Using a Digital Library of Images for Communication: Comparison of a Card-Based System to PDA Software

Trudi Miller[a], Gondy Leroy[a], John Huang[a], Serena Chuang[a], Marjorie H. Charlop-Christy[b]
[a] School of Information Systems & Technology, Claremont Graduate University
[b] Department of Psychology, Claremont McKenna College
Claremont, California, USA

***Abstract* -- Autism spectrum disorder has become one of the most prevalent developmental disorders and one of the main impairments is difficulty with communication. One method of augmentative and alternative communication is the use of the Picture Exchange Communication System (PECS) to create messages using a series of images printed on cards and organized in binders. We are developing a digital alternative based on an image library that is displayed on a personal digital assistant (PDA). We conducted an initial user acceptance study that compared the effectiveness and usability of both systems. The study showed that the PDA system was able to communicate messages to adult recipients as effectively as PECS. However, the PDA was perceived to be more current, of higher quality, easier, and more normal looking than the PECS binder.**

I. INTRODUCTION

Autism spectrum disorder is a serious developmental disorder that afflicts more than 500,000 children in the United States; it is more common than childhood cancer or Down's syndrome [1]. One of the primary impairments is difficulty with communication. Between one-third to one-half of people diagnosed with autism do not have functional verbal communication skills [2]. Research is being done in neuroscience, psychiatry, medicine, psychology, and many additional fields to determine causes and, eventually, a plan for prevention. The thousands of children who struggle with communication need immediate help. Frustration runs high for the children and those who want to understand.

We are working on a new digital, image-based messaging system that uses personal digital assistants (PDAs) as the medium for creating and viewing messages. Our research has been driven by the desire to enhance the success of a physical image library with the benefits afforded from the dynamic nature of a digital library. Digital products developed to date have focused on high-functioning learners [3], and can require extensive training and customization. Lower functioning learners who struggle to form two word sentences require a simple, intuitive interface without eliminating the benefits afforded from more complex systems.

II. BACKGROUND

A. Communication with Images

Every day we are bombarded by image-based communication. Red traffic lights, road signs, and the skull and crossbones on household cleaners all communicate without the aid of words. Effectively communicating with images requires that involved parties agree upon the meaning of the pictures chosen. Agreement can be achieved through learning, as is the case with traffic lights, or through the use of images that unambiguously depict the underlying concept. Ware [4] describes "sensory symbols" as those images whose meaning is self-evident and does not require learning to recognize. This type of image leads to successful image-based communication, since no training is required. This is especially important when working with autistic children, who cannot endure lengthy training sessions in image/concept mapping.

A successful image-based system currently used to augment the communication of autistics is the Picture Exchange Communication System (PECS) [5]. Introduced by Bondy and Frost [6], the system has achieved success for researchers, caregivers, and autistic children. PECS uses a binder-like tool in conjunction with structured training to help non-verbal autistic children communicate with their parents and caregivers. PECS incorporates small cards that have word and image pairs.

A typical PECS tool, henceforth referred to as the PECS binder, consists of a three-ring binder that has several strips of Velcro that run perpendicular to the rings on both the front and the inside back cover (Figure 1A). Laminated image and word pairs are fastened to these strips with Velcro. When users become more proficient, several pages with images attached using Velcro are added to the binder. The images are grouped in a user specific manner. For example, the images needed most often can be grouped on the first page or the images of the most preferred items (e.g. chocolate, French fries, toys) can also be combined.

