RESNA 2001

Annual Conference Proceedings

RESNA 2001

The AT Odyssey Continues

RENO

June 22 - 26, 2001

Reno, Nevada

John Ascuaga's Nugget Hotel

PROCEEDINGS
of the
RESNA 2001
Annual Conference

The AT Odyssey Continues

June 22-26, 2001

John Ascuaga's Nugget Hotel
Reno, Nevada

Richard Simpson, PhD ATP
Editor

Ken Kozole
Jeff Symons
Conference Co-Chairs

RESNA PRESS

Proceedings of the RESNA 2001 Annual Conference
Reno, Nevada
June 22-26, 2001

Volume 21
ISSN 0883-4741
ISBN 0-932101-43-7

RESNA PRESS
1700 North Moore Street, Suite 1540
Arlington, VA 22209, (703) 524-6686

Printed in the United States of America
Dependable Printing Company, Inc.

Foreword

On behalf of the local committee we would like to welcome you to Reno for the RESNA 2001 Annual Conference! This year's theme entitled "RESNA 2001- The A.T. Odyssey Continues" suggests that our quest for the latest information regarding assistive technology and its application is a continuous adventure. With that goal in mind, RESNA offers a unique opportunity for those who attend the annual conference. Not only are attendees provided with a variety of learning experiences, but also the opportunity to network and share information with others who share the same challenges. In an effort to make the 2001 Conference the best, we asked others and ourselves: "Why do you come to RESNA?" The answers were varied, but we found mostly people come for the courses, the presentations, the exhibits and to connect with colleagues. We solicited people about the type of courses and presentations they preferred, and the kind of exhibitors they wanted to see. As a result, many RESNA members went the extra mile to make sure we could offer these learning experiences and exhibitors. A big part of your learning experience is in the Exhibit hall. Come and see how our special emphasis on getting you the most innovative and leading edge information from manufacturers and research groups resulted in a full hall of exhibitors.

As conference Co-chairs we feel that our job is to make sure you all have a great conference. If there is anything we can do to make the conference better for you, please let us know. You can leave a message at the RESNA main desk, leave a message at our rooms or page us. We hope you'll find the conference exciting, informative and fun! Reno and the surrounding area have much to offer. Get some friends, take a break and visit the local area, attractions, shows, and Lake Tahoe. We hope that you will find this conference interesting, useful, and fun. ENJOY!

Ken Kozole
Jeff Symons
RESNA 2001 Conference Co-Chairs

Mary Binion
RESNA President

Preface

Welcome to RESNA 2001. This year's conference includes over 200 presentations on all facets of assistive technology through concurrent sessions, scientific platform sessions, interactive poster presentations, computer demonstrations, and the Research Symposium.

This Proceedings of the RESNA Conference attempts to capture some of the information that will be exchanged during the activities and events of the Conference. The scientific papers included in this document contain everything from recent scientific research to practical designs to case studies. Scientific content is grouped into 8 categories:

- Technology for Special Populations
- Augmentative and Alternative Communications
- Computer Access and Use
- Environmental Accommodations
- Functional Control and Assistance
- Service Delivery & Public Policy
- Research and Functional Outcomes
- Seating and Mobility

In addition, the winning papers for the Student Scientific Paper and Student Design competitions are also included.

RESNA 2001 resulted from the efforts of many people. Tony Langton, in particular, has led the planning and organizing at both the local and national levels. Thanks go to Brenda Sposato, coordinator for the concurrent sessions which parallel the scientific sessions, and to the topic coordinators for the review process of the scientific papers: Alex Mihailids, Kevin Caves, Ivanora Alexander, Marty Blair, John Goldthwaite, Tariq Rahman, Shirley Fitzgerald, and Mark Schmeler. Thanks also go to the numerous reviewers of the individual scientific papers for their efforts in determining the final program. Jack Winters and Charlie Robinson are to be commended for their leadership in shaping the Telecommunications Research Symposium. As always, the efforts of Susan Leone are greatly appreciated, and Larry Pencak has proven to be a tremendous addition to RESNA.

Enjoy the Conference.

Rich Simpson, PhD
Chair, Scientific Program

PATRONS

. . .RESNA gratefully acknowledges conference support from the following PATRONS

CIRRIE—Center for International Rehabilitation Research Information and Exchange
Independence Technology, LLC, a Johnson & Johnson Company
DEKA Research & Development Corporation
National Institute on Disability and Rehabilitation Research (NIDRR)
Nevada Assistive Collaborative
Nevada Disability Forum
Nevada Centers for Independent Living
Provail
Sunrise Medical
The Whitaker Foundation

. . . AND recognizes the assistance of the following organizations

Beyond Ability, Inc
College Misericordia
Easter Seal Society—Idaho Falls
The Langton Group
Marquette University
Nevada Assistive Technology Collaborative
Northern Nevada Center for Independent Living
Project Threshold
San Diego State University
San Francisco State University
Shriner's Hospital—Salt Lake City
University of Illinois at Chicago
University at Buffalo
University of Pittsburgh

Conference Organizing Committee

Conference Co-Chairs
Ken Kozole, Shriner's Hospital, Salt Lake City, UT
Jeff Symons, Project Threshold, El Dorado Hills, CA

Meetings Committee Chair
Anthony Langton, The Langton Group

Computer Tech Lab
Denis Anson OTR, College Misericordia

Concurrent Sessions Program
Brenda Sposato MEBME ATP, University of Illinois at Chicago

Instructional Program
James Lenker OTR, University at Buffalo

Research Symposium
Jack Winters PhD, Marquette University
Richard Simpson PhD ATP, University of Pittsburgh

Scientific Program
Richard Simpson PhD ATP, University of Pittsburgh

Student Design Competition
Glenn Hedman ME ATP, University of Illinois at Chicago

Student Scientific Paper Competition
Richard Simpson PhD ATP, University of Pittsburgh

TA Project Liaison
Nancy Meidenbauer

Volunteers
Linda Szczepanski, University of Pittsburgh

Reno Local Arrangements Committee
Joel Bohl, Northern Nevada Center for Independent Living
Ronald Gaal, San Francisco State University
Paul Gowins, Nevada Tech Act Program
Paul Haugan, Nevada Tech Act Program
Judy Hammock, San Diego State University
Jon Lyksett ATP, Easter Seal Society, Blackfoot, ID
Caren Sax, San Diego State University
James Willcox, Beyond Ability Inc

PATRONS

. . .RESNA gratefully acknowledges conference support from the following PATRONS

CIRRIE—Center for International Rehabilitation Research Information and Exchange
Independence Technology, LLC, a Johnson & Johnson Company
DEKA Research & Development Corporation
National Institute on Disability and Rehabilitation Research (NIDRR)
Nevada Assistive Collaborative
Nevada Disability Forum
Nevada Centers for Independent Living
Provail
Sunrise Medical
The Whitaker Foundation

. . . AND recognizes the assistance of the following organizations

Beyond Ability, Inc
College Misericordia
Easter Seal Society—Idaho Falls
The Langton Group
Marquette University
Nevada Assistive Technology Collaborative
Northern Nevada Center for Independent Living
Project Threshold
San Diego State University
San Francisco State University
Shriner's Hospital—Salt Lake City
University of Illinois at Chicago
University at Buffalo
University of Pittsburgh

Table of Contents

Environmental Accommodation (Topic 4)

Functional Control and Assistance (Topic 5)

Service Delivery and Public Policy (Topic 6)

Student Design Competition

Student Scientific Paper Competition

Technology for Special Populations
(Topic 1)

THE COACH: AN INTELLIGENT CUEING DEVICE FOR ASSISTING PEOPLE WITH DEMENTIA

A. Mihailidis [1,2], G.R. Fernie, Ph.D., P.Eng. [1], J.C. Barbenel, Ph.D. [2]
[1] Centre for Studies in Aging, Sunnybrook & Women's College HSC, Toronto, Canada
[2] Bioengineering Unit, University of Strathclyde, Glasgow, Scotland

ABSTRACT

The COACH-- Cognitive orthosis for assisting activities in the home, is an intelligent cueing device that is being developed to help people with dementia during their activities of daily living. The device uses artificial intelligence to "watch" the user and his/her surrounding environment, learn from his/her actions, adapt to individual preferences, and issue varying levels of cue detail. This paper will focus on the rationale behind this research, and describe the device's development.

STATEMENT OF PROBLEM / RATIONALE

It is estimated that one out of three people over the age of 85 has dementia [1]. Dementia is characterized by a decline in cognitive function and memory, and often results in an affected person not being able to complete activities of daily living (ADL) because he/she becomes disoriented and confused. A common solution is for a caregiver to constantly watch the person, and provide verbal reminders when necessary. This loss of independence and privacy can be especially upsetting for toilet-related activities.

It is hypothesized by the authors that independence can be improved through the use of an intelligent computerized device that provides reminders needed by the user, and monitors his/her progress during an ADL.

BACKGROUND

A computerized cognitive device, or prosthesis/orthosis, can be used to assist people with brain injury through ADL and vocational tasks by providing cues and audible alarms [2] [3] [4]. However, there is virtually no literature that describes such devices being developed for people with dementia except for results published from a pilot study conducted by the authors. In this study it was shown that a user with moderate-to-severe dementia completed an ADL task (handwashing) in response to a computerized device that used a recorded voice for cueing [5].

A cognitive device must be adaptable. It needs to be able to handle variations not only in how its user completes an activity, but in how the user might fail as well. The majority of previous devices achieved this through input from the user, and/or by manual re-programming of the software by either the user or a caregiver. These actions are less likely to be completed by a person with dementia or a more severe cognitive disability. To be effective for this population a cognitive device must be able to adapt automatically and on-line. Perhaps artificial intelligence (AI) techniques can be used to incorporate this more effectively than past devices.

DESIGN

The design objective was to create a device that uses AI programming techniques to intelligently and rationally guide a person with dementia through an ADL task, and that can automatically adapt its strategies to best assist its user. This resulted in a prototype of a computerized device—the COACH. Figure 1 shows the general architecture of the COACH.

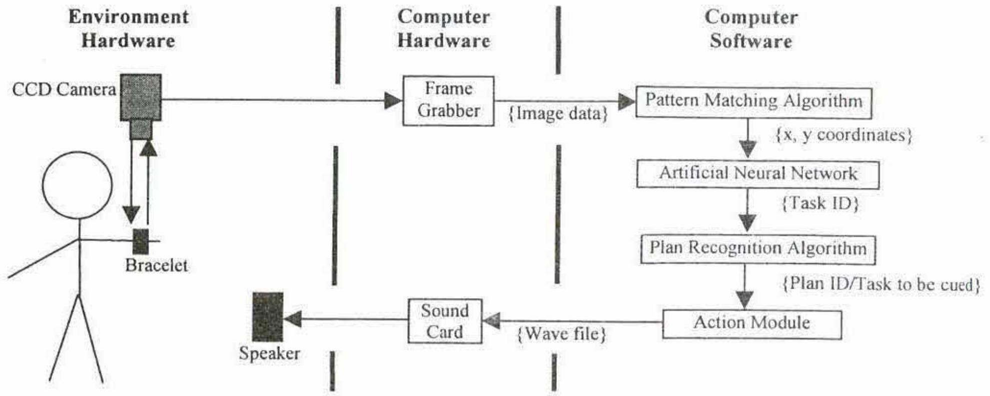


Figure 1 - Architecture of the COACH

DEVELOPMENT

The COACH consists of a hardware component that tracks the actions of the user, and a software component that analyzes these inputs and makes decisions.

The hardware consists of a monochrome charged-coupled device (CCD) video camera that is located above the workspace. This camera is connected to a frame-grabber card (IMAQ-1408 from National Instruments[1]) located inside the computer that runs the device software. In addition, a mat comprised of a series of switches is located on the floor in front of the counter. This mat lets the device know whether the user is standing at the sink.

The software was developed using Labview v.5.1[1] and Matlab v.5.3 [2]. There are three main algorithms in the software—the **artificial neural network (ANN)**, the **plan recognition algorithm (PRA)**, and the **action module (AM)**. In addition to these three modules, a pattern-matching algorithm is used to track the position of a unique marker that the user wears around his/her wrist (a bracelet). Using this algorithm and the images from the camera, the x and y coordinates of the pattern are calculated and provided to the three main algorithms.

The ANN uses probability theory to "learn" which tasks correspond with various inputs from the environment (i.e. spatial coordinates of the user's bracelet/hand). The network classifies the inputs into task identification numbers, and allows easy training of the device for any ADL task by using training data acquired for the activity being performed. Using the output from the ANN, the PRA then determines which plan (i.e. which sequence of tasks), the user is completing, or predicts which plan the user is attempting in order to correct his/her actions. Finally, the AM is responsible for selecting and playing a pre-recorded verbal cue only when necessary. It has the capability of playing several different verbal cue details to the user for a particular task before assistance from a caregiver is required. Moreover, the selection of the required cue detail is based on an individualized performance history, which allows the device to learn about the user's abilities, tendencies, and habits. The performance history is a running average of the user's success rates for each individual task in the overall activity.

In addition to using spatial coordinates, the velocity of the user's hand is also calculated in an algorithm prior to the modules described above. This additional input allows for a rudimentary low-pass filter to be applied to the data. This filter ensures that data points collected while the

---

[1] National Instruments: Austin, Texas, (512) 794-0100
[2] The Mathworks, Inc: Natick, MA, (508) 647-7000

user's hand is in transition are not passed from the pattern-matching algorithm to the remaining software.

PRELIMINARY EVALUATION

Testing with surrogate users during an example of an ADL, the handwashing task, is being completed to remove any bugs that may exist. Preliminary data regarding the device's operation has shown it performing at approximately a 90 percent success rate with respect to its ability to classify inputs from the environment, and correctly guide a user when a mistake has been made. This efficacy rate will improve as more refinements are made to the device's algorithms.

Evaluation of the device with several actual users (during handwashing) using a single-subject research design will be completed in the near future.

DISCUSSION

To date the COACH can be trained to monitor a user during an ADL task using unobtrusive methods, provide varying levels of cue detail depending on the user's past performance, and automatically adapt it's cueing strategy to fit the user's habits and preferences (as long as these habits are correct).

The preliminary evaluations have shown that some improvements still need to be made to the software, specifically in improving its efficiency. These evaluations also indicate that more training data will be required than initially thought in order for the device to fully monitor and assist a user through any task or situation during the handwashing activity. The exact amount of data and number of trials that will be required is still to be determined.

REFERENCES

1. McDowell, I (1994). Canadian Study of Health and Aging: Study methods and prevalence of dementia. Canadian Medical Association Journal, 150(6): 889-913.
2. Kirsch, N.L, Levine, S.P., Lajiness, R. (1988). Improving Functional Performance with Computerized Task Guidance Systems. ICAART Montreal: 564-567.
3. Napper, S.A. Narayan, S. (1994). Cognitive Orthotic Shell. RESNA Proceedings Nashville: 423-425.
4. Bergman, M.M. (1997). People with cognitive challenges can enjoy rapid success in acquiring skills and managing their lives: The exciting breakthrough of cognitive orthotics. In: The Proceedings of the 1997 Technology and Persons with Disabilities, California State University, Northridge (CSUN).
5. Mihailidis, A. (1998). The Use of an Automated Cueing Device to Assist People with Dementia during Handwashing Master of Applied Science Thesis, Department of Mechanical & Industrial Engineering, University of Toronto: Toronto, p.157.

ACKNOWLEDGEMENTS

This work is supported in part by the Alzheimer Society of Canada and Lifeline Systems Inc.

Alex Mihailidis (alex.mihailidis@swchsc.on.ca)
Centre for Studies in Aging, Sunnybrook & Women's College HSC
2075 Bayview Avenue, Toronto, Ontario, Canada, M4N 3M5
Tel: (416) 480-5858, Fax: (416) 480-5856

MODEL FOR THE FUNCTIONAL APPLICATION OF ASSISTIVE TECHNOLOGY: COGNITIVE LIMITATIONS

Haynes, S., M.E. BME, Center for Rehabilitation Technology
Georgia Institute of Technology
Atlanta, Georgia 30318

ABSTRACT:

In order to effectively apply assistive technology (AT) interventions, the AT provider must look beyond the diagnosis and assess the functional abilities and limitations of the person needing assistance. This paper proposes a model to help AT providers move beyond categorical diagnoses of cognitive limitations and focus on four common areas of cognitive functional limitations: Perception, Expression, Memory, and Processing. By focusing on these areas of function, the AT provider will be better able to identify the appropriate type of assistive technology intervention.

BACKGROUND:

The effective application of assistive technology (AT) for any disability requires the consideration of many different elements. Before an AT provider can effectively make a recommendation, they must consider the tasks involved, the abilities and preferences of the person who is to complete the tasks, and the environment in which the tasks will be completed (1, 2). This information may be gathered (and should be confirmed) through multiple sources. In an effort to provide timely service, AT providers may find themselves relying too much on the stated diagnosis to provide guidance in the recommendation of AT. The stated diagnosis often encompasses a broad range of functional limitations and abilities that vary greatly between people. Therefore, in order to identify the person's abilities, the AT provider must purposefully shift their focus from the categorical diagnosis (e.g. learning disability, blindness, spinal cord injury, etc.) to the functional limitations of the person before recommending AT intervention.

This paper presents a model for the functional application of assistive technology in regard to **cognitive limitations.** Cognitive disabilities are the source of disabling conditions for many people with disabilities. In 1992, the category of learning disabilities and mental retardation alone accounted for 2.6 percent of disabling conditions for people in the United States (3). The model will help guide the AT provider to the appropriate *type* of AT device for specific cognitive functional limitations. This model may also help referral sources understand how to provide clearer descriptions of the person's situation in initial referral documentation, thereby speeding up the service delivery process.

OBJECTIVE:

Although the etiology for each of the diagnosed cognitive disabilities (e.g. stroke, acquired brain injury, learning disability, etc.) is different, there is significant overlap in functional limitations. The objective of the model is to categorize the functional limitations of various diagnosed cognitive impairments in such a way that an AT provider may quickly and accurately focus on the appropriate type of AT interventions.

METHOD:

When making a recommendation for AT intervention, it is important to consider the tasks that the person is trying to perform. It has been shown that, for the purpose of problem solving, humans may be represented as information processing systems. In the model presented by Simon and Newell (4) "input" was considered to be the sensory system, "output" was the motor system. However, the categories in system are too broad to effectively lead an AT provider to appropriate AT intervention. Focusing only on the cognitive function while using the same computer analogy, the corresponding areas of are Perception (input), Expression (output), Memory (storage), and Processing (change). The description of each category is as follows:

Perception (Input)

Perception refers to a person's ability to understand information that is accurately sensed. A person who has no sensory impairment (i.e. no hearing or vision loss) or has had the sensory loss corrected with the use of assistive technology may still have difficulty decoding the information received from the sensory organs. In this sense the "input" into the brain is affected.

Expression (Output)

Expression refers to a person's ability to demonstrate his or her thoughts or feelings both through verbal and non-verbal means. An expressive functional limitation may restrict a person *from* expressing himself or herself as intended or it may cause a person *to* express himself or herself in ways that are not intended or are not appropriate.

Memory (Storage)

The problems with memory fall into two basic categories: *storage* and *retrieval.* Storage refers to the act of developing specific neural pathways that will retain specific information that has been perceived. Retrieval refers to the act of locating the specific neural pathways, which lead one to the desired information.

Processing (Change)

Processing refers to a functional limitation that prevents a person from making use of the information that they already have or from going through the necessary "process" of obtaining information.

By assigning appropriate functional limitations to each of these four categories, the AT provider is encouraged to identify the manifestation of the diagnosed disability. Table 1 shows the functional limitations for each category. Each of the functional limitations leads to a particular type of assistive technology or compensation strategy. For example, a person with a learning disability who's functional limitation is visual perception may benefit from text-to-speech software. Whereas a person with a learning disability who's functional limitation is dysgraphia may benefit from a standard word processor.

TABLE 1

PERCEPTION	EXPRESSION	MEMORY	PROCESSING
• Receptive Aphasia • Visual Perception • Auditory Perception	• Expressive Aphasia • Dysgraphia • Cognitive Motor Dysfunction • Behavioral Expression	• Visual Memory • Auditory Memory • Procedural Memory • Amnesia	• Attention and Concentration • Executive Functions • Visual Processing • Auditory Processing • Dementia and Mental Retardation

RESULTS:

This process was described in an assistive technology handbook that was presented to 19 State Vocational Rehabilitation AT Providers and 2 State Vocational Rehabilitation AT Managers. The handbook also showed how diagnosed disabilities such as LD, ABI, and Stroke could result in various combinations of the functional limitations listed above. Based on the specific functional limitation, the handbook directed the AT provider to a list of appropriate types of AT and compensatory strategies. After reviewing the document, these providers were surveyed and asked to comment on the benefits of this model, in addition to other features of the handbook. Results and comments from that survey will be available for presentation at the RESNA 2001 conference.

DISCUSSION:

The key to successful application of assistive technology is to understand the person's abilities, disabilities, and the specific task that is being attempted. One should always be cautious about trying to "categorize" people with disabilities or using a "formula" to assign appropriate assistive technology solutions. This model however, seeks not to categorize the people but rather to group like functional limitations in such a way that it will naturally lead the AT provider to likely options for AT intervention. For example, Mental Retardation was listed with Dementia under "Processing", because the functional limitations associated with Mental Retardation are similar to those of advanced Dementia. Therefore, AT intervention should stem from the same type of technology.

A similar model could also be developed surrounding the topics of sensory impairments or mobility impairments using different categories. These models are useful not only to guide the AT provider, but they also help paint a broad picture of AT intervention that can be useful as a training tool for those less familiar with AT. It is important to note that the provider must not neglect to perform a thorough evaluation and consider all aspects of the person's abilities, mobility, sensory, cognitive, and psychological before attempting to recommend an AT intervention.

REFERENCES:

1. Cook, A.M., and Hussey, S.M., (1995) *Assistive Technologies: Principles and Practice.* St. Louis, MO, Mosby publishers.
2. Beigel, Andrew R. (March 2000). Assistive Technology Assessment: More Than the Device. Intervention in School and Clinic, vol. 35, Issue 4, p237, 7p.
3. Mitchell P. LaPlante, Ph.D. and Dawn Carlson, Ph.D. (August 1996) Disability in the United States; Prevalence and Causes, 1992. Published by U.S. Department of Education, National Institute on Disability and Rehabilitation Research (NIDRR).
4. Newell, A., Simon, H., (1972) *Human Problem Solving.* Englewood Cliffs, N.J., Prentice-Hall publishers.

ACKNOWLEDGEMENTS:

Research funded by the Georgia Division of Rehabilitation Services and the state of Georgia.

Scott Haynes, M.E. BME
Center for Rehabilitation Technology
490 10th Street, NW
Atlanta, GA 30318
(404) 894-9156; scott.haynes@arch.gatech.edu

BLIND NAVIGATION USING RADIO FREQUENCY IDENTIFICATION TAGS

Hugh W. Adams and Peter G. Fairweather
IBM Thomas J. Watson Research Center
Yorktown Heights, NY 10598
{badams, peterf}@watson.ibm.com

I. ABSTRACT

Efforts to use technology to provide navigational aids for blind people divide themselves into two groups. The first involves the avoidance of obstacles or dangers in the immediate environment. The second type is navigation to a location, providing information about the user's current position and a route or at least a direction to a destination. Some of these use Global Positioning Satellites (GPS) to provide large area navigational support. Others base their operation on local, location-specific infrared transmitting signs. This paper proposes the development of an extremely inexpensive, highly accurate solution that operates well within the workplace, public settings, or large cities using radio frequency identification (RFID) tags to provide navigation data.

BACKGROUND

GPS Based Systems

The GPS system depends upon twenty-four global positioning satellites orbiting the earth that can transmit messages to GPS receivers. Receivers determine their position by taking the difference between the time stamp in the message and the local time in the receiver. The receiver must communicate with at least three satellites to obtain a two dimensional fix and four satellites for a three-dimensional fix. GPS does not work well in urban settings, particularly along sidewalks next to buildings that block and bounce the satellite signals. Moreover, it does not work at all inside the buildings where people spend most of their lives.

The picture at the left, an A-1 Electronics prototype, is an example of current GPS system packaging. As the effort to reduce the size of the unit proceeds, a cell phone containing a GPS receiver will probably evolve. It could be used to connect to a central fixed site where a server will provide the Geographic Information System (GIS) database, speech recognition, text to speech, and differential GPS position information.

Advantages of GPS Navigation Systems

- Data is available to any device that can receive the signal.
- Rich geographic information system databases have been developed

Disadvantages of GPS Navigation Systems

- GPS does not work indoors nor outside if surrounded by tall buildings
- Signal error too high for walking with starts, stops, and turns
- Commercially available geographic information systems are not rapidly updated with information needed by pedestrians.

An Alternative: Infrared Receiver-based Systems

So-called "talking sign" systems transmit data via infrared from a fixed position to receivers that can be tuned to receive navigation information. While the infrared receiver can provide users with implicit orienting information, by the same token, they can only receive navigational information if they have already aimed the receiver at the sign. Crandall (1) describes and critiques the use of "talking signs" on streets and crosswalks surrounding a subway station in San Francisco.

Advantages of Infrared Navigation Systems

- Operate well both indoors and out, subject to line-of-sight constraints
- Signal reception provides the user with orienting information.
- Information carried by signals can be updated to reflect environmental changes.

Disadvantages of Infrared Navigation Systems

- Signs require a power source
- Improper orientation or aim can miss signals entirely
- Navigation is limited to the signs that can be seen.

According to Crandall (1), the San Francisco experiment has been the only infrared-based implementation for navigational use by the blind in the context of a public service.

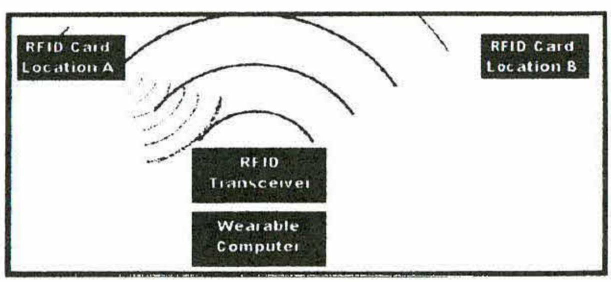
A RADIO FREQUENCY IDENTIFICATION-BASED SYSTEM FOR NAVIGATION

Radio Frequency Identification (RFID) systems normally use mobile tags and fixed transceivers, such as are found in automatic automobile toll payment devices. We invert this normal order of things, having the blind user carry a transceiver through fields of stationary tags.

RFID tags do not require a conventional power source as they transmit data in response to a signal sent from a transceiver. This keeps their costs low, around one dollar each, and widespread commercial applications continue to reduce even this cost. Low power limits the transceiver range to nine feet, so navigation system could be implemented by populating an area with tags along corridors, offices, and waypoints within or among buildings. This approach will provide businesses and government agencies with a low-cost avenue to access by persons with visual disabilities. Positioning tags numbering, at most, in the hundreds can provide navigational independence. The more expensive transceivers could be supplied only to those needing them while at the site.

