best practices were established to ensure that the utilization of the LMS and VC were conducive for the desired learning and pedagogical outcome. Often referred to when speaking of physical environments (Burgstahler and Cory 9), the term “accessible” in the case of cyberlearning must also consider the virtual as well as physical environment of all participants (Myhill et al 157). The key tenets of creating an accessible cyberlearning environment required the adoption of Universal Design for Learning (UDL) principles and best instructional design practices for online teaching and learning. The first tenet, UDL, was developed at the Center for Applied Special Technology (CAST), and is described as a flexible approach to curriculum design that offers ALL learners full and equal opportunities to learn. The primary principles of UDL are as follows: provide multiple means of representation, provide multiple means of action and expression, and provide multiple means of engagement. According to Coombs, cyberlearning, “by its basic nature, limits the availability of some of the learning modalities discussed by CAST” (8), but by adhering to the three primary guidelines of UDL, the initial limitations are no longer barriers.

To establish effective instructional design practice for online teaching and learning, the major guidelines established for the CIDP were that all courses should contain strong course structure and content, course introduction, course communication, course organization and design, course assessment, and course feedback and evaluation. Applying these basic principles for online teaching and learning to the LMS and VC environment required the CIDP team to create faculty training on how to effectively use Blackboard Learn (BL) and Collaborate (BC) to address the needs of ALL learners. For example, utilizing the blog feature in BL for asynchronous course discussion versus the discussion board was implemented in all CIDP courses due to the inaccessibility of the threaded discussions with screen readers. Another example of the modifications made to the VC was using the video functionality for sign language interpreters. The accessible cyberlearning best practices that have been designed and implemented in all of the CIDP courses ensure that the learning environment supports ALL.

Creating an Accessible Cyberlearning Environment

The IDPP cyberinfrastructure process was developed as part of the research and development necessary to support the final conceptualization and planning of the Cyberinfrastructure. During this phase, the research team was tasked with creating an accessible cyberinfrastructure to administer the institute and deliver asynchronous and synchronous content. The goal was to identify a recommended organizational structure and activities for the IDPP, along with a collection of social practices and accessible technologies to support the administrative operations of the institute and to deliver content. The objective of this component was as follows:

1. **Preliminary Research**
   - Conduct scholarly and practitioner literature review
   - Research ICT and political climate in region
   - Identify relevant social practices and necessary organizational elements for administering the IDPP
2. **Evaluation**
   - Identify and evaluate potential technologies and platforms for the cyberinfrastructure
   - Evaluate the proposed CI's accessibility compliance and fulfillment of identified tasks
3. **Testing**
   - Construct a functional demo portal of the IDPP's potential cyberinfrastructure

- Test accessibility manually and with automated tools (WCAG 2.0 standards)
- Conduct user testing for accessibility and usability (collaborate with MLK Library)

The first step towards a recommended suite of technologies was to identify a pool of candidates for evaluation. A series of web searches was conducted to identify the best, most accessible LMS and VC. After identifying candidate technologies, the next task was to evaluate each for functionality and accessibility based on matrices that initially identified social practices and the WCAG 2.0 accessibility standards.

After careful evaluation of the available LMSs and VCs, it was clear that Blackboard Learn and Collaborate were the two most progressive technologies readily available to help serve in establishing the cyberlearning environment. It does need to be mentioned that after the initial evaluations, BL had acquired many of the competitors, so selecting a LMS became more limited. In addition, the CIDP program was going to be based at a host university that already had an agreement with BL, and BC was a new acquisition that combined the best assets of two the most popular VC's, Elluminate and Wimba. Lastly, to ensure that enhancing the accessibility would be an on-going process, IDPP members were added to the accessibility tasks force for both respective platforms to help inform Blackboard how to best support the needs of ALL.

Methodology for Evaluating Accessible Cyberlearning

As stated by Burgstahler, "[S]ome people with disabilities, even if they use assistive technology, cannot access the content of electronic and information technology products—World Wide Web pages, video clips—if they are not designed to be accessible to them" (11). It is imperative that the CIDP program uses an iterative evaluation approach to accessible cyberlearning to ensure that as technology changes so do the standards of providing an accessible cyberlearning environment. This iterative evaluation approach is both formative and summative and will happen at key semester and program milestones. The iterative design approach is a student-centered approach that takes into account UDL, online teaching and learning, instructional design and faculty training, student motivational factors, as well as the entire cyberinfrastructure. It is through this iterative approach to evaluation that the CIDP program can ensure that the program provides exemplary support to ALL participants:

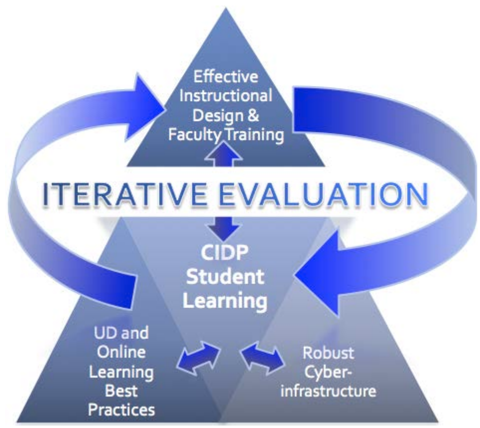

Fig. 2. CIDP Iterative Evaluation

"Good planning and good plans involve iteration; simple cause-and-effect thinking is no longer enough," when establishing an accessible cyberlearning environment (Chance 40).

Preliminary Results

The CIDP program graduated its first cohort of students in December of 2012. These students were blind or visually impaired, deaf or hard of hearing, or mobility impaired. Upon formative evaluation of students and faculty, it was noted that BL in general functioned well but having to learn how different faculty members organized course material caused some initial confusion. Blackboard Collaborate was conducive for most learners but the chat feature was not accessible to students using screenreaders. It is clear from the feedback from students and faculty that an exemplary execution of an accessible cyberlearning environment was not fully achieved, but the infrastructure was proficient, and ALL learners were able to participate in the program and gained knowledge and experience that positions them well to serve as change agents and leaders in disability and public policy. Our iterative evaluation approach provides continuous feedback that is used to inform decision-making and improve the cyberlearning environment.

Conclusions

The goal of the CIDP Master's degree program is to empower graduates to become global disability policy leaders via a rigorous theoretical and practical curriculum. The infrastructure needed to deliver this type of program to learners in the ASEAN region and instructors all over the world requires an accessible cyberlearning environment. This environment must support courses that incorporate Universal Design for Learning principles, and are accessible to blind or visually impaired, deaf or hard of hearing, and mobility impaired students. In addition, the cyberinfrastructure consists of an innovative combination of virtual tools to make the program as accessible as possible. Our evaluation methods allow us to be responsive to student needs and continually improve the accessible cyberlearning environment. Improvements have already been made following the evaluation of the first cohort of students. The CIDP accessible cyberlearning environment supports courses that prepare persons with disabilities to impact and influence the public policies that directly affect the disability community. Iterative evaluation will continue to be an ongoing critical component of implementing the CIDP Master's program to ensure the accessible cyberlearning environment adapts to the changes in technology and student needs to prepare them to be global disability public policy leaders and change agents, the ultimate goal of the CIDP.

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Social Media, Public Emergencies, and Disability

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Abstract

Longitudinal survey research data from two surveys conducted in 2010-2011 and 2012-2013, respectively, on the use of social media and other media and devices during public emergencies by people with disabilities are analyzed. The survey data show that television remains the primary means for receiving and verifying public alerts. In the two years between the two emergency communications surveys the alerting methods used to receive emergency alerts have shifted towards wider use of mobile and Internet based technologies while the methods used to verify alert information have remained relatively stable. Rates of social media use for receiving and verifying alert information on the dominant social networking platforms have more than doubled.

Keywords

Social Media, Emergency Alerting, Emergency Communications, Disability Access

Introduction

The number of social media users has doubled from 2008 to 2011 to 59% of Internet users in the United States (Hampton et al 3). This increase in social media use among those over the age of 35 is most prominent, with that age group currently representing more than half of all adult users (Hampton et al 8). This broadening and deepening of social media use beyond younger people and early technology adopters has created new opportunities and challenges for communications during public emergencies.

The extraordinary speed with which social media has become commonplace in emergency situations is recognized by the public authorities on the national, state, and local levels. The Department of Homeland Security Science & Technology Directorate (DHS S&T) and the Federal Emergency Management Agency (FEMA), for instance, jointly run the Integrated Public Alert and Warning System (IPAWS), which includes social media among the messaging systems it is charged with integrating (Department of Homeland Security 1). Numerous state and local safety authorities also have established their presence on some of the most used social media services, particularly Facebook and Twitter (Mitchell, Bennett, and LaForce 55).

The opportunities and possible limitations of social media use during emergencies are of critical import for persons with disabilities, who generally have greater challenges receiving, understanding, and responding to emergency-related communications and other information (Frieden 4-7). Within the emergency management community there is widespread concern and conjecture that the public often turns to social media prior to official directives, thus potentially putting themselves in harmful scenarios.

Little research has been conducted about the social media behavior and attitudes of people with disabilities during public emergencies. Do they seek and get their initial alerts about an impending or ongoing public emergency via social media or from other sources, including traditional broadcast media? Do they verify those alerts at all, and if so, which communications technology do they use? And, finally, do they pass on to others alerts or information they have acquired related to the emergency?

In late 2010-early 2011 the Rehabilitation Engineering Research Center for Wireless Technologies (Wireless RERC) invited people with disabilities to participate in our Survey on *Emergency Communications and People with Disabilities* (2010/2011 Survey). Two years later, in an effort to better understand the use of social media for dissemination of emergency alerts and information, and assess trends in usage by people with disabilities, the Wireless RERC updated and rereleased this survey (2012/2013 Survey). This survey was designed to collect data on the use of traditional (e.g. television, radio) and newer technologies (e.g., text messages, social media) for receiving and reacting to public alerts and warnings, by people with disabilities.