The binder's front cover is roughly three inches shorter than the back cover. The remaining space is occupied by a

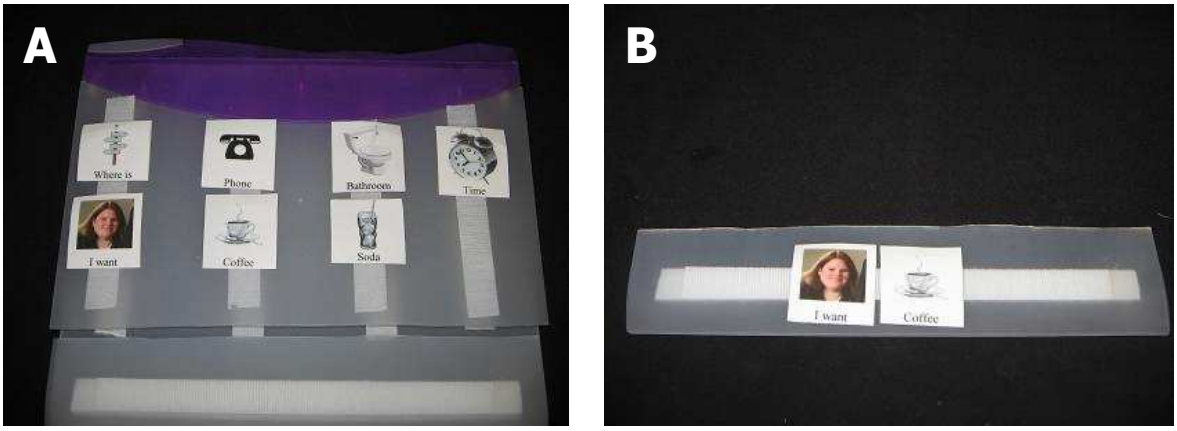

Figure 1 – Images of PECS-style binder (A: binder, B: sentence strip).

separate rectangular strip of plastic made out of the same material as the binder's cover. Both the strip and the inside back cover are affixed with Velcro. This strip is referred to as the 'sentence strip' because the autistic child places images onto this strip, then hands it to the message recipient for interpretation (Figure 1B). Through the creation of image sequences, the user can generate expressive messages.

PECS has proven successful with clinicians, parents, and autistic children. The majority of the evidence supporting its success has been anecdotal, though a few favorable case studies have been published [7, 8]. In the first comprehensive quantitative study conducted with PECS, Charlop-Christy *et al.* [9] found that using the PECS system increased communication and reduced negative behaviors in autistic children. Their study used a multiple-baseline design and demonstrated increases in verbal speech as well as a reduction in problem behaviors.

The evolution of image-based communication to PDA based software would continue to augment communication while providing additional benefits not available with the PECS system. The autistic children may not have cards with images of their favorite items available (e.g. picture of parent, unique toy). To add a custom image, a parent must have access to both a camera and a lamination machine. With PECS, the image cards can get lost as the Velcro that affixes them to the binder wears out and the cards can fall out of the binder and become lost. The large size of the PECS binder causes teachers with multiple autistic students to find the storage and maintenance of multiple PECS binders overwhelming.

The artifact addresses these problems through both its physical and logical design. Physically, the PDA's small size makes it convenient for both children and caregivers. Logically, the child's digital image library is uploaded and stored on the Internet portal's server. Even if the entire PDA was lost, the child's image library could be quickly restored to a new PDA. Our digital approach means that a parent does not need a laminating machine or printer to add a new image to their child's PDA. With the PDA application, the images are stored both within the device and on the Internet portal, providing a level of redundancy that protects the digital library's integrity against loss or theft of the PDA itself.

B. User Interface Design for Handheld Devices

Over the past few years, the processing power and display quality of handheld devices has increased while prices have decreased. This makes it possible to provide progressively sophisticated software on handhelds. However, because the screen size is smaller, the user interface needs to be optimally designed. Luchini *et al*. [10] applied traditional user interface (UI) design theory to PDAs, specifically recommending streamlining and automating. Streamlining is the process of displaying only crucial information onscreen at a specified time. Automating involves reducing the amount of information that needs to be entered, and decreasing the number of required commands.

Our PDA application's UI is highly customizable so that caregivers can control how many images and folders appear. This gives each individual user substantial control over the interface's complexity. A child new to the device might have a single folder with only two images, while a more advanced user might have five folders with four images in each. The UI can be updated as the child requires additional images.