Because the tags are programmable, they could contain not only location coordinates, but other limited information to support navigation. However, it is most likely that the tags would be used to supply a portable computer with an index into a database of richer, easily updated information that could include paths to emergency exits, telephone numbers, changes to the physical environment, or personal navigation routes.

The figure to the right illustrates components of a RFID navigation system. Tag A has been excited by the transceiver signal and is broadcasting its data to the transceiver. Tag B is out of range, but the computer might be able to interpret the fact that A can be sensed, but B cannot.



Advantages of RFID-based Navigation Systems

- Can be used where people spend the most time, indoors or out.
- The tags require little investment and maintenance and no power.
- Complexes of tags can provide rich data for navigation.

Disadvantages of RFID-based Navigation Systems

- Tags must be positioned and programmed.
- Single tags cannot orient users unless combined with other environmental information.

PROGRESS ON AN RFID-BASED NAVIGATION SYSTEM

We have been concerned with identifying how well RFID technology can be adapted to situations where the transceiver moves and the tags do not, handling uncertain signal reception, and inferring from observations of complexes of tags.

The components permit tags to be read by the transceiver when they appear within an arc of 45° with a radius of approximately nine feet. As a person walks with the transceiver through an area populated with tags, they appear or disappear to the transceiver as they move into or out of its reception arc. Movement and orientation of the transceiver affect tag visibility, as do variable tag signal strength and the reflection or absorption of signals nearby objects.

The appearance and disappearance of tag signals requires cautious interpretation. For example, transient tag signals detected by the transceiver may have been reflected from a metal door down the hall. Information about the consistency of a signal can be analyzed by itself as well as in terms of prior knowledge about current position and tag geography. For instance, if the navigation application has confidence that the user is at a particular point and a signal arrives from a tag that is known to be thirty feet away, the system will assign that signal low validity.

Similarly, the appearance and disappearance of legitimate tag signals enable the monitoring application to hypothesize about a user's movement along a path. To do so successfully, the application must be *geographically self-aware*, that is, it must maintain estimates of its possible positions validated against a prior model of tag geography. We are beginning to understand all the meta-geographic information with which that model must be augmented, such as common user goals (e.g, "the way to the cafeteria with the fewest stairs") or connectivity (e.g., "tag 27 and 28 can be sensed together from a position near tag 26, but 28 cannot be reached by walking").

The system needs to support a range of user interfaces depending on the users' capabilities and usage context. We are developing it to be useful for workers to support activities such as building maintenance or equipment inspection where geographical or spatial contexts are critical to the storage, retrieval, and interpretation of information. Non-visual interfaces (2) will be generated for those uses and users that require them. That work lies beyond the scope of this communication and will be explained in future ones.

REFERENCES

1. Crandall W., Remote Infrared Signage Evaluation for Transit Stations and Intersections, *Journal of Rehabilitation Research and Development*, Vol. 36, No. 4, October 1999

2. Asakawa, C. and Takashi, I. User Interface of Non-visual Web Access System, *Transactions of the Information Processing Society of Japan*, Vol. 40, No. 2. August 2000.

Hugh W. Adams
IBM Thomas J. Watson Research Center
Route 134
Yorktown Heights, NY 10598

LEARNING DISABILITY, THE INTERNET AND SELF: A ROLE FOR AT PROFESSIONALS?

Jane K Seale
Centre of Rehabilitation Engineering
Kings College London

ABSTRACT

This paper reports a survey of personal home pages written by people with Down's Syndrome and investigates the extent to which they use the pages to explore or express their identity. Opportunistic sampling of the pages listed by five Internet Service Providers revealed twenty personal home pages of adults with Down's Syndrome. Thematic analysis of the content, form and language of the pages revealed similarities and differences in the way the page owners expressed and perceived their self-identity. The results suggest that the personal home page has the potential to allow adults with Down's Syndrome to express multiple identities: identities that are the same and different to other people with Down's Syndrome.

BACKGROUND

When people with a learning disability reject the label "learning disability" it is argued that they are not denying that they have a particular learning disability, they are denying that they are less worthy than non-handicapped people [1]. Furthermore, people with learning disabilities may manage their identities and vary them according to local, contingent or interactional reasons. In other words, their identity may not be static [2].

The Internet is rapidly becoming accepted an element of computer culture that enables us to think about identity and produce "narratives of self"[3]. The style, structure and vocabulary of a page may reveal unintentional information about identity [4]. Personal home page authors can use different building blocks to produce very different kinds of home pages, which in turn may project different images or identities [5].

The Internet may enable people to manage their identity by allowing them to acknowledge their group identity and share their experiences with people in identical circumstances [6]. Conversely it can also offer an opportunity for disabled people not to have to acknowledge how different they are to the rest of the population [7]. Whether or not the Internet has the potential to allow people with disabilities to manage their identity is likely to depend on a number of factors including technical skills [8].

This paper will report the results of a survey of personal home pages written by people with Down's Syndrome and investigate the extent to which they used the pages to explore or express their identity.

RESEARCH QUESTION

Are people with Down's Syndrome using home pages as a tool to express or explore their identity.

METHODOLOGY

The sampling methodology used in this study involved opportunistic sampling. The pages of five Internet Service Providers were sampled. The keywords used to conduct the search were learning disabilities, mental handicap, mental retardation and Down's Syndrome. Of the pages sampled, a home page was included in the study if it met the following criteria:

- The page belonged to someone with Down's Syndrome. This was by explicit reference e.g. "I am Down's Syndrome" or through explicit referral from another page e.g. " this page belongs to my friend who has Down's Syndrome"
- The page belonged to someone aged thirteen or over and therefore could be defined as an adult (by explicit reference e.g. " I am 23" or indirect reference to adult activities such as college or work)

A simple thematic analysis of all text, links and images was conducted in order to try and categorise the home pages.

RESULTS

The opportunistic sampling technique revealed twenty personal home pages that met the inclusion criteria. A thematic analysis allowed the pages to be placed into three main categories:

1. This is me, I am a member of a family and the Down's Syndrome community
2. This is me, I a member of the Down's Syndrome community
3. This is me, I am a member of a family

The home pages in the first category contained Personal, Family and Down's Syndrome information. Six of the twenty home pages sampled fell into this category. They tended to be bigger than other pages in terms of how many images and links they contained. Five of the home pages were sole sites and not part of a bigger site (e.g. family) four of the six home pages included a personal email address.

The pages in the second category contained Personal and Down's Syndrome information. Five of the twenty home pages sampled fell into this category. Four of the five home pages had more external links than internal links and the nature of these external links was a mixture of personal interests and Down's Syndrome or disability information.

The pages in the third category contained Personal and Family Information. Eight home pages sampled fell into this category. All eight pages referred minimally to Down Syndrome. Five pages included photographs of family members. Seven of the home pages were hosted by a family web site and five home pages included the email address for a family member.

DISCUSSION

All twenty home page owners acknowledged membership of the Down's Syndrome group to some extent. Indeed if they had not, it would have been more difficult to find the pages in the sampling process. The page owners acknowledged their membership of the Down's Syndrome group by either providing direct statements and descriptions, photographs of themselves or links to Down's Syndrome information. In doing so, these people do not appear to be stigmatised by their label of Down's Syndrome or denying group membership. The different categories that the home pages fell into suggest that the home page owners are using their home pages to construct and present multiple selves.

However, care needs to be taken in interpreting whether the self being presented is how the person actually since eight of the twenty pages were written in the third person. In a lot of the cases it is clear that the "third person" was a family member. One possible reason why so many pages were written in third person is that the person with Down's Syndrome may have technical difficulties in authoring and publishing web pages themselves. They may therefore rely on their relatives to author and publish their pages on their behalf. This may explain why seven home pages were part of a family web site and five home pages included the email address for a family member rather than the person themselves.

It may therefore be useful to explore the extent to which AT professionals could provide technical assistance in the self-presentation process without overly influencing the nature of the "self" that is presented. Such assistance might involve advising on alternative access devices, providing web-authoring training or hosting home pages.

CONCLUSION

The results suggest that the personal home page has the potential to allow adults with Down's Syndrome to express multiple identities. Further work needs to be done however to investigate how adults with Down's Syndrome may be helped by AT professionals to take more control over the construction and presentation process. In providing such assistance AT Professionals may challenge their own sense of professional identity and purpose.

REFERENCES

1. Jahoda A et al (1986). Stigma and the self-concept of people with a mild mental handicap *Journal of Mental Deficiency Research*, 32 103-115
2. Rapley M et al (1998). Invisible to Themselves or Negotiating Identity? The Interactional Management of "Being Intellectually Disabled" *Disability & Society*, 13 5 807-827
3. Turkle S (1995). *Life on the Screen: Identity in the age of the Internet*. New York. Simon and Schuster.
4. Miller H (1995). *The Presentation of Self in Electronic Life: Goffman on the Internet* [WWW document] URL http://www.ntu.ac.uk/soc/psych/miller/goffman.htm [25/01/2000]
5.Chandler D (1998). *Personal Home Pages and the Construction of Identities on the Web* [WWW document] URL http://www.aber.ac.uk/~dgc/webident.html [25/01/2000]
6. Stephens A et al (1999). *Using Cyber Communities to Break Down Disability Walls* [WWW document] URL http://www.dinf.org/csun_99/session0196.html [22/02/2000]
7. Nelson JA (1994). *The Virtual Community: A Place For the No-Longer-Disabled* [WWW document] URL http://wwww.csun.edu/cod/94virt/vcnld_1.html [22/02/2000]
8. Sinks S and King (1998). *Adults With Disabilities: Perceived Barriers That Prevent Internet Access* [WWW document] URL http://www.dinf.org/csun_98/csun98_152.htm [22/02/2000]

Dr Jane K Seale, Centre of Rehabilitation Engineering, Department of Medical Physics and Engineering, Kings College, Denmark Hill, London, SE5 9RS.
020 7346 1653, jane.seale@kcl.ac.uk

EVALUATING THE RESPONSE OF CHILDREN WITH AUTISM TO A ROBOT

Iain Werry[1] & Kerstin Dautenhahn[2] & William Harwin[1]
1. Department of Cybernetics, University of Reading, UK
2. Department of Computer Science, University of Hertfordshire, UK

ABSTRACT:
Since 1998, the Aurora project has been investigating the use of a robotic platform as a tool for therapy use with children with autism. A key issue in this project is the evaluation of the interactions, which are not constricted and involve the child moving freely. Additionally, the response of the children is an important factor which must emerge from the robot trial sessions and the evaluation methodology, in order to guide further development work.

BACKGROUND:
The term autistic spectrum disorder (ASD) encompasses a range of disabilities and includes Pervasive Developmental Disorder – Not Otherwise Specified (PDD-NOS), Aspergers Syndrome and the diagnosis of autism. Depending on the designation, ASD affects between five and fifteen people in every ten thousand. The effects vary considerably between people, but common symptoms are hyper-sensitivity, learning and developmental problems and problems and avoidance of social interaction. The National Autistic Society state three main symptoms of autism, which they term the 'triad of impairments'. These are deficits in 1) social interaction, 2) social communication and 3) imagination and generalisation. While autism is a life-long disability, a number of therapy programs exist to help the person to cope with daily living. One of the most popular of these is the TEACCH program (Treatment and Education of Autistic and related Communication handicapped Children) [1] which centres on a philosophy of promoting pro-active behaviours by using unrestricted learning and positive reinforcement.

THE AURORA PROJECT:
The Aurora project (Autonomous Robotic Platform as a Remedial Tool for Children with Autism) [2, 3, 4] was started in 1998 to investigate the use of a robotic platform as an aid to the therapy of children with autism, specifically in the area of social interaction and communication. In line with the TEACCH program, where situations are presented to the child who is able to respond, it was thought that a robot would allow the child to interact in an unrestrained manner. Also, it was thought that a wheeled robotic platform would be most familiar and reassuring for the children, due to television and similarities with vehicles.

In the long term, the project aims to provide an additional method of therapy and learning for the teachers of autistic children. Short term goals of the project are to allow the children to experiment and interact with the robot and to gauge the response that this platform elicits from the children. One of the most challenging aspects of the project is to develop a methodology to evaluate the interactions between the children and the robot. Since the project does not aim to constrict the children in any way, both the robot and child are able to move around a room and to interact in any way that they are able. However, the unrestrained nature of the interaction makes evaluation of the effects difficult. In response to this, a micro behaviour analysis was developed, based on [5]. The next sections focus on methods and results of a comparative study involving the robot and a non-robotic toy.

METHOD:

Robot trials take place in a room – approximately 2 meters by 3 meters – at a school for autistic children and the robotic platform used is robust enough for the children to push it around and play naturally. Four male children interacted with the robot, with ages ranging from 7 to 11 years and all where mid to high functioning. The robotic platform is 30cm by 40 cm and weighs 6.5kg. Eight infrared sensors allow obstacle avoidance and a pyro sensor to detects the children, while it is programmed with a library of behaviours such as obstacle avoidance and speech output. Average trials last for ten minutes, for four minutes the child was able to interact either with the robot, or with a similar size and shape toy truck, for two minutes both the toy and the robot (which is now turned off) are present and the last four minutes involve the toy or robot (whichever was not used previously). However, this plan is occasionally altered, by a teacher from the school, who is on hand in case the children become distressed and in order to observe when the child should end the interaction.

Trials are evaluated using the video record and each second of the video is analysed for a number of behaviour parameters, to quantify the interaction. The behaviour parameters used fall into two categories – the first category consists of behaviours where the focus of the behaviour is important, eg the child handling the robot or an object in the environment, and the second category consists of behaviours where the focus is indeterminate or less important, for example the child may say a phrase where it is difficult to determine the target. The behaviour parameters are:

Category One: *eye gaze, eye contact, operate, handling, touch, approach, move away, attention.*

Category Two: *vocalisation, speech, verbal stereotype, repetition, blank*

Operate (to use the robot by its sensors), handling (moving the object through force) and touch are grouped into a single category to represent the total contact time. Eye gaze attempts to describe what the child is looking at, while eye contact is judged as situations when the child looks at the perceived 'head' of the object (the heat sensor for the robot, the front windscreen for the toy. The blank parameter record the instances when the child is doing nothing or very little and notes are made to catch any behaviours which may be relevant but which are not otherwise covered.

RESULTS:

		Touch	Handle	Operate	Seconds	Contact	Gaze
Child A	Robot	26.33%	42.70%	0.00%	452	69.03%	81.64%
	Toy	11.79%	45.12%	-	246	56.91%	40.24%
Child B	Robot	18.61%	5.28%	18.06%	360	41.95%	60.56%
	Toy	3.33%	57.22%	-	360	60.55%	71.67%
Child C	Robot	11.26%	72.64%	0.00%	435	83.90%	93.33%
	Toy	0.00%	2.99%	-	134	02.99%	14.18%
Child D	Robot	1.93%	0.23%	17.08%	363	19.24%	53.99%
	Toy	19.33%	37.67%	-	300	57.00%	60.33%

Figure 1: The percentage of time for behaviour parameters. Contact time is the total of touch, handle and operate.

These results in figure 1 show that the robot and the toy have similar contact times, with two children having a higher percentage for the robot and two with the toy. However, the trial times are generally longer for the robot, indicating that the children are happy interacting with it.

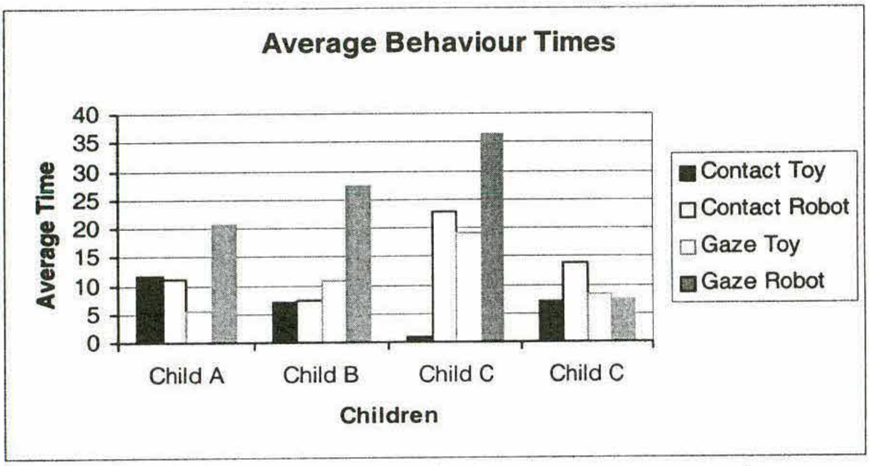


Figure 2: The average time of behaviours for toy and robot.

Figure two shows the average length of the behaviours, with most averages being higher for interaction with the robot. The results show that the children are not afraid of the robot and that they are able to interact and to play with it at ease. This quantitative characterisation of human-robot interaction patterns with individual children provides a foundation for further work in order to develop the robot as a therapy device.

REFERENCES:

[1] Watson, L. R. & Lord, C. & Schaffer, B. & Schopler, E. (1989). *Teaching Spontaneous Communication to Autistic and Developmentally Handicapped Children.* Irvington Publishers, Inc. New York.

[2] Werry, I. & Dautenhahn, K. (1999). Applying Mobile Robot Technology to the Rehabilitation of Autistic Children. *SIRS'99 Proceedings, 7th International Symposium on Intelligent Robotic Systems,* Coimbra, Portugal, July 1999.

[3] Dautenhahn, K. & Werry, I. (2000). Issues of Robot-Human Interaction Dynamics in the Rehabilitation of Children with Autism, *Proc. From Animals To Animats, The Sixth International Conference on the Simulation of Adaptive Behavior (SAB2000),* Paris, France (Sep, 2000).

[4] Aurora Web Page: http://www.aurora-project.com – last accessed: 07/12/2000

[5] Tardiff, C. & Plumet, M-H. & Beaudichon, J. & Waller, D. & Bouvard, M. & Leboyer, M. (1995). Micro-Analysis of Social Interactions Between Autistic Children and Normal Adults in Semi-Structured Play Situations. *International Journal of Behavioural Development, 18 (4),* 727 – 747.

ACKNOWLEDGEMENTS:

This project is supported by an EPSRC grant (GR/M62648). The robotic platform used is kindly donated by Applied AI Inc, and we are grateful for the continued support of the NAS and the staff and pupils of Radlett Lodge School, and Patricia Beevers.

Iain Werry: Cybernetic Intelligence Research Group, Department of Cybernetics, University of Reading, Whiteknights, PO Box 225, Reading, RG6 6AY
Email: I.P.Werry@reading.ac.uk

TECHNOLOGY AND MULTIPLE SCLEROSIS—THE INSIDER PERSPECTIVE

Dagmar Amtmann, Ph.C., Kurt L. Johnson, Ph.D; Kathryn Yorkston, Ph.D.

ABSTRACT

People with Multiple Sclerosis (MS) often benefit from using technology to maintain or increase their independence and participation in employment, education, and recreation. In addition to mobility and vision problems, many people with MS also experience cognitive changes, such as difficulties with memory and word finding that could also be accommodated with technology. In this paper we present a case study of the issues around assistive technology confronted by a graduate student who also works as a programmer. He is reluctant to disclose his limitations, prefers to discover his own compensatory technology and accommodation, and does not seek professional assistance.

BACKGROUND

Research teams at the University of Washington Department of Rehabilitation Medicine have conducted a series of qualitative research projects to study the "insider perspective on living with MS." In this paper we present a case study that in many ways highlights experiences and perspectives of a group of individuals we have interviewed. Our case study is of a 29-year-old male student who is enrolled in a graduate program in a scientific field and works as a computer programmer. Bill (this is not his real name) was diagnosed with MS five years earlier and reported that he has encountered significant barriers to his graduate study and programming related to cognitive changes (especially difficulties with memory and word finding), fatigue, unpredictability of symptoms, and significant changes in his vision.

Although over 95% of people with MS in various surveys have been employed at one time, at the time of the surveys (average time following MS diagnosis from 5 – 17 years), employment rates had dropped to approximately 25% (2), (3), (4), (5). Physical disability factors clearly play a key role in reducing access to employment, but environmental barriers and lack of accommodation in the workplace also serve as significant barriers to employment for people living with MS (8), (9), (11). Cognitive deficits have increasingly been found to be associated with higher rates of unemployment for people living with MS. At least half of the individuals living with MS will develop cognitive symptoms (6). Individuals with MS who have left employment are more likely to have cognitive deficits and are more likely to be isolated socially (6), (11). Assistive technology may be part of the compensatory strategies addressing all of these functional limitations to enhance participation in education, work, and community.

METHOD

Qualitative methodology is well suited for research in when we seek to understand the perspective of individuals living with health conditions. We interviewed 22 individuals from throughout the Pacific Northwest for a minimum of one hour. Interviews were audio-taped and transcribed and the transcription verified. Transcripts were then coded by consensus among the research team and entered into the qualitative research software package Ethnograph (12). Themes that illustrate unique experiences of individual informants and perspectives shared across informants were then developed by consensus. For this presentation, we have selected one of the interviews that provides a valuable insight into the barriers faced by an individual with MS. We have adapted the qualitative methodology to study this case intensively and present quotations from the informant as data.

RESULTS

Bill did not disclose his disability until it was impossible for him to hide the problems (especially the problems with his vision).

"I used to TA quite a bit, and I'd write stuff on the board and I couldn't see it. If someone asked me a question about 'what does that say?' I'd have to sort of trick them into pointing me to where on the board. This was all prior to actually coming out with the disease. I tried to keep it a secret as long as possible."

Once he decided to disclose his disability he used the disclosure itself as an accommodation.

"I basically come out up front and let people know that I have these impairments, and that I will probably run into some problems given some of that."

Bill seems to have discovered the features and strategies that allow him to function better on his own. It appears that he hadn't asked for any accommodations from the employer (such as working at home part time, a quiet room, or air-conditioning) even though heat, sensory overload, and light conditions make it difficult for him to perform at times. The main accommodation is that his work is flexible and he can take work home when necessary.

"I can perform at my own progression, at my own speed. If there is a deadline it's not like I have to perform in the next few minutes. I don't have to get that order on the table in five minutes. I can take it home and work on it through the night where it's cool and it's dark, after a pot of coffee. I don't have someone breathing down my neck for the most part. If I take work home, it's like a time stop. I can do it right so then the next time they see me it'll be done."

He learned about and uses the high contrast feature that helps him to see the computer screen better. This is a built-in feature of the Windows operating software that changes the display settings.

"I've changed all my computers at work, at school, and at home to high contrast black background with white lettering. It helps a lot."

Bill also uses word processing in many different ways to accommodate his memory problems, difficulties with writing and organization of writing, editing, etc.

"I like the computer because you can cut and paste a lot. When you write down stuff on a piece of paper you have to remember that over here on this piece of paper I wrote down this important fact. I can't keep that in my memory. It's just too much."

"Right now I'm writing a program that involves filtering wave forms, and I have, of course, trouble remembering certain filter design equations. So I have to look those up and I'll write that on the computer, I'll just open up a blank text file and write down what I need to know. And then, with that text file and my program next to each other, I can go through my program and sort of insert that text in there."

Many difficulties Bill experiences (particularly his inability to see his handwritten notes when he presents, or the need for reading large amounts of written material for his graduate studies) could be accommodated using technology, but due to his reluctance to ask for accommodations and to see a technology specialist these issues have not been addressed.

DISCUSSION

Bill's case study illustrates issues that have frequently surfaced in our interviews with people with MS. Many interviewees have been reluctant to ask for accommodations and when they requested accommodation, they have wanted to be in charge of the process. Accommodations which are the least intrusive are preferred as Bill has chosen adaptations of off the shelf technology. Requesting accommodations for cognitive impairments has been viewed as unacceptable and seen as an admission of incompetence for most people with MS we interviewed and yet these functional limitations can be readily addressed through applications of assistive technology. Rehabilitation professionals working with people with MS may be able to serve the technology needs of their clients better by offering a range of options and allowing the user to set the pace and chose the kind of accommodations most acceptable to them. Creative uses of main stream technologies (display and magnification features, using word processors as memory aids) and showing them how to use email, paging technology, and word processors to accommodate their cognitive changes may increase the acceptance rate of technology interventions.

REFERENCES

1. Beatty, W., C. Blanco, et al. (1995). Demographic, clinical, and cognitive characteristics of multiple sclerosis patients who continue to work. *Journal of Neurologic Rehab* 9(3): 167-173.
2. Edgley, K., M. Sullivan, et al. (1991). A survey of multiple sclerosis. Part 2: Determinants of employment status. *Canadian Journal of Rehabilitation* 4(3): 127-132.
3. Jackson, M., C. Quaal, et al. (1991). Effects of multiple sclerosis on occupational and career patterns. *Axone* 13(1): 16-17;20-22.
4. Kornblith, A., N. LaRocca, et al. (1986). Employment in individuals with multiple sclerosis. *International Journal of Rehabilitation Research* 9(2): 155-165.
5. LaRocca, N., R. Kalb, et al. (1985). Factors associated with unemployment of patients with multiple sclerosis. *Journal of Chronic Diseases* 38(2): 203-210.
6. Murray, T. (1995). The psychosocial aspects of multiple sclerosis. *Neurologic Clinics* 13(1): 197-223.
7. Rao, S., G. Leo, et al. (1991). Cognitive dysfunction in multiple sclerosis: II. Impact on employment and social functioning. *Neurology* 41(5): 692-696.
8. Roessler, R. (1996). The role of assessment in enhancing the vocational success of people with multiple sclerosis. *Work* 6: 191-201.
9. Rumrill, P. (1996). Employment and multiple sclerosis: Policy, programming, and research recommendations. *Work* 6: 206-209.
10. Rumrill, P. (1996). *Project Alliance Final Performance Report*. New York, National Multiple Sclerosis Society.
11. Rumrill, P., J. Steffen, et al. (1996). Job placement interventions for people with multiple sclerosis. *Work* 6: 167-175.
12. Seidel, J. (1998). *The Ethnograph* (Version 5.0). Thousand Oaks, CA: Sage Publications Software.

ACKNOWLEDGMENTS

This research was conducted by the National Rehabilitation Research and Training Center on Multiple Sclerosis (MS) funded to the University of Washington Department of Rehabilitation Medicine in 1999 by the National Institute on Disability and Rehabilitation Research.

Dagmar Amtmann, Ph.C.
University of Washington Center for Technology and Disability Studies
Box 357920
Seattle, WA 98195-7920
(206) 685-4181, (206) 543-4779 (fax), dagmara@u.washington.edu

THE STAKEHOLDERS FORUM ON HEARING ENHANCEMENT

S. Bauer, Ph.D., Co-Director, RERC on Technology Transfer
V. Stone, Ph.D., Director Research and Evaluation, RERC on Technology Transfer

ABSTRACT

The Demand Pull Project on Hearing Enhancement facilitates the transfer of new and innovative technology into the hearing products marketplace. The Stakeholders Forum is a critical step in this Project at which important unmet customer needs and feasible technology solutions to address these needs are identified. Forum participants include manufacturers, researchers, clinicians, end-users and other stakeholders whose knowledge and perspectives are critical to the transfer process. The Forum is shown to be an effective means by which to identify unmet market needs and pre-competitive technology solutions desired by manufacturers.