Research Methodology and Respondent Profile

For the more recent survey, data were collected from November 1, 2012 through March 30, 2013 using convenience sampling to draw a sample of adults over age 18 with any type of disability. Participants were recruited through the Wireless RERC's Consumer Advisory Network (CAN), a nationwide network of consumers with disabilities. In addition, the research team conducted recruiting outreach via its Internet and social media assets, including the Wireless RERC website, and its Twitter, Facebook and LinkedIn accounts. Recruiting was also carried out by asking individuals working on disability issues at the national, state and local levels to disseminate the invitation to participate to their networks of people with disabilities.

Respondents represented the full range of disabilities, including sensory (hearing and vision), cognitive, mobility, dexterity, and speech limitations (Table 1). Data were collected via the web, voice phone call, and in-person interviews. The total number of respondents to the first survey was 1384, 1150 of whom reported having at least one of the disabilities listed above. The respondent age range was 18-91, with a mean age of 52. The total number of respondents to the more recent survey was 1772, 1179 of whom indicated that they had at least one of the disabilities listed above. The respondent age range was 19-98, with a mean age of 52. Minors under age 18 were not recruited to participate in either survey due to concerns over conducting research with vulnerable populations. The response data for the 429 respondents to the 2012/2013 survey who reported not having a disability are used here for comparison.

Table 1 Percentage of Respondents by Disability Type – 2010/2011 and 2012/2013

	2010/2011	2012/2013
Seeing (blind or low vision, even when wearing glasses)	36%	21%
- Low vision	19%	14%
- Blind	17%	7%
Hearing (deaf or hard of hearing, even when wearing aids)	40%	43%
- Hard of hearing	22%	23%
- Deaf	18%	19%
Frequent worry, nervousness, or anxiety	--	25%
Concentrating, remembering or making decisions	20%	22%
Speaking so people can understand you	9%	16%
Using your arms	--	13%
Using your hands and fingers	19%	18%
Walking, standing or climbing stairs	45%	44%

Source: Wireless RERC, *Surveys on Emergency Communications and People with Disabilities*, 2011 and 2013.

Discussion: Public Emergency Alerts--Receiving, Verifying, and Sharing

In the two years between the two emergency communications surveys the alerting methods used to receive emergency alerts have shifted towards wider use of mobile and Internet based technologies while the methods used to verify alert information have remained relatively stable. In the 2010/2011 survey, traditional broadcast media in the form of television and radio were the most frequently used media (41% and 25% of respondents, respectively) by which respondents with disabilities received emergency alerts. Email (20%), direct observation of surroundings (18%), phone calls (18%), and social media (18%) were all tightly ranked among the next five (Table 2). Text messaging ranked low with 13% of respondents reporting having received alerts via this medium.

In the 2010/2011 survey, social media was not listed as a choice in the general alerting methods question. In the 2012/2013 survey, television remained the most common medium for receiving alerts (55%), but text messages, which previously ranked low at 13% of respondents in the earlier survey, ranked second at 32% (tying with e-mail) and followed by phone call (landline or mobile) and sirens and alarms (23%), radio (21%), and direct observation (20%). The use of social media was tied for eighth most frequently used medium for receiving alerts (19%) and 7th for verifying alerts (17%), only slightly higher than in the previous survey.

Table 2 Methods of Receiving and Verifying Alerts (Longitudinal Comparison)*

	Alerted		Verified	
	2010/2011	2012/2013	2010/2011	2012/2013
Television	41%	55%	27%	57%
Email	20%	32%	7%	16%
Phone call (landline, mobile phone)	18%	23%	12%	16%
Sirens or other alarms	16%	23%	--	20%
Text message	13%	32%	4%	13%
Radio (regular radio)	25%	21%	15%	21%
Direct observation of your surroundings	18%	20%	22%	38%
Social media	**18%**	**19%**	**16%**	**17%**
Internet news	12%	19%	15%	33%
Direct contact with someone nearby	--	12%	--	26%
NOAA Weather radio	--	14%	--	15%
Emergency app installed on Smartphone	--	10%	--	8%
Instant messaging/chat	1%	2%	1%	5%
TTY	<1%	<1%	<1%	1%

Source: Wireless RERC, *Surveys on Emergency Communications and People with Disabilities*, 2011 and 2013.

* For the 2010/2011 survey, respondents were asked if they *ever* received an alert via any of these media or platforms. For the recent survey, respondents were asked how they received and verified the *most recent* alert. Also, some media included in the recent version of the survey were not included in the corresponding question in the earlier survey. The item for social media used different language in the two surveys.

Table 3 Methods of Receiving Alerts (By Disability Type, 2012/2013 Survey)

	Seeing	Hearing	Anxiety	Thinking	Speaking	Using Arms	Using hands	Walking, standing
Television	53%	44%	59%	51%	55%	57%	61%	56%
Email	29%	31%	23%	25%	26%	28%	32%	24%
Phone call (landline, mobile phone)	26%	13%	24%	24%	24%	31%	28%	26%
Sirens or other alarms	24%	11%	27%	24%	19%	27%	27%	26%
Text message	19%	31%	27%	27%	27%	22%	21%	21%
Radio (regular radio)	26%	9%	22%	22%	17%	27%	24%	24%
Direct observation of your surroundings	18%	16%	23%	20%	22%	26%	23%	21%
Social media posting from public agency or personal network	19%	21%	20%	20%	25%	18%	23%	16%
Internet news	17%	20%	18%	17%	21%	22%	21%	15%
Direct contact with someone nearby	16%	12%	15%	12%	16%	19%	16%	12%
NOAA Weather radio	17%	8%	13%	13%	13%	16%	16%	15%
Emergency app installed on Smartphone	11%	8%	8%	9%	8%	8%	10%	8%
Instant messaging/chat	3%	2%	4%	5%	5%	6%	6%	3%
TTY	1%	<1%	1%	1%	2%	1%	1%	1%

Source: Wireless RERC, *Survey on Emergency Communications and People with Disabilities*,2013.

Drilling down shows that response rates for most of the listed methods for receiving emergency alerts are consistent across the several disability types, except for respondents with hearing loss (Table 3). As anticipated, people with hearing loss use communications technologies that rely mostly on sound less frequently than others. Across disability types television is the number one medium used, ranging from 44%-61% of respondents with each disability type. Email is in second place for every disability type except respondents with anxiety and those with a mobility disability. For them, sirens and text messages are the second most frequently used medium for receiving alerts. The majority of respondents with disabilities rely on mobile or Internet technologies as their secondary means for receiving emergency alerts.

Social media use for receiving alerts was most frequently reported by respondents with difficulty speaking (25%), and least used by people with difficulty walking and standing (16%). For this latter group, higher average age might be contributing to this result. Despite the relatively low ranking, these results show that social media are used to receive emergency alerts by a substantial percentage of people with all types of disability.

Social Media Platforms and Emergency Alerting

Substantial percentages of respondents with disabilities in the 2012/2013 survey said they used social media on a daily basis (Table 4). Indeed, the daily usage of social media on desktop computers, laptop computers, and tablet computers by respondents with disabilities is slightly higher than the daily usage of non-disabled respondents. Cellphones are the only device type used less by respondents with disabilities than respondents without disabilities to access social media. Notably, in the 2012/2013 survey, cellphones were the device most often used to access social media. This is in stark contrast to the results of the 2010/2011 survey which found cellphones to be the least likely device used.

Table 4 Daily Use of Social Media Across Hardware Platforms (2012/2013 Survey)

	Disability	No-Disability
Desktop computer	36%	33%
Laptop computer	35%	27%
Tablet computer	19%	18%
Cellphone	41%	46%
Other (gaming console, etc.)	5%	4%

Source: Wireless RERC, *Survey on Emergency Communications and People with Disabilities, 2013*.

Table 5 shows a comparison between the 2010/2011 survey data and the 2012/2013 survey data with regard to specific social media platforms used by social media users for receiving and verifying alerts. Though other social networks such as Google+ were included as a choice for respondents on the more recent survey, the only networks on both the 2010/2011 survey and the 2012/2013 survey were Facebook, Twitter and YouTube. In the two years since the first survey, social media users more than doubled their use of each of these three platforms for receiving and verifying alerts. Since these are currently the dominant social media platforms, these results suggest a substantial increase in general in the use of social media for receiving and verifying alerts.

Table 5 Social Media Sites Used to Receive and Verify Emergency Alerts

	Received alert (2010-11)	Received alert (2012-13)	Verified alert (2010-11)	Verified alert (2012-13)
Facebook	12%	32%	9%	24%
Twitter	5%	10%	3%	7%
YouTube	1%	5%	1%	3%

Source: Wireless RERC, *Surveys on Emergency Communications and People with Disabilities*, 2011 and 2013.

Facebook and Twitter remain the most commonly used platforms among respondents with disabilities. Forty nine out of the 50 states (98%) and 74% of the top 100 cities (based on population according to the U.S. Census Bureau) also use Facebook and Twitter to disseminate emergency information. However, Twitter is used more frequently by authorities than Facebook. There is a disconnect between the platform most used by emergency managers to *disseminate* emergency information and the platform most used by the population with disabilities to *receive* emergency information. This disconnect *potentially* impacts the effectiveness of social media as an emergency information source by people with disabilities.

Conclusions

Two main conclusions about the use of social media during public emergencies can be drawn from the survey response data presented here. First, social media represent important channels for communication for people with disabilities during emergencies. Moderate percentages of people with disabilities have used social media to receive and verify emergency information (19% and 17% respectively). Second, these data show the importance of mobile platforms for accessing social media for respondents with disabilities and respondents who reported having no disability. Pluralities of both groups (41% and 46%, respectively) reported accessing social media on cellphones, with additional numbers who access social media on tablets. Continued research on social media use by people with disabilities and by alerting authorities could improve social media communication between the two groups, thereby potentially increasing the effectiveness of emergency alerting via social media.

Note

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Math and Science Standards for All

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Abstract

The National Council of Teachers of Mathematics and the National Science Education Standards have emphasized the importance of math and science instruction, respectively, for all students. However, grade level core content math and science instruction has been predominantly unavailable for students with an intellectual disability. Four programs, *Early Numeracy*, *Teaching to Standards: Math*, *Early Science*, and *Teaching to Standards: Science*, have been developed to teach grade level core content mathematics and science as inquiry for elementary grades, and for middle and high school grades. All four programs have been validated through classroom trials. Research demonstrates that these programs are effective in teaching grade aligned core content math and science as inquiry to individuals with an intellectual disability.