Karkkainen and Laarni [11] point out that a UI should be designed around the task it is intended to perform, not how traditional computer applications are supposed to look. The development of our PDA application's UI centers on image-based communication, with the images and the communication strip being the central focus (Figure 2).

The principles of UI design are especially important given the characteristics of autistic children. Non-verbal autistic children may not be able to read or write. We needed to ensure that the user interface is usable by those who cannot read. Sensory images, whose meaning is self-evident, were used to assist the children in easily navigating the interface and choose a representative image.

To the best of our knowledge, we are not aware of any PDA studies with autistic children in the published literature. We believe the children will be capable of and enjoy using this digital alternative to communication. There is substantial

Figure 2 – Digital library application's user interface
(A: Image library as seen by child, B: Two images selected, C: Displaying message to parent)

research documenting the successful use of software with autistic children. Bernard-Opitz *et al*. [12] found computer-based simulations could be used to teach autistic children problem-solving strategies. Hetzroni and Tannous [13] used computer software to reduce echolalia, the repetition of recently heard speech patterns, in autistic children.

III. IMAGE-BASED COMMUNICATION SOFTWARE FOR HANDHELD DEVICES

Our image-based communication has two components: the PDA application and an Internet portal (Figure 3). The PDA operates as a stand-alone communication device, but can be updated and maintained through our Internet portal.

The PDA application is used by the autistic child to create and display messages. Our software on the PDA uses tab-based folders to display groups of images. The digital library user interface is divided up into three horizontal parts: tab-based folder list, digital library of images, and sentence strip (Figure 2A). The tab menu allows user to switch between different picture groups (e.g. the food group consisting of images of French fries, chocolate, apples, etc.). When the child touches an image, it moves to the sentence strip (Figure 2B). For example, if the child wants to know where the restroom is, s/he can select "Where is" and "bathroom" as different images to be displayed in the sentence strip. If s/he makes a mistake, s/he can touch the image on the sentence strip to move it from the sentence strip back to its original place within the folder. Once the images conveying the child's needs are conveyed on the sentence strip, s/he clicks the PDA's physical button. This action displays the message for interpretation, which clears the screen and displays the sentence "The user is trying to communicate:" above the images used in the message. The images are centered on the screen. It also disables the touch screen, preventing the message from being altered when the child hands the device to the message recipient (e.g. parent) for interpretation. Figure 2C displays the interface that the parent would see. Once the message has been communicated, the touch screen and folder based software can be re-enabled by pressing the center button