BACKGROUND

The Rehabilitation Engineering Research Center on Technology Transfer (T^2RERC), partnered with the Rehabilitation Engineering Research Center on Hearing Enhancement to conduct the *Demand-Pull Project on Hearing Enhancement* in 1999 - 2000. The goal of each Demand Pull Project is to facilitate the introduction of products incorporating new and innovative technology into the marketplace.(1)

This Project focused on four technology areas related to hearing enhancement: Earmolds, FM, Inductive and Infrared assistive listening systems (ALS) and Microphone technologies. The two RERC's hosted a Stakeholder Forum on Hearing Enhancement in New York City in June, 2000. Critical goals of the Forum included: 1) identifying important and unmet customer needs, 2) establishing that meeting these needs represent a significant business opportunity, 3) establishing requirements (function, performance, cost, etc.) for technology solutions to address these needs and 4) establishing that manufacturers are not likely to develop or obtain these technology solutions (by means other than technology transfer). Preliminary work by the T^2RERC included developing an Industry Profile and preparing White Papers for each technology area as a basis for discussion at the Forum. A consumer panel (8 technology users) and a series of expert interviews (10 researchers and 10 manufacturers) gave input for the White papers, which summarized customer needs, business opportunities, and an overview of each technology. They were reviewed for accuracy and completeness by a PhD audiologist under sub-contract to the T^2RERC and by staff at the RERC on Hearing Enhancement.

METHOD

Technology transfer is the movement of a technology from Technology Developers (laboratory researchers) to Product Producers (manufacturers). Technology-transfer efforts will generally be unsuccessful unless: 1) Product Customers (end-users, clinicians) have significant, unmet needs; 2) Technology Developers identify feasible technological solutions to address these needs and 3) Product Producers are unable to develop or obtain this technology without assistance (e.g. high cost, lack R&D capabilities etc.). Resource Providers assist dissemination efforts, help to locate technology and provide funding.(2) It is therefore critical that Forum participants include appropriate representation from each stakeholder group.

The two RERC's worked together to identify highly appropriate Technology Developers and Product Producers for recruitment. End-users were recruited from advocacy groups (Self Help for Hard of Hearing, League for the Hard of Hearing) because of their knowledge of hearing technology and related issues. To help recruitment efforts, food and hotel costs were covered for all participants with transportation provided in selected cases.

Prior to the Forum, all participants received the white papers and a letter explaining the Forum process, their role in this process, expected outcomes and benefits to participants. The Forum conducted 8 focus groups (4 each day) to discuss the four technology areas. The number in each group varying between 13 and 20. Each attendee participated in two different technology groups. End-users were assigned to groups corresponding to their familiarity with and use of hearing technology. Other stakeholders indicated their groups of interest beforehand.

Each group session ran approx. 2½ hours, typically with two breaks. Each session's team consisted of: a moderator, a scribe (to record and summarize information), a technical person (to clarify points for the moderator) and a recorder (to summarize key points, assist with item ranking). To ensure full and equal access to the discussion, each room had a portable infrared assistive listening system (from Audex) with portable receivers and real-time captioning (also used to capture the full discussion). Pre-prepared scripts controlled the use of time and guided the protocols for each technology area. Moderators used a set of probing questions to ensure full coverage of customer needs, state of current technology, desired refinements and innovations, barriers to developing or obtaining technology and technology sources.

Participants evaluated each discussion session by answering survey questions on a 5 point scale (1=very poor to 5=very good). For each technology area, data for the two days were combined for analysis. To evaluate the overall Forum, participants were asked to complete a summative survey.

RESULTS

There were about 65 Forum participants (small variation is due to a few persons attending on single days) that included: Product Producers (8 hearing aid; 2 earmold; 2 infrared ALS; 2 inductive ALS; 1 FM ALS; and 4 electronic component manufacturers), Technology Producers (7 RERC-Hearing Enhancement, 5 advanced technology manufacturers; 5 other researchers), Product Consumers (13 end-users; 4 clinicians; 2 ALS installers) and Resource Providers (12). The 14 end-users (8 male, 6 female) ranged in age from 16 to 84 years. They reported having mild/moderate (5) or severe (8) hearing loss with 6 end-users claiming significant feedback problems. End-user technology use included: hand-held or body-worn microphones (6); hearing aids with T-coils (13); analog hearing aids (13); digital hearing aids (7); FM-ALS (9); and IR-ALS (7). All but one end-user was a member of an advocacy group (see Table 1).

	Earmolds		**FM**		**IL&IR**		**Microphones**		**Total**	
Day	One	Two	One	Two	One	Two	One	Two	One	Two
Product Producers	3	5	5	3	6	2	4	9	18	19
Technology Developers	2	2	6	5	6	4	3	4	17	15
Product Customers	3	3	4	7	5	3	6	6	18	19
Resource Providers	4	3	3	4	2	3	3	1	12	11
Totals	12	13	18	19	19	12	16	20	65	64

Table 1: Participant Distribution Across Groups

Mean scores (out of 5.0) for the group sessions (Ear molds n=25; FM systems n=27; IR & IL systems n=25; Microphones n=28) include: "content was relevant" (4.0, 4.4, 4.2, 4.2); "addressed most important aspects of topic" (4.6, 4.1, 4.5, 3.9); "went into sufficient depth" (4.7, 4.0, 4.1, 4.0); "purpose of group was clear" (4.5, 4.2, 4.3, 4.1); and "discussion achieved its purpose" (4.4, 4.0, 4.1, 3.9). Positive responses from the summative survey (Technology Developers n=11; Product Producers n=9) include: "groups helped you identify new business opportunities" (TD 4, PP 6); "exposed you to new or innovative technology" (TD 10, PP 6); "helped identify new direction for product development" (TD 8, PP 9); "helped you identify needs for new technology" (TD 7, PP 5) and "gave you an opportunity to network with manufacturers, researchers, clinicians and others" (TD 11, PP 9). Participants also agreed that: "White Papers provided an appropriate background for the Forum" with mean scores of 4.5 for End-users; 4.7 for Technology Developers; and 4.3 for Product Producers.

A complete listing and detailed analysis of the Forum data is not possible in a short paper but is available on line at http://cosmos.buffalo.edu/t2rerc/demand.html. A brief summary of high priority technology needs follows:

Earmolds: computerized ear canal measurement (e.g. 3D laser scanning); automated earmold production (e.g. one-day turnaround, CAD/CAM); advanced materials (e.g. reverse thermal gels) and composite earmolds (e.g. multi-material, inflatable pneumatic, etc.). **Inductive ALS:** pre-fabricated modular loops (or mats); intelligent loop amplifiers (or driver/adaptors for general loop amplifiers); and 3D telecoils (or equivalent) for hearing aids and body-worn receivers. **Infrared ALS:** system for natural, small group communication; universal (FM/IR) portable receiver; narrow-spectrum diodes for IR receivers; low power, high efficiency diodes for IR transmitters; improved IR transmitter modulator circuit; and smart transmitter diodes (e.g. adjust transmission power in response to ambient IR level). **FM ALS:** universal personnel communication system consisting of a transmitter, repeater and receiver, would work with all hearing aids, headphones, and consumer products such as cell phones. **Beam-Forming Microphone Technology:** body-worn microphones; tabletop microphones (e.g. for ALS replacing microphones and wires); binaural hearing aids (with wireless bi-directional communication link); and improved directional hearing aids.

Afterward, forum data was integrated with prior work to generate Problem Statements. These represent specific technological refinements and innovations desired by manufacturers with consensus support from all other stakeholder groups. The statements were disseminated through proceedings, websites, newsletters, journal articles and email and phone contacts inviting solutions from Technology Developers. As technology proposals are received, the T^2RERC will screen and broker promising proposals to manufacturers in the hearing industry.

DISCUSSION

To determine whether the Forum is an effective means by which to identify pre-competitive technology needs, a number of simple questions can be asked. Were all stakeholder groups represented? Were appropriate participants recruited? These questions were addressed by the careful recruitment efforts outlined above. Were participants properly prepared? Was the Forum objective clear? Were the technology groups well run? Do participants believe that the Forum was effective? Survey results suggest that these issues have also been addressed. Overall, these preliminary results suggest that the Forum was an effective means by which to identify pre-competitive technology needs. Participants also cited many collateral benefits such as networking opportunities, exposure to new technology and ideas for new product development.

REFERENCES

1. Bauer, S, & Lane, J. (2000). *The Demand Pull Project on Wheeled Mobility.* Paper presented at the RESNA 2000 Annual Conference - Technology for the New Millennium, Orlando, Florida.
2. Lane, J. (1999). Understanding Technology Transfer. *Assistive Technology, 11*(1), 5-19.

Acknowledgement - This is a publication of the RERC on Technology Transfer, funded by the National Institute on Disability and Rehabilitation Research of the Department of Education under grant number H133E980024. Opinions contained in this publication are those of the grantee and do not necessarily reflect those of the Department of Education.

Contact: Dr. Stephen Bauer, 616 Kimball Tower, Center for Assistive Technology, University at Buffalo, Buffalo, NY 14214-3079; Phone: 716-829-3141; Email: smbauer@cosmos.buffalo.edu.

USING A PALMTOP PDA FOR REMINDING IN PROSPECTIVE MEMORY DEFICIT

Stacie L. Tackett & David A. Rice
Biomedical Engineering, Tulane University
Janet C. Rice, Biostatistics, Tulane University
Grant J. Butterbaugh, Psychology, Louisiana State University Medical Center

ABSTRACT Prospective memory failure often accounts for poor medication adherence. This study explores the possibility of using personal digital assistants (PDAs) to remind people with prospective memory failure. Preliminary testing in normals shows that PDA use reduces the number of timing errors while performing a set of scheduled tasks ($p < 0.001$). These results suggest that off-the-shelf palmtop technology can serve as effective aids for reminding. It also provides a means to monitor performance.

BACKGROUND Medication nonadherence in the elderly and others can lead to morbidity and institutionalization. Reminding technology can be employed to increase the independence of the elderly and to reduce their required level of care. Previous studies (1) have used calendars, pill wheels, pagers(1), telephone systems(2), voicemail(3), laptop computers, and portable electronic devices in attempts to increase the medication adherence of those suffering from prospective memory failure. Most of these devices lack a logging function to record patient actions. Flannery et al.(4) used a reminding program for a laptop computer that logged the response of a subject to specific questions relating to medication adherence and allowed researchers and physicians to further analyze the data. The current study incorporates a similar log.

RESEARCH QUESTIONS This study attempted to determine if palmtop technology can serve as a reminding system for those with prospective memory failure. This study also examined the ability of the subjects to use an Internet webpage for giving feedback.

METHODS Two Palm V handheld devices and attachable modems formed the hardware of the reminding system. Since the supplied software provides no timestamped logs, we added On-Time-Rx (AmeliaPlex, Inc), a medication reminder program. We also added Palmscape, an Internet browser, to access the website designed for this project.

Four subjects tested the system during a two-week period. For a control week each subject compiled a paper task list with planned and completed action times. During each day the subject wrote the actual completion time on the list. The weeklong experimental period required subjects to program tasks with scheduled completion times into the On-Time-Rx reminding program. The PDA sounded an alarm at the assigned time, and the subjects reported their actions on the touch screen. Two subjects performed the control period first while the other two performed the experimental period first. There were two types of tasks. The first were tasks chosen by the subjects that they needed to complete, and the second consisted of tasks assigned by the researchers requiring the subjects to be attentive.

RESULTS The subjects provided a total of 626 trials. Each subject responded for seven days while using a PDA and seven days while not using a PDA.

The distribution of the deviations of response times from scheduled response time are shown below. Excluded are tasks for which there was no response or for which the time was not recorded.

error (min)	no PDA	%	PDA	%	total	%
-180 - -61	14	4.3	0	0	14	2.4
-60 - -31	11	3.4	0	0	11	1.9
-30 - -1	45	14.0	5	1.9	50	8.6
0	106	32.9	155	59.2	261	44.7
1 - 30	93	28.9	91	34.7	184	31.5
31 - 60	30	9.3	11	4.2	41	7.0
61 - 180	23	7.1	0	0	23	3.9
Total	322	100.0	262	100.0	584	100.0

We define a success as a deviation of zero. Missed tasks were counted as failures, but tasks for which the time deviation was unknown were deleted from analysis. There is a strong association between rate of success and PDA use (Chi sq = 41.45, df = 1, $p < 0.001$).

PDA	Failure	Success	Total
No	227 (68.2%)	106 (31.8%)	333 (100.0%)
Yes	112 (41.9%)	155 (58.1%)	267 (100.0%)
Total	339 (56.5%)	261 (43.5%)	600 (100.0%)

The impact of the PDA was different for the two subjects who used the PDA the first week as compared to the two who used it the second week. For those who used the PDA during the first week the success rates are similar for both weeks. For those who used the PDA second the success rate is better when using the PDA than when not. Order of PDA significantly modifies the impact of using a PDA (Chi sq = 39.12, $p < 0.001$).

	Used PDA First			Used PDA Second		
PDA	Fail	Succeed	Total	Fail	Succeed	Total
No	90	84	174	137	22	159
	51.7%	48.3%	100.0%	86.2%	13.8%	100.0%
Yes	78	89	167	34	66	100
	46.7%	53.3%	100.0%	34.0%	66.0%	100.0%
Total	168	173	341	171	88	259
	49.3%	50.7%	100.0%	66.0%	34.0%	100.0%
	Chi sq = 0.86, p = 0.35			Chi sq = 74.47, p < 0.001		

We divided the deviations into three categories. The first is -180 through -11 minutes which indicates doing the task early. The second is -10 through 10 minutes which indicates doing the task on time, and the third is greater than ten minutes which indicates doing the task late. There is an association between PDA use and type of deviation (Chi sq = 76.99, df = 2, $p < 0.001$). Using the PDA reduced the number of early completions.

	Deviation in Minutes			
PDA	(< -10)	(-10 - 10)	(> 10)	Total
No	48 (14.9%)	162 (50.3%)	112 (34.8%)	322 (100%)
Yes	3 (1.1%)	219 (83.6%)	40 (15.3%)	262 (100%)
Total	51 (8.7%)	381 (65.2%)	152 (26.0%)	584 (100%)

There were two types of tasks. One set was defined by each subject and consisted of things that s/he needed to get done. The other set was busy work that required the subject to be attentive. The type of task does not affect the success rate (Chi sq = 2.14, $p = 0.16$) nor the impact of PDA use on success rate (Chi sq = 0.01, $p=0.98$).

Subjects reported only slight problems through the interactive web form. We received daily reports during the experimental period. The subjects successfully used radio buttons, check boxes, dropdown menus, and text entry fields. Subjects reported the need for a confirmatory message following form submission and learning difficulties using Palmscape.

DISCUSSION We believe that the main reason that PDA use produced better results was the alarm that provided a stimulus as well as specific instructions for each task. The small improvement and the good overall error rate of the PDA first subjects suggests that the PDA may provide a habilitation or training function that persists at least a week. The logging function of the reminding program effectively gathered the data at no cost to the user. Such logs permit monitoring medication adherence as well as self-review by a patient. The Internet reporting showed that it can be used to report to a remote monitor or caregiver, but our subjects were familiar with the web. Limitations to the use of this technology include the need to train naive users and potential difficulty to use for people with limited dexterity or visual acuity. These results suggest that further testing is merited in target populations with prospective memory deficit.

REFERENCES 1. Wilson BA, Evans JJ, Emslie H, Malinek V, (1997) Evaluation of NeuroPage: a new memory aid. J. Neurology, Neurosurgery, and Psychiatry, 63,113-115.
2. Friedman RH, Kazis LE, Jette A, Smith MB, Stollerman J, Torgerson J, Carey K. (1996) A telecommunications system for monitoring and counseling patients with hypertension. Impact on medication adherence and blood pressure control. American J. Hypertension, 9, 285-92.
3. Leirer VO, Morrow DG, Tanke ED, Pariante GM (1991) Elders' nonadherence: it's assessment and medication reminding by voice mail. The Gerontologist, 4, 514-20.
4. Flannery MA, Butterbaugh GJ, Rice DA, & Rice JC (1997). Reminding technology for a prospective memory disability: a case study. Pediatric Rehabilitation, 1,239-244.

ACKNOWLEDGMENT The authors thank the Joe W. and Dorothy Dorsett Brown Foundation for support of this project.
Corresponding Author: David A. Rice, Department of Biomedical Engineering, Tulane University, 500 Lindy Boggs Center, New Orleans, LA 70118.

AN INTERACTIVE MAZE GAME DEVICE FOR PRE-HANDWRITING EXERCISES

Jeremy M. Bowman
Dept. of Biomedical Engineering
University of North Carolina at Chapel Hill
Chapel Hill, NC 27514

ABSTRACT

Handwriting is an important skill. However, many children have difficulties with handwriting. They need a device that allowed them to practice fine motor control and hand-eye coordination before they learn to write. The device presented in this paper is a portable, easy to use system that uses maze solving as a pre-handwriting task. The device was tested with several special needs children at an elementary school. The children were eager to work the maze, and responded well to the feedback.

BACKGROUND:

For many years, humans have relied on writing as a way to record events and ideas, and as a way to communicate with others. As a result, having good handwriting skills is important.

Many children have difficulty learning to write properly, as a result of a physical or cognitive disability, poor hand-eye coordination, or poor motor control. Occupational or physical therapy for these children at an early age helps integrate the cognitive and physical skills needed for good handwriting (1).

A therapist in the Durham County school system (North Carolina) was looking for a pre writing task to help her special needs kids develop fine motor control en route to developing writing skills.

STATEMENT OF PROBLEM:

Before a child learns proper letter formation, they work on pre-handwriting tasks to develop motor control and hand-eye coordination. A commonly used pre-writing task is solving mazes because it encourages children to make small, controlled movements in order to stay within the maze pathway (2). Pre-writing tasks typically require feedback and prompts from a therapist, teacher, or parent. Alternatively, an assistive device could supply these prompts, which would increase the independence of the student. A pre-handwriting tool was needed that was simple to use for both teacher and student, portable, and able to keep the child's attention through visual and/or audio stimulation.

The teacher or therapist designs a maze on a PC using the accompanying software. They download it to the microcontroller, print a hardcopy of the maze, and attach it to the graphics tablet. The device then tracks the movement of the student through the maze. As long as the student stays within the pathway of the maze, they receive positive feedback. If they stray from the path, the device provides negative feedback. The maze game allows the student to work on fine motor control while having fun!

DEVICE DESIGN

As shown in figure 1, the prototype device consists of three main parts: a pair of microcontrollers that act as the "brains", a graphics tablet that tracks the movement of the user, and circuitry. The therapist wanted a device that was portable so that it could be used in a variety of settings. While a PC is required to design a maze and download it to the device, afterwards it can be used as a standalone device.

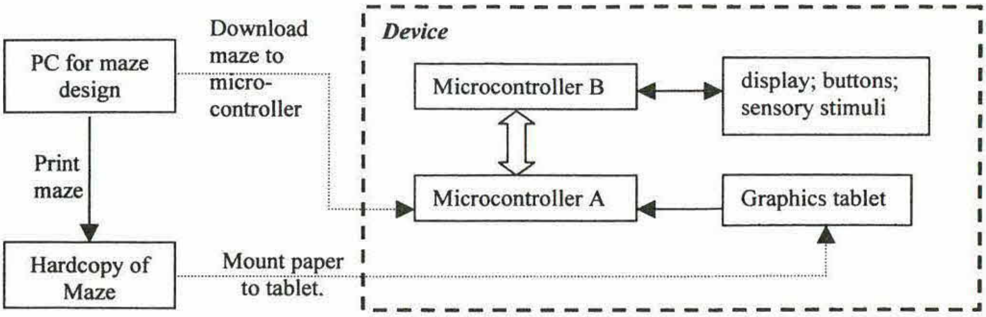


Figure 1. Block Diagram of System Control

The design of the device is divided into three parts: the programming of the maze design program on a PC; the programming for the Basic X microcontroller (Netmedia, Tucson, AZ, www.basicx.com) used to acquire data from the tablet; and the circuitry.

The goal for the programming of the microcontroller is to acquire maze design data from the PC, and to acquire and process the pen location data from the tablet.

The circuitry of the device incorporates all the components that provide the user with audio and/or visual stimulation: a buzzer, a music integrated circuit (IC), a voice recorder/playback IC with microphone circuitry, and LED's in the shape of a smiley face. In addition, the Wacom graphics tablet (Vancouver, WA, www.wacom.com) connects to the device via a serial port, as shown in figure 1.

DEVELOPMENT OF DESIGN

The maze game is written as a separate piece of software that is used independent of the device. The program is written in Microsoft Visual Basic (Redmond, Washington). The teacher, therapist or supervising adult is presented with a blank 16 x 16 grid in which the user can click the mouse button once and then draw the desired shape of maze they want (Figure 2). The user can then save the maze for future use or modification. They can also print a hard copy of the maze to be used on the graphics tablet. And finally, they can download the maze to the microcontroller via the serial port of the computer. The printed hard copy and the download function are intended to be used together, as the microcontroller has to know the shape of the maze that the student working through. The maze program takes the maze grid and represents each square as a 1 or 0 based on the color of the square. For example, the first 8 squares in the first column of fig. 2 are represented as 11001110. The program then sends this binary data to the microcontroller where they are stored in the electronically erasable programmable read only memory (EEPROM). As the user solves the maze, the tablet sends the (x, y) data corresponding to pen location. The microcontroller uses calibration data to determine the relative location of the pen within the maze. The microcontroller then uses downloaded information on the shape of the maze to determine if the student is within the maze pathway.

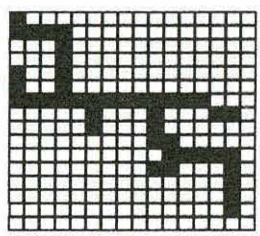


Figure 2. Representation of maze

Because of the complexity, two microcontrollers are used in the device (Figure 1). The microcontroller "A" is used to handle communication and data gathering from the tablet. This microcontroller guides the user through system calibration, so that the device can tell the orientation of the maze on the tablet. It also keeps track of the shape of the maze, and whether or not the user is staying in the pathways. The microcontroller "B" handles the menu driven user interface and the control of the stimuli. The user is able to choose which stimuli will be used for positive feedback and negative feedback. The two microcontrollers are in constant communication with each other, so the appropriate stimuli can be activated based on the performance of the student.

The microcontroller triggers activation of the sensory stimulation circuits, and interfaces with the button inputs and an alphanumeric LCD display. The LCD display and four buttons are used for a menu driven user input. They are mounted to the lid of a project box that housed the circuitry of the device.

EVALUATION

The maze game was taken to Hillandale Elementary School where three different special needs children tried the maze under the supervision of the project's consulting therapist, Edie Kahn. Ms. Kahn designed a maze for the students using the software, and loaded it onto the microcontroller. The feedback was set so that the buzzer was used as negative reinforcement. The students seemed to enjoy using the maze. The versatility of the device was shown when it became apparent that one of the students actually liked to hear the buzzer go off. Then, the device was easily reconfigured to use the buzzer as positive feedback, which was appropriate for that student.

DISCUSSION

With such importance placed on writing and writing skills, it is useful to have a device that allows students to independently enhance their fine motor skills. The device discussed in this paper is an easy to use, portable device that helps students practice an important pre-writing task.

In the future, the design of this device could be changed to handle multiple maze downloads, incorporate handwriting analysis, and increase the variety of stimuli.

ACKNOWLEDGMENTS

I would like to take this opportunity to thank Dr. Richard Goldberg for his constant encouragement and support during the design. I would also like to thank Edie Kahn for her input into the design and for letting us play with her special needs children. I would like to thank Wacom for their donation of the writing tablet, and NSF grant BES 9981867 for financial support of this project.

REFERENCES

1. Bruni, Maryanne. Fine Motor Skills in Children with Downs Syndrome: A Guide for Parents and Teachers. Woodbine House, New York; 1998.

2. Kahn, Edith. Personal communication, June – August 2000.

Jeremy M. Bowman
Dept. of Applied Science, Biomedical Engineering track
University of North Carolina at Chapel Hill
Chapel Hill, NC 27599

DESIGN OF ASSISTIVE TRAINING STAIRS

Mark Kurfman, Karthik Sampath, Aditya Velivelli,
Janet Callahan, Balaji Chandrasekaran,
Basic Engineering Department
University of Missouri-Rolla
Rolla, MO 65409

ABSTRACT

Students who are physically or emotionally challenged often face difficult challenges when learning tasks such as washing dishes, opening doors, or even climbing stairs. It is the later task that this paper addresses. Stairs can be a very difficult challenge for disabled persons. Often stairs have different heights and sometimes there are no handrails. Disabled persons must face each of these different challenges. This paper outlines the design and construction of a training stair device that will meet the needs of physically challenged elementary school students.

BACKGROUND

The Wyman Elementary School Developmental Pre-School in Rolla, Missouri is designed to provide students that have either physical or mental challenges with the extra support and education needed for them to succeed. The students, ages 4-5 years, have disabilities ranging from minor behavioral problems to severe physical challenges. These children not only face the challenge of getting an education, but they must also learn how to live in the real world. One major challenge for these students is learning how to climb stairs. Climbing stairs is a simple task for many people, but a very difficult task for these students.

The need for training stairs for physically challenged students is not a new problem. There are currently many products available for purchase that will satisfy the need of providing a device for students to learn to climb stairs on. What makes the training stairs that are currently available not applicable to Wyman Elementary School is some of the attributes that their training stairs must possess. For example,

- The Developmental Pre-School is currently located in a modular classroom, so the training stair device must require very little space.
- Being located in a modular classroom means that there is very little useable space, so the device must also be portable.
- The stairs must be quickly setup and taken down because the time students spend with the physical therapist is limited to only a few hours a week.
- The stairs must allow for different heights so the students can learn on a smaller height and then progress to larger more difficult heights.

With no current training stair possessing all of these attributes, the need for a new version of training stair is created.

STATEMENT OF PROBLEM

The objective of this project is to design and construct a set of training stairs for the Wyman Elementary School Developmental Pre-School. After performing a market analysis and finding no products that currently satisfy all of the customers needs, it was determined that this is not only a viable design project but also one that will benefit mankind.

PRODUCT DEVELOPMENT

The development of the training stairs consisted of four distinct phases (1). The first phase of which is *Clarifying The Task At Hand.* In order to clarify the task, the customers of this product were interviewed. The customers consist of a teacher, a physical therapist, an occupational therapist, and the students of Wyman Elementary Developmental Pre-School. Since the students could not be interviewed, they were observed while using their current training stair device. The students currently use a rocking boat (a semi-circular shaped toy with a seat on each end) for the children to practice climbing stairs. This device has only two steps, and no handrails. Some of the children have depth perception problems, and the fact that they can see the floor through the steps causes problems. The steps are not standard sized steps, so the children are not being exposed to everyday situations that they will need to cope with. Next, the therapists and teacher were interviewed in order to understand the problem and determine the customers needs. The customer needs were weighted on a scale from one to five with one being least important and five being most important. The top five customer needs are listed below in Table 1.