Key Words

Standards, Intellectual Disability, Math, Science

Introduction

Over the past decade, teaching academic skills aligned to state standards to students with moderate and severe disabilities has evolved from participation and engagement in grade-aligned content (e.g., Carter, Sisco, Melekoglu, and Kurkowski) to demonstration of grade-specific content mastery (Browder, Trela, Courtade, Jimenez, Knight, and Flowers). Fostered by No Child Left Behind legislation (NCLB, 2002) and the Individuals with Disabilities Education Act (IDEA, 2004), US students with significant intellectual disabilities are expected to show progress on their state's content standards in the areas of English/language arts, math, and science. In response to such initiatives, and the need to expand the experimental research literature of math and science instruction for students with significant intellectual disabilities, four instructional programs were developed as a result of research conducted by the University of North Carolina at Charlotte under two separate projects: First --Reading, Writing, Math, and Science for students with significant cognitive disabilities and, Second --Project Mastery. The four resulting programs are *Teaching to Standards: Math, Teaching to Standards: Science, Early Numeracy* and *Early Science*. The Attainment Company has been the publishing partner for products that have resulted from these research efforts.

Studies conducted under both grants have responded to the need to develop models of assessing the general curriculum in math and science emphasizing (a) standards-based IEPs, (b) alignment to grade level general curriculum, and (c) use of research-based instructional strategies to teach academic skills to students with significant disabilities. In the content domain of math, the National Council of Teachers of Mathematics established that

> All students, regardless of their personal characteristic, backgrounds, or physical challenges must have opportunities and support to learn mathematics. Equity does not

> mean that every student should receive identical instruction; instead, it demands that reasonable and appropriate accommodations be made as needed to promote access and attainment for all students. (NCTM, 2002)

Research conducted by Browder, Jimenez, and Trela, and Jimenez, Browder, and Courtade has demonstrated that such accommodations as the use of manipulatives, graphic organizers, and task analytic instruction can provide middle and high school students with intellectual disabilities access to demonstrate mastery of grade-aligned math content.

In the content domain of science, national initiatives have been focused on achieving a scientifically literate society (American Association for the Advancement of Science, AAAS, 1989). In 1996, the National Research Council (NRC) publication of the National Science Education Standards (NSES) not only acknowledged this goal but extended AAAS's philosophy promoting scientific literacy, "regardless of age, gender, cultural or ethnic background, disabilities, aspirations, or interest and motivation in science" (NRC 2). The National Research Council (NRC) asserts that "inquiry is a set of interrelated processes by which scientists and students pose questions about the natural world and investigate phenomena; in doing so, students acquire knowledge and develop a rich understanding of concepts, principles, models, and theories" (NRC 214). Within the National Science Education Standards (NSES), inquiry is described as a critical component of a science program. Through inquiry-based instruction, students can learn in a way that represents how science actually works. In inquiry-based instruction, students follow a problem-solving process that is applicable to the real world. Using an inquiry-based approach to teach science allows students with significant disabilities to experience and understand the environments they live in and have the opportunity for access to the same instruction that their general education peers are receiving.

Discussion

Four different research studies are summarized to demonstrate the academic success of students instructed under *Early Numeracy*, *Teaching to Standards: Math*, *Early Science* and *Teaching to Standards: Science*. Research studies were conducted with students identified as having a significant intellectual disability (IQ 55 or below). Additionally, each study focused on including students with multiple disabilities and intensive communication needs (e.g., use of alternative communication devices). In addition, all programs were developed with direct alignment to national standards (NCTM; NSES). Using alignment criteria developed by the National Alternate Assessment Center (Browder, Wakeman, Flowers), programs were developed to align to national standards using alternate achievement standards. While more recent standards have been developed in math (Common Core State Standards) and science (Next Generation Science Standards), the alignment of these programs has remained strong, and in some ways has become even greater. For example, the Next Generation Science Standards builds upon the NSES to provide greater emphasis on the inquiry process in science education, which is illustrated in both *Early Science* and *Teaching to Standards: Science.*

Early Numeracy

Research shows that early knowledge in mathematics is indicative of success in mathematics in later years of life (National Mathematics Advisory Panel). For most students, these early numeracy skills are developed prior to any formal schooling as a result of their interactions and experiences; however, for students with moderate and severe disabilities, this may not be the case. This population of students may need formal instruction to develop these skills (Bruer). Just as phonemic awareness builds the foundation of reading in very early grades, early numeracy skills build the foundation in mathematics. *Early Numeracy* is a curriculum designed to build number sense in elementary-aged students with disabilities, including students with intellectual disabilities and autism. The program was designed to be used with students who lack a solid foundation, or need to build fluency of early numeracy skills. *Early Numeracy* provides strategies to improve skills in the areas of counting with one-to-one correspondence, number identification from 1 to 10, rote counting, creating sets, beginning addition with sets, symbol use, identifying and creating ABAB patterns, calendar skills, nonstandard units of measurement, and standard units of measurement with a ruler. *Early Numeracy* is based on the premise that it is not too late to develop early numeracy skills in children with moderate and severe disabilities and in doing so students will be able to gain greater access to grade level standards. The content for *Early Numeracy* was selected based primarily on recommendations from the *Early Childhood Mathematics Education Research: Learning Trajectories for Young Children*, developed by Sarama and Clements in 2009. *Early Numeracy* also aligns with four of the five content standards set forth by the National Council of Teachers of Mathematics (NCTM): *Numbers and Operations*, *Algebra, Geometry*, *and Measurement* (NCTM).

Based on the research conducted to develop *Early Numeracy*, Saunders, Bethune, Spooner and Browder suggest using six separate steps to develop instruction targeting mathematics acquisition for students with moderate to severe disability. These steps are: 1. Create Objectives, 2. Identify a real-life activity, 3. Incorporate evidence-based practices, 4. Include instructional supports, 5. Monitor progress, and 6. Plan for generalization. With these six steps as the framework for *Early Numeracy*, Browder, Jimenez, Spooner, Saunders, Hudson, and Bethune conducted an exploratory single-subject study. A multiple probe research design was used across three math units with seven elementary aged students with moderate and severe disabilities, including autism. Three special educational teachers taught the math curriculum in small groups in addition to three special education paraprofessionals who facilitated instruction in an inclusive setting. Results demonstrated that all seven students made gains in all three units, both in the small group setting and in the trials embedded in the general education class by the paraprofessional.

Teaching to Standards: Math

For students with intellectual disabilities in middle and high school, a review of research indicated that most studies focused on numbers and operations or money skills (Browder, Spooner, Ahlgrim-Delzell, Wakeman, and Harris), which is a small subset of the standards for grade aligned content in mathematics. In a comprehensive literature review using the National Council of Teachers of Mathematics (NCTM) core areas of math, findings identified geometry, algebra, and problem solving as areas in need of evidence-based instruction in order for older students with significant disabilities to gain access to NCTM math standards. Based on these findings, the research team developed interventions to teach grade level academics aligned with general education curriculum to students with significant disabilities. The resulting product was *Teaching to Standards: Math.*

Multiple research studies were conducted to develop and evaluate *Teaching to Standards: Math* (Jimenez, Browder, and Courtade; Browder, Jimenez, Trela; Browder, Trela, Courtade, Jimenez, Knight and Flowers). Specifically, Browder, Jimenez and Trela investigated the effects of the curriculum with four students identified as having a moderate or severe disability, ages 11 to 13, with IQ's ranging from 30-41. The research took place within a self-contained classroom in a general education middle school. The research protocol was a multiple probe across math units, with mathematics instruction (lessons from the curriculum) as the independent variable and acquisition of math responses as the dependent variable. The research demonstrated that all four students showed significant gains across all four units: Geometry, Algebra, Data Analysis and Measurement.

Early Science

Using the literature reviews of science conducted by Courtade, Spooner, and Browder, and Spooner, Knight, Browder, Jimenez, and DiBiase, evidence-based instructional strategies to incorporate in the *Early Science* curriculum were pinpointed. Courtade and her colleagues' 2007 review of 11 studies that had some intersection with science standards outlined by the NSES identified systematic prompting and feedback as an important research-based practice. In contrast, these reviewers also advocated for new methods that could be used to teach scientific inquiry. The research reviews also noted the need for instructional supports to develop science instruction that address more breadth and depth of science education (e.g., not only vocabulary instruction). All research findings were integrated into the product, *Early Science*. With the *Early Science* curriculum, students are provided with access to science content that has been streamlined and prioritized, giving students an opportunity to learn grade-level content with alternate achievement. The curriculum specifically embeds repeated practice, evidence-based systematic instruction practices, and builds students' inquiry processes throughout each unit.

Early Science research was conducted with three elementary students identified with a severe disability, including one student who was non-verbal. The three students' ages ranged from 6 to 8 years old. Students were served within a self-contained classroom in their neighborhood elementary school. In this research effort, Smith, Spooner, Jimenez and Browder used a single-subject multiple probe research design across behaviors (science units) to investigate the effect of the curriculum on student science vocabulary and concept attainment.

The research findings demonstrated significant gains across all four science units with all three students.

Teaching to Standards: Science

Similar to the development efforts of the *Early Science* curriculum, researchers reviewed the literature on teaching science to this population, finding great need to expand the literature base to support instruction in inquiry science across the national standards. For *Teaching to Standards: Science,* teachers of students with intellectual disabilities taught four science units representing three of the eight national science content standards. A forth standard, science as inquiry, was embedded within each of the units. The science content standards included life science, physical science, and earth science. Classroom research included 21 students ranging in age from 14 to 20 years with IQ's ranging from 33 to 53. Ten students were identified as having a severe intellectual disability while 11 were classified with an autism spectrum disorder (Browder et al, "Teaching Mathematics"). Twenty lesson plans were executed in a small group setting in each of the special education classrooms. The pre-test / post-test in the quasi-experimental design measured a 14% gain in scientific inquiry and a 16% gain in scientific vocabulary. In a social validity measure, teachers agreed that the intervention was useful, practical, and beneficial to students.