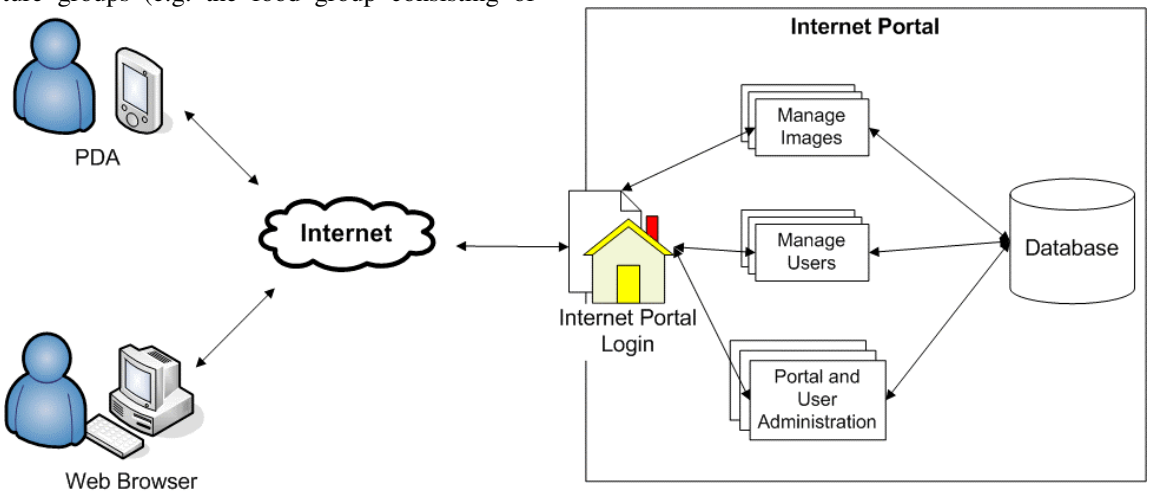

Figure 3 – Architecture of administering the PDA application through our Internet portal.

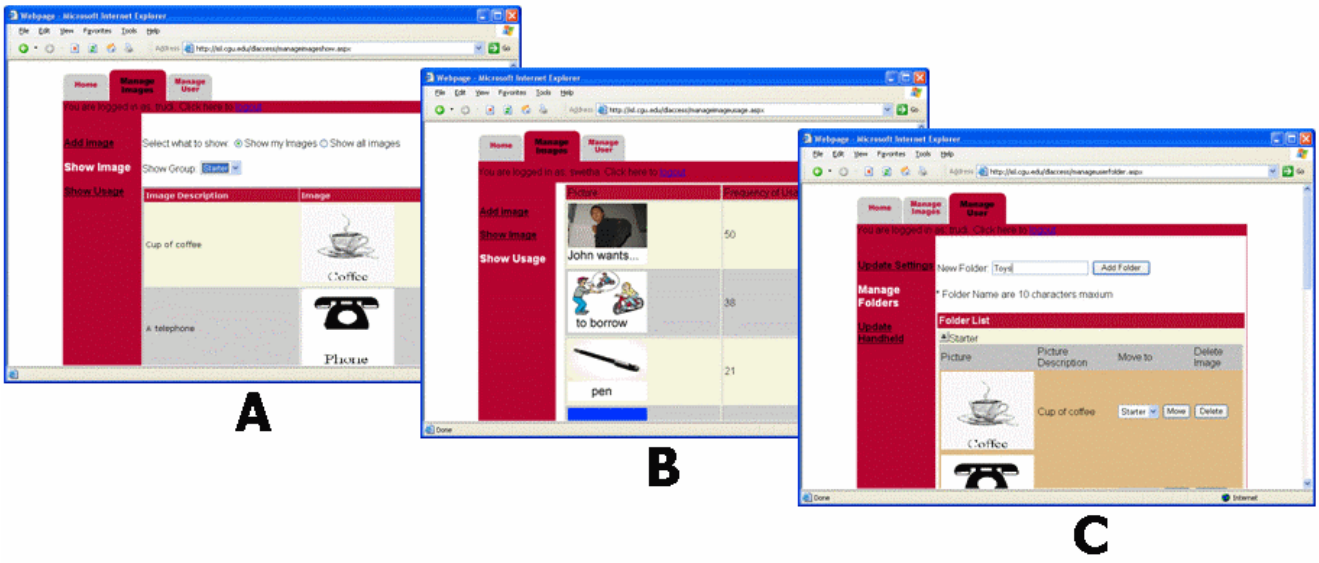

Figure 4 – Screenshots of the Internet portal for managing the digital library.
(A: Displaying the user's available images; B: Viewing usage of specific images;
C: Customizing the PDA's UI by moving images between folders.)

of the PDA. The Internet portal (Figure 4), accessible via web browser, can be used to work with all images within the library or images that pertain to a specific user. A parent or caregiver logs into the website to maintain the specific digital library related to their child. The portal allows the parent to view their currently available images (Figure 4A). Portal users can also view the number of times that their PDA has used a particular image (Figure 4B). Based on the usage report, parents can customize the images available, quickly adding new images (e.g. a new friend) or removing images that have fallen into disuse (Figure 4C). If the child is not using the toilet image to express the concept "bathroom", the parent can remove it from the library and add another image that is more representative of the bathroom to the child (e.g. sink, bathtub). If the child is overwhelmed by the number of images that appear, some may be relocated to another folder or removed from the device altogether.