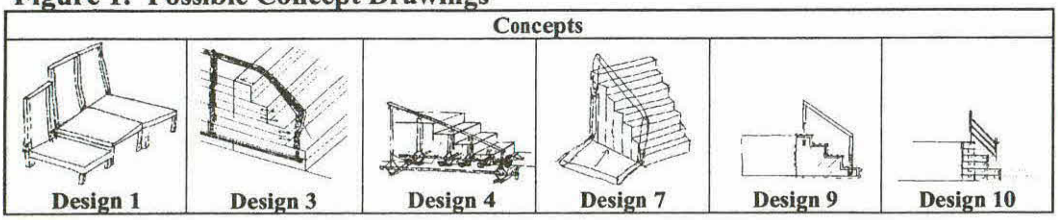
Table 1: Top Five Customer Needs

Customer Need	Rating
1. Adjustable Stair Height	5
2. Removable Handrails	5
3. Adjustable Height Handrails	5
4. Portable	5
5. Non-skid Steps	5

The second step in the design process is the *Conceptual Design Phase.* After gathering all the customer needs, the customer needs were related to functions that the training stairs must have in order to meet those needs. These functions were then combined into a functional model of the product. The functional model gives a form-free picture of all of the functions that the training stairs must perform. The functional model allowed for the generation of more creative concepts for the training stairs.

Next, ten different conceptual designs were developed to satisfy the customer needs gathered in the previous step of the *Conceptual Design Phase.* In order to determine which design to continue developing, a Pugh chart was used to select the best design among all of the designs. The Pugh chart was applied by first choosing a datum design, and then rating each design against the datum. Each design was rated using a specified set of criteria. Some of the concepts can be seen in Figure 1 below.

Figure 1: Possible Concept Drawings



Design 10 was selected from the Pugh chart. This design allowed an unlimited number of stair configurations because it was made up of many blocks, which could be attached to each other with Velcro. A scaled prototype of this Velcro design was made and shown to the customers. After a demonstration of the prototype, the customers did not approve of this design because they felt it would take too long to assemble. Thus we discovered the latent customer need of short set-up time, so the *Conceptual Design Phase* was revisited.

Since there is a new customer need, the Pugh Chart was recalculated in order to choose a design that fit the new customer need. A design similar to Design 3, shown in Figure 1, was chosen. The new design is very similar to bleachers in a gymnasium. This design was originally not chosen because of an estimation made about the cost of building materials. Originally, this design used a more costly slide design therefore making it rank lower than the original selection of Design 10 in the Pugh chart.

The third step in the design process is the *Embodiment Design*. Since the final design has been selected, structural analysis was performed to calculate the dimensions of the structural members. Following current building codes, all of the structural members of the stairs were sized to meet the loading conditions required in commercial buildings. Simple static plate and beam analysis were used to calculate the required values. From these calculations 3/4 inch pine boards, 2x4 s, and 1/2 inch plywood were chosen as the building materials. Wood was chosen as the building material not only because it met the structural requirements, but also because it is easy to build with. With the design chosen and the material selected, a prototype was built in order to test the feasibility of the design.

The final step in the design process is the *Detail Design Phase*. This phase of the design process consisted of determining the specifics about the manufacturing processes to be used and finalizing the detailed drawings. After testing the prototype, a 2-D AutoCAD assembly drawing was created to build the training stairs. Figures 2 and 3 below are two pictures of the training stairs.

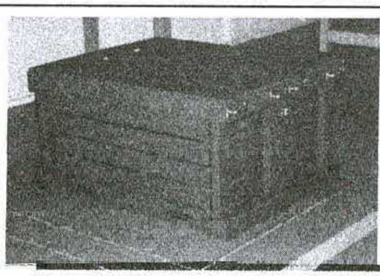


Figure 2: Stairs retracted

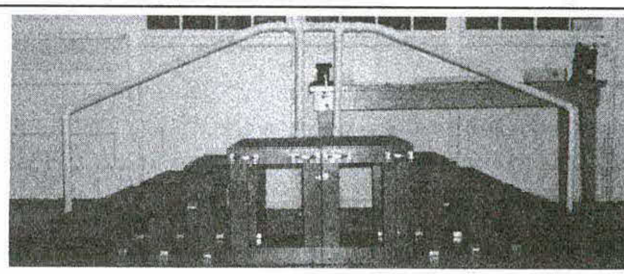


Figure 3: Stairs deployed

DISCUSSION

The final design of the training stairs meets all of the needs specified by the customer. The completed stairs feature steps that slide in and out of a central unit, taking care of the set up time, height adjustment, and space requirements. Also, the central unit has wheels, making it portable. Finally, there is an abrasive paint applied to the surface of the steps to accommodate the non-skid customer requirement. Although only the top five customer needs are discussion herein, all of the customer needs were met. Therefore the design is a success.

ACKNOWLEDGMENTS

We would like to thank Drs. Stone and McAdams, of the University of Missouri-Rolla, and Kathy Hrovat, of Wyman Elementary, for their help and guidance on this project.

REFERENCES

1. Pahl G, & Beitz W (1996). *Engineering Design: A Systematic Approach* (2nd ed.) London, England. Springer-Verlag.

DESIGN AND DEVELOPMENT OF A VESTIBULAR SWING

Yuvaraj Annamalai, Blaine Christensen,
Rajesh Radhakrishnan, and Ravi Kiran Yekula
Graduate Students, Mechanical Engineering Dept,
University of Missouri-Rolla,
Rolla, MO 65409

ABSTRACT

The aim of this project was to design and prototype a vestibular swing for use by autistic children at Wyman Elementary School, Rolla, MO. A swinging or spinning motion calms an autistic child when his/her anxiety is high. The swings available in the market either do not satisfy the requirements of our customers or are very expensive. A design that incorporates both swinging and spinning motions (Vestibular swing) was successfully prototyped in this project.

BACKGROUND

Many autistic individuals seem to have impairment in one or more of their senses. This impairment can involve the auditory, visual, tactile, taste, vestibular, olfactory (smell), and proprioceptive senses. Sensory integration techniques are often used to treat dysfunctional tactile, vestibular, and proprioceptive senses. Some of the techniques involve swinging a child on a swing in various ways to help normalize the vestibular sense and rubbing different textures on the skin to normalize the tactile sense (1). A vestibular swing can be defined as a swing that swings and spins and helps in calming an autistic child.

Teachers at Wyman Elementary School are responsible for tutoring some children with autistic disabilities. They had a need for a swing that would help calm these children when under states of excitation or distraction. They also required a swing that will fit inside the classroom, be collapsible when not in use and be cost effective. Since the vestibular swings available in the market did not meet the above requirements, it was decided to develop a product that would satisfy the specified criteria. This task was taken up as a team project for the Modern Product Design course at University of Missouri —Rolla. Our customers were the teachers (who outlined the requirements) and the children. Initially, customer requirements were collected from the teachers at Wyman Elementary School and were used as a basis for the design.

PROBLEM STATEMENT

The objective of this project was to design, manufacture, test and deliver a vestibular swing to the customers, as per their requirements. Some of the requirements were: a swing that spins/ swings, is easy to operate, holds up to a 110 lb child, accommodates a 4-1/2 feet child in the "superman" position, is easy to install, is safe and occupies less space.

DESIGN

Several modern design theories and fundamentals were applied to the design of the vestibular swing to help develop an efficient design which best satisfies the expectations of our customers. The design process for the vestibular swing consisted of the following steps: customer needs identification, functional model development, concept generation, concept selection, detail design and analysis, and development of proof of concept test. These and other methods like tuning parameter design, robust design etc. provided a rigorous basis for developing concepts conforming to customer needs, to select the best one and analyze its viability (2).

A total of ten different concepts were generated for the swing. These included swings attached to the ceiling, walls or ground. Rocking motions were also taken to substitute for swinging or spinning motions. These concepts were then fed through concept selection methods called the Pugh chart and the Decision matrix to help select the best model given the set of customer specified criteria. A collapsible A frame unit, standing on the ground, with both swing and spin motions derived from an overhead frame, was selected over other concepts.

Once this was done, mathematical models were constructed to determine certain design parameters and to test the viability of the design by doing static and dynamic analyses. Working Model¤ was also used to do kinematic analysis. An 8in:5ft scale model for the selected design was made from wood to test whether it satisfies basic customer requirements of swing and spin. The results validated the design and the design was cleared for final prototyping.

This design satisfies customer requirements better than the other models considered because of the following advantages: easy operation and installation, can be collapsed quickly by removing two bolts, A frames for the sides provide stability, a locking mechanism provided at the overhead bearing easily isolates the swinging and spinning motions, and the design conforms to the customer specified requirement of simplicity.

DEVELOPMENT

An A frame swing design that is collapsible and that also incorporates the spin motion was developed. Collapsibility conserves the space when the swing is not in use, which is an innovation to the existing designs available in the market. Spin motion, an innovation in the swing also satisfies the customer need.

Square steel tubing was used for the framework of the swing. Steel base plates for supporting the side frames were used as foot plates. Eyebolts and D-clips were used to attach the swing to the swing frame. A turntable bearing was selected for the spin motion. 4-ply plywood was used for the platform of the swing. Hinges ensured that the swing was collapsible. Grade 8 Bolts, Nuts and Washers were used for assembly. 1/2 inch nylon rope was used to suspend the platform swing. The component dimensions were: two steel square tubing back legs of height 80.65 inches and two steel square tubing front legs of height 81.65 inches, two square base plates of width 12 inches, two bearing mounting plates, 5x7 inches, and four square foot plate flanges of width 4 inches. Grinding, drilling, welding and cutting operations were performed to manufacture the product. The vestibular swing was cycle tested using varying loads above the maximum requirement.

The entire cost of the swing came out to be $400 dollars, which does not include the labor cost and the manufacturing costs. Our product s total cost will be in the range of $1200 - $1300. This would still be considerably lower than the ones available in the market, which costs around $2400 (only for the frame), thus making our product very cost effective.

CONCLUSIONS

After testing, the swing performance proved to be satisfactory. The vestibular swing was completely assembled and presented to Wyman Elementary School on December 20th 2000. The

advantages of our design are simplicity, collapsibility when not in use, and the safety of the product.
Swing has been in use for the last four months and its operation has been smooth and noiseless. The teachers at Wyman Elementary are satisfied with the performance of the swing. The children enjoy using the swing.

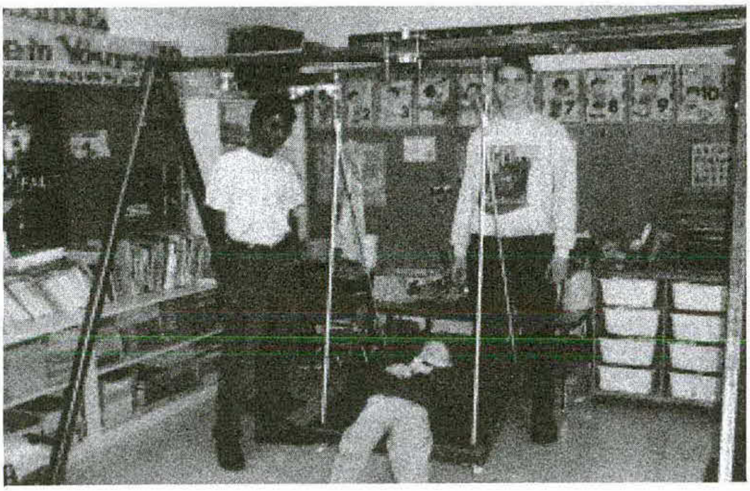


Figure 1: Vestibular Swing at Wyman Elementary

REFERENCES

1. Edelson S.M, Overview of Autism , http://www.autism.org/overview.html
2. Wood K.L, Otto K, Product Design: Techniques in Reverse Engineering, Systematic Design and New Product Development, First edition, Prentice Hall, 2000.

ACKNOWLEDGMENTS

This project was funded by the Mechanical and Basic Engineering Departments, University of Missouri-Rolla.

PROJECT CONTACT INFORMATION

Robert B. Stone, Ph.D.
Assistant Professor of Basic Engineering
University of Missouri-Rolla
102A Basic Engineering Building
Rolla, MO 65409-0050
573.341.4086
Fax: 573.341.6593
e-mail: rstone@umr.edu

Daniel A McAdams, Ph.D.
Assistant Professor of Mechanical Engineering
University of Missouri-Rolla
106B Mechanical Engineering Building
Rolla, MO 65409-0050
573-341-4494 (voice)
573-341-4607 (fax)
e-mail: dmcadams@umr.edu

Voice-Activated Remote Control

Yiu Wong
Assistive Technology Program
Electrical Engineering Department
University of Massachusetts – Lowell
Lowell, MA 01854

ABSTRACT

A voice-activated remote control has been developed to assist an adult who has limited use of his hands. This controller allows the user to control the functions of TV, Cable and VCR entertainment system by using voice command. This hand free controller device allows disables with limitation of using their hands to be able to control their entertainment system simply by speaking.

BACKGROUND

The voice-activated remote control device is mainly based on the use of voice recognition technology. Voice recognition technology has grown dramatically over the last decade. The accuracy and the response time of voice recognition processors have been greatly improved. Therefore, voice recognition technologies have become more popular and widely use in our society. Especially, the use of voice recognition technology has been helping people with disabilities to be able to control devices and appliances with voice commands.

In October of 2000, Derryl has been referred to me as my client of the Assistive Technology at the University of Massachusetts Lowell. Derryl is a disable who has no control of his arms and legs. He can speak and able to control his head movement very well. He spends most of the time on wheelchair or on his bed. Due to his disabilities, he is unable to control the entertainment system in his bedroom. He could not change the channel or volume of the TV and unable to use the VCR. He needs to rely on other house members to help him to do so. This had caused a lot of inconvenience for him.

STATEMENT OF PROBLEM

The objective of this project was to design a voice-activated remote control that could be used to control the TV, cable box, and VCR entertainment system.

RATIONALE

The first phase of this project was to understand what kind of entertainment system the client would want to control such as the TV, cable box and the VCR in his bedroom. I also discussed with him about what kind of functions he would like to control over his entertainment system as a list of requirements that to be controlled by voice commands. It was decided that the voice-activated remote control would be able to do the same function controls as the regular remote controller of the TV, cable box and VCR.

After specification and requirements were decided, I began to do research and development. Throughout the development, I have scheduled meeting with my client to discuss about the project's progress.

DESIGN

In the voice-activated remote control design, it basically consists of three parts: a voice recognition system, a universal remote controller, and a logic circuit which connects the two. The voice recognition processor used in this project was the Voice Direct™ 364 from Sensory Inc. Voice Direct™ 364 is a speaker-dependent speech recognition module, allowing training of up to 15 words with duration of 2.5 sec each. Using sophisticated speech recognition technology, Voice Direct™ 364 maps spoken commands to system control functions. Each time one of the words is recognized, output pins on the module are toggled high for 1 second. With proper use, greater than 90% accuracy can be achieved. A logical circuit will decode the outputs of the processor. Then the logical circuit will assign which function of the universal remote should be on.

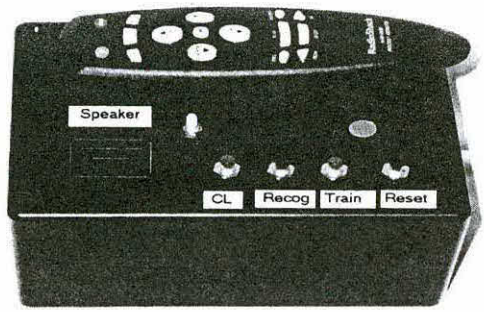
The second part of the design is the universal remote controller. I have decided to use a single 3 in 1 universal remote to control the TV, cable box and VCR. Therefore, the universal remote was modified inorder to be controlled by the logical circuit. Inside the universal remote there is an infrared signal processor sends out infrared signal to control appliances. The infrared signal processor packaged in a 28 pins IC chip. With correct pin-to-pin connection, an infrared signal correspond to those pins connections will be sent out for controlling appliances. For example, if pin 1 and pin 11 of the processor are connected together, an infrared signal for POWER ON will be send to the TV.

The third part of the design is the logic circuit. The purpose of the logic circuit is to control the pin-to-pin connections of the infrared signal processor corresponds to the output module of the voice recognition processor. This logic circuit consists of combination sets of logical gates to do the decoding and switches to do the pin-to-pin connections. Reed relays were used to act as switches to do the pin-to-pin connections. Reed relays serve in many applications requiring low and stable contact resistance, low capacitance, high insulation resistance, long life and small size. In this project, when a reed relay receives an active high signal from the logic circuit it will connect two assigned pins of the infrared signal processor together. Once the pins are connected, the appropriate infrared signal will be sent out from the remote.

DEVELOPMENT

The voice-activated remote control device basically consists of two parts. A universal remote and a 8x5x4 inches box containing the voice recognition processor and the logic circuit. A picture of the complete unit is shown in Figure 1. The universal remote control was modified to have its control wires extended through its plastic cover into the box. Therefore, the logic circuit and the relays in the box will be able to communicate with the infrared signal processor in the remote. There are several buttons located on the top of the box for words training purposes. There is also a speaker located inside the box. The purpose of the speaker is to use speech prompting to report memory status, provide training instruction and notify user when there is an error occur. A microphone is placed on top of the box for the voice recognition processor to recognize voice commands. The unit is design to be powered by 4 AAA batteries or a 5 Volt DC adapter.

Figure 1 – Voice-Activated Remote Control Unit



EVALUATION/DISCUSSION

The voice-activated remote is easy to use and user friendly with speech prompting technology. The unit is small size, portable and affordable. The entire unit including the remote is cost about $120 to make. The cost is must less than other voice-activated remote control which must be connect to a computer. The computer will increase the cost dramatically with hundreds of dollars. One feature of this unit is that the universal remote is detachable from the control box. When the remote is detached, it can be used as a regular remote controller, which is very convenience.

To start using the unit, first, user needs to train the Continuous Listening (CL) word by pressing the CL Button. This CL word is the word user must say before saying the second stand-alone word for accessing the 15 processor voice recognition memories. After the CL word was successfully trained, user is required to train the other 15 voice recognition memories by pressing the Train button for training each one. Each word represents one of the 15 functions of the remote. The order of word training for all 15 remote function is fully explained in the user manual. For example, user must train word one memory to represent the POWER function of the remote control and train word two memory to represent the VCR Mode function of the remote control and so on, up to word fifteen. If user made a mistake during training, user can press down both the Recog and Train buttons for 1sec to clear all memories and start the training over again.

Once the unit is trained, user can press the Reset button once and start using the unit. When user want to use the remote, user first speaks the CL word to the micro-phone and look at the green light carefully. Once the unit recognizes the CL word, the green light will blink once. Right after the green light blinked (about 1 sec or so), user should say one of the stand-alone words which was trained into the 15 memories during training. When the voice recognition processor recognizes the voice command, the box will control the remote to send out the correct signal that corresponds to the voice command.

ACKNOWLEGEMENTS

This project was supported and funded by the Assistive Technology Program and the Research Foundation of University of Massachusetts Lowell. I also want to thank Professor Donn Clark and Mr. Alan Rux of the Assistive Technology Program for giving me supports and advises on completing this project.

VOICE ACTIVATED RADIO CONTROL TRUCK

Visay B. Sisoukraj
Assistive Technology Program
University of Massachusetts Lowell
Electrical Engineering Department
Lowell, MA 01854

ABSTRACT

As technology is becoming more advanced, so is voice recognition. Our society has become more adapted to speech the recognition system available today. This technology has not been used to its fullest capacity in one area. That is among the handicap, especially children who are unable to make full use of their hand movement. Voice activated radio control cars or trucks will give these kids a sense of pride enjoyment in their life. They too can play with a toy that is adaptable to their needs, in a way that is similar to thousand of able body children, who are able to make use of standard radio control toys.

BACKGROUND

Most of us do enjoy playing with our toys, especially children. As the technology is becoming more advanced, the toy manufactures have marketed more sophisticated toys. Yet, many of these toys manufacturers target their market to only able body people. Many of these toys make it difficult or impossible for children who have limited use of their hands to play with them. When witnessing the children at one of the local rehabilitation center, I saw these kids playing with their toys. They seemed so limited as to what they can play with. This inspires me to think of, I could do something about this. Originally, I was going to modify a doll that required to be squeeze to activate certain tasks. Later our group uses this idea of voice activated toy car as a product for our company in capstone proposal class. Then Professor Clark ask us pursue this idea and bring it to reality.

PROBLEM

Children and adults alike love to play with their radio control cars or trucks. However, those with limited or no use of their hands may find it impossible to do so. There is no availability of voice activated radio control toy vehicles on the market today. These people are deprived much of the joy that come with playing with such a toy, while the able body people take for granted.

DESIGN

The speech recognition technologies are become more advanced, but are not yet perfect. There are all kinds of radio control toy vehicles in the market today. Designing an interface circuit to work with speech recognition and radio control circuitry is something that can be easily done. Speech recognition used was HM2007 kit from the Images Company for $100. Its capability of recognized up to 40 words, each word with a maximum length of .92 seconds. The recognition accuracy can be achieved at 95% or greater. The drawback to this chip is a speaker dependent. There is only six basic commands needed to control this voice activated radio control truck. These commands are forward, reverse, stop, left, right and straight. These commands can be utilized by allocated four words space or location for each command. Therefore, users can train in all four locations for greater percentage of recognition accuracy. This system can also be shared by four different users; each person can train at one location. The interface circuit was achieved by using basic logic design. This is done by process output signals, from speech recognition circuitry to controlled four movement in the radio control unit. The radio control truck used for this project is a 1/14 scale Dodge Ram Truck by New Bright Industries, and it was purchased for $34.99.

DE VELOPMENT

The first step of this design was to determine what kind of signal was required to control the forward, reverse, left and right movement in a radio control unit. It was determined that this controller forces the forward (reverse as well as left and right) contact to ground in order to move the truck. There is no variable speed to this, once the contact is made the truck starts to move right away.

The next step is to determine how the speech recognition circuitry worked, what kind of output signals does it give? The output signal for speech recognition is decimal code in a binary format, data D0 to D7. For example, when activate a counter of 01, data D0 would go from low to high (see table 1). The output signal is logic high, and the input signal that required for controlling the truck's four basic moments has to be ground. A transistor was selected to control each of the four outputs signal, as to convert the logic high output to ground (see figure 1).

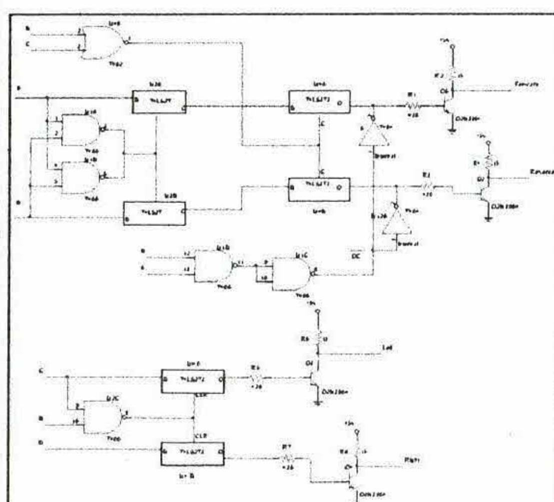
The interface circuit consists of six IC, eight resistors and four transistor. There are two sections to this circuit, forward, reverse and stop are divided into one section and the other section is left, right and straight. U1A and B (74LS00) and U3 (74LS273) were used to ensure that forward and reverse would not activate at the same time. U4 (74LS373) is an Octal D-type Transparent Latches, this is serve as to holds the output signal at logic high while the left or right command is activated. In addition, when U1C and D go high (stop command) then output buffer of U4 would clear all signals. In the second section of the circuit left, right and straight is controlled by U5A (74LS00) and U6A (74LS273). When U5A is turned on, U6A will be clear, and in turn, it will clear either left or right. The clock (CLK) is taken from a 3.58 MHz Crystal Oscillator that connects to pin 2 and 3 of the HM2007. Pin 2 is the output; this pin is connected to pin 11 of 74LS273. Both circuits shared a single 9VDC battery. The 7805 voltage regulator was used to obtain +5 VDC. Also, there is a 3.5 VDC lithium battery uses for retained memory for the static RAM. This battery should last for a long time, since the power consumption here is very small.

The Dodge Ram truck speed as discovered to be too fast for children to play with, especially the handicap. In order for a child to use it, the truck's speed needs to have the ability to be adjustable. This was accomplished by adding 10Ω, 3 watts potentiometer in series with one of the motor control's line.

Table 1: Output Signal Speech Recognition Circuit

Output from Connector 6 (D0 to D7)								Display
D(8)	C(4)	B(2)	A(1)	D(8)	C(4)	B(2)	A(1)	Count
0	0	0	0	0	0	0	1	01
0	0	0	0	0	0	1	0	02
0	0	0	0	0	0	1	1	03
0	0	0	0	0	1	0	0	04
0	0	0	0	0	1	0	1	05
0	0	0	0	0	1	1	0	06
0	0	0	0	0	1	1	1	07
0	0	0	0	1	0	0	0	08
0	0	0	0	1	0	0	1	09

Figure 1: Interface Circuit



EVALUATION

This truck is equipped with variable speed control. The truck performs well at low speed and it easy to maneuvers even in confined areas. At high speed, a larger area is required to operate. Because the truck is considerably fast. This is only a prototype system; it is not yet perfect, there are some work is needed. For example, error code 55 (word to long), this causes truck to turn left and sometime forward. This is due to the sharing of same data busses as forward and left commands.

The microphone is an essential part of the voice recognition systems. Therefore, a good microphone is needed. The microphone that came with HM2007 kit, the cable founded to be too short. In addition, cable was mounted right to the PCB. This required a user to bend down as to give a command. A longer microphone cable is necessary in for the user's mobility. A standard over the head PC microphone was selected over the tie clip type. This type of microphone gives a better percentage of recognition accuracy, because the distance between the mount piece and the speaker is close and constant. The microphone used came with 8-ft cord, 1/8" (3.5 mm) plug and frequency range of 100 to 16,000 Hz. Impedance of 32Ω, and sensitivity of -56 dB +/- 3dB, V/μbar@1kHz.

DISCUSSION

This project demonstrates that voice activation can be added to any radio control toy vehicle in the market today. We have the technology as this project shows, to accomplish this task at reasonable price. The parts for this prototype radio control truck cost about $200.00. If this were to put in mass production, the price should drop significantly.

REFERENCE

1. SAMSUNG Logic Families Data Book 1986

ACKNOWLEDGMENTS

This project was supported by university of Massachusetts, Lowell. Capstone Project supported by Professor Donn Clark and Alan Rux. Thank to John O'Fallen, Bob Hanlon, Hai Lui, Art Reed, and Paul Brockman in helping with the project. In addition, thank to my wife who had been helping me with my grammar.