Conclusions

As noted by the National Council of Teachers of Mathematics, all students, including students with disabilities, must have opportunities and support to learn mathematics. Research studies conducted with *Early Numeracy* and *Teaching to Standards: Math* demonstrate that students with an intellectual disability can and do learn grade level content standards in mathematics when provided with appropriate supports and instruction (Browder et al, “A Meta-Analysis;” Browder et al, “Teaching Mathematics”).

In science, engaging students in the inquiry process helps students develop an understanding of scientific concepts, an appreciation of “how we know” what we know and an understanding of the natural world of science. As a result, students achieve the skills necessary to become independent inquirers about the natural world. Students at all grade levels and in every domain of science, regardless of disability, should have the opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry. These goals are achieved for students with an intellectual disability with both *Early Science* and *Teaching to Standards: Science*.

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The iPad and Preschool Children with Learning Difficulties

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Abstract

Preschool children learn through exploration of their environment, and a review of the research literature has revealed that learning can be enhanced through exploration that also includes the use of digital technologies. Although research can be found illustrating the use of computer assisted instruction to enhance learning with preschool children, research on the use of touch screen tablets with this population is just beginning to emerge. These devices offer the possibility of exploration in a new way, with ease of interaction on the touch screen, thousands of early learning applications, engaging multimedia capabilities, and reasonable cost. They have great potential as an early learning digital tool. However, little information exists on how this potential can be utilized effectively with young children with learning difficulties. The focus of this study was to look at the use of early learning applications loaded on the iPad, one of the touch tablets available, by preschool children with learning difficulties. The study also examined the applications that the children and parents chose to use, parent perceptions of the use of the iPad by the child, parent/child interactions while using the iPad, and the supports that parents and families needed to use the iPad effectively.

Keywords

iPad, apps, early childhood, learning difficulties, special needs, preschool

Introduction

Young children naturally learn about their environment through play and exploration, and digital technology tools offer opportunities to extend this exploration in new and innovative ways. Over the past decade, a growing number of interactive games and educational software packages have been implemented in early childhood education (Wang et al 1), and the computer has become a recognized tool in the education of young children (Nikolopoulou 173). There may also be distinct advantages in the use of digital technology for young children with disabilities. The use of digital technologies may help to stimulate interest in learning and support active exploration for children who are less able to explore the environment, or learn in typical ways because of their disability (Primavera, Wiederlight and DiGiacomo 6). Preschool children with disabilities may have a huge need for technology for learning, communication, and play. Yet their exposure to suitable technology for play and learning may be limited due to a lack of access to appropriate technology tools.

A number of studies in the literature have indicated that the use of computer technologies with young children can be beneficial and can provide children with an opportunity to learn and practice skills in an engaging and interactive environment. Roschell, Pea, Hoadley, Gordin, and Means (92) found that the use of computer based technologies can be very simulating and motivating for young children. Hitchcock and Noonan (145) found that computer assisted instruction of early academic skills was successful in improving skills. Johnson, Perry and Shamir (209) looked at the skills of 180 preschool and kindergarten children and reported that the children demonstrated positive changes in skills when using computer-assisted instruction. Li and Atkins (1715) reported that early computer exposure during preschool years was associated with the development of concepts and cognition.

Although there is some research in the literature regarding the use of various computer and assistive technologies with young children, there is no information regarding the use of the iPad with young children with disabilities. A search of several databases, including ERIC, revealed no results using the terms “early childhood,” “iPad/iPad2,” “preschool,” and “disabilities.” The literature available on the use of the iPad appears to largely be limited to papers describing the technology and its capabilities, descriptions of the administrative or practical uses at postsecondary level, and a few pilot students in grades K to 12. The iPad offers a means of learning and interacting in new ways that have not been previously explored (Valstad and Rydland 9). The iPad, with its ease of interaction on the touch screen with multi touch finger gesture controls, thousands of applications from which to choose, engaging multimedia capabilities, and reasonable cost, has great potential as an early learning digital tool. However, little information exists on how this potential can be utilized effectively with young children with disabilities. The focus of this study was to look at the use of early learning applications loaded on the iPad by preschool children with mild to moderate learning difficulties. The study also examined the applications that the children and parents chose to use, parent perceptions of the use of the iPad by the child, parent/child interactions while using the iPad, and the supports that parents and families needed to use the iPad effectively.

Discussion

This was an exploratory study on the use of the iPad for early learning with 6 preschoolers between the ages of 3 and 5 with mild to moderate learning difficulties, who were receiving support from a rural community organization in Alberta, Canada. The learning difficulties experienced by these children differed from child to child, and included speech and language delays, fine and gross motor problems, difficulties with social skills development, attention deficits, and behavioral issues. Once the children were identified by the community organization, the researcher contacted each family to see if they would agree to participate in the study. The parents and staff member who worked with the child in the community organization were interviewed prior to the commencement of the study to identify the child's strengths and weaknesses. The parent and staff members' current use and familiarity with technology was explored, as well as their perspective on the use of the iPad in early learning. The parents were also asked to keep a journal regarding their child's use of the iPad. Following a brief introduction to the device by the researcher, each child received an iPad to use at home for a 6 week period. Each iPad was loaded with a number of early learning applications that addressed a range of early learning opportunities including early literacy, early math, interactive story books, puzzles, coloring, drawing, tracing letters, and a number of interactive cause and effect games. Observations of the child were also conducted as the child received the iPad and completed the initial app activities. The data collection at the completion of the study included a post interview with the parents, a document filled out by the parent identifying the apps the child used, and observations of the child using the iPad and their favorite apps.

A number of positive results were noted across the children. None of the children in the study had difficulties learning how to navigate with this tool. During the initial activities with the researcher, the majority of the children were able to learn how to effectively use appropriate touch for navigation on the iPad. Two of the children had not quite mastered the touch in 20 minutes, but with prompting and one or two more sessions to practice with their parent, were able to use the tool. Over the course of the research, all of the parents reported that the children used the iPad independently and did not require help to find the apps that they wanted to use, or to use the apps. In fact, the parents reported that the children insisted on using the iPad independently and were able to do so.

All of the parents in the study reported that the apps on the iPad completely captured their child's attention. They found that their child was engaged for extended periods of time and often practiced tasks over and over. Even skills such as tracing and coloring seemed to capture their child's interest, although the children typically would not be interested in tasks like this. The majority of the parents reported that their children had learned a number of preschool skills during the 6 week period that they used the iPads. A much unexpected result was that 5 out of 6 of the parents reported that their child had acquired printing skills through using tracing applications. Although it is not possible in this kind of a study to totally attribute this skill acquisition to the use of tracing apps on the iPad, all of the parents indicated that their child found the tracing applications to be particularly interesting and engaging and that their child was very interested in practicing letter formation over and over again independently. A number of other areas of growth were also identified by the parents. One child learned to count to 30 on a favorite early math application. Several of the children learned to print their name and had even generalized the skills to printing their name on paper with a pencil. Several children had progressed to completing puzzles on apps that were considerably more difficult than what they were able to complete at the beginning of the study. One parent commented that he was certain that his child was "thinking faster" while engaged in problem solving apps.

A number of positive outcomes were identified that are related to the parents of the preschool children. None of the parents in the study reported that they needed any training and support to use this technology. The parents were all interested in having their child use this tool. They were all comfortable using the iPad and having their child use the iPad.

Several drawbacks were reported by the parents during the research. Many of the parents felt that their child liked to spend too much time using the apps on the iPad. Despite the fact that the children appeared to be engaged in the activities and learning, several parents reported a need to monitor the time spent on the iPad and to balance the child's day with other kinds of activities. It was also noted that one of the children in this study abandoned the learning activities on the iPad to play games with no cognitive demands on other technologies available in the household.

Conclusion

Overall, the results of this exploratory study were very positive. Even though the study was conducted with only 6 preschool children with learning difficulties, each of the children was able to use the apps on the iPad independently. The cognitive threshold for use of a technology has been substantially lowered on the iPad. Even young children with learning difficulties can master the navigation very quickly. This tool provides access to technology for children with disabilities who might not be able to access other types of technology without support. It provides preschool children with the opportunity to play and learn without adult direction and allows them have control over their own learning experience once the apps are loaded on the iPad by an educator or parent.

As discussed above, the parents reported that the children were very engaged with the learning apps on the iPad. For children with learning difficulties, who often get disenfranchised from the learning process even at an early age, access to applications to work on preschool skills may help to keep them more actively interested and engaged. Even more importantly, for preschool children with significant attention problems, for whom learning in traditional ways is very challenging, the engaging multimedia on the iPad may provide the stimulus to keep them engaged in learning for longer periods of time.

All of the parents reported that the children demonstrated gains in their learning in one or more areas. Several of the children made gains in learning in areas they would not normally be interested in practicing. This may be due to the fact that they are very engaged in the learning activities and are able to practice the same tasks over and over again until they are mastered. The multimedia apps also reinforce learning as they often have obvious reinforcement for correct responses built into the app, and they engage the child through a variety of auditory, visual, and tactile feedback.

The iPad is a valued mainstream technology, and there is no stigma involved in its use for children with learning difficulties or their families. The desirability of the iPad may reduce typical technology abandonment issues that occur when complex assistive technologies are introduced into the home for children with learning difficulties. The iPad is simple to use and very engaging. Several of the families were considering buying an iPad for their child at the end of the research. They saw many positive outcomes occur through the use of the iPad during the research, and the cost was within the family budget. This willingness of the families to purchase mobile technology for their child may help eliminate funding issues, which can be a significant barrier to access technology. These parents were also very willing to purchase apps that would support their child. They have the ability to access these apps and can afford them. They do not need a professional, school, or program to buy apps for their child. However, the parents do need information as to what apps are suitable for their child's developmental level and interests, and they want to purchase quality apps.

There are drawbacks to the use of the iPad with preschool children. One drawback is that the child may want to spend more time playing and exploring on the iPad than the parent would like. This drawback could be addressed by the parents, by designating a certain amount of time for the child to have access to the iPad each day or week. Visual reminders of when this time will occur and how long it will be would help the child plan and anticipate access. It is also important to choose the apps for the iPad carefully. The apps should match the child's developmental level, but also provide options to extend skills to a more advanced level. The preschool children in this study particularly liked playing with interactive learning games, but given a choice some children will choose games that do not require thinking or cognitive engagement.