The digital library PDA application, which was written with the Visual Basic.NET Compact Framework, uses SQL Server Compact Edition to store the folders and their images, and runs on Windows CE. The PDA application is updated and managed using the digital library Internet portal. The Internet portal was designed using Visual Basic.NET and ASP.NET, and stores its information in a SQL Server database.

IV. RESEARCH QUESTIONS

Our goals with the PDA application are two-fold: to make software that conveys image-based messages clearly to the general public regardless of first language, age, or gender, and to create a user interface that autistic children can use.

Figure 5 illustrates how the PDA application will be evaluated:

- Medium: compared with the existing PECS (paper-based) system
- Situation: if messages are easily understood in different situations (e.g. at home, at school, at a restaurant with strangers)

We must first demonstrate the effectiveness of the software for Receivers before testing and training with autistic children (Senders) can begin. Since PECS has proven successful, our system meeting or surpassing its standard of quality would merit both recognition and further investigation.

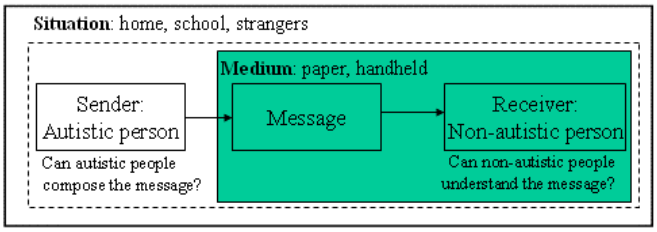

Figure 5 – Dimensions to be evaluated: Situation, Sender/Receiver, and Medium.

The current study compares the comprehension and user acceptance of the PDA to its paper counterpart (PECS) in messages to strangers (shaded section of Figure 5). If the PDA is ineffective in communicating simple messages, its interface can be redesigned before expending any effort in attempting to convey more complex messages. Feedback from the user study can be incorporated into the next iterative development cycle. We have begun testing the PDA based software with autistic children, so it is imperative that we temper our desire to improve the

software with the need to maintain consistency for our users. Sudden changes would lead to frustration and possibly abandonment of the system, so we will ensure that the pace of the development accommodates our users' needs.

V. EVALUATION OF DIGITAL LIBRARY PDA APPLICATION

A. User Study

i. Study Design. We used a between-subjects comparison of PECS and the new PDA application. We recruited subjects who were at least 18 years old, able to speak and read English (to complete the survey, not to interpret the message), and not legally blind. The subjects were approached in various normal social settings (e.g. at a public park, in an office building lobby). We conducted the study in this manner to ensure that a broader range of languages, ages, and educational levels were included. We also wanted to study our device in its intended (non-laboratory) setting. No compensation was offered, and participation was purely voluntary. Once recruited to participate, it was briefly explained to the subject that they would need to interpret a message made out of images.

We used 4 different, realistic tasks: asking for directions to the bathroom, asking for directions to a telephone, wanting soda, or wanting coffee. The tasks were generated through discussion with a public school teacher who had 8 years of experience in working with autistic children between the ages of 12 and 17. For each task, we used two images: the first displayed the sentence starter (e.g. "I want"); the second displayed the noun (e.g. "soda"). All tasks were used with both the PDA and PECS binder, and were randomly assigned to subjects.

ii. Comprehension of Message. Comprehension was evaluated by measuring the length of time it took the subject to discern the message and how accurate their interpretation was. The message interpretation was rated on the summative scale outlined by Frokjaer *et al.* [14] with 1 being Very Low, and 5 being Very High. The time taken was evaluated in five separate time sections, with 5 representing the fastest time and 1 representing not interpreted within the three minutes allotted.