Visay B. Sisoukraj
41 Bowers Street 2nd Floor
Lowell, MA 01854-3504
(978) 458-2141
visays@worldnet.att.net

VOICE CONTROLLED TOY CAR

John M O'Fallon
Assistive Technology Program
Electrical Engineering Department
University of Massachusetts/Lowell
Lowell, Massachusetts

ABSTRACT

The need for technology to assist people with disabilities has rarely been disputed. In many areas, our society has become more aware and accommodating to those with different needs, but little attention has been placed on enhancing the ability of the disabled to enjoy the nonessentials of life, such as playing with toys. A voice-controlled toy, such as a radio controlled car, can give a children with limited hand use a degree of freedom and independence in their play that they may have yet to experience. With new advances in technology, the cost of modification, after research and development, is now under $100.00. This makes speech controlled toys a viable option for disabled children.

BACKGROUND

The explosion of technology has permeated seemingly every aspect of our lives; children's toys have been no exception. Many toys, such as the Furby, contain various sensors, detectors, output devices and even microcomputers. Nevertheless, even as the deluge of technology continues to flow, the application of this new technology has yet to be as thoroughly applied to toys for use by disabled children. Parents of a disabled child, depending on the child's abilities, may have limited choices for suitable toys for their children although the technology exists to create toys for children with many differing abilities. This reality is the reason for building a voice controlled toy car. Children, and adults, who have limited or no use of their hands, can use this car giving them the freedom to play with a toy.

PROBLEM

Children with limited or no use of their hands may find most, if not all, of the available toys difficult to impossible to use. These children are deprived of much of the play that able-bodied children take for granted. They may be limited to passive activities, such as watching TV, or activities that are more involved only when assisted by a caretaker. Speech activated radio controlled toys would allow the child a new degree of freedom and independence. Once the toy was activated, the child would be able to control the toy with out the intervention of the caretaker.

DESIGN

The most efficient way to create the car would be to use an existing radio controlled car, an existing stand-alone speech recognition device, and unite the two units with an interface circuit. The r/c car could be any presently on the market, but the best choice would be a slower car with only the basic commands: forward, backward left and right. The cars that are very fast or do specialized tricks may be too fast or complicated for voice control. The car chosen, A Nikko 'Road Hog' met these constraints but was slowed down further to allow time for the vocal commands to be processed. The speech recognition unit must be accurate, easy to use and low cost. The unit chosen, a Sensory Inc. VD364 boasts 99% accuracy, user-friendly voice prompts and a cost of $50.00. The interface between the two units must be reliable, cheap and flexible. The best choice seemed to be a microprocessor combined with an op-amp. The microprocessor, which can be found for under $5.00 provides a cheap and flexible interface when combined with an op-amp to drive the transmitter circuitry.

Along with the basic directional controls found on traditionally controlled r/c cars, some special features may be beneficial to special needs users. Already implemented are half speed, slalom, and figure eight features with room for five more. All these commands can be activated and deactivated by a single vocal command. This eliminated the number of commands that need to be spoken. For example, the slalom command alternates left and right until cancelled which eliminates the repeated vocalization of left and right.

DEVELOPMENT

The voice-controlled car was conceived for a class project, but after some research it was determined that this was a viable task for a senior electrical engineering final project. The initial concept was simple buy an off the shelf r/c car, a stand-alone speech recognition unit, and combine the two using a microprocessor.

The first step consisted of researching the available speech recognition units (SRU), cars and microprocessors. After much Internet research the Images Co. HM2007 was chosen as the SRU, and the Scenix SX28 as the microprocessor. As limited information of the internal workings of the specific r/c cars is available, a low priced basic functionality car was purchased off the shelf. The remote control of the car turned out to be perfectly suited for modification. Each of the four directional controls, forward, backward, left, and right, could be activated be applying +9V to one of four jumpers on the circuit board.

Next, the internal workings of each component were determined. After training the SRU with the appropriate commands, the SRU would output the appropriate two digit BCD corresponding to one of 40 memory locations upon recognizing a spoken word. A small program was written for the microprocessor, which would interpret the BCD output of the SRU and set the appropriate combination of the four output pins. Each one of these pins fed into an op-amp, which boosted the +5V output of the processor to the +9V needed by the remote control transmitter.

This conglomeration of circuit boards was connected together, using a plethora of jumper wires, on a sheet of Styrofoam. The car worked well except for the chosen SRU, which had problems with accuracy. At different times the SRU would recognize nearly every word while at other times seemed to miss nearly every word, therefore a replacement needed to be found. The Sensory Inc.VD364, the replacement SRU, performed much better with an estimated 95% correct recognition. This accuracy came at the price of slower response, about one second between commands. As the time to traverse a room at full speed was less than one second, the car collided with objects when used indoors.

To improve the controllability of the car with the increased response time, the car was slowed down by adding an "slow down" vocal command. By using the microprocessor to quickly turn the forward or backward output signal on and off, the car would move at a slower, though jerkier rate. When using this command when in a confined area the car becomes much easier to control.

After the circuit was constructed, and software written, the unit was packaged into a battery powered hand held unit. The final unit came equipped with power management features, and a head worn microphone. This unit underwent testing by various people to determine its performance and ease of use.

EVALUATION

The car performs well when the each user programs his or her own voice templates into the SRU, a process that takes about one minute. After programming and some training each test subject was able to control the car to a fair degree of accuracy. Testing was also done on younger children aged three and four who found the programming process to tedious and difficult and then soon lost interest. The difficulty arose in saying the correct command words at the correct time with a consistent volume and timber.

In confined areas the car requires some training and skill to maneuver with out crashing. When used in open areas, the car performs quite well maneuvering as requested with most every command. The car also responds well when the user relies on a preprogrammed voice template. Though not as accurate as when the user's voice is programmed into the unit, the accuracy was sufficiently high to allow several users to use the car with out reprogramming.

Many areas still need to be addressed before one could consider producing this device beyond the prototype level. This prototype was constructed by hand with point to point wiring, which tends to be less reliable than PC board construction. Background noise and variances in the user's voice can cause the car to ignore a command. Many times the noise generated by the car's motor was loud enough to cause missed commands. In addition, the excitement in a user's voice when confronted with an impending crash would sufficiently change the voice to the point where the car would not respond, and then of course crash.

DISCUSSION

This prototype voice controlled toy car demonstrates how a toy can be modified to accept spoken commands. After the initial development has been done, the cost of parts per unit is under $100.00, which is not unreasonable, considering the benefits to a disabled child who might use the toy. The use of vocal commands for a toy car or other similar device is still not a viable substitute for manually operated controls when other options exist. But, for those who have no other option speech recognition can give them the ability to control their world in new and exciting ways.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the support of Professor Donn Clark and Alan Rux who together lead the assistive technology program at the University of Massachusetts at Lowell. Professor Clark first saw the viability of the car and encouraged its development. In addition, thanks to Bob Hanlon who first conceived of a voice controlled toy car, And finally thanks to Visay Siskorage and Hai Lui who are developing a similar car. They provided insight and direction in the development and design as they struggled with their own creations.

John M O'Fallon
11 Corinthian Dr.
Lowell, MA 01854
978-458-8551
jmofallon@hotmail.com

Augmentative and Alternative Communication
(Topic 2)

EFFECT OF SPEECH RATE ON COMPREHENSION AND ACCEPTABILITY OF SYNTHESIZED NARRATIVE DISCOURSE

Kyung-Eun Kim and D. Jeffery Higginbotham
Communication and Assistive Device Laboratory
Department of Communicative Disorders and Sciences
State University of New York at Buffalo
J. William Gavin
Department of Speech, Language and Hearing Sciences
University of Colorado at Boulder

ABSTRACT

This study investigated the effect of speech rate on listener comprehension and subjective judgments when listening to synthesized narrative stories (MacinTalk Pro). Fifty able-bodied adults individually listened to synthesized stories at five different speech rates between 8.75 to 140 words per minute (wpm). For each story, listeners answered multiple-choice comprehension questions and rated their subjective judgments about the communication competence of the speaker. Analyses revealed significant differences related to speech rate for both comprehension performance and subjective judgments. Seventy words per minute emerged as an optimal rate for narrative discourse comprehension, with increases in speech rate resulting in more favorable ratings of communication competence.

BACKGROUND

The slowness of communication speed in augmented communication can be summarized as a "Rate Problem" to be improved for better communication of individuals using Augmentative and Alternative Communication (AAC) systems. The average AAC communication rate is usually less than 10 wpm (1), resulting in speech rates more than 10 times slower than natural speakers. This slow rate imposes several significant barriers on speaking partners' ability to perceive and comprehend utterances produced by augmented speakers in interactive contexts (2, 3, & 4).

Despite technological improvements in the AAC field, communication device constraints and/or communication limitations still prevent augmented speakers from engaging in and sustaining real-time interactions. Although the rate effect of synthetic speech on listener comprehension and acceptability has been recognized as one of the top three research topics to be investigated for successful use of AAC devices, the practical rate effect of synthetic speech still has not been adequately documented.

RESEARCH QUESTION

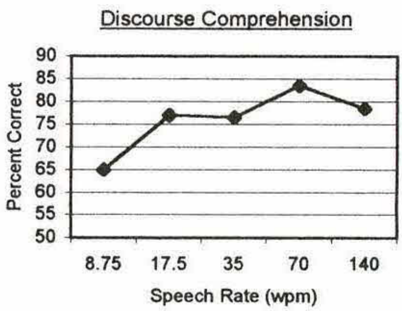
The purpose of this study was to investigate the impact of speech rate on synthesized narrative comprehension and subjective judgments of listeners. Research questions included:

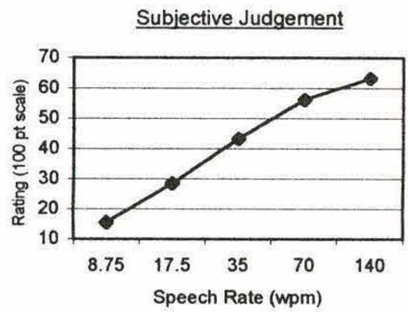
- What is the relationship between speech rate and comprehension performance?
- What is the relationship between speech rate and subjective judgments?

METHOD

Fifty able-bodied individuals participated in this study as listeners. The listeners were individually tested over a two-and-half-hour period, listening to five stories at five different speech rates that were randomly assigned from a pool of 10 narratives (5). After listening to each story, listeners answered multiple-choice comprehension questions, then answered 10 subjective judgment questions of a competence evaluation questionnaire (100-point scale). All stimulus materials for experimental conditions were randomly assigned to participants using a partial Latin Square design.. All narrative stimuli, comprehension questions and the communicative competence rating scale were presented via the computer. Speech rate served as independent, within subject variable. Dependent measures included percent of correct responses for comprehension questions and subjective judgments rating scores. To meet the criteria for normality and equal variance assumptions, all data were transformed using the arcsine transformation method (6). A repeated measures ANOVA was employed and pairwise comparisons were made using the Tukey HSD and individual t-tests. The level of significance was set at $p < .05$.

RESULTS





Figures 1a & 1b: Discourse Comprehension and Subjective Judgement across Five Speech Rates.

Listener comprehension performance across speech rates displayed a curvilinear trend with significant linear, quadratic and 4^{th} order components. Comprehension performance increased significantly between 8.75 and 17.5 wpm, was stable between 17.5 and 35 wpm, then, improved significantly at 70 wpm. Finally, comprehension performance declined significantly between 70 and 140 wpm.

Analysis of listener's subjective judgments revealed significant linear and quadratic trend components across speech rates. As shown in Figure 1b, listeners rated their experiences more positively as speech rate increased, accompanied by a slight downward deflection between 70 and 140 wpm. All between-rate comparisons were statistically significant.

DISCUSSION

The results of this study indicate that faster speech rates have a significant positive effect on both listener discourse comprehension and subjective judgments of communication competence at least up through 70 words per minute. At the slowest speed (8.75 wpm), both comprehension and subjective judgement were at their lowest point – an important finding, given that the average reported communication speeds approximate this communication rate (1, 2, 7, & 8).

Improvement in comprehension and subjective judgments with faster speech rates is also in line with recent findings by Todman (4) showing systematic improvements communication competence ratings as a function of faster communication speed. Interestingly, the optimal listener comprehension rate of 70 wpm is asupported by previous research findings from our lab indicating comprehension processing problems associated with synthetic speech played at normal speech rates (7, & 9). Unlike comprehension performance, subjective judgment scores systematically increased with speech rate. Perhaps this measure is a more sensitive indicator to changes in speech rate than the comprehension task, or taps other communication related dimensions not addressed by the comprehension measure. Finally, these results provide clear - although limited - empirical evidence that faster AAC technologies can substantially improve listener comprehension and their communication competence perceptions of the device user. Using these data as an initial benchmark, we encourage the manufacturing community to research and develop technologies to provide AAC speakers with the means to achieve and sustain communication speeds from 20 words per minute upwards to approximately 70 words per minute. Additional research needs to be conducted to more precisely specify these speeds and associated task demands.

REFERENCES

1. Beukelman, D. R., & Mirenda, P. (1998). Augmentative and Alternative Communication: Management of severe communication disorders in children and adults. 2nd ed., Baltimore, MD: Paul H. Brookes Publishing Co.
2. Higginbotham, J. D., Wilkins, D. P. (1999). Slipping through the timestream: Social issues of time and timing in augmented interactions. In D. Kovarsky, J. Duchan, & M. M., Maxwell. (Eds), Constructing Incompetence.
3. Sweidel, G. B. (1992). Management strategies in the communication of speaking persons and persons with a speech disability. Research on Language and Social Interaction. 25, 195-214.
4. Todman, J. (2000). Rate and quality of conversations using a text – storage AAC system: A training study. Augmentative and Alternative Communication.
5. Brookshire, R. H., & Nicholas, L. E. (1994). Discourse Comprehension Test, Tucson, AZ: Communication Skill Builders.
6. Kirk, R. E. (1995). Experimental Design: Procedures for the Behavioral Sciences. 3rd ed., Pacific Grove, CA: Brooks/Cole Publishing Co.
7. Higginbotham, J. D., Drazek, A. L., Kowarsky, K., Scally, C., & Segal, E., (1994). Discourse comprehension of synthetic speech delivered at normal and slow presentation rates. Augmentative and Alternative Communication. 10 (3), Sept. 191-202.
8. Venkatagiri, H. S. (1991). Effects of rate and pitch variations on the intelligibility of synthesized speech. Augmentative and Alternative Communication. 7 (4), Dec. 1991, 284-289.
9. Higginbotham, J. D., Scally, C. A., Lundy, C. A., & Kowarsky, K. (1995). Discourse comprehension of synthetic speech across three augmentative and alternative communication (AAC) output methods. Journal of Speech and Hearing Research, 38 (August), 889-901.

ACKNOWLEDGMENTS

This study was partially funded by Mark Diamond Research Fund from the University at Buffalo and by the Rehabilitation Engineering Research Center on Communication Enhancement.

A COMMUNICATION "TOOLS" MODEL FOR AAC INTERVENTION WITH EARLY COMMUNICATORS

Cynthia J. Cress, Ph.D.
University of Nebraska-Lincoln

ABSTRACT: This paper presents a conceptual model of communication for young children based on the numbers and types of communicative tools that they use for conveying messages. These tools include both tangible and intangible aspects of communication, including the use of behavior, language, messages, symbols, and other people for communication. Particular aspects of the model represent tools used by non-speaking children who rely on AAC. A brief overview discusses the roles of tools in communication for speaking and non-speaking children, including the roles that adults play in providing certain tools themselves to scaffold children's early communication. Implications for AAC intervention and assessment are included.

BACKGROUND

Typically developing children's control of early linguistic experiences within interactions tends to rely upon on nonverbal behavior tools that facilitate later linguistic development. For instance, referential gestures, such as "gestural labels", tend to be produced first in routine contexts with joint attention to an object, and gradually become symbolic means of referring to that object out of context (1, 2). Children with severe motor and communicative impairments have restricted opportunities for controlling communication tools through gesture or other referential movements. For instance, a child with poor hand/arm control will have more difficulty learning to give items to request actions in the conventional manner displayed by children without disabilities. Children with severe physical impairments tend to be at risk for language delays resulting from limited opportunity for productive language expression, poor modeling of successful communication using alternative communication modes, and poor adaptation of the communicative environment to unique characteristics of non-spoken communication strategies (3).

If children with physical and/or cognitive impairments are at risk for poor spoken language development, we need to explore alternative early strategies. An augmentative and alternative communication (AAC) system is "an integrated group of components, including the symbols, aids, strategies, and techniques used by individuals to enhance communication" (4). While some intervention emphasizes the symbols and technologies, early AAC intervention also addresses gestures and partner strategies that support presymbolic communication. Communicative expectations for typically developing children are based on extensive research and published developmental milestones. Such developmental milestones are not available for children with severe communicative, physical, and/or sensory impairments (5). Also, if a child's communicative performance is limited, we cannot simply use children's responses or lack of them to estimate children's communicative competence and plan an appropriate set of accessible communicative strategies. This article applies a developmental model of communicative tools based on principles of typical and disordered spoken language development to communication by non-speaking children who rely on technology for communication.

OBJECTIVE: The communication "tools" model has been developed to represent the potential sources of cognitive difficulty in controlling augmented communication for young non-speaking children, in order to plan AAC intervention to improve children's effective communication tools "one hard thing at a time". Specific questions include: a) How do we estimate or change relative difficulty of a communicative strategy for a non-speaking child? b) How do we predict and facilitate next steps in the development of a communication strategy for a child relying on AAC?

APPROACH

Given the difficulty of estimating the communicative complexity of various AAC strategies, intervention in young children's AAC systems often jumps from simple to complex without a thorough understanding of the relationships among different communicative strategies or relative sources of difficulty between strategies. For instance, a frequent goal for a prelinguistic non-speaking child is to learn the cause/effect relationship between hitting an electronic switch and hearing a voice output message or seeing a toy respond to the switch activation. Once the child successfully hits such as switch, a frequent follow-up goal might be to use the voice output switch to convey a spoken message to a listener to request an action. While the physical behaviors and external tools are roughly equivalent for these two types of activities, the underlying cognitive and communicative complexity is considerably different. The following table outlines a model of communicative tools for non-speaking children.

Table 1: Type of Communicative Tool	Example
Child initiates a behavior	Reaches own arm out and controls its movement
+ Toy or other direct object	Pushes switch with arm movement
+ Message Content	Child enjoys and wants to continue tickle game
+ Symbolic representation	Chooses picture symbol representing "tickle"
+ External Device	Controls a nonbehavioral means of communication
+ Language	Conveys specific semantic content: More tickle
+ Voice Output	Hears "more tickle" from device
+ Affects other person's behavior	Partner attends to and interacts with child
+ Communicative Outcome	Child anticipates/reacts to specific tickle activity

The first tool that children must control is their own body (a one-tool system), including eyegaze, sound, or movement. Most early tools aren't physical objects but separate aspects of interaction (e.g. a message is a type of tool). Children may have a repertoire of signals that they produce consistently that familiar partners recognize, even if those signals are not produced with the intent to communicate to a partner. Other communicative tools can be added to the child's behavior to form communicative signals of two or more tools. For instance, a child might smile (own behavior) to directly elicit a social response from an adult (adult behavior), for a two-tool system. Similar two-tool systems may combine the child's behavior with a toy (e.g. shaking a rattle) or with a communicative message (e.g. vocalizing a distinct protest sound). Tools that speaking children may add in more complex messages include anticipation of a specific response, language, and spoken word output. Additional tools common to early AAC include a symbolic representation (such as a representative picture symbol or sign), external device (such as a switch that plays a prerecorded message), and the spoken voice output of such a device. The external device and its voice output message are considered separate tools, since children can interact with the physical device without attending to the voice output produced. Also, the task of deciding to communicate using an external device not part of one's body is presumed to add metacognitive load to the communication task above that presented by the voice output of the message alone.

In Table 1, nine tools intervene between the child and the desired outcome, although fewer tools may be used in supported play. For instance, children could anticipate the tickle response by hitting the switch without understanding the language/symbolic content or the function of the switch as a specific communicative mode (Behavior + Object + Message + Voice Output + Other Person + Anticipation of Outcome = 6 tools). More simply, a child who enjoys hitting switches as a two-tool system (Behavior + Object) might be exposed the voice output interaction in order to prompt a three- or four-tool communication event (Behavior + Object +/or [Message] +/or [Anticipate outcome]). At first, the partner provides the message (tickle) for the child with contingent feedback for their behavior, to prompt the child to convey or anticipate the tickle message independently.

DISCUSSION:

Assessment: Comparing the relative difficulty of a communication strategy. If a communication task is too difficult for a child, partners can try reducing or scaffolding the number of tools that are necessary to accomplish particular communicative goals. Reducing complexity of a communication situation often involves partners supporting more of the "tools" necessary for a child to be successful. For instance, pushing a voice output switch to hear a familiar voice is usually a two-tool system (behavior + object). However, using the same switch to request "more juice" is actually a very complex behavior, involving: Child's behavior + Object + Other person's behavior + Message Content + Language [+ Symbolic representation] + Device. A more realistic next step beyond the first use of the voice output switch might be to add only one additional communicative tool to the two-tool interaction, such as behavior + object + message content (which could still be "more juice"). In order to help the child learn to associate the message content with that activity, the adult would provide the juice immediately contingent upon the child's behavior, and provide direct feedback that the switch output control resulted in the juice being offered. The responsibility for managing the language, other person's behavior, and communicative nature of the device would be provided by the partner, to scaffold the child's behavior into a more complex communicative act with support. The extent to which a child can successfully control a multi-tool signal within a given situation can depend upon the child's state and relationship to the desired result. The more complicated or frustrating the task, the simpler the child's communicative signal needs to be. For instance, when a child is upset, he/she is more likely to use a simple behavior that adults respond to immediately (such as fussing) than a complex behavior at their threshold of "tools". In a highly familiar and predictable context, such as a feeding routine, a child is more likely to be able to incorporate multiple tools and challenge their current communicative skills.

Intervention: Goal development based on communicative tools. Intervention based on a tools model focuses on two types of goals: expanding children's potential combinations of tools at their current level of complexity, and increasing their number of communicative tools for familiar contexts and activities. Expanding a child's current variety of tool combinations involves prompting new communicative situations in which a child's signals can control an event without adding more combined tools than seen in his/her repertoire of signals. For instance, a child who only produces three tool signals in a few situations (such as behavior + other person + message to request more "Row your Boat") would be prompted to expand three-tool signals into other familiar contexts (such as behavior + toy + message to indicate "turn it on"). As the child builds a repertoire of three-tool signals, additional tools can be added to familiar signals to expand them into four-tool signals. For instance, the adult might prompt the child to look toward the partner before turning on the toy, to prompt adding the "other person" tool to the toy message. For "Row your Boat", a four-tool combination might involve adults modeling a specific gesture or symbol for this song to distinguish it from other preferred songs requested by the child.

REFERENCES
1. Acredolo, L., & Goodwyn, S. (1988). Symbolic gesturing in normal infants. Child Development, 59, 450-466.
2. Thal, D., & Bates, E. (1988) Language and gesture in late talkers Journal of Speech & Hearing Research, 31 115-123.
3 Reichle, J., York, J. & Sigafoos, J. (1991). Implementing augmentative and alternative communications: Strategies for learners with severe disabilities. Baltimore: Paul H. Brookes.
4. ASHA (1991). Report: Augmentative and alternative communication. ASHA, 33 (Suppl. 5), 9-12.
5. Cress, C.J (2001). Expanding children's early augmented behaviors to support symbolic development. In J. Reichle, D. Beukelman, & J. Light (eds). Volume 2: Implementing an augmentative communication system: Exemplary strategies for beginning communicators. Baltimore: Paul H. Brookes.

ACKNOWLEDGMENTS: Supported in part by research grant #1 K08 DC00102-01A1 from the National Institute on Deafness and Other Communication Disorders (NIDCD), National Institutes of Health. The author wishes to particularly thank the families and children who participated in these research activities.
Cynthia J. Cress, Ph.D., 202G Barkley Memorial Center, Lincoln, NE 68583-0732, ccress1@unl.edu

AAC SELECTION RATE MEASUREMENT: A METHOD FOR CLINICAL USE BASED ON SPELLING

Barry A. Romich[1,3], Katya J. Hill[2,3], and Donald M. Spaeth[3]
[1] Prentke Romich Company, Wooster, OH 44691
[2] Edinboro University of Pennsylvania, Edinboro, PA 16444
[3] University of Pittsburgh, Pittsburgh, PA 15260

ABSTRACT

The rate at which a person who relies on AAC (augmentative and alternative communication) can make choices from an array determines the speed of communication. Automated language activity monitoring (LAM) tools allow the measurement of selection rate based on logged data generated by actual AAC system operators. A method for measuring selection rate based on spelling speed is presented. Implications are significant for clinical assessment and intervention.

BACKGROUND

The AAC clinical processes initiate with a team commitment to work toward the goal of AAC. The team agrees to provide the supports and services that result in the most effective communication possible for the individual. Generally, effective communication is accomplished through spontaneous novel utterance generation (SNUG). For people who rely on AAC, one measure of communication effectiveness is communication rate, which is almost always far slower than natural speech. Therefore, every effort must be made to maximize communication rate for this population. Communication rate is influenced by many factors. By far the most significant factor can be the language representation method (LRM) employed for accessing core vocabulary. However, the speed of making selections also can be an important factor.

Once the team has determined the LRM(s), decisions regarding the most appropriate selection technique must be made. Research on how different AAC configurations affect speed and efficiency is needed to facilitate the clinical decision-making process for motor access (1). For most teams, determination of selection techniques (e.g., keyboard vs. headpointing) has been qualitative ratings of speed and reliability. Decisions relative to selection rate have been based on clinical intuition, trial-and-error counts, or not documented.

Recent work has resulted in AAC language activity monitoring (LAM) (2, 3) for clinical use, funded in part by the National Institute for Deafness and Other Communication Disorders on NIH, and a comprehensive universal logfile standard (4). These developments have made available tools to collect language sample quantitative data on which to base assessment and intervention decisions. LAM data is being used to produce quantitative AAC performance summary measures.

A method for measuring selection rate proposed in late 1999 has been used clinically (5) since that time. While the results have been useful, the method requires that the subject produce a particular pattern of selections. While this is not onerous, it does require an intentional setup and thus may be done infrequently in the course of normal therapy.

OBJECTIVE

The objective of this work is to provide a method of extracting selection rate measurement from normal LAM data. Selection rate can be used for the comparison of different selection techniques on systems of different array sizes, the measurement of progress in learning to use a particular technique, and changes in rate that might occur as a result of other short term (e.g., fatigue) or long term (e.g., learning curve, physical improvement or deterioration) factors.

METHOD

The human interface information transfer rate has historically been measured in terms of bits per second. (The rate for able-bodied people is generally considered to be under 100 bits per second. (6)). Consistent with historical measures, for this work the selection rate also is being reported in terms of bits per second.

The size of the array (A) (e.g., number of keys on a keyboard) from which choices are being made determines the number of bits (N) that are available with each choice. $A = 2^N$. $N = \ln(A) / \ln(2)$. The integer number of bits (N) for various array sizes (A) is presented in this chart:

A	N
128	7
64	6
32	5
16	4
8	3

Thus, if a person were able to make one choice per second from a keyboard with 128 keys, the selection rate would be seven bits per second. It is important to make the distinction here that the selection rate is not the same as the AAC communication rate. While the selection rate influences the communication rate, other factors, such as the language representation methods employed, do as well.