This exploratory study is the first of a number of studies aimed at examining the use of the iPad with preschool children with disabilities and focused on preschool children with learning difficulties. Due to the very limited scope of the study and the small number of preschool children involved, there is not yet sufficient evidence to determine the best practices of the use of this tool with this population. However, given the positive results that this study produced, the use of this device as an early learning tool for children with learning difficulties should be explored further. In addition, it would be interesting to explore further whether the study outcomes were the result of the design of the learning applications used, or the simple touch interaction of the screen that is likely most suited to this population.

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S-K Smartphone Based Virtual Audible Signage

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Abstract

People with visual disabilities are at a clear disadvantage for using printed labels, signs, and other visual cues to aid independent travel. Remote Audible Infrared Signage (RIAS) has been shown to be effective in providing valuable orientation information for blind travelers; however limited RIAS transmitter and receiver deployment impact its availability. The Smith-Kettlewell Virtual Audible Signage (VAS) project uses ubiquitous smartphone technology to simulate the proven RIAS interface by using an iPhone as a receiver for virtual transmitters that mark signs and landmarks in the real-world environment. The virtual signs are recorded in an online database, and location and orientation sensors on the phone allow it to be used as a haptic pointing device that simulates the RIAS user experience. This paper describes an experiment to evaluate pointing accuracy of the VAS prototype, as well as the assessment of an audible warning signal presented when confidence in the orientation information was low. The system showed consistent performance with minimal impact of the presence of the warning on increased pointing error.

Keywords

Accessible signage, blind wayfinding, iPhone, GPS

Introduction

A world without access to printed signs often leaves people with vision loss lacking the necessary information to successfully navigate the physical environment. Identifying street corners, public buildings, transit stations and open spaces, like parks, is a challenging task without the information embedded in signs that are often taken for granted as a means for environmental access. The Smith-Kettlewell Virtual Audible Signage (VAS) project builds on proven benefits of Remote Infrared Audible Signage (RIAS) to augment the availability of accessible signage without the need to install transmitters or distribute receivers. The VAS prototype uses ubiquitous smartphone technology to provide a RIAS-like audible signage system by using the smartphone's built-in Global Positioning System (GPS) and orientation sensors. Similar to RIAS, VAS uses a gestural interface to locate audible signs with the smartphone as the receiver. The audible signs are records in an online database and are subsequently available via an iPhone app to provide virtual talking signs to visually impaired pedestrians as they engage in way-finding.

Background

RIAS, an infrared, wireless communication and orientation system was developed as a reliable and successful accessible signage system in indoor and outdoor environments (Crandall et al). Research demonstrates that RIAS significantly improves the ability of blind people to find very specific locations, such as entrances to buildings or rooms in indoor environments (Brabyn and Brabyn). Auditory signage reduces barriers to efficient transit use (Marston and Church) and dramatically improves performance for a variety of tasks including finding bus stops, boarding correct buses, and finding entrances and exits in public transportation terminals (Golledge and

Marston). RIAS also reduces the stress and anxiety associated with navigation and public transportation use (Golledge and Marston; Golledge, Marston, and Costanzo). A strong benefit of RIAS is the spatial/directional precision with which locations can be identified (Marston). However, the RIAS system requires hardware transmitters installed in the physical environment and dedicated hand-held receivers to decode the infrared information.

Virtual Audible Signage (VAS) is an additional approach to traditional RIAS that combines ubiquitous mobile phone technology with a cloud-based database. Since VAS uses smartphone technology and location based services (LBS) it lacks the spatial accuracy of RIAS. However, there are many research efforts that have confirmed the feasibility of using GPS to locate blind travelers in a variety of environments (Giudice and Legge). Perhaps most notable for the current project is the haptic pointer interface (HPI) project. HPI successfully demonstrated that the combination of GPS, a computer driven geodatabase, and an electronic compass attached to the end of a receiver can localize locations in outdoor environments (Loomis, Golledge, and Klatzky). Therefore, we hypothesize that a tool like VAS may prove useful for providing signage to large outdoor undefined geographic features such as parks, monuments, college campuses and much more.

Tool Development

The VAS prototype has been developed for Apple's iOS platform (i.e., iPhone, iPod Touch, and iPad devices), and has been evaluated on the iPhone 4S model. The VAS prototype utilizes a combination of the iPhone's built-in sensors to evaluate location and orientation of the device including global positioning system (GPS) to estimate location (as well as location error), magnetometer (i.e., compass) to periodically calibrate direction, and MEMS gyroscopes to detect rapid changes in orientation. Using these sensors, the VAS prototype can calculate where the iPhone is, as well as what direction it is pointing. Combining this information with an online database of virtual sign locations and associated audio messages, VAS allows the iPhone to play specific audio information when the device is pointed in the appropriate direction. In addition, the familiar RIAS characteristic of a clear signal when the receiver is pointed directly at the source, with increasing static as the receiver points away from the transmitter, has also been simulated for the virtual audible signs.

GPS location estimates always have some error associated with them. The error can vary depending on local geography, as well as the quality of the GPS receiver and antenna being used (Gustafsson and Gunnarsson). The iPhone GPS provides an estimate of this spatial error, allowing VAS to know both its location, and the spatial uncertainty. This is essential because the larger the spatial error, the less certainty the system has regarding the direction of nearby virtual audible signs. The system will therefore associate a confidence factor with each virtual audible sign in the environment. Distant signs are assigned a higher confidence factor, and closer signs will have confidence values that are more dependent on the estimated GPS error. Low GPS uncertainty will lead to increased confidence for nearby signs.

The built-in compass of the iPhone is not well suited to estimating quick changes in direction. Its values are averaged over a relatively large time interval, and it is often subject to local magnetic interference. However, the built-in gyro of the iPhone 4S model is extremely responsive and has minimal sources of interference. In order to allow users to quickly point the iPhone-based VAS prototype in different directions and receive real-time feedback, the software uses a combination of compass- and gyro-based information. When the iPhone is relatively stable with minimal magnetic interference, the gyro-based orientation is calibrated to that direction. The gyros can then measure orientation offsets from that calibrated direction. The system periodically recalibrates in order to counteract drift in the gyros.

Each virtual sign record in the database includes:

- Location--latitude and longitude of the virtual audible sign.
- Audio message--the message that the sign repeats, such as "Main entrance to Student Union."
- Orientation--the direction in which the virtual audible sign is "facing."
- Transmission angle--if the angle is narrow, you need to be directly in front of the sign and pointing straight at it to hear it. Wider angles allow the sign to be heard from locations further to the side.
- Range--How close the user needs to be to the virtual sign in order to hear it. Virtual audible signs with larger range values can be heard from further away.

Although this project offers many rich areas of investigation, this paper focuses on two major problems:

1. The development of a confidence factor for virtual audible signs based on estimated GPS error;
2. A user interface that can provide feedback on the sign's location and content, as well as an estimate of location confidence.

Experimental Methods

A pilot field experiment was conducted to test the development of the confidence factor and the user interface of the VAS prototype. The experiment consisted of a blind participant who tested the VAS prototype and a sighted researcher to record pointing accuracy information.

Three locations (or virtual signs) were programmed as experimental points: a bus stop, a playground, and a bench all located in or near Alta Plaza Park in San Francisco, California.

A compass was attached to the end of an iPhone 4S, and base compass readings were taken of each of the three experimental locations relative to the location of the stationary blind participant. The blind participant then pointed the iPhone in the direction of each of the three experimental virtual signs using the gestural interface and auditory message as feedback. A sighted researcher recorded the compass heading after the blind participant indicated they were pointing at the virtual sign. This process was repeated 8 times for each experimental virtual sign, taking one reading from each virtual sign in turn until 8 readings were taken for each target.

The confidence factor for each virtual sign was calculated by taking the distance to the virtual sign divided by the estimated error. If the confidence factor was less than 3, there is a feedback sound or an uncertainty alert when the blind participant pointed at the virtual sign.

Results

The results (table 1) show the compass reading for each 8 of the trials and includes the true compass heading reading for each experimental virtual sign, mean, standard deviation and error estimates. Error was calculated by dividing the standard deviation by the square root of n-1.

Table 1 Compass Reading Results

Virtual Sign	True	T1	T2	T3	T4	T5	T6	T7	T8	Mean	SD	Error
bus stop	260	260	258	248	254	260	260	256	256	256.5	4.10	1.45
play ground	182	164	172	176	168	164	170	168	166	168.5	4.10	1.45
bench	116	108	118	102	112	112	116	114	114	112	5.01	1.77

The table displays the compass reads for the virtual sign for eight experimental trials. The cell "True" indicates the true compass reading of the virtual sign relative to the location of the participant.

Discussion

This experiment was intended to evaluate the effectiveness of the device and the methods used, rather than a behavioral study. Therefore, the use of a single subject is not only reasonable, but preferable, as it reduces pointing error resulting from individual differences. The number of readings for each location (n=8 for each virtual sign) is not sufficiently large to draw statistical inferences about the performance of the system. However, some broad conclusions are implied. Pointing error does not appear to be much larger for virtual signs in the near field than for those at greater distances. Similarly, pointing error is reasonably small, even for those signs that consistently included the uncertainty alert. This implies that the selection of a critical value of confidence factor equals 3 is either too large to be useful, or the uncertainty is not significantly contributing to errors in pointing.

VAS simulates the analog, directional, audio/haptic interface of RIAS. This provides the ability to clearly identify the direction of a source by maximizing signal-to-noise of the audible sign (i.e., finding the orientation where the sign's signal is clearest). However, the sensors used in VAS (i.e., GPS, compass, and gyroscope) introduce some level of inherent uncertainty in the direction of the virtual sign. When sensor error is low, the system can have a high level of confidence that it is presenting accurate orientation information. However, when sensor error is high, the user should be alerted to the fact that confidence for the orientation information is low. This prototype system implements a simple interface that pulses a brief burst of noise in with the sign's message once per second only when the confidence factor does not exceed a specified threshold. This interface allows the user to continue listening to the audio information from the virtual sign, but also communicates that its orientation information is not to be relied upon.