iii. Usability. Usability was evaluated with a questionnaire that includes with a brief demographic section inquiring about the subject's age, gender, and education level. To ensure that subjects did not have uncorrected vision impairments a question asked if they needed glasses or contact lenses to read, and if so, were they wearing them. The usability portion of the questionnaire consisted of four section. Three of the sections were based on the ISO 9241 [15] standard and measured efficiency, effectiveness, and satisfaction of the interface; the actual items are in Table 2. Each of these was comprised of 7-point Likert scale items with 1 being 'Strongly Agree' and 7 being 'Strongly Disagree'. The fourth section consisted of a semantic differential scale, a type of scale used in usability studies for over 20 years [16, 17]. Semantic differential scales are those that place two adjectives, typically opposites, on either side of a scale; the actual pairs are in Table 2. An example from our questionnaire is "Low Quality" and "High Quality", where the values 1, 2, and 3 represent levels of relatively low quality, 4 represents neutral, and 5, 6, and 7 represent levels of relatively high quality. In addition to the quantitative data, we also asked participants for their comments about the system after each question and at the end of the survey.

B. Results

i. Overview. Forty-four subjects were recruited in total. Data from three participants' were excluded from calculation due to incompleteness or misunderstanding the scale being used. One participant wrote contradictory answers. He wrote "Yes" under the item 'The pictures were easy to see', but chose 'Strongly Disagree' on the scale. His intent could not be determined and his survey was discarded. The final dataset had 20 PDA application surveys and 21 PECS-style surveys.

The majority of our subjects were female, spoke English as a first language, and were between the ages of 24 and 44 (Table 1). More native English speakers evaluated the PECS system than did the PDA system. The highest educational level of the PECS subjects was higher than those who used the PDA.

ii. Comprehension of Message. Comprehension was evaluated through the level of message interpretation and the time taken to interpret the message. Both systems were equally effective for communicating the messages; there was no significant difference between the two for either time or comprehension level. For the PDA and the PECS binder, subjects expressed that the message created by the system was easy to understand. It is worth noting that the longest amount of time taken to interpret any of the messages was less than 2 minutes.

In praising PECS and the PDA, subjects commented that the words below the pictures greatly assisted them in understanding the message; one said "Without the words below the picture, it would have taken me longer to understand 'where is'". Two participants expressed enthusiasm about our idea of using images to communicate, and that it would greatly assist autistic children. One said "Yes, it will help [autistic children] to communicate and not be so shy…This is a great project you guys have in mind."

iii. Usability. We performed t-tests to compare the PDA and PECS-style systems (Table 2). Both the PDA and PECS were considered equally efficient in terms the pictures being easy to see, the amount of time it took to understand the message, carrying of the system, and the unit being self-contained. The images used with the PECS-based system were considered to be of a more appropriate size than the PDA version ($p < .05$). In terms of effectiveness, the PDA and PECS were considered equivalent for understanding what each picture represented and understanding the message as a whole.

Table 1 – Demographic overview of study subjects.

N = 41		PECS	PDA
Gender	Female	17	15
	Male	4	5
Mean Age		34.9	30.9
First Language	English	17	13
	Spanish	2	5
	Other	2	2
Highest Level of Education	High School	0	5
	Some College	8	7
	Completed College	7	5
	Completed Graduate Degree	6	3

Table 2 – Means and standard deviations for each question of the questionnaire (t-test, * indicates $p < 0.1$, ** $p < 0.05$, and *** $p < 0.005$)