Language samples from LAM are reported in the following format: **20:37:00 "content"**. The time stamp is a 24 hour format with one second resolution. A space and two quotation marks follow the time stamp. The content of the language event being recorded is between the quotation marks. Each event is presented on a new line.

The original selection rate measurement required the subject to enter a series of specific selections. The LAM would time stamp and record these selections. For individuals who spell as a normal part of their communication, and the letters are selected with a predictable number of selections (generally one), spelled word LAM data can be used to determine selection rate.

The timestamp of the event of the first letter(s) of the word is the start time (S). The time stamp of the last letter (or SPACE) of the word is the end time (E). The selection rate (SR) in bits per second is defined as follows, where L is the number of letters (including SPACE) following the first event selected during the spelling process, A is the number of locations in the selection array used for normal communication, and NS is the number of selections required per letter. $SR = NS ((L) \times \ln(A) / \ln(2)) / (E - S)$. For example, if the LAM data showed that a word of eight letters (L = 8) following the first event was spelled (from an array (A) of 128 keys) with direct access to the letters (NS = 1), the first event was at 09:37:17 (S), and the last letter was selected at 09:37:27 (E), then the selection rate would be 5.6 bits per second.

The above process is applied to all spelled single words with no multiple or repeated letters and no error correction in the language sample. Considering that spelling may be interrupted or erratic, the reported selection rate is the weighted average (by L) of all calculated selection rates above the mean. The need for multiple calculations makes this potentially much more time consuming than the original method if done manually. However, as a feature in an automatic analysis program it provides routine selection rate measurement with no additional clinical procedure.

DISCUSSION

AAC professionals, in order to increase the selection rate, generally will want to maximize the number of keys available to the user. However, range of motion and pointing skill put limits on what can be done in this area. Fitts' Law (7) offers some theoretical predictions on how quickly an individual can make choices of targets of a given size located a given distance from a starting point. Since the application of Fitts' Law in the clinical setting would require information not generally available, the more practical approach is actual trials on keyboards of different sizes.

The development of selection skills requires training time. With quantitative measurement of performance, rational decisions can be made relative to level and stability of performance.

Consideration of error correction is not provided in the above procedure. This is because the number of selections necessary to correct an error is a function of features of the AAC system. The time used in generating errors is included in the test, but no consideration of correction time.

The AAC clinician is cautioned that other factors can influence communication rate. Some of these factors can be far more significant than the typical differences between some selection techniques. For example, motor planning can be important in developing communication speed. Also, an alphabet-based language representation method may produce only a single letter per selection while a whole word per selection may be produced by other methods. And navigating from screen to screen to access single meaning pictures can be problematic and time consuming.

The availability of methods for measuring selection rate has implications in the areas of clinical intervention, outcomes measurement, and research. The end result of the use of these tools is the enhanced communication and higher personal achievement of people who rely on AAC.

By having measurement tools and methods, additional information on the acquisition of personal AAC performance will be forthcoming. Understanding the characteristics of the learning process should impact AAC assessment approaches.

REFERENCES

(1) Glennen SL & DeCoste D (1997). Handbook of Augmentative and Alternative Communication. Singular Publishing Group, Inc. San Diego. pg. 249.

(2) Romich BA & Hill KJ (1999). A language activity monitor for AAC and writing systems: Clinical intervention, outcomes measurement, and research. Proceedings of the RESNA '99 Annual Conference. Long Beach, CA. pp 19-21.

(3) Hill, K & Romich B (1999). AAC language activity monitoring and analysis for clinical intervention and research outcomes. *CSUN*. Los Angeles, CA.

(4) Higginbotham DJ & Lesher GW (1999). Development of a voluntary standard format for augmentative communication device logfiles. Proceedings of the RESNA '99 Annual Conference. Long Beach, CA. pp 25-27.

(5) Romich, B, Hill, K & Spaeth, D (2000). AAC selection rate measurement: tools for clinical use. Proceedings of the RESNA 2000 Annual Conference. Orlando, FL. pp 61-63.

(6) Lucky RW (1989). Silicon Dreams New York, NY: St. Martin's Press.

(7) Fitts P (1954). The Information Capacity of the Human Motor System in Controlling the Amplitude of Movements. *Journal of Experimental Psychology*. Vol. 47, No 6.

Barry A. Romich, P.E.
Prentke Romich Company, 1022 Heyl Road, Wooster, OH 44691
Tel: 330-262-1984 ext. 211 Fax: 330-263-4829 Email: bromich@aol.com

A SUMMARY MEASURE CLINICAL REPORT FOR CHARACTERIZING AAC PERFORMANCE

Katya Hill[1,2] and Barry Romich[1,3]
[1] University of Pittsburgh, Pittsburgh, PA 15260
[2] Edinboro University, Edinboro, PA 16412
[3] Prentke Romich Company, Wooster, OH 44691

ABSTRACT

Augmentative and alternative communication (AAC) evidence-based clinical practice requires quantitative measurement of communication performance. This paper presents a clinically useful report of summary measures based on automated data logging. These summary measures provide the quantitative data necessary for a structured and methodical approach to characterizing AAC performance. Together with traditional qualitative data collection procedures, AAC users and their facilitators will have a standardized report that provides comparable, compatible, and reliable statistical analysis of performance for guiding the therapy process and measuring outcomes.

BACKGROUND

Clinical evidence characterizing the performance of individual augmented communicators has been limited at best. Few AAC clinicians collect language samples (1). Even when they do, they seldom undertake quantitative analysis that would result in performance data. More frequent clinically, AAC practitioners have relied on traditional qualitative methods to collect evidence and make assessments of outcomes.

Automated logfile data and the clinical tools associated with language activity monitoring (LAM) have provided the field with innovative methods to gather language samples. A set of basic LAM tools, developed in part under a grant from NIH, is available for use with most text-based AAC systems (2) and a comprehensive universal logfile protocol has been defined and is implemented in at least one system (3). Samples collected with these tools can be edited, coded, and analyzed using a variety of automated and manual methods. The result is a set of summary measures that have proven useful in AAC clinical service delivery.

Studies are beginning to appear regarding the performance of augmented communicators using the LAM to collect data. These early studies have looked at the frequency distribution of the various language representation methods used by augmented communicators for spontaneous novel utterance generation (SNUG) (4, 5). One study reported on the use of the LAM with a young child using an AAC device to collect evidence on vocabulary use and early word combinations (6). Current trends with the development of performance monitoring tools and outcomes measurement would indicate continued growth in the reporting of similar studies.

Standardized assessment tools will make it easier to accumulate and compare aggregate outcomes across various parameters (7). A clinical protocol to report summary measures obtained from automated data logging provides a foundation to facilitate application of these tools for clinical decision-making, outcomes measurement, and research.

OBJECTIVE

The product is a standardized summary measure report based on LAM data. The purpose is to have a systematic, principled approach to reporting summary measures that is comparable, compatible, and has reliable quantitative data for a variety of clinical applications. The LAM report can be used in conjunction with any additional qualitative data or assessment instruments collected clinically.

METHOD

Operational procedures have been developed for five basic functions needed to generate the reporting protocol. The functions start with the uploading of raw LAM data and, based on the logfile, continue with the editing, coding, analysis, and report generation. Figure 1 represents that process involved in generating a LAM report.

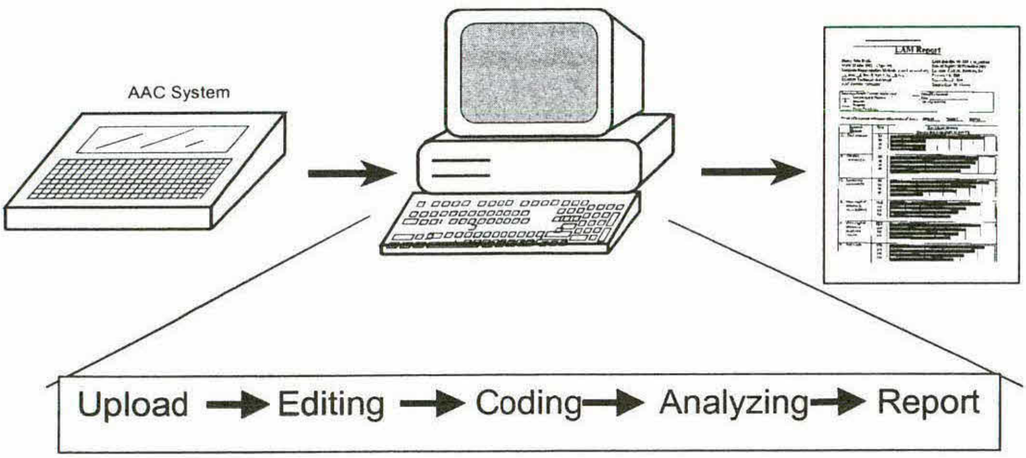


Figure 1: Steps to convert LAM data to a summary measure report.

The LAM report header contains basic personal information on the subject, AAC device and selection technique information, sample date and time information, and the method of language sample generation. Specific summary measures included at this time are: A) Total number of utterances, B) Complete utterances as a percentage of total utterances, C) Spontaneous utterances as a percentage of total utterances, D) Mean Length of Utterance in words (MLUw), E) Mean Length of Utterance in morphemes (MLUm) (A morpheme is an element of meaning. Some words can have multiple morphemes.), F) Total number of words, G) Number of different word roots, H) Average communication rate (words per minute), I) Peak communication rate (words per minute), J) Selection rate (bits per second), K) Language Representation Method analysis, L) Word selection errors per utterance, M) Spelling errors per word spelled.

In addition to the summary measures, appended reports could include the following: 1) Raw LAM data, 2) Edited utterances, 3) Coded utterances, 4) Word list in alphabetical order, 5) Word list in frequency order, 6) Word list by Language Representation Method, 7) Word list comparison to reference lists.

The data is presented numerically and graphically using a bar chart. Up to three historic references are included with the current data to provide easy identification of trends. The summary measure report is a single sheet, both sides. Additional specific reports can be appended to the

LAM Report as considered clinically useful. Figure 2 represents two sections of the report showing performance over time for the frequency of language representation method (LRM) use and word selection errors.

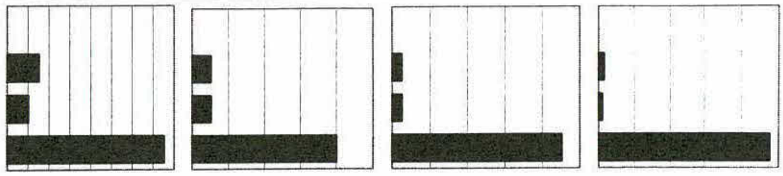
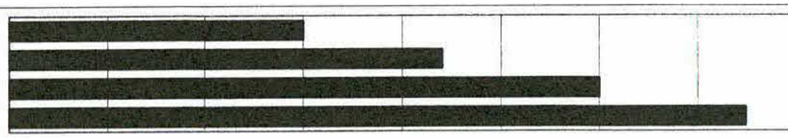
Language representation method (LRM) usage for spontaneous utterances (%)	Pic: 0 Spe: 3 Wpr: 2 Sem: 95	
Word selection errors per utterance	**.30** .44 .60 .75	

Figure 2: Typical presentation of data in the LAM Report.

DISCUSSION

A standardized report format will help to add structure to the work of the AAC clinician. It also will help to build a common foundation of information and knowledge that will facilitate the accumulation of evidence to support AAC clinical practice.

REFERENCE

1) Beck, A.R. (1996). Language assessment methods for three age groups of children. *Journal of Children's Communication Development*. 17(2): p. 51-66.

2) Hill, K. & Romich B. (1999). AAC language activity monitoring and analysis for clinical intervention and research outcomes. *C-SUN*. Los Angeles, California.

3) Higginbotham, D.J., Lesher, G.W., & Moulton, B.J. (1999). Development of a voluntary standard format for augmentative communication device logfiles. in *Proceedings of the RESNA '99 Annual Conference*. Arlington, VA: RESNA Press.

4) Hill, K.J. & Romich, B.A. (1999b). Language activity monitoring for school-aged children: Improving AAC intervention. *American Speech-Language-Hearing (ASHA) Convention*. San Francisco, CA.

5) Hill, K.J. & Romich, B.A. (1999a). Identifying AAC language representation methods used by persons with ALS. *American Speech-Language-Hearing (ASHA) Convention*. San Francisco, CA.

6) Tullman, J. & Hurtubise, C. (2000) Language activity monitoring on a young child using a VOCA. *In Proceedings of the Ninth Biennial Conference of the International Society for Augmentative and Alternative Communication*. Washington DC.

7) Jutai, J., Ladak, N., Schuller, R., Naumann, S. & Wright, V., (1996). Outcomes measurement of assistive technologies: An institutional case study. *Assistive Technology* 8:110-120.

CONTACT

Katya J. Hill, M.A. CCC-slp
Edinboro University of PA, Edinboro, PA 16444
Tel: 814-734-2431 Fax: 814-723-2184 Email: khill@edinboro.edu

OPERATIONAL PROCEDURES FOR PREPARING LOGFILES FOR COMMUNICATION RATE ANALYSIS

Katya Hill[1,3], Barry A. Romich[1,2], Jennifer Thiel[3]
[1] University of Pittsburgh, Pittsburgh, PA 15260
[2] Prentke Romich Company, Wooster, OH 44691
[3] Edinboro University, Edinboro, PA 16412

ABSTRACT

Automated data logging for AAC has become a reality with the development of performance monitoring tools such as the Language Activity Monitor (LAM). In order to facilitate widespread application of accumulated LAM performance data, procedures need to be documented and disseminated for editing logfiles to increase the usefulness of raw logfile data. One of the most valued clinical summary measures is communication rate, which can be calculated using logfile data either manually or automatically with software. However, reliability of the reported results is based on adherence to operational procedures established for each method of analysis. This paper presents procedures developed to automatically calculate communication rate.

BACKGROUND

AAC automated language activity monitoring (LAM) provides the field of AAC with tools needed to collect and analyze language samples in a variety of clinically useful contexts (1). The essential function of the LAM is the recording of each language event and the time that it occurs. Hill and Romich (2) as well as Higginbotham (3) have proposed a standard protocol for automated data logging to address compatibility issues and to facilitate the widespread application of actual user-performance data collection. Presently, the LAM function is available as an add-on device or computer monitor for any AAC system with a serial port representation of language events and as an internal function in newer high–end AAC devices. Recorded language samples include content and time stamps. The following is an excerpt of a raw LAM logfile converted to four columns:

16:26:05 "It's "	16:26:45 "l"	16:26:49 " "	16:27:11 "what "
16:26:08 "faster"	16:26:45 "l"	16:26:58 "everything "	16:27:14 "I "
16:26:14 "than "	16:26:46 "i"	16:27:02 "out "	16:27:19 "used "
16:26:41 "sp"	16:26:47 "n"	16:27:05 "which "	16:27:22 "to do "
16:26:42 "e"	16:26:48 "g"	16:27:08 "is "	

This example illustrates that the raw LAM logfile data requires editing to improve the usefulness and value of the time and content information recorded. The editing process is required to prepare the logfile for analysis. Specific procedures are required based on the software application used for analysis and the summary measures selected for reporting. To date, operationalized procedures have been developed for logfiles to be reliably edited for several analysis programs. The software programs are selected based on the summary measures available for analysis that have been proven to be clinically useful. Since communication rate is a summary measure considered highly valued and frequently requested by AAC consumers and practitioners, the focus of this paper is the procedures for editing logfiles for communication rate analysis and setting up Augmentative Communications Quantitative Analysis (ACQUA) program to provide the desired report.

STATEMENT OF THE PROBLEM

In order to maximize the usefulness of logfile data, procedures need to be developed for editing the logfiles in preparation for analysis. Specific procedures needed to be identified for editing raw LAM logfiles for calculating communication rate using the ACQUA program(4). In order to develop editing procedures, the following problems were identified: 1) the need for a systematic approach for defining and calculating communication rate, and 2) the need to incorporate this definition into any suitable software application, such as ACQUA.

APPROACH

A standard method for calculating peak and average communication rate in the clinical setting has been proposed by Romich and Hill (5). The method provides a listing of steps to be followed for converting raw LAM data into peak and average words per minute. ACQUA was developed for computing a wide variety of AAC usage statistics based on logfile data. The Romich and Hill method for peak and average communication rate calculation was added to ACQUA version 1.0. Several logfile editing procedures needed to be developed for the program to automatically calculate the same results obtained through manual calculation methods. Since ACQUA does not provide for editing capabilities within the application, editing of the raw logfiles is performed once the data is uploaded into a word processor. The most important editing step involves utterance segmentation and the insertion of an utterance terminator. Frequently, a previously prepared language transcript is used as a model for the utterance segmentation process.

A total of twelve editing rules have been documented for ACQUA to calculate communication rate. The editing process requires the following basic steps. 1) insert utterance terminators at the end of the last word of an utterance, 2) if a terminator exists, move it to the end of the last word of the utterance, 3) take out error words, 4) delete all pre-stored messages.

ACQUA requires the following features be selected to perform the peak and average rate calculations: 1) set Type = Utterances, 2) set Size = Global, 3) set Gap = 1, 4) in tool options select exclude first entry, 5) in tool options check peak value over data windows.

Pilot study data comparing the manual method with ACQUA results indicate that the statistical analyses are consistent using these operational procedures. A prototype LAM report and Communication Rate Worksheet have been designed to record and report the results for clinical application. Tables 1 and 2 are examples of analyzed reported logfile data.

Table 1: Example of results reported on Communicate Rate Worksheet for picture description task

Utterance	Words After 1st Event	Start	End	Time (sec.)	Rate (WPM)
She is just washing away, not knowing that the water is about to run over.	14	12:26:27	12:27:17	50	16.80
The brother is trying to get a cookie from the jar and it looks like it could fall.	17	12:28:18	12:29:22	64	15.94

Table 2: Communication rates for four augmented communicators' performance during an interview.

Subject	AAC System	Selection Technique	Average Rate (WPM)	Peak Rate (WPM)
1	Unity/Deltatalker	Direct keyboard	22.01	46.67
2	Unity/Liberator	Direct keyboard	18.91	35.29
3	Custom/Vanguard	Direct keyboard	16.74	20.00
4	Unity/Pathfinder	Optical Headpointing	15.55	28.00

DISCUSSION

Over 40 logfiles under two sampling conditions (picture description and interview) have been edited following the procedures described in this paper. Early inter-rater reliability in utterance segmentation is 96%, and 100% for word-by-word agreement. The use of these editing procedures is a component of the application of tools for measuring AAC performance. Standardized editing procedures provide clinicians with reporting protocols that are comparable, compatible and have reliable quantitative data for a variety of clinical applications. As improvements are made to available tools clinicians will have access to even more time efficient and accurate methods. These tools will increase the application of evidence-based practice using performance measurement based on automated data logging. This in turn will benefit people who rely on AAC through improved clinical intervention service and more consistent, periodic performance reporting.

ACKNOWLEDGEMENT

The authors wish to acknowledge the support and cooperation of the AAC-RERC. In particular, they would like to express their appreciation for the collaborative efforts with Jeff Higginbotham, State University of New York-Buffalo, and Greg Lesher and Rod Rinkus at Enkidu Research, Inc.

REFERENCES

1. Romich, B.A. & Hill, K.J. (1999) A language activity monitor for AAC and writing systems: Clinical intervention, outcomes measurement, and research. *in Proceedings of the RESNA '99 Annual Conference*, Arlington, VA: RESNA Press. 19-21.

2. Hill, K.J. & Romich, B.A. (1999). A proposed standard for AAC and writing system data logging for clinical intervention, outcomes measurement, and research. *in Proceedings of the RESNA '99 Annual Conference*, Arlington, VA: RESNA Press. 22-24.

3. Higginbotham, D.J. & Lasher, G.W. (1999). Development of a voluntary standard format for augmentative communication device logfiles. *in Proceedings of the RESNA '99 Annual Conference*, Arlington, VA: RESNA Press. 25-27.

4. Lesher, G.W., Rinkus, G.J., Moulton, B., & Higginbotham, D.J. (2000) Logging and analysis of augmentative communication. *in Proceedings of the RESNA '00 Annual Conference*. Arlington, VA: RESNA Press. 82-84.

5. Romich, B.A. & Hill, K.J. (2000). AAC communication rate measurement: tools and methods for clinical use. *in Proceedings of the RESNA '00 Annual Conference*, Arlington, VA: RESNA Press. 58-60.

Katya Hill
102 Compton Hall
Edinboro University of Pennsylvania
Edinboro, PA 16444
Tel: (814) 732-2431 Fax: (814) 732-2184
Email: Khill@edinboro.edu

DOMAIN-SPECIFIC WORD PREDICTION FOR AUGMENTATIVE COMMUNICATION

Gregory W. Lesher, Ph.D. and Gerard J. Rinkus, Ph.D.
Enkidu Research, Inc.
247 Pine Hill Road
Spencerport, NY 14559

ABSTRACT

Many augmentative communication systems employ word prediction to help minimize the number of user actions needed to construct messages. Statistical prediction techniques rely upon a database (model) of word frequencies and inter-word correlations derived from a large text corpus. One potential means to improve prediction is to create a set of models derived from domain-specific corpora, dynamically switching to the model most appropriate for the current conversation. Using telephone transcripts to generate prediction models for 20 different topic domains, we have observed a clear benefit to including domain-specific models in an overall prediction scheme.

BACKGROUND

Statistical word prediction systems for augmentative communication commonly utilize both word frequencies and inter-word correlations (word contexts). An *ngram* prediction model utilizes the past $n-1$ words to predict the nth (current) word. Easily derived from large samples of text, ngram models can provide impressive prediction performance – Lesher (1) reports on a trigram (n=3) model derived from a 3 million word corpus that yielded keystroke savings in excess of 54%.

There have been numerous techniques suggested for enhancing traditional ngram word prediction, including recency, syntactic analysis, and syntax-based ngrams. One technique that has not been fully explored is the use of domain-specific ngram models – models derived from text samples that are focused on distinct subjects or genres. In theory, these ngram models could be dynamically swapped in and out of use to match the direction of an ongoing conversation.

The text used to train a word prediction system should match as closely as possible the kind of messages produced by the augmented communicator. Although core vocabulary stays fairly constant (2), fringe vocabulary may change substantially through the course of a day as different topics and settings are encountered. The same is likely to hold true for inter-word correlations. We know of no studies that have attempted to quantify the effect of domain shifts on word prediction efficacy. As a precursor to developing a system that can automatically shift between appropriate domain-specific models, we undertook to find the keystroke savings possible in such a system.

Utilizing transcripts from the Switchboard Corpus, a series of 2,400 telephone conversations organized into approximately 60 topic domains (for example, recycling, food/cooking), we have quantified the performance gains associated with utilizing domain-specific ngram models. Although this corpus does not involve augmented communicators, it is conversational, large, and organized into specific topical domains – by far the most suitable large corpus currently available.

RESEARCH QUESTION

The question we addressed is: Can the use of domain-specific ngram models appreciably enhance word prediction performance in the context of augmentative communication? While our early studies indicated that database domain specificity did not play a significant role in system performance, recent pilot studies indicated that this question merited a more focused investigation.

METHODS

We chose to study the 20 most frequently occurring topic domains in the Switchboard Corpus. The testing texts for each of these 20 target domains was generated by concatenating all conversations of that domain from the first 12.5% of the corpus. The remainder of the corpus was used to generate the domain-specific training texts. We generated two other training texts: 1) 'Small', consisting of 5% of the training text for each of the 20 target domains, resulting in a text approximately the same size as the average of the 20 domain-specific training texts; and 2) 'Big', comprised of the entire training text. Trigram models were created for each of the 22 training texts.

The experiments were carried out using our IMPACT augmentative communication software. Running in emulation mode, this system can simulate a human using its interface to produce a message. The testing interface consisted of a standard QWERTY keyboard augmented by a dynamic 6-word prediction list. Keystroke savings (KS) were used as the performance measure.

RESULTS

We measured the performance of four prediction model configurations on each of the 20 domain-specific testing texts. The four configurations were: 1) 'Small' only; 2) 'Auto', meaning that the prediction model was derived from the same domain as the testing text; 3) 'Big' only; and 4) 'Big+Auto', a blending of two ngram models. Figure 1 shows performance on 10 representative domains. Table 1 shows average performance over all 20 domains for the four configurations.

Not surprisingly, the 'Big+Auto' configuration, with its equally weighted general and specific components yielded the best results, followed in turn by 'Big', 'Auto', and 'Small'. The almost 2% advantage of 'Big' over 'Auto' is also reasonable given its much larger training text size. However this effect is also due to the fact that the conversants were generally not experts in these domains. This boosts the relative importance of those testing text statistics correlated with *conversation* in general and the 'Big' training text constitutes a fairly large and therefore reliable sample of such general conversational statistics.

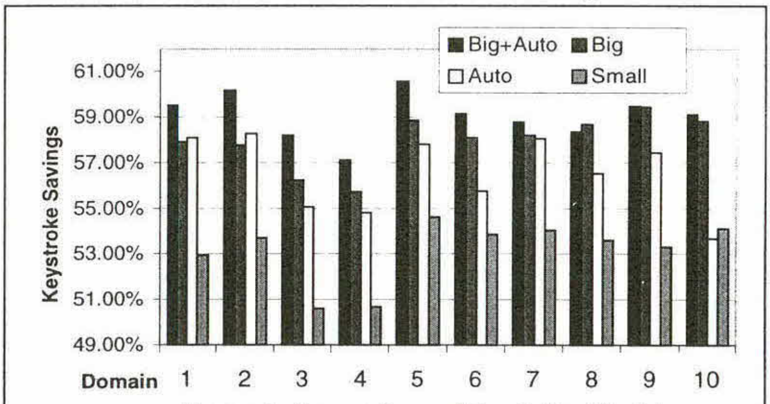


Figure 1: Comparison of Predictive Models

The 'Small' training text is only about 1/40th the size of the 'Big' training text, yet it covers a significant fraction of the domains that 'Big' does, thus rendering it a far less reliable sample of general conversational statistics. This accounts for our most interesting result which is the nearly 3% advantage of the 'Auto' configuration over the comparably-sized 'Small' configuration. Thus, for a given model size, using a model derived from text of the same domain as the testing text yields better prediction than using a model derived from a more general pool of text. As noted earlier, this is because the 'Auto' models provide a better match between the training and testing text word usage patterns.

Table 1: Average KS for four configurations

Config.	Ave KS
Big+Auto	58.74%
Big	57.81%
Auto	55.91%
Small	53.00%

Finally, we emphasize that the 'Big+Auto' configuration exceeds the 'Big' configuration by nearly 1%, despite the fact that it is only very slightly larger than the 'Big' configuration. This reinforces our main finding of the benefit of using domain-specific prediction models and suggests that as we consider larger and larger total model storage capacities, we expect the greatest incremental improvements to result from additions of domain-specific training text rather than of general text. This is the subject of ongoing studies.

DISCUSSION

Since it appears that domain-specific databases can provide substantial improvements in word prediction, where can appropriate databases be found? Existing corpora such as the Brown, Switchboard, and British National Corpora consist of text categorized roughly along various domain boundaries – topic, genre, sophistication, etc. By dividing these corpora along these categories, a series of baseline domain-specific models could be derived.