It is important to note that total sensor error as used in the calculation of the uncertainty factor can be introduced through GPS error, compass error, and Gyroscope drift. Only GPS error is accounted for in the current prototype VAS system. Future iterations of the system should enable more reliable calculation of the confidence factor by including error components introduced by the compass and gyroscope as well.

Impacts and Conclusions

VAS has the potential to greatly enhance the circumstances in which accessible signage can be provided. Although RIAS is a mature technology, it remains challenging to install the necessary transmitter infrastructure in many outdoor settings such as parks, college campuses, bus shelters, etc. VAS offers the potential for the proven benefits of RIAS to be extended to these contexts with no infrastructure required. The use of the iPhone as our prototype platform demonstrates the potential of users to take advantage of an existing hardware platform with rapid adoption among blind and visually impaired users, as well as many other demographics. This means that no extra receiver hardware needs to be purchased or distributed to users.

The prototype VAS system continues a tradition of research and development investigating location-based wayfinding technologies for blind travelers. While the VAS project requires additional research to improve confidence factor readings, the gestural interface has proven to be effective for a smartphone-based talking sign system. Continued developments will include extending the prototype to other smartphone platforms such as Android.

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Assistive Technology Support for Complex Reading

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Abstract

Kurzweil 3000 is an assistive technology designed for individuals with learning disabilities, especially dyslexia. While this technology has existed for years and has been widely employed by college disability resource centers, we know relatively little about how this technology and others like it support the reading practices of college level students. To investigate this research question the Usability/Accessibility Research and Consulting lab, in partnership with the Writing in Digital Environments research center (both at Michigan State University) conducted a usability evaluation of Kurzweil 3000 with users who have dyslexia, and this paper presents preliminary findings.

Keywords

Learning Disabilities, Assistive Technology, Usability, Reading, Literacy

Introduction

As the accessibility community seeks to better address the needs of individuals with learning disabilities, building understandings of how assistive technologies support the work practices of individuals with these disabilities becomes increasingly important. Despite the fact that assistive technologies like Kurzweil 3000 have been around for years, we know relatively little about how these technologies impact the specific ways individuals with learning disabilities accomplish real world tasks.

Kurzweil Education Systems, the developer of Kurzweil 3000, has cited numerous studies in cognitive and educational psychology that provide a theoretical basis for the support that Kurzweil 3000 can provide (Kurzweil Education Systems 1-13), and the Iowa Text Reader Project has performed a longitudinal study of the impact that Kurzweil 3000 had on the academic performance of middle school students (Hodapp and Rachow 199-219). However, so far research on how this technology supports the practices of college students has been extremely limited. Furthermore, the theoretical research put forth by the creators of Kurzweil 3000 does not take into account the differences between reading within a K-12 environment and the reading tasks faced by college students, graduate students, and adult workers.

In order to better understand how these technologies support the practices of individuals with learning disabilities, and to provide feedback for future developers of similar assistive technologies, the Usability/Accessibility Research and Consulting lab, in partnership with the Writing in Digital Environments research center conducted a usability evaluation of Kurzweil 3000 with users who have dyslexia.

Methods

The usability evaluation consisted of one-on-one sessions with six college students (all of whom have been diagnosed with dyslexia), including four who had experience with Kurzweil 3000, and two who had experience with similar assistive technologies (technologies that used text to speech). The hour and a half long sessions were conducted at the Michigan State University Usability/Accessibility Research and Consulting laboratory in East Lansing, Michigan.

In each session, participants filled out a basic demographic questionnaire, and the Adult Reading History Questionnaire (see Lefly and Pennington 286-96). Then participants completed three tasks that involved reading a document using Kurzweil 3000 and afterward filled out a third questionnaire and answered questions about the strategies they used during the session. The reading tasks were based on Sellen and Harper's study of real world reading practices (75-105), Jeanne Chall's five stage model of reading development (9-39), and Rosalie Fink's research on the literacy history of successful dyslexics (311-46), and the tasks were also indicative of college level reading assignments. Tasks included providing basic information on the genre of the document (a technical communication journal article on creating humane graphical representations of data), creating an outline of the document, and writing a one to three paragraph summary of the document.

The researchers analyzed task times, the overall strategies used by the participants, the complexity of the outlines created by participants, and breakdowns in work practices.

Discussion

Based on task time analysis, as well as examination of the specific techniques participants used during the sessions, two groups (with 3 participants each) emerged, each employing distinct strategies. One group spent a large amount of time during task two (29-37 minutes), while the second group spent relatively equal time on both tasks two and three (7-15 minutes on task two and 9-14 minutes on task three). Surprisingly, despite the fact that the first group spent more time on task two, they did not produce more detailed outlines. Outlines from group one were on average seven points and sub-points, versus group two's average of eleven points and sub-points. Overall, group two made more detailed outlines in less time than group one, resulting in total task times that were on average far shorter (24 minutes versus group one's 44). See Figure 1 and Table 1 for more specific data on task times and outline complexity.

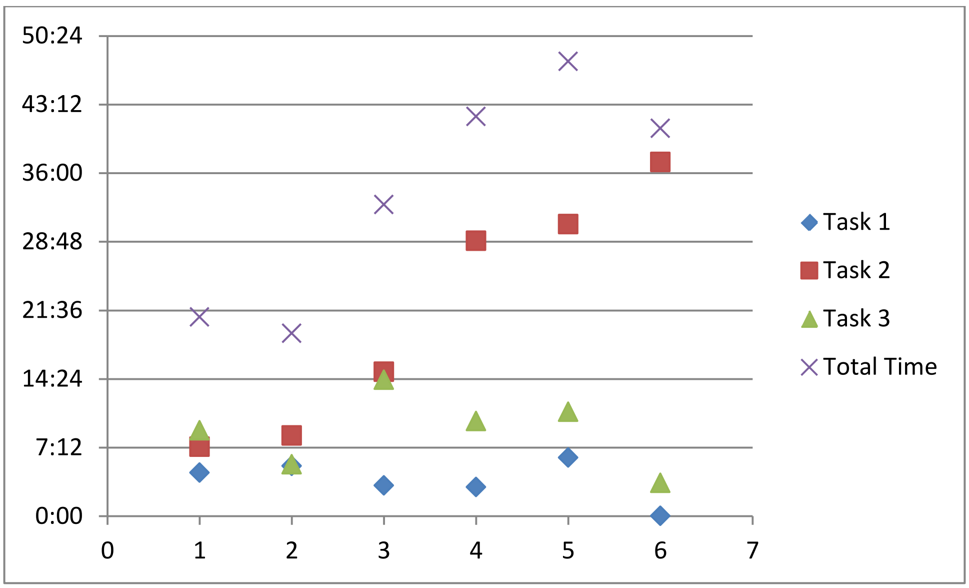

Fig. 1. Scatter plot of task times for all participants.

Table 1 Times for each task as well as the total task time and outline complexity for each participant. Participants are ordered by their task two times.

Participant	Task 1	Task 2	Task 3	Total Time	Outline Complexity
1	4:35	7:18	9:01	20:54	5
2	5:16	8:29	5:27	19:12	14
3	3:14	15:09	14:18	32:41	15
4	3:04	28:54	9:59	41:57	6
5	6:08	30:38	10:57	47:43	10
6	0:02	37:10	3:30	40:42	4

The overall strategy of the first group was characterized by highly linear reading, i.e., starting at the beginning and reading through to the end. This group also used the text-to-speech feature to read virtually the entire document, and while some of the members did skip sections, they almost always returned to read them in full.

In contrast, the second group used the text-to-speech feature less frequently; instead they skimmed the document “unassisted” for long periods of time, and then used the text-to-speech feature to read sections they wanted to read more closely. Less usage of this feature did not mean that this group used assistive technology less in their daily lives, or that they were less experienced with Kurzweil 3000 (in fact the participant who used Kurzweil 3000 most often was one of the participants who used the text-to-speech feature least often, and both groups had highly experienced and less experienced participants). Instead these participants used this feature strategically, much in the same way that an unassisted reader would skim a document to find relevant sections, and then read those sections more closely. Overall, this group also read less linearly, often going back and rereading sections or skipping ahead to look at section titles and figures. Furthermore, in the post session interview, most members of this group also talked about explicit strategies that involved skimming.

Both groups also encountered common breakdowns that made the kind of non-linear navigation that characterized the strategy of the second group difficult. In particular, most participants had difficulty navigating between pages. For instance, participants expected Kurzweil 3000 to allow for continuous scrolling between pages; however, to advance between pages users must either allow the text-to-speech feature to auto-advance them, or use the page navigation buttons found at the top of the page. This led many of the participants, even ones with the most experience using Kurzweil 3000, to have difficulty determining whether the document had more than one page. Most participants eventually found the page navigation buttons, but some participants resorted to work-arounds like using the forward button to advance the text-to-speech feature to the next page.

In addition to page navigation issues, Kurzweil 3000 further complicated navigation within the document by directing focus when users want to split focus. For instance, many participants tried to examine figures while the program's text-to-speech feature read the passages that referred to them, but Kurzweil 3000 directs the focus to the sentence being read making scrolling to different sections while it reads impossible. One participant in particular commented that he liked to allow the program to "read to me while I'm thinking of stuff to type," indicating the split focus could be an effective component of individual strategy. Difficulty controlling focus, as well as difficulty navigating within the document also made it harder for participants to quickly find and refer to figures within the document.

Overall this analysis indicates that providing clear and easy-to-use features for navigating within the document, such as allowing continuous scrolling, would improve the performance of both groups by better supporting the reading strategies that resulted in both faster and more accurate reading, reducing confusion about document length, and making it easier to find and refer to figures.

Conclusion

In continuation of this research, the UARC and WIDE research centers plan to further analyze the existing data, run two additional participants in this study, as well as two additional groups (participants with dyslexia and participants without dyslexia) reading a printed version of the same document used in this study in order to provide comparison on task times and strategies between all three groups, and to better understand the relationship between strategy and the technology used.