N = 41	PECS		PDA	
Lower score indicates stronger agreement	Mean	Std Dev	Mean	Std Dev
EFFICIENCY				
The pictures were easy to see	1.2	0.44	1.7	1.42
The pictures were an appropriate size	**1.5****	**0.70**	**2.5****	**1.91**
It took too long to understand the message	5.8	2.00	6.6	1.19
The system would be easy to carry and transport	2.0	1.41	1.6	1.39
The system is self-contained	1.9	1.14	1.6	1.40
EFFECTIVENESS				
It was easy to understand what each picture represented	1.4	0.80	1.5	0.83
It was easy to understand the message from the combined pictures	1.3	0.72	1.4	0.82
SATISFACTION				
I liked the system	1.7	0.96	1.3	0.82
I was comfortable using the system	1.4	0.70	1.3	0.67
I would be likely, in the future, to assist someone using the system	1.6	1.14	1.6	0.94
The system is an appropriate means of communication	1.6	0.80	1.4	0.68
I would recommend this system to someone who had difficulty communicating verbally	1.4	0.81	1.4	0.70
The person creating the message looks normal while using the system	**1.5***	**0.70**	**1.2***	**0.52**
The person creating the message looks normal while carrying/transporting the system	**1.6****	**1.00**	**1.1****	**0.31**
I felt intimidated by this type of communication	5.7	2.12	5.6	2.50
OPPOSITES – *Lower score more related to left hand item*				
Low Quality / High Quality	**5.7****	**1.38**	**6.5****	**0.84**
Cryptic / Understandable	6.5	0.93	6.4	**1.12**
Complicated / Simple	6.6	0.67	6.3	1.53
Outdated / Current	**6.1*****	**0.90**	**6.8*****	0.41
Dull / Stimulating	5.8	1.30	6.3	**1.33**
Difficult / Easy	**6.6***	**0.80**	**6.9***	0.31
Frustrating / Satisfying	6.2	1.00	6.6	**0.68**
Terrible / Wonderful	**6.0***	**1.20**	**6.5***	0.76

The PDA outperformed PECS in two areas of satisfaction. People thought that carrying the PDA looked more normal than the PECS binder ($p < .05$). We also found a strong trend that creating the message with a PDA looked more normal than with the PECS binder ($p < .1$). The PDA and PECS were similarly likable, comfortable to use, and considered appropriate for communication. Subjects were equally likely to assist people using either system and to recommend the system to those who had difficulty with verbal communication. Users were not particularly intimidated by either system.

In the semantic differential scale items the PDA application was considered to be of higher quality ($p < .05$) and substantially more current/less outdated ($p < .005$) than the PECS system. There were strong trends that the PECS system seemed more difficult than the PDA application ($p < .1$) and that the PDA system was more wonderful than PECS ($p < .1$). Both PECS and the PDA were comparable in understandability, simplicity, stimulation, and satisfaction.

VI. CONCLUSIONS AND DISCUSSION

Throughout the design process, focus remained on solving the problems encountered by autistic children and those who care for them. The existing physical system was a conceptual starting point, but then focus shifted towards exploiting the benefits afforded by a digital system (e.g. dynamic image population, size of PDA).

Both the Pocket PC and the PECS binder were effective to convey messages to strangers. The time taken and the quality of interpretation were equivalent for both systems. However, the PDA is a more acceptable alternative to the PECS system for communicating messages. User acceptance was higher with the PDA than PECS in that creating a message looks more normal on the PDA. The PDA was also seen as more current, higher in quality, less difficult, and more wonderful than the PECS binder. It is important to note that the PECS binder used for this experiment was brand new, so prior use did

not contribute to a perception of it being used and thus lower quality or outdated.

However, there are lessons to be learned. The images on the PDA were perceived as too small by the study participants, even though all were able to interpret the message presented. It is possible that glare on the screen of the PDA contributed to their perceived frustration with the size of the images. Our PDA application includes a landscape feature that rotates the interface 90 degrees. A design consideration for the future would be incorporating scaling for images so that they resized larger to take advantage of this additional space. This orientation would not be foreign to children, who are already familiar with such orientation from handheld game systems like Nintendo's GameBoy Advance and Sony's PlayStation Portable (PSP).