Our research team is also investigating the feasibility of culling appropriate databases from the internet using an autonomous "web crawler" (3). While the web offers a wealth of text – perhaps as much as a trillion words – this text varies widely in content, style, and sophistication. We have developed a prototype web crawler capable of searching out and retrieving specific genres of text. Such a system opens up exciting new possibilities for domain-specific word prediction since it can potentially produce very large databases – an important determiner of word prediction accuracy (1).

This paper has focused on prediction databases specific to a particular *topic* domain. The model can clearly be extended to other domain classification schemes such as style, formalness, or genre. For example, at different points during a day, a student might be working on an essay for class, a work of fiction, and a letter to a friend. By switching domains between appropriate text genres (essay, narrative, and correspondence), a word prediction system could take advantage of the word usage and syntactic peculiarities of each genre to offer more appropriate predictions.

The performance enhancements described above assume that the appropriate ngram model is always being applied to a conversation. Certainly this could be true if the augmented communicator manually switched databases as needed. Of more interest, however, is a system that *automatically* switches databases. We are currently developing a system that utilizes local conversational context to determine the current domain. Preliminary results show that on a limited set of topic domains, 80% domain switching accuracy is possible.

REFERENCES

1. Lesher, G.W. (1998). *Advanced Prediction Techniques for Augmentative Communication.* Final Report, Department of Education SBIR Phase I Contract RW97076002.

2. Beukelman, D., Yorkston, K., Pobleto, M., & Naranjo, C. (1984). Frequency of word occurrence in communication samples produced by adult communication aid users. *Journal of Speech and Hearing Disorders*, 49, 360-367.

3. Lesher, G.W. & Sanelli, C. (2000). A web-based system for autonomous text corpus generation. *ISAAC 2000*, Washington, DC.

ACKNOWLEDGMENTS

This study was supported in part by a National Institute of Deafness and Communication Disorders (NIDCD) Small Business Innovation Research grant (1 R43 DC04383-01).

Gregory W. Lesher
Enkidu Research, Inc., Spencerport, NY 14559
716-352-0507, 716-352-0508 (fax), lesher@enkidu.net

EVALUATING COMMUNICATION RATE IN INTERACTIVE CONTEXTS

Jennifer L. Cornish, Department of Linguistics
D. Jeffery Higginbotham, Department of Communicative Disorders and Sciences
University at Buffalo

ABSTRACT

This research project focuses on the analysis of communication rate during conversational interaction. We report on our current research involving: a) the development of a computer assisted tool for transcribing interactive discourse, b) a protocol for segmenting and analyzing meaning and information transfer and c) initial findings from three augmented communicators and their partners.

BACKGROUND

One of the primary goals of the augmentative communication field has been to speed up the productions of augmentative communicators, which can be summarized as the *rate problem* (1). Commonly calculated as a ratio between the number of physical actions or units of information produced by an individual or dyad over a standard period of time, the majority of research in communication rate has focused on non-interactive tasks in experimental contexts (2,3,4,5,6). Relatively little attention has been paid to the measurement of communication rate during social interaction, though it is the primary communication activity for the majority of augmented communicators. Interactive rate measurement problems include:

a) Accounting for the augmented speaker's message preparation time.
b) Dealing with speaker overlaps
c) Accounting for message co-construction during conversation.
d) Determining the information conveyed by a telegraphic utterance.

In each of the these cases, the application of the words-per-minute measure may underestimate the augmented speaker's communication rate and obfuscates the temporal dynamics and each participant's contribution to the interaction. The empirical assessment of interactive communication rate is critical to understanding what communication rates (individual or dyadic) that are necessary to sustain and shape various interactive forms of communication. (7,8).

RESEARCH GOALS

The goal of this project is to develop a comprehensive approach to measure the temporal and content characteristics of interactive communication that takes into account interactive and device-related phenomena unique to augmentative communication. This includes developing:

- Transcription technologies to improve the ease and precision of transcribing interactive communication involving augmented speakers.
- Transcription procedures to permit the analysis of interactive discourse involving augmented speakers using a variety of augmentative technologies and communication strategies. This system accounts for both temporal and proposition-type information as well as grammatical structure, co-construction and omissions.
- A preliminary temporal and informational analysis of 4 interactions involving augmented speakers and their non-augmented interlocutors.

This first phase of research largely focuses on the development of a standard system of classifying different types of units that represent utterance content, specific structural information about those utterances, and information on co-construction and omission. These units and information can then be investigated as to their interrelation with communication rate.

NOVEL METHODOLOGIES

Implementing an Effective Transcription Tool: Sonic Foundry's SoundForge

Digital video presents many potential advantages for interaction analysis, but many current software tools are inaccurate, cumbersome and inefficient (takes 1 hour to transcribe a minute of video). The software package Sound Forge functions as a media player/editor with sound wave and video interface. The researcher can directly views and manipulates the media (expand, contract, forward, backward). Transcriptions are made by directly selecting the segment of sound or video, then annotating. The annotations including associated temporal information (e.g., onset, offset, duration) can then be copied into a text file or spreadsheet for analysis. Transcription with SoundForge markedly improves transcription efficiency (up to 75%), as well as the temporal precision of the transcription.

Figure 1: SoundForge Screen

Designing an Analytical Tool: BU/SU Analysis

Segmentation of utterances into *Big Units* (BUs) represents our first attempt at dividing linguistic and gestural interaction into segments that represent both meaning and structure. The criteria for delineating these units are based on both ideas in basic linguistic theory, theories of disordered communication, and observations of augmentative interactions. The following are examples of BUs.

- *Transitive verbs, their subjects and NP or infinitival arguments;*
- *Intransitive verbs and their subjects; passive verb, its subject and its by-phrase;*
- *"To be" verbs, their subjects and predicates; Yes/No responses;*
- *Sentence-level adverbs; Question words or other questioning strategies;*
- *Phrase-level conjunction; idiomatic expressions; adjunct prepositional phrases*

BU can then be segmented into 'Small Units' (SUs). These units can be used to understand the grammatical complexity of utterances. BUs and SUs are described in detail elsewhere (8)

PRELIMINARY INVESTIGATION OF INTERACTIVE COMMUNICATION RATE

The first phase of our investigation has focused on obtaining distributional characteristics of BUs for augmented and natural speakers. Data reported here is focuses on three augmented speakers and their partners during different communication activities (lecture, conversation) and with different communication media (language board, electronic device, natural speech) (see Table 1). Although our analyses are in a very preliminary phase it is interesting to note the 10 – 15 fold disparity in BU duration and a 10- to 30 fold discrepancy for BUs per minute, for augmented versus natural speakers. The formulation and production costs associated with speaking is particularly revealing in the regression analyses in which there is statistically significant positive correlation between BU druration and the number of words per BU for each of the three augmented speakers. In contrast, for the natural speakers, no statistically significant relationship between the measures is noted and the correlation approximates 0. Also note the disparity of Carol's BU rate compared to Jeff's and Roys, reflecting her role as a communication board facilitator versus conventional addressee.

Table1:
Frequency and Duration Data for Augmented and Natural Speaker Communication.

Speakers	Number of Words		Speaking Duration			Regression: BU Dur. X Words/BU	
	Total	Median Words/BU	Total (in minutes)	Median BU (in seconds)	BU per Minute	R-squared (adjusted)	Prob.
Augmented							
Ted (VOCA/Instruct)	36	1.5	4.6	15.5	3.1	.35	0.02
Jen (Board/lect)	128	2	8.7	9.6	5.1	.65	0.01
Gerry (Board Conv)	20	3	2.1	16.4	3.3	.53	0.04
Natural							
Jeff (Ted)	100	2	0.5	1.0	58.0	.14	0.25
Roy (Ted)	126	2	0.6	0.8	58.1	.00	0.37
Carol (Gerry)	43	3	0.2	0.6	110.5	.00	0.39

DISCUSSION

Our research has primarily focused on the development of the tools for analyzing interactive communication rat with an emphasis on the quantitative analysis of meaning (i.e., Big Units). Although preliminary, We are beginning to reveal the temporal costs associated with interactive communication. The next focus of our work will be to detail the role of gesture and co-construction in the message production process.

REFERENCES

1. Beukelman, D. R., & Mirenda, P. (1992) . Augmentative and alternative communication: Management of severe communication disorders in children and adults. Baltimore, MD: Paul H. Brookes publishing Co.

2. Horstmann Koester, H. & Levine, S. (1994a). Learning and performance of able-bodied individuals using scanning systems with and without word prediction. Assistive Technology, 6, 42.

3. Lesher, G., Moulton, B., & Higginbotham, D. (1998). Techniques for augmenting scanning communication.. Augmentative and Alternative Communication

4. Mathy-Laikko, Pamela; West, Carol; Jones, Rebecca (1993). Development and assessment of a rate acceleration keyboard for direct-selection augmentative and alternative communication users, Technology & Disability, v2 n3 p57-67.

5. Todman, J. (2000). Rate and quality of conversations using a text – storage AAC system: A training study. Augmentative and Alternative Communication.

6. Higginbotham, D. J.& Wilkins, D. P. (1999). Slipping through the timestream: Social issues of time and timing in augmented interactions. In D. Kovarsky, J. Duchan, & Maxwell, M. (Eds), Constructing Incompetence: Disabling evaluations in clinical and social interaction, Hillsdale: Lawrence Ehrlbaum. 49-82.

ACKNOWLEDGMENTS

The authors wish to acknowledge support from the National Institute on Disability and Rehabilitation Research of the U.S. Department of Education under grant #H133E980026. The opinions expressed are those of the authors and do not necessarily reflect those of the supporting agency.

Computer Access and Use
(Topic 3)

A SURVEY TO SUPPORT THE DEVELOPMENT OF AN INTERFACE DEVICE FOR INTEGRATED CONTROL OF POWER WHEELCHAIRS, COMPUTERS, AND OTHER DEVICES

Katya Hill[1,3], Barry A. Romich[1,2], Edmund F. LoPresti[1], Donald M. Spaeth[1],
Jennifer Thiel[3], Rick Creech[4], Douglas Hobson[1]
[1] University of Pittsburgh, Pittsburgh, PA 15260
[2] Prentke Romich Company, Wooster, OH 44691
[3] Edinboro University, Edinboro, PA 16412
[4] Pennsylvania Training and Technical Assistance Network

ABSTRACT

A survey was developed to provide professional and consumer input into the design and development of an interface device for integrated control of power wheelchairs, computers, and other devices. The purpose of the survey was to collect and analyze data on the various components considered essential in the design of a prototype integrated controller. The web-based survey allowed for recruitment, consent, and survey completion to occur through the Internet or e-mail exclusively. Survey results indicate a strong desire for the use of integrated controls.

BACKGROUND

Many people who rely on powered wheelchairs have limited abilities to physically control a variety of needed output devices to perform common daily activities (1). A person with high-level spinal cord injury, who controls a powered wheelchair with a proportional chin mounted joystick, might need a computer for educational, vocational, or personal pursuits. A person with cerebral palsy, who controls a powered wheelchair with a proportional joystick operated with one foot, may need to control an augmentative and alternative communication (AAC) device.

In these and other cases, the clinician and consumer often identify only one control site as reliable, effective, and acceptable relative to performance and comfort. In addition, controllers and devices require space in an already limited "real estate" available to the user. Current technology solutions to multiple assistive device needs necessitate the use of either separate or "distributed" controllers placed in different locations or separate controllers interchanged at the same location. Consequently, the use of distributed controls results in cumbersome arrangements of input devices or may limit the number of assistive devices that an individual can operate (2).

Development of integrated control systems has attempted to address the problems of distributed controllers (3, 4). However, these systems have not developed or evaluated a universal interface technology. In addition, minimal information is available which identifies factors for recommending appropriate integrated controls (2). Tools for monitoring the access rate for comparing various input methods for AAC users are just now becoming available (5).

Some wheelchair control systems offer the option of an "environmental control" function. This typically provides four switch outputs that can be activated when the wheelchair joystick is moved in the corresponding directions (up, down, left, right). Accessory items are available that use those switch outputs. For example, those switch outputs may be converted to mouse emulation for use with a computer or AAC system. However, since the proportional information available from the joystick position has been reduced to four switches, pointing performance has been reduced as well.

OBJECTIVE

A Likert-type survey was developed and distributed as part of a RERC project encompassing the design, development, and evaluation of strategies and devices to promote the electronic integration of external devices with powered wheelchairs and the single control of these devices, ensuring their compatibility and usability. The purpose of the survey was to collect and analyze data on the following issues considered essential in the design of a prototype integrated controller:

- identification of all major proportional control formats used in powered wheelchairs, computer access, AAC, robotics, entertainment, and other areas of assistive technology;
- identification of specific outcomes that lead to the definition of the control bus adapter(s).
- determination of whether multiple adapters are more commercially viable than a single adapter that does everything.

METHODS

After survey development, a recruitment announcement was distributed through email and the Internet including the following listserves: 1) the RESNA SIG-11/09 listserves, 2) WheelchairNet listserve, and 3) ACOLUG (Augmentative Communication On Line User Group) listserve,

Participants fell into the categories of consumers and professionals. Consumers were considered users of powered wheelchairs with proportional control. Professionals included service providers to consumers who would benefit from integration of electronic external devices, individuals pursuing research in the development of controllers for assistive technology, and manufacturers.

The project began when the investigator activated the web site for the completed survey and posted recruitment notices. Upon receipt of a recruitment announcement as a listserv posting or personal e-mail message, potential respondents were asked to return e-mail consent. Upon receipt of consent, the sample respondents were given the web site address and password for the survey. Security measures in designing the web site and providing a password controlled access to the site and avoided duplication of responses.

The survey required approximately 20-30 minutes for completion. No response was associated with a particular individual, and the data was tabulated and analyzed in a manner to insure confidentially and anonymity of participants.

RESULTS

Data from 14 professional respondents were analyzed using descriptive statistics. Clinical service providers made up the majority of professional respondents (61%) and the second largest group was researchers (23%). Only one manufacturer and one supplier completed the survey. In addition, five consumers completed the survey.

All of the professional respondents felt that an integrated device would be useful for their clients. In addition, 100% of the respondents felt that an integrated device would be useful for people with disabilities in general. When asked to identify which was more useful for the client, a single integrated control or multiple device adapters, 83% identified a single all-purpose integrated control and 17% preferred the availability of multiple device adapters.

The following functions/options that should be performed by an integrated control were identified on an open-ended question: computer access/mouse (92%); ECU/EADL control (54%); AAC control (38%); wheelchair accessories (31%); switches/scanning abilities (23%). Additional single responses included the following suggestions: removable from chair, auto detection of device, user parameter adjustments, ability to control more than one device at a time.

Respondents identified the following communication protocols for use or access: Universal Serial Bus (USB), Apple Desktop Bus (ADB), Infrared (IRDA), parallel port/serial port (RS232), Radio Frequency (IEEE standards or/Bluetooth), General Input Device Emulating Interface (GIDEI). In addition, safety concerns included the following suggestions: clear indication of what device is in use; immediate "kill switch"/emergency shut off; backup/emergency access; interference with other devices.

Consumer responses were in agreement with features and functions for an integrated controller as well as concerns about safety. Only two respondents had tried an integrated control to operate multiple devices. Of these, one found the controller to be very easy to use, while the other respondent found the controller to be difficult to use. Three respondents were interested in using their wheelchair controller to control other devices. The respondents indicated a preference for using an integrated controller for environmental control and computer access.

DISCUSSION

The results from this survey confirm the market interest in integrated controls. While the expected performance improvement as a result of a true proportional control is as yet unknown and therefore unappreciated, the survey results provide some justification for the continued development of integrated controls.

REFERENCES

1. Angelo J, & Trefler E. (1998). A Survey of Persons Who use Integrated Control Devices. *Assistive Technology, 10*:77-83

2. Guerette P, & Sumi E. (1994). Integrating Control of Multiple Assistive Devices: A Retrospective Review. *Assistive Technology, 6*:67-76.

3. Bresler M. (1989). The Tamara System: Integrated Control of Mobility, Communication, and Environment. *Proceedings of the 12th RESNA Conference*, New Orleans, LA.

4. Romich B. (1984). Expressive Communication, Computer Access, Mobility and Environmental Control in an Integrated System. *Proceedings of the 2nd International Conference on Rehabilitation Engineering*, Ottawa, Canada.

5. Hill, K., & Romich, B. (1998). Language research needs and tools in AAC. *Annals of the Annual Biomedical Engineering Conference*, Cleveland, OH.

ACKNOWLEDGMENTS

Funding for this study was provided by the University of Pittsburgh Rehabilitation Engineering Research Center on Wheeled Mobility, National Institute on Disability and Rehabilitation Research, US Department of Education, Washington, DC (Grant #H133E990001). Opinions expressed in this paper are those of the authors and should not be construed to represent the opinions of NIDRR.

Katya Hill
102 Compton Hall, Edinboro University of PA, Edinboro, PA 16444
Tel: 814-732-2431 Fax: 814-732-2184 E-mail: khill@edinboro.edu

TOWARD DEVELOPMENT OF AN INTERFACE DEVICE FOR PROPORTIONAL MOUSE EMULATION THROUGH A POWER WHEELCHAIR CONTROLLER

Edmund F. LoPresti[1], Barry A. Romich[1,2], Donald M. Spaeth[1], Katya J. Hill[1,3], Douglas Hobson[1]
[1]University of Pittsburgh, Pittsburgh, PA 15260,
[2]Prentke Romich Company, Wooster, OH 44691, [3]Edinboro University, Edinboro, PA 16412

ABSTRACT

A Joystick to Mouse Adapter is being designed which will allow a power wheelchair joystick to provide proportional control of a computer cursor. This will provide people with the ability to use a single input method for both devices. A wheelchair controller could provide proportional mouse emulation either by directly controlling the position of the computer cursor or by controlling the speed and direction of the cursor. The Joystick to Mouse Adapter will be used to test these different control methods. More generally, the Adapter will be used to evaluate the feasibility of an intermediary device for translation between various input devices and assistive technologies.

BACKGROUND

Many people who use power wheelchairs also require access to computers and other assistive technologies, such as augmentative and alternative communication (AAC) devices and Electronic Aids to Daily Living (EADLs). Often, each device has a separate input method. However, a person may have a limited ability to physically operate these devices, and may only be able to achieve reliable and effective control at a single site (1). In this situation, the person may attempt to control multiple input devices mounted at the same site, or may rely on a caregiver to switch input devices when the person wishes to change tasks. A third alternative is to use an integrated control system. An integrated control system allows a person to operate several pieces of assistive equipment through a single, universal input device (2).

One particular application of an integrated control system is to provide computer access through a person's wheelchair controller. Some devices already translate between a wheelchair joystick and a computer, such as the DrivePoint (Bloorview MacMillan Centre, Toronto, Canada) and MouseMover (Dynamic Controls, Christchurch, New Zealand). However, these devices translate information about joystick position into switch inputs which allow a person to control the direction of cursor movement, but do not provide proportional control of cursor speed. It would be desirable for a proportional wheelchair joystick (one which allows the driver to control both wheelchair direction and wheelchair speed) to also control both cursor direction and speed on the computer.

A joystick could control the computer cursor using either position control or velocity control. With position control, the position of the cursor on the computer screen is a function of the joystick position. With velocity control, the velocity (direction and speed) of the cursor is a function of the joystick position (3). In order to select a stationary icon, the user of a position-control system will move the joystick to a position associated with the position of the icon on the screen. The user of a velocity-control system will move the joystick once to select a direction and velocity for the cursor, and move the joystick back to the center in order to stop the cursor on the icon.

Some research has been conducted to compare these control scenarios. Jagacinski and colleagues had subjects use a single-dimensional joystick to capture on-screen targets (4). Fitts' Law was found to apply whether the joystick controlled cursor position or cursor velocity. The Fitts' Law slope was steeper for velocity control than for position control, such that position control was faster for targets with index of difficulty above 4.7 bits. An index of difficulty of 4.7 bits corresponds to a situation in which the distance to a target (i.e. an icon on the computer screen) is 13 times the width of the target. If the distance the cursor must travel to the icon is less than 13 times the width of the icon, then velocity control would offer faster performance. If the cursor must travel a longer distance, then position control would offer faster performance. A higher Fitts' Law slope for velocity control, as well as faster movement times for position control at high index of difficulty, was also found for an isometric (force-sensing) joystick (5). These studies indicate that selection of a stationary icon with a position-control system is generally superior to selection with a velocity-control system (3). However, position control is not exclusively superior. The advantage of position control is greater for longer movements, or for selecting smaller icons. For targets with a sufficiently low index of difficulty, velocity control is superior.

Position control has other potential drawbacks. In a position-control system, it is necessary to hold the joystick at a desired position while also performing a mouse button click. If the joystick is not held steady it will return to the center position, causing the computer cursor to return to the center of the screen. With velocity control, a person can release the joystick and the cursor will stay in one location, since the center joystick position corresponds to zero velocity. The person can then concentrate on performing a button click.

Also, position-control systems and velocity-control systems will be sensitive to a loss of calibration in different ways. If a position-control system is properly calibrated, there will be a joystick position that corresponds to every location on the computer screen. If calibration is lost, some screen locations may have no corresponding joystick position. Those screen locations will be inaccessible. This situation can arise because communication between the mouse and the computer typically takes place in one direction; the computer receives information about the mouse position, but sends no information about cursor position.

When a velocity-control system is properly calibrated, each joystick position will correspond to a particular cursor velocity. In particular, the cursor will have zero velocity when the joystick is at the center position. If this calibration is lost, the computer will not recognize the correct center position for the joystick. The cursor may then drift even when the joystick is centered.

These calibration problems can be solved by detecting when the joystick is in the center position and either sending the computer a command to center the cursor (in position control) or by sending signals to indicate no change in cursor position (in velocity control). The velocity control solution can be implemented entirely by hardware connected to the joystick, while the position control solution will require altering the computer's software to accept the centering command.

STATEMENT OF THE PROBLEM

While research indicates that selection of a stationary icon with a position-control system is generally superior to selection with a velocity-control system, this superiority could be mitigated by factors affecting real-world computer control. It is desirable to evaluate whether position control or velocity control is most useful for cursor control in an actual graphical user interface.

DESIGN

A prototype Joystick to Mouse Adapter will be used to determine whether position control or velocity control is most useful for joystick control of a graphical user interface. The Adapter will intercept control signals from a wheelchair joystick. It will first determine whether to use the joystick information for wheelchair driving or for computer control. If the joystick is being used to drive the wheelchair, the control signal will proceed to the wheelchair controller as usual. If the joystick is being used to control the computer, a signal will be sent to the wheelchair controller to suspend driving.

When the joystick is being used for computer control, the horizontal and vertical position of the joystick will be used to determine a desired cursor position (in position-control mode) or a desired cursor velocity (in velocity-control mode). The Adapter will send a signal to the computer, and the computer will respond to this signal as if it originated from a standard mouse. Two switches on the adapter will be used as left and right mouse buttons. External switches can be used as well.

The Joystick to Mouse Adapter will initially translate between a single input device (an Invacare wheelchair controller, Invacare Corporation, Elyria, Ohio) and two target devices. These target devices will include a computer using either the Microsoft serial mouse protocol or the Microsoft PS/2 mouse protocol and an AAC system that accepts mouse input for direct selection.

DISCUSSION

A wheelchair joystick could control a computer cursor using either position control or velocity control. A person's performance with either method could be affected by factors such as the size and spacing of icons in different computer applications, use of mouse buttons, and loss of calibration between the joystick signal and the cursor position. The Joystick to Mouse Adapter will be used to evaluate both methods. These results will contribute to the development of integrated control systems for power wheelchairs and computers.

The Joystick to Mouse Adapter itself represents one approach to an integrated control system. In this approach, an independent interface device acts as a translator between other devices. Ideally, this system would require minimal alteration of the component devices since the interface device will make use of their existing communication protocols. Once the Adapter has been used to test the feasibility of this approach, it will be expanded to accept input from other wheelchair controllers. The Adapter will eventually provide the basis for a more general system, which will act as a translator between a single input device (such as a wheelchair controller) and multiple external devices (such as computers, AAC devices and EADLs). Such a universal interface method would allow consumers to integrate the assistive technologies and input methods that are best for them, without concern for limitations in compatibility between devices.

REFERENCES

1. Angelo J, & Trefler E. (1998). A Survey of Persons Who use Integrated Control Devices. *Assistive Technology. 10*:77-83
2. Guerette P, & Sumi E. (1994). Integrating Control of Multiple Assistive Devices: A Retrospective Review. *Assistive Technology. 6*:67-76.
3. Jagacinski, RJ. (1989). Target Acquisition: Performance Measures, Process Models, and Design Implications. in Applications of Human Performance Models to System Design. G.R. McMillan, D. Beevis, E. Salas, M.H. Strub, R. Sutton, and L. van Breda, (Eds.). New York, NY: Plenum, p. 135-149.
4. Jagacinski, RJ, Hartzell, EJ, Ward, S, Bishop, K. (1978). Fitts' Law as a Function of System Dynamics and Target Uncertainty. *Journal of Motor Behavior.* 10(20):123-131.
5. Kantowitz, BH, Elvers, GC (1988). Fitts' Law with an Isometric Controller: Effects of Order of Control and Control-Display Gain. *Journal of Motor Behavior.* 20(1):53-66.

ACKNOWLEDGMENTS

Funding for this study was provided by the University of Pittsburgh Rehabilitation Engineering Research Center on Wheeled Mobility, National Institute on Disability and Rehabilitation Research, US Department of Education, Washington, DC (Grant #H133E990001). Opinions expressed in this paper are those of the authors and should not be construed to represent the opinions of NIDRR.

Edmund F. LoPresti
5044 Forbes Tower, University of Pittsburgh, Pittsburgh, PA 15260
Tel: 412-647-1283 Fax: 412-647-1277 E-mail: edlopresti@acm.org

USING QUADRATURE EMULATION TO CONNECT PROPORTIONAL CONTROLS TO PERSONAL COMPUTERS THROUGH A STANDARD MOUSE

Donald. M. Spaeth[1,2], Rory A. Cooper[1,2], Songfeng Guo[1], Christina L. Wong[1,3]
1. Human Engineering Research Laboratories, VA Pittsburgh Healthcare System, Pittsburgh, PA
2. University of Pittsburgh, Department of Rehabilitation Science & Technology, Pittsburgh, PA
3. Mechanical Engineering Department, Carnegie Mellon University, Pittsburgh, PA

ABSTRACT

An electronic circuit has been developed that allows a power wheelchair joystick to be used as a computer mouse. The circuit works by translating the joystick's proportional signals into quadrature signal patterns the mouse normally samples through rotary encoders. The joystick can be connected to a PC computer through a commercial mouse controller chip. Clinical applications of this circuit include integrated controls and the option of using proportional controls not currently available with mouse port connectivity.

BACKGROUND

Individuals with upper extremity impairments are sometimes unable to use a commercial pointing device such as a mouse or trackball. Special pointing devices are available for individuals with good head control (1,2). Software is available that can translate game port input signals from a game control into mouse movement (3).