More than anything, this research demonstrates that understanding the range of strategies used by individuals with learning disabilities to read is essential to developing assistive technologies that effectively support those strategies. In particular this study highlights the importance of creating assistive technologies that allow for fluid navigation within documents. By making designs that emphasize navigation, developers will better facilitate the strategies that are most effective at reducing the time needed to complete complex reading tasks successfully, as well as remove barriers to learning those strategies.

Furthermore, because the participants who got the most benefit out of the technology also used highly developed strategies for engaging with documents, this study also suggests that in the case of high level literacy, assistive technologies should be supplemented with education that emphasizes effective reading strategies.

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3D Simulation of an Accessible Biomedical Lab

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Abstract

Accessibility of biomedical and chemistry laboratories is essential to enable students and scientists with physical disabilities to actively participate in science, technology, engineering, and mathematics (STEM) educational, research and vocational activities. The Institute for Accessible Science (IAS) decided to address this need through accessibility driven renovation of a laboratory space at Purdue University known now as the Accessible Biomedical Immersion Laboratory (ABIL). In order to broaden the reach of this innovation, a 3-D computer simulation modeled after the physical space was conceived. This simulation was designed not only to provide persons with physical disabilities a training facility for practicing lab techniques but also to provide a test bed for studying laboratory accessibility and ergonomics. The 3-D ABIL simulation is freely available online through IAShub.org and provides a unique opportunity for individuals from disparate locations to visit and experience the space virtually. Users can explore ABIL's lab work triangle and safety features from the first-person perspectives of standing, sitting in a wheelchair, or having limited vision. Future use of this simulation will be centered on enabling users to perform actual lab tasks from the aforementioned perspectives.

Keywords

Accessibility, persons with disabilities, science, laboratory, 3-D, computer simulation, STEM

Introduction

The use of 3-D simulation technology to aid persons with disabilities (PWDs) has been suggested since its inception. According to the literature, the focus of simulation technology has often been as a rehabilitation tool for chronic medical conditions, such as autism, cerebral palsy (Wang and Reid), traumatic brain injury (TBI) (Rose, Brooks, and Rizzo) and stroke (Holden). The development of 3-D architectural modeling software opened the door for the use of this technology outside the clinical realm for evaluating structural accessibility (Jimenez-Mixco et al). More recent work suggests simulation technology has been employed to train or pre-expose PWDs to hazardous, unfamiliar or physically taxing activities including street crossing (Wright and Wolery), driving, mobility aid use, even exercise (Erren-Wolters et al). The idea of using simulation technology to train individuals with disabilities how to manipulate equipment and navigate specialized environments to enhance their understanding and skill level is far less prevalent, underdeveloped in fact.

Our interest in a 3-D simulation lies in its ability to simulate environments such as a biomedical laboratory. Through a laboratory simulation, we desire not only to expose PWDs to the field of lab research, but to assess how they work in this environment in order to design more ergonomic and accessible spaces and equipment. More than 10% of all postsecondary students have a disability and about 30% of these have mobility, visual or other physical impairments (NCES 2008). Although the participation of undergraduate students with disabilities (SWDs) in the fields of science, technology, engineering, and mathematics (STEM) is comparable to that of their able-bodied peers, only a fraction of SWDs continue on to graduate studies and even fewer pursue laboratory-based doctorate degrees (National Science Foundation). A vast majority of interviewed SWDs indicated they chose not to pursue fields of study traditionally involving intensive laboratory research, such as biomedical science, medicine, or biomedical engineering, due to perceived inaccessibility and “hands-on” laboratory requirements (Duerstock; Mansoor et al).

We developed a 3-D simulation based on a physical "wet" lab space, known as the Accessible Biomedical Immersion Laboratory (ABIL) to combat this talent drain. This system allows us to 1) demonstrate the accessible features incorporated in this built environment, 2) provide alternate first-person perspectives within the space for wheelchair or standing users, and 3) conduct a series of ergonomic workflow experiments by rearranging or modifying the virtual environment instead of having to alter the physical space.

Methods

Accessible Biomedical Immersion Laboratory (ABIL)

An existing biomedical or "wet" laboratory space located at the Discovery Learning Research Center (DLRC) at Purdue University was used as a model for the simulation. This laboratory space, also known as ABIL, was built as a learning laboratory for interdisciplinary scientific projects and research. Working with the Office of University Architects in 2011, the IAS began accessible renovations of this unique educational space referencing the Americans with Disabilities Act (ADA) building standards, participant recommendations, and the literature (Blake-Drucker; Smyser).

Simulation Platform

The virtual simulation was developed using the multiplatform authoring software, Unity Engine. The Unity Engine's rendering capabilities, graphical effects, and physics based handling simplified the simulation of visual impairments and alternate navigation as well as demonstrated the complications caused by non-wheelchair accessible equipment.

In order to construct the simulation, still pictures were taken of the different features within ABIL such as the lab work triangle and emergency shower/eyewash; then these were used to build an exact 3-D virtual model of the lab space (Fig. 1).

Fig. 1. 3-D Rendering of ABIL

The 3-D simulation consists of four paired lab workbenches, three fume hoods, and lab sinks, as well as a teacher's lab workstation up front (right).

Research Participant

The physical accessibility of the architectural modifications was evaluated by a male with quadriplegia using anthropometric parameters, including arm reach, counter height, and depth and knee clearance. While using a power wheelchair to ambulate the space, the participant evaluated the accessible sink, fume hood, adjustable-height lab bench, as well as operation of the emergency shower/eyewash.

Results

Lab Workspace Accessibility

The modifications in ABIL focused on the architectural features necessary for performing typical biomedical laboratory techniques, a laboratory work triangle composed of lab bench, sink, and fume hood. As seen below, the lab sink was modified to support wheelchair user access by lowering the countertop and removing the cabinets underneath, providing leg clearance. A shallow sink with rear drain was installed to provide adequate knee clearance and enable the user to peer inside the sink. In addition, the faucets were mounted at the front edges of the sink to be within arms' reach.

Fig. 2. Comparison of Physical Lab Sink to 3-D Rendering

The left image shows the ABIL sink while the right is a capture from the simulation.

First-Person Vantage Points

In addition to demonstrating the accessibility modifications made to the actual ABIL environment, the simulation allows the user to navigate within the space from alternate perspectives. During initial development (Figure 3), two vantage points from the perspective of the simulation user were provided--one from that of an approximately 6 feet tall walking individual and the other from an individual in a wheelchair. Differences in lines of sight were evident throughout the simulation experience but movement within was also considered for each perspective. Since wheelchair users cannot travel side to side, movement was constrained to forward and backward with rotation right or left, thus mimicking actual wheelchair navigation.

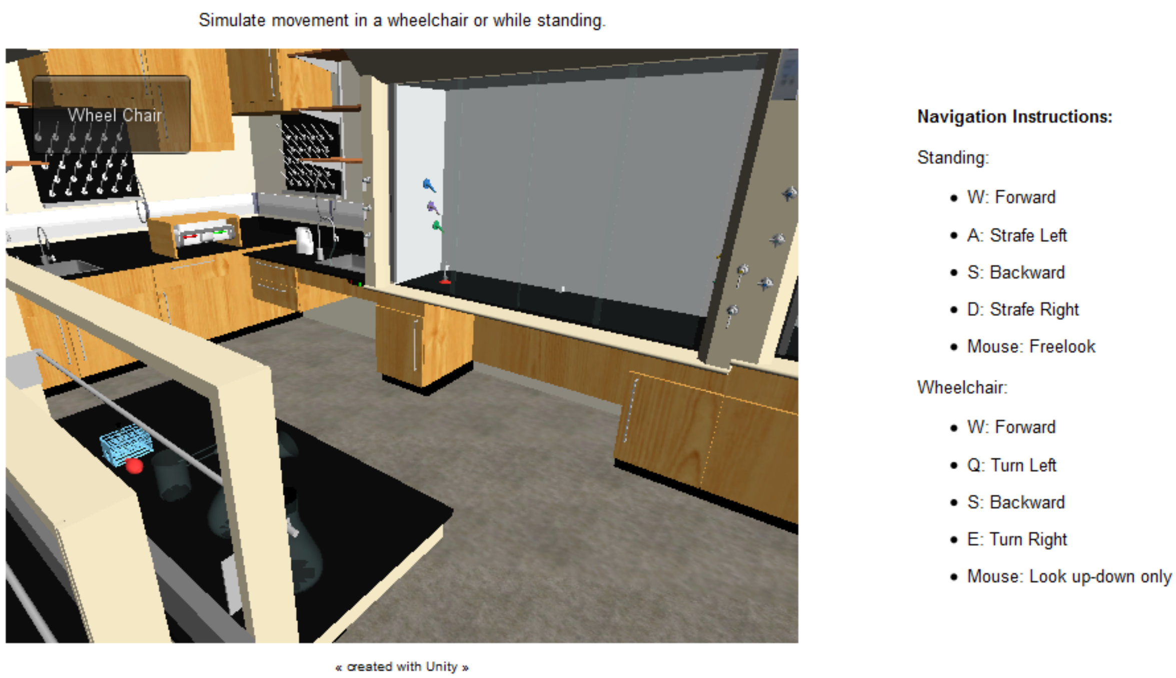

Fig. 3.1. 3-D Simulation from Standing

Image is from the vantage point of a standing person viewing the lab work triangle.

Fig. 3.2. 3-D Simulation from Wheelchair Perspectives

Images depict a wheelchair user's perspective of the lab work triangle and the height-adjustable workbench.

Discussion

We were interested in introducing PWDs to the field of laboratory research by allowing them to explore a 3-D virtual representation of a typical biomedical laboratory. By being exposed to this environment in advance, PWDs gain an understanding of laboratory navigation, devise resolutions to physical barriers they may encounter, and attain an ease within this sometimes intimidating environment. In addition, we intend to utilize hub metrics and user feedback to generate a guide for accessible laboratory design, furthering our mission to promote inclusive laboratory science.