The next step is to incorporate the feedback from this study into the next iteration of the software's design. The primary change will be that when a message is communicated, the images will automatically resize to fill the display. For two image messages like those used by our target early learners, this would increase the size of the images by up to 100%. This will address the users' perception that images displayed on the PDA were too small. The next design prototype will then have its comprehension and acceptability tested along to the additional dimensions specified in Figure 5. At the same time, the Internet portal site will be enhanced further. Usability testing with autistic children will continue, with feedback from the children and their caregivers contributing to the next prototype.

ACKNOWLEDGMENTS

This project was sponsored in part by a grant from the Verizon Foundation. The authors wish to thank the study participants and Patricia Reed for their assistance with this paper.

REFERENCES

1. National Center on Birth Defects and Developmental Disabilities, *About Autism, Autism Information Center, NCBDDD, CDC*. 2005, Center for Disease Control.
2. Autism, C.o.E.I.f.C.w., *Educating Children with Autism*, C. Lord and J.P. McGee, Editors. 2001, National Academy Press: Washington, DC.
3. DynaVox Technologies, *Dynavox Technologies > Products > MightyMo/MiniMo*. 2005, http://www.dynavoxsys.com/Default.aspx?tabid=36.
4. Ware, C., *Information Visualization: Perception for Design*. 1st ed. 2000: Morgan Kaufmann Publishers.
5. Pyramid Educational Consultants, I., *PECS*. 2005, http://www.pecs.com/page5.html.
6. Bondy, A.S. and L.A. Frost, *The picture exchange communication system*, in *Focus on Autistic Behavior*. 1994. p. 1–19.
7. Kravits, T.R., et al., "Brief Report: Increasing Communication Skills for an Elementary-Aged Student with Autism Using the Picture Exchange Communication System". *Journal of Autism and Developmental Disorders*, 2002. **32**(3): p. 225-230.
8. Ganz, J.B. and R.L. Simpson, "Effects on Communicative Requesting and Speech Development of the Picture Exchange Communication System in Children with Characteristics of Autism". *Journal of Autism and Developmental Disorders*, 2004. **34**(4): p. 395-409.
9. Charlop-Christy, M.H., et al., "Using the Picture Exchange Communication System (PECS) with Children with Autism: Assessment of PECS Acquisition, Speech, Social-Communicative Behavior, and Problem Behavior". *Journal of Applied Behavior Analysis*, 2002. **35**(3): p. 213-231.
10. Luchini, K., C. Quintana, and E. Soloway. *Design Guidelines for Learner-Centered Handheld Tools*. in *CHI 2004*. 2004. Vienna, Austria: ACM.
11. Karkkainen, L. and J. Laarni. *Designing for Small Display Screens*. in *NordiChi 2002*. 2002. Arhus, Denmark: ACM Press.
12. Bernard-Opitz, V., N. Sriram, and S. Nakhoda-Sapuan, "Enhancing Social Problem Solving in Children with Autism and Normal Children Through Computer-Assisted Instruction". *Journal of Autism and Developmental Disorders*, 2001. **31**(4): p. 377-384.
13. Hetzroni, O.E. and J. Tannous, "Effects of a Computer-Based Intervention Program on the Communicative Functions of Children with Autism". *Journal of Autism and Developmental Disorders*, 2004. **34**(2): p. 95-113.
14. Frokjaer, E., M. Hertzum, and K. Hornback. *Measuring usability: Are effectiveness, efficiency and satisfaction really correlated?* in *ACM Conference Human Factors in Computing (CHI'00)*. 2000. New York: ACM Press.
15. ISO, *Ergonomic requirements for office work with visual display terminals (VDTs) -- Part 11: Guidance on usability*. 1998, ISO: Geneva, Switzerland.
16. Industry USability Reporting Project, *Common Industry Format for Usability Test Reports*. 1999, National Institute of Standards and Technology.
17. Baroudi, J.J., M.H. Olson, and B. Ives, "An empirical study of the impact of user involvement on system usage and information satisfaction". *Communications of the ACM*, 1986. **29**(3): p. 232-238.