The Human Engineering Research laboratories (HERL) has built and investigated several isometric joystick prototypes over the past decade for use as alternative controls on electric powered wheelchairs (4,5). We are currently investigating whether individuals with upper extremity impairments can effectively perform mouse cursor manipulation with this type of joystick.

The HERL isometric joystick offers two signal sources that can be sampled and translated into mouse format: Serial RS232 data (12 bits, X and Y axis, 100 Hz used for data collection) and Speed and Direction analog signals generated by the joystick to emulate typical position sensing joysticks. This interface is plug compatible with most power wheelchairs. While the digital data most accurately represents the operator's hand forces, the analog signals are a commercial standard used on many electric wheelchairs; a mouse translator for this format would have application beyond our immediate research project.

PROBLEM DESCRIPTION

We desired to connect a research analog control to a computer mouse port. We considered developing micro controller code that would permit the isometric joystick to transmit directly to a computer using a standard mouse protocol such as Microsoft Serial or PS/2. This approach would be tedious, difficult to debug and require an additional handshaking line. We searched for any commercial mouse controller chips that would accept asynchronous RS232 or analog voltages as input. The mouse controllers chips we reviewed all used quadrature sampling. We did identify one mouse controller that took input from an integrated Hall effect transducer (6). This chip was deemed unsuitable because it was a very small surface mounted device and not practical to rewire.

RATIONALE

Based on our product review, we decided to try and create a hardware circuit to translate the proportional signals from our isometric joystick into quadrature signals commercial mouse controllers normally receive at their input pins. An inexpensive, massed-produced mouse controller chip would take care of all the nuances of interacting with the target computer including managing all the button protocols. The target computer could use a standard mouse driver. Quadrature emulation should also work with mice and trackballs used with Macintosh and Sun platforms. A future clinical application for this hardware could be an integrated control allowing consumers to access their computer with the same joystick they use to drive their wheelchair. A wheelchair with an infrared cordless mouse could automatically "couple up" when driven within range of a computer station.

DESIGN

Mice and trackballs translate operator movements into two streams of digital data. The rotating ball drives two orthogonal shafts each connected to a separate shutter wheel. Each wheel spins between a light source and two phototransistors. When one of the phototransistor is exposed to a light pulse, its impedance drops sharply and it pulls an input pin on the micro controller to a high state. The phototransistors are arranged 90 degrees out of phase generating different pulse patterns for clockwise and counter clockwise rotation (7). This technique is called quadrature and the stream of two bit pairs (dibits) is an application of Gray code. The controller uses these dibit sequences to calculate the speed and direction of the X and Y shutter wheels and sends updated values to the computer every 25 to 30 milliseconds. Since the controller's actions are based solely on the state of its input pins, external digital data can be substituted with frequency representing magnitude and Gray code sequences indicating direction.

Three lines from a wheelchair joystick are required to define steering intent: a reference line set at +6 volts, an X-axis line (Speed) and a Y axis line (Direction). The Speed and Direction lines are DC analog signals that vary from +4.8 volts to +7.2 volts. This voltage range represents full reverse to full forward on the Speed line and hard left to hard right on the Direction line. When compared with the reference, these signals are bipolar and swing between -1.1 and +1.1 volts. Our task was to translate these X and Y analog signals into the required Gray code dibits - a multi-step process.

DEVELOPMENT

In order to translate a wheelchair joystick into a mouse, we had to amplify the joystick signals, convert the bipolar signals into absolute values, generate pulse streams with frequency proportional to signal magnitude and translate the pulse streams into sequencing Gray code dibits. We built a simple complementary amplifier with NPN and PNP transistors. We were able to achieve adequate gain with a split +3, -3, battery power supply assembled from four standard 1.5-volt D cells. We used the same batteries in the digital section, by shifting the ground reference to obtain a one-sided, +6 volts. A voltage comparator was used to track signal polarity. The amplified bipolar signals were used to drive four infrared LEDs (X and Y axis with a separate LED for each polarity), the LEDs. We used phototransistors to read the LED and obtain X and Y axis absolute values. Magnitude-to-frequency conversion was performed by two 555 timers configured as square wave generators with our phototransistor inserted in the RC timing section. The frequency varying pulse stream was converted to sequencing binary two bit values by driving the clock of a four bit binary counter. Any two adjacent output pins from the binary counter can be sampled. Choosing a different pair of pins one is one way to change the gain. We translated the two bit values from the binary counter into two bit Gray code with two Exclusive Or Gates. One Gray code bit is created by an Exclusive Or of the two bits currently on the counter. The second Gray code bit is created by an Exclusive Or of the least significant counter bit and the direction status bit sampled by the voltage comparator. When the direction status bit is set to one, the resulting Gray code automatically cycles forward through 00,10,11,01 and the mouse will send positive updates to the computer moving the cursor either up or to the right. When the direction status bit is zero, the Gray code pattern reverses to 00,01,11,10 and the computer cursor moves downward or to the left.

The last step was to interface the X and Y Gray code streams to a mouse chip. We used photo couplers to minimize the risk of damaging the mouse's sensitive detection circuits. Our optical couplers were wired in parallel with the existing phototransistors inside the mouse. We blocked the mouse's internal LED light references with small pieces of electrical tape. The internal phototransistors stayed in a high impedance state and our external phototransistors became the signal.

PROGRESS TO DATE

A working "proof of concept" prototype has been fabricated (Figure 1). LEDs were included throughout the trial circuit to assist in tracking the logic. At low frequencies, we clearly observed the mouse cursor advancing one pixel each time the Gray code LEDs transitioned. When the voltage comparator switched logic states, the cursor reversed direction. We found experimentally that a pulse rate ranging from zero Hertz (joystick centered) to about 250 Hertz (joystick fully deflected) provided comfortable cursor control.

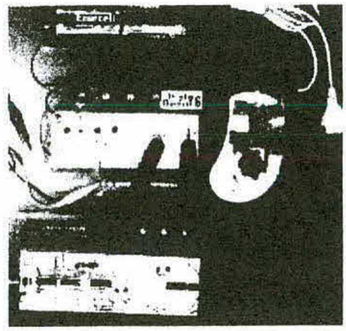


Figure 1. Experimental joystick to mouse circuit.

EVALUATION/DISSCUSSION

Six unimpaired individuals from our lab have informally evaluated the prototype joystick mouse. All were readily able to direct the cursor around the screen at various velocities and directions without difficulty. The proportional response is similar to commercial products, giving us confidence that our Gray code algorithm will work effectively at the cursor velocities needed for normal computer interaction.

The prototype amplifier needs to be tuned with trimmers to maintain good diagonal cursor movements; a sign that our amplifier is non-linear. In order to obtain digital data and repeatable accuracy in upcoming isometric joystick studies, we plan to carry out the digital to Gray code transformation using the isometric joystick's internal micro controller, coupling the final Gray code to a mouse chip. A microprocessor-based Gray code generator will make it possible to investigate more sophisticated force-to-frequency algorithms.

Quadrature emulation circuits show promise as a method for interfacing analog controls to computer mouse ports. Our trial circuit has served us well by demonstrating the viability of this technique. Improvements for the next prototype should include dual IC packages, eliminating the LEDs and substituting more linear voltage-to-frequency converters. The major component count can be reduced to four transistors and four logic chips allowing the entire circuit to fit on a single 2" X 6" board. We will continue to investigate our analog hardware for clinical applications.

REFERENCES

1. HeadMaster™, Prentke Romich Co., Wooster, Ohio.
2. HeadMouse™, Origin Instruments,Grand Prairie, TX.
3. Gus Joystick Software, Gus Communications Inc., Bellingham, WA.
4. Cooper RA, Widman LM, Jones DK et.al. (2000). "Force Sensing Control for Electric Powered Wheelchairs". IEEE Transaction on Control Systems Technology, Vol 8, No 1.
5. Cooper RA, Jones DK, Fitzgerald S, Boninger ML, Albright SJ (2000). "Analysis of Position and Isometric Joysticks for Powered Wheelchair Driving". IEEE Transactions on Biomedical Engineering, Vol 47, No 7.
6. "Hula Point™" User Company, New York, NY.
7. Torrens R (2000). "Mice: How They Work", http://www.4qd.co.uk/taq/meeece.html

ACKNOWLEDGEMENTS

U.S. Department of Veterans Affairs, Office of Research and Development, Pre-Doctoral Fellowship.

EFFICACY OF THE WORD PREDICTION ALGORITHM IN WORDQ™

Tom Nantais, Fraser Shein, Mattias Johansson
Bloorview MacMillan Centre
Toronto, Ontario, Canada

ABSTRACT

Word prediction software is a tool used by individuals who have physical difficulty selecting keys as well as by individuals who have cognitive difficulty with spelling. The quality of word predictions is an important consideration for both purposes. This paper describes simulations to test the prediction algorithm in a new product called WordQ. Keystroke savings with the most successful configuration of WordQ ranged from 46% to 53% depending on the text source. The average number of correct keystrokes needed to make a correct prediction ranged from 1.73 to 1.82.

BACKGROUND

Word prediction programs were originally designed for individuals with physical disabilities to reduce the physical demands of typing (1). Relatively recently, these programs have been adopted by educators to provide assistance to students with learning difficulties that impact on the mechanical aspects of generating text such as spelling (2). Commercial word prediction programs have gradually begun to include features specifically targeted for this purpose, such as integrated text-to-speech capabilities. Among other things, speech feedback allows a user to browse through the choices in the prediction list with the keyboard or mouse and have each choice spoken aloud. A new product developed by our group, WordQ, further integrates this type of text generation assistance with the software that people typically use for word processing on personal computers. Details about WordQ's features can be found in (3) and on the world wide web at www.wordq.com.

Although products like WordQ tend to include a large number of user-interface features, the quality of the word predictions remains a central issue. For individuals who have physical difficulty targeting the correct key, high-quality prediction means higher keystroke savings, and a corresponding reduction in the physical difficulty of entering text. For persons with spelling difficulties, a good prediction algorithm reduces the number of correct keystrokes that need to be supplied before the desired word appears in the list.

The prediction module in WordQ combines basic knowledge of word usage with optional customization to each user's vocabulary. The base language model was developed by analyzing a large sample of text gathered from the Internet. This model incorporates word and word-pair frequency statistics as the basis for predictions. The word-pair information influences the prediction algorithm directly: words that tend to follow the user's previous word are given a higher priority. As well, the language model can be set to adapt with use so that the words that a person commonly uses gradually become more likely to be predicted. The model can also learn the user's common word pairs.

RESEARCH QUESTIONS

The purpose of the simulations described in this paper is to estimate some basic performance statistics for WordQ's prediction algorithm. What percent keystroke savings is possible under simulation conditions? How many correct keystrokes must a user typically supply before the correct prediction is made? How do these results depend on the main components of the WordQ prediction algorithm: use of word-pair knowledge and adaptation?

METHOD

WordQ's pre-release source code was modified to permit these simulations. During a simulation, the program opened a text file and injected each character to the prediction algorithm in turn as if it had been typed. Table 1 contains a short description of the three diverse text sources that drove these simulations. These documents were written by three different individuals. After each character was injected, the resulting predictions were compared to the original text to keep a running total of performance statistics.

Sample	Description	Words
A	Satirical social commentary	58,422
B	Political analysis/biography	14,030
C	Scientific dissertation	44,127

Table 1: Description of text samples used in simulations

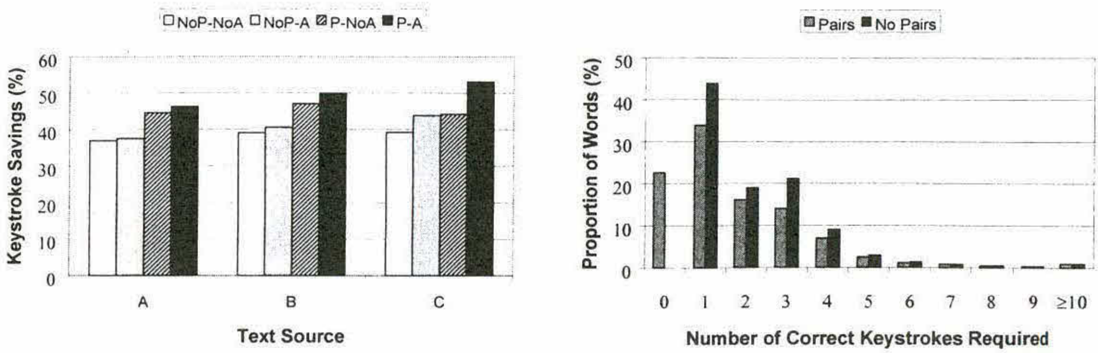
Along with the three text sources, WordQ's two main prediction features (use of word pairs and adaptation) were systematically manipulated, resulting in a total of 12 simulations. Each simulation started with the same language model, which featured a base vocabulary of 15,000 words and a backup dictionary on disk of 60,000 words. To test validity, each simulation was preceded by a rehearsal run which generated a detailed prediction log showing input characters, the resulting predictions and the simulator's scoring decisions. The log was verified manually before the full simulation.

RESULTS

Table 2 shows the performance statistics for the 12 simulation runs. The keystroke savings, also illustrated in Figure 1a on the next page, range from 37.0% to 53.1% depending on the features enabled and the text source. The results show that use of word pair information adds approximately 5-10% to the overall keystroke savings. Adaptation made a relatively small contribution to savings, except for the case of text source C, in which there was an apparent interaction between use of word pairs and adaptation. This is not surprising given the unusual nature of the text in C (a scientific dissertation). Figure 1b shows the distribution of required correct keystrokes before the desired word is displayed in the prediction list for two simulations contrasting the use and non-use of word-pair information. When WordQ took advantage of word pairs, nearly 23% of words were predicted after no keystrokes, through next word prediction alone.

		Keystroke Savings (%)		Mean Req'd Correct Keystrokes	
		No Adaptation	Adaptation	No Adaptation	Adaptation
Text A	No Pairs	37.0	37.5	2.32	2.29
	Pairs	44.6	46.3	1.89	1.80
Text B	No Pairs	39.1	40.6	2.36	2.27
	Pairs	47.1	49.9	1.90	1.73
Text C	No Pairs	39.2	43.8	2.69	2.40
	Pairs	44.2	53.1	2.38	1.82

Table 2: Performance Statistics for simulations with three different text sources. The shaded boxes show the best results, which occurred when both adaptation and use of pairs information were enabled.



(a) (b)

Figure 1: (a) Comparison of keystroke savings for all 12 simulations. (b) Histogram showing the distribution of correct keystroke requirements for text source A only, both with and without pairs information.

DISCUSSION

In these simulations, WordQ was shown to be able to eliminate approximately half of the required keystrokes, with word pair information playing an important role, and adaptation playing a lesser role, except when the text is on a very specialized subject. These results depend on a simulated user who makes no typing mistakes and always selects the desired word from the list as soon as it appears. Testing with actual users is the only way to determine if these laboratory measures of efficacy will translate into similar measures of effectiveness in the real world.

REFERENCES

1. Treviranus, J. & Norris, L. (1987). Predictive programs: writing tools for severely physically disabled students. *Proceedings of RESNA 10th Annual Conference*, Washington D.C.: International Association for the Advancement of Rehabilitation Technology, pp. 130-132.
2. MacArthur, C. A. (1996). Using technology to enhance the writing processes of students with learning disabilities. *Journal of Learning Disabilities, 29(4)*, 344-354.
3. Shein, F., Nantais, T., Nishiyama, R., Tam, C. & Marshall, P. (2001). Word cueing for persons with writing difficulties: WordQ. *Proceedings of the Sixteenth Annual International Conference on Technology and Persons with Disabilities*, California State University at Northridge, Los Angeles, CA, March.

ACKNOWLEDGMENTS

Financial support for this project was provided by the Ontario Rehabilitation Technology Consortium, supported by the Ontario Ministry of Health and Long-Term Care. A number of individuals have provided technical assistance at various stages of the project: Shae Birch, Simon Frank, Fiona Kong, Colin Laine, Sherri Parkins, Pat Stoddart, John Temprile and Jeffrey Tucker.

Fraser Shein, Ph.D., P.Eng.
Bloorview MacMillan Centre
350 Rumsey Road, Toronto, Ontario, Canada M4G 1R8
(416) 425-6220 x. 3538 fax: (416) 425-1634 email: fshein@bloorviewmacmillan.on.ca

COMPUTER CONTROL USING SURFACE EMG SIGNALS

Kim D. Adams[1], John Goldthwaite[2], Thane Plummer[3], Melody M. Moore[4], Philip R. Kennedy[1]

[1]Neural Signals, Inc., Atlanta, GA; [2]Georgia Tech, Atlanta, GA; [3]Neuralynx, Inc., Tuscon, AZ, [4]Georgia State University, Atlanta, GA

ABSTRACT

The Muscle Communicator uses electromyographic (EMG) activity to perform cursor navigation and text entry. The rate of text entry using an on-screen keyboard is measured for ten normal subjects using their thumbs and their jaw and three subjects with disabilities using their most controllable muscle sites. Normal subjects attained rates of 5.6 words per minute (wpm) with their thumbs and 4.2 wpm with their jaw and subjects with disabilities attained a rate of 4.3 wpm. All subjects attained rates within the ranges found in the literature for HeadMaster and mouthstick and their rates were higher than those found for scanning and tongue touch pad.

BACKGROUND

Many individuals with severe disabilities are only able to use a computer through a single switch interface which is slow and cognitively demanding. The theoretical maximum text entry rate using automatic row-column scanning is 5 words per minute (1). However, it is typical for users to take several minutes to complete one word (1,2). This paper describes the Muscle Communicator, an alternative computer interface that uses surface electrodes to record electromyographic (EMG) activity in muscles with little or no kinetic motion. Cursor navigation is accomplished using three muscle sites, one for cursor control in the x direction, one in the y direction and one for a mouse click. Text entry is accomplished by navigating the cursor over an on-screen keyboard. Alternately, text entry via Morse code is performed using one recording site for a dot and another for a dash. This paper reports the results of ten normal subjects and three subjects with disabilities performing text entry using the Muscle Communicator and an on screen keyboard.

RESEARCH QUESTION

Is the rate of text entry using the Muscle Communicator comparable to rates using other alternative access devices? How do the results of people with disabilities compare to those without?

METHOD

Ten normal subjects include seven males aged approximately 18 to 50 and three females aged approximately 25 to 40. Subjects with disabilities include three males aged approximately18 to 50 years and relevant information is shown in the table below.

Initials	Disability	Muscle Site	Usual computer access method
DC	Spinal Muscular Atrophy	Thumb Flexors	Regular keyboard and mouse
JG	Spinal Cord Injury	Wrist Extensor	Regular keyboard and mouse – 1 finger
RR	Amyotrophic Lateral Sclerosis	Toe Flexors	Regular keyboard and mouse – 1 toe

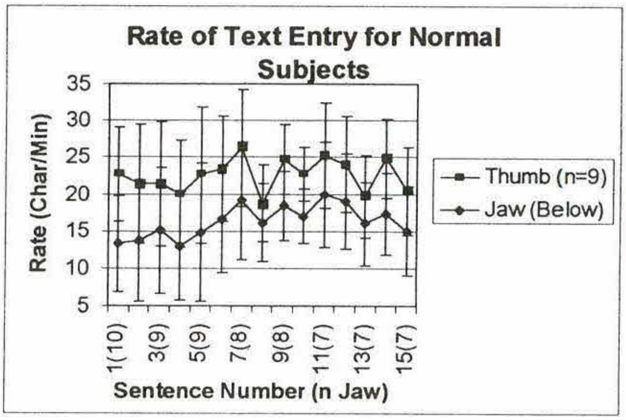
Hardware consists of an interface box that receives analog input from standard electrocardiograph (ECG) cables and outputs digital signals through an RS-232 data port. A Windows NT computer runs translation software that converts the RS-232 signals to either mouse movements or Morse code. The researcher adjusts device sensitivity, input delay (to eliminate switch bouncing) and cursor speed.

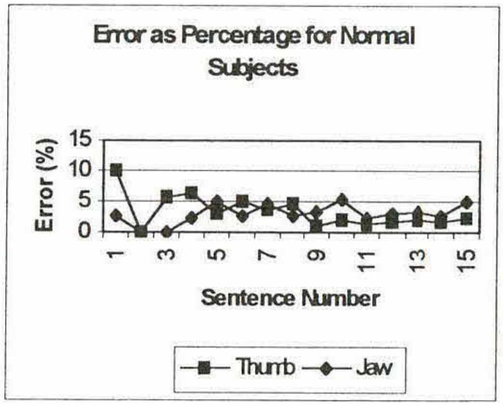
Normal subjects used two sets of muscles to perform the trials. Seven users began by using the right and left thumb flexors, right for x direction and left for y. Three users began by using the right and left jaw muscles to perform a shorter version of the trials. Trials with the thumbs were performed to establish optimum rate. The jaw was used so that comparisons can be made to people with disabilities. It is assumed that most subjects would have the use of their jaw muscles. Subjects with disabilities were assessed for their most controllable muscle sites. All subjects performed the mouse click by raising their eyebrows. The sensitivity of the Muscle Communicator is adjusted until the user indicates satisfaction that the device feedback correlates to their contraction/relaxation.

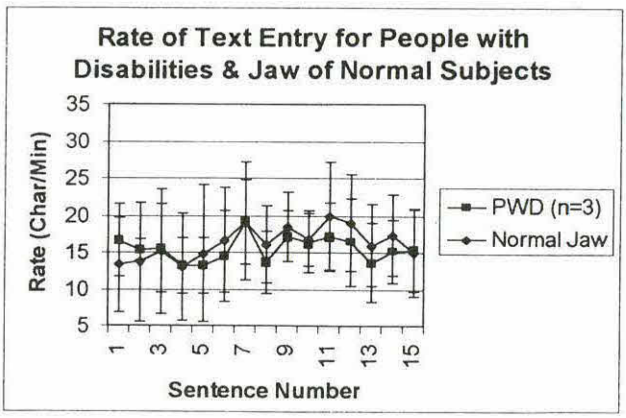
A custom, frequency based on-screen keyboard is used so that memorization of the QWERTY layout is not an advantage for some users. The space key is placed at the top left hand corner and the cursor jumps back to this space after each mouse click. A computer automated program prompts users for input and then stores the time to complete each exercise and test, time to complete each letter, and the number of errors. The researcher increases cursor speed as the user demonstrates accuracy. After practicing the exercises, the subject takes a two-minute typing test. Subjects with disabilities also take the two minute typing test with their present method for accessing the computer.

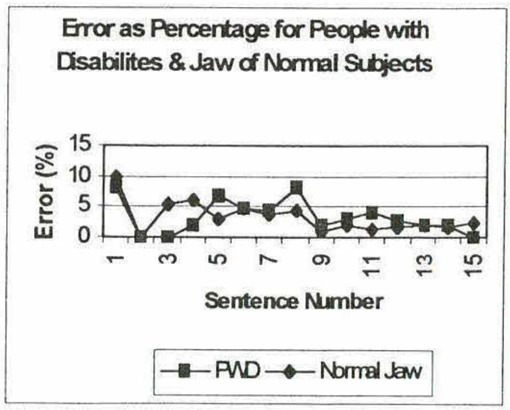
RESULTS

The following graphs show rates of text entry for the 15 exercises. The first set of graphs show rates and standard deviation for normal subjects using their thumbs and jaw. Some normal subjects had great difficulty isolating their left and right jaw function and were unable to complete all exercises in the given time. Thus, the sample size is smaller for the later sentences and is indicated on the graph. Error is shown as a percentage, showing that x% of the entries are expected to be errors. The second set of graphs show the rates for subjects with disabilities along with normal subjects using their jaw.









The following chart shows text entry rates for the two minute typing tests.

Subject Group	Char/min (wpm)	Std. Dev.	Errors/min
Normal Thumbs (n=9)	28.2 (5.6)	5.6	0.5
Normal Jaw (n=7)	20.9 (4.2)	5.4	0.4
People with Disabilities (n=2)	21.6 (4.3)	6.9	0.8

DISCUSSION

Each subject group follows the same trend for the exercises. There is a dip in rate for exercise 8 because that is when the letters at the far side of the keyboard are introduced. The dips at exercises 13 and 15 are when the shift key is introduced. The rates obtained by the people with disabilities were very close to those obtained by normal subjects using their jaw. Rates of text entry for the two minute typing tests are higher than those seen for the 15 exercises because typical sentences are composed of more frequently used letters which are closer to the keyboard "jump back" position. The rate obtained by normal subjects using their thumbs in the two minute typing trials, 28.2 char/min (5.6 wpm) is almost four times higher than the rate observed in a preliminary study using an earlier prototype, 7.1 char/min (1.4 wpm) with 0.1 errors (3). The literature for other alternative access devices reports rates of 3 to 10 wpm for HeadMaster, 4 to 6.6 for mouthstick, 2 for tongue touch pad, and 3.5 wpm for scanning (2,4,5,6). All subjects using the Muscle Communicator attained rates within the range attainable with the HeadMaster and mouthstick and the rates are higher than those for tongue touch pad and scanning.

The number of errors during the exercises is high. Most of the errors occurred when the user became de-synchronized with the letter that the testing program was requesting. When a shifted character was requested, errors were high due to a limitation in the testing program, so they were disregarded. Once the user learns to control each of the functions, x, y and click, they only need to familiarize themselves with the location of the letters on the keyboard. Even though these exercises were shortened from the set used for Morse Code training, they can be shortened even more.

Device sensitivity, flexibility, and directed cursor control make this device potentially very effective for people with severe disabilities. RR presently types with one toe at a rate of 45.0 char/min (9.0 wpm) with 0 errors. The Muscle Communicator particularly impressed him because he would like to use it instead of scanning when his disease progresses. Future work includes obtaining results from a total of 30 subjects with disabilities. Subsequently, all subjects will be tested for rate of text entry using Morse Code.

REFERENCES

1. Anson, D, (1997) "Alternative Computer Access: A Guide to Selection." F.A. Davis, Incorporated. Philadelphia, PA.
2. Simpson, RC, Koester, H, (1998). "Further Exploration of Adaptive One-Switch Row-Column Scanning for Text Entry", RESNA Proceedings, 257-259.
3. Adams, KD, Goldthwaite, J, Moore, MM, and Kennedy, P, (2000). "A Surface EMG Connection for Cursor Control and Morse Code", RESNA Proceedings, 101-103.
4. Angelo, J, Deterding, C, & Weisman, J, (1991). "A comparison of three optical headpointing systems." Assistive Technology, 3(2), 43-49.
5. Lau, C, O'Leary, S, (1993). "Comparison of Computer Interface Devices for Persons With Severe Physical Disabilities". American Journal of Occupational Therapy, 47(11): 1022-1030.
6. Campbell DeVries, R, Deitz, J, Anson, D, (1998). "A Comparison of Two Computer Access Systems for Funcitonal Text Entry", American Journal of Occupational Therapy, 52(8), 656-665.

ACKNOWLEDGMENTS: Funded by the National Institutes of Health, NINDS, SBIR #1R43NS40640-01.

CONTACT: Kim Adams, Neural Signals, Suite