The Unity™ simulation platform, chosen for its versatility, will aid us in our future plans to develop more simulations such as an ergonomic simulation incorporating anthropometric data. As for this simulation, we intend to expand the navigational perspectives to include low vision. Furthermore, we intend to conduct ergonomic and space analyses within ABIL as PWDs perform common laboratory procedures, then incorporate this information within another simulation enabling users to familiarize themselves with performing common laboratory experiments. We have already begun developing 3-D models of “wet” lab glassware and scientific instruments that will be manipulated by these simulation users.

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S-K Smartphone Barcode Reader for Blind Users

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Abstract

We describe a new smartphone app called BLaDE (Barcode Localization and Decoding Engine), designed to enable a blind or visually impaired user to find and read product barcodes. Developed at The Smith-Kettlewell Eye Research Institute, the BLaDE Android app has been released as open source software, which can be used for free or modified for commercial or non-commercial use. Unlike popular commercial smartphone apps, BLaDE provides real-time audio feedback to help visually impaired users locate a barcode, which is a prerequisite to being able to read it. We describe experiments performed with five blind/visually impaired volunteer participants demonstrating that BLaDE is usable and that the audio feedback is key to its usability.

Keywords

Visual impairment, blindness, assistive technology, product identification

Introduction

The ability to identify products such as groceries and other products is very useful for blind and visually impaired persons, for whom such identification information may be inaccessible. There is thus considerable interest among these persons in barcode readers, which read the product barcodes that uniquely identify almost all commercial products.

The smartphone is a potentially convenient tool for reading product barcodes, since many people carry smartphones and would prefer not to carry a dedicated barcode reader (even if dedicated readers may be more effective than smartphone readers). A variety of smartphone apps are available for reading barcodes, such as RedLaser and the ZXing project (for iPhone and Android, respectively), and a large amount of research has been published on this topic (Wang et al.; Wachenfeld et al.). However, almost all of these systems are intended for users with normal vision and require them to center the barcode in the image.

Aside from past work by the authors ("An Algorithm Enabling Blind Users"; "A Mobile Phone Application"), the only published work we are aware of that is closely related to BLaDE is that of Kulyukin and collaborators, who have also developed a smartphone video-based barcode reader for visually impaired users (Kutiyanawala et al.; Kulyukin et al.). However, this reader requires the user to align the camera frame to the barcode so that the barcode lines appear horizontal or vertical in the camera frame. By contrast, BLaDE lifts this restriction (see next section), thereby placing fewer constraints on the user and simplifying the challenge of finding and reading barcodes.

At the time that this manuscript was originally submitted, the one commercially available smartphone barcode reader expressly designed for visually impaired users, Digit-Eyes (http://www.digit-eyes.com/) did not provide explicit feedback to alert the user to the presence of a barcode before it could be read; however, after time of submission, such feedback was added to a later version of Digit-Eyes, in response to requests from Digit-Eyes customers (Digital Miracles). The Codecheck iPhone app (http://www.codecheck.info/) for Swiss users, which also provides such feedback, is based on an early version of BLaDE ("Codecheck").

BLaDE Description

The BLaDE system (see Fig. 1) provides real-time feedback to first help the user find the barcode on a product using a smartphone camera or webcam and then help orient the camera to read the barcode. Earlier versions of the computer vision algorithms and user interface were described in ("An Algorithm Enabling Blind Users"; "A Mobile Phone Application"), and details of the latest version are described in our technical report ("BLaDE"). BLaDE has been implemented both as an Android smartphone app and for use on a Linux desktop computer with a webcam. It has been released as open source code, available at http://sourceforge.net/p/sk-blade, so that anyone can use the software or modify it free of charge.

Fig. 1. BLaDE smartphone app

BLaDE takes several video frames per second and analyzes each frame to detect the presence of a barcode in it. The detection algorithm functions even when only part of the barcode is visible in the image, or when the barcode is too far away from the camera to be read.

Moreover, the barcode can appear at any orientation in the image and need not appear with its bars aligned horizontally or vertically. Whenever a barcode has been detected in an image, an audio tone is issued to alert the user.

The audio tone is modulated to help the user center the barcode in the image and bring the camera close enough to the barcode to capture detailed images of it. Specifically, the tone volume reflects the size of the barcode in the image, with higher volume indicating a more appropriate size (not too small or too big) and hence more appropriate viewing distance; the degree of tone continuity (from stuttered to continuous) indicates how well centered the barcode is in the image, with a more continuous tone corresponding to better centering. A visually impaired user first moves the camera slowly so as to find the barcode; further feedback helps the user to move the camera until the barcode is sufficiently well resolved and decoded. If BLaDE reads a barcode and is sufficiently confident of its reading, the system reads aloud the barcode number (or information about the barcode such as the name of the product).

Experiments with Visually Impaired Users

The development of BLaDE has been driven by ongoing feedback from blind and visually impaired users. Preliminary experiments with two blind volunteer participants led to the current version of BLaDE as well as a training procedure for new users. We conducted a controlled experiment with five additional blind/visually impaired participants (all of whom have either no light perception or insufficient vision to find a barcode on a package) using the current BLaDE version.

Before the actual experiment, the training session acquainted each participant with the purpose and operation of BLaDE and focused on several topics: (1) Holding the smartphone camera properly. This entails maintaining an appropriate distance from and orientation to a product of interest (specifically, with the smartphone screen held roughly parallel to the surface of the product, at a distance of approximately 4-6 inches) and taking care to not cover the camera lens with fingers. An important concept that was explained to those participants who were not already familiar with it was the camera's field of view, which encompasses a certain range of viewing angles, and which explains why an entire barcode may be fully contained within the field of view at one viewing distance but not at a closer distance. (2) How to use BLaDE to search for a barcode, emphasizing likely/unlikely locations of barcodes on packages and the need for slow, steady movement. Several barcode placement rules were explained, such as the fact that on a flat, rectangular surface, the barcode is rarely in the center and is usually closer to an edge; on a can, the barcode is usually on the sleeve, rarely on top or bottom lid. Participants were told that the search for a product barcode usually requires exploring the entire surface area of the package using two kinds of movements: translation (hovering above the product, maintaining a roughly constant height above the surface) and approaching or receding from the surface. (3) How to adjust camera movement based on BLaDE feedback. Participants were advised to first translate the camera to seek a tone that is as continuous as possible (indicating that the barcode is centered), and then to vary the distance to maximize the volume (indicating that the appropriate distance has been reached); if the tone became stuttered, they were advised to translate again to seek a continuous tone, and continue as before.

Each participant continued with a practice session, in which he/she searched for and read barcodes on products that were not used in the subsequent experiment. The experimenter turned off the audio feedback in some practice trials in preparation for the experiment, which compared trials with feedback on and feedback off.

In the experiment each participant had to find and read barcodes on 18 products, consisting of 4 barcodes, each printed on a sheet of paper, and 14 grocery products including boxes, cans, bottles and tubes. In advance of the experiment, 10 of the products were chosen at random to be read with feedback and 8 without; the sequence of products was also fixed at random, as was the starting orientation of each product (e.g., for a box, which face was up and at what orientation).

Each participant was given up to 5 minutes to search for and read the barcode on each of the 18 products, for a total of 90 = 5 x 18 trials; if the barcode was not located within that time then the trial for that product was terminated. Of the 50 trials conducted with feedback on, the barcodes were located and read successfully in 41 trials (82% success rate, with a median time of 41 sec. among successes); of the 40 trials conducted with feedback off, the barcodes were located and read successfully in 26 trials (65% success rate, with a median time of 68 sec. among successes). The data are summarized in Table 1. In all trials, whenever a barcode was read aloud to the user, the barcode was correctly decoded.

A 2x2 contingency table analysis to compare success rates with and without feedback yields a p-value of $p=0.056$. While just below the level of statistical significance (which is likely due to the low number of subjects), this result suggests a trend that feedback improves users' chances of finding and reading barcodes. This is consistent with feedback from the users themselves, who reported that the feedback was helpful. In our opinion, BLaDE's ability to help users locate barcodes is a crucial function of the system that greatly mitigates the challenge of searching for and reading barcodes.

Table 1.Comparision of Successes and Failures

	Number successes	Number failures
Feedback on	41	9
Feedback off	26	14

Discussion

Our experience with BLaDE underscores the difficulty that blind users face in using a barcode reader, which requires them to search for barcodes on products in order to read them. This search can take longer on a smartphone-based system due to the much slower rate of processing, smaller detection range and narrower field of view compared with a dedicated system, implying a tradeoff between ease of detection and the burden of having to own and carry a separate device. Empirically we found that the search process tends to be shorter for smaller products (which present less surface area to be searched) and for rectangular packages (curved surfaces are awkward to search, forcing the user to rotate the package relative to the camera). Audio feedback is important for speeding up the search process, and the key to improving BLaDE or other smartphone-based barcode readers in the future lies in improving this feedback. Two main improvements to the audio feedback can be considered. First, the maximum distance at which a barcode can be detected could be extended, which would allow the user to search a larger region of a package at one time. If the maximum allowable distance was long enough, then an entire side of a rectangular package could be searched in a single video frame. This will require using higher resolution video frames when searching for barcodes without sacrificing the processing speed (currently several frames per second). This can be achieved by improving the search algorithm to take advantage of the continually increasing processing power of modern smartphones. Second, it may be worthwhile to experiment with different types of audio feedback. For example, while the current BLaDE feedback indicates how centered a barcode is in the image, explicit audio feedback could be added to indicate what direction (left, right, up or down) the user needs to translate the smartphone to center it. While some users may find this additional information useful, it does complicate the user interface (and may introduce additional lag if the information is conveyed with verbal feedback), which could be unappealing to other users.

Conclusion

Experiments with blind/visually impaired volunteer participants demonstrate the feasibility of BLaDE, and suggest that its usability is significantly enhanced by real-time feedback to help the user find barcodes before they are read.

We are exploring commercialization options of BLaDE, including collaboration with an organization interested in releasing a consumer-oriented smartphone app that includes detailed information associated with a barcode (e.g., preparation instructions for packaged items). Since BlaDE has been released as an open source project, developers can add additional functionality to suit their needs. This way, we aim to facilitate the development of high-quality barcode scanners that can be used by blind and visually impaired persons.

Acknowledgments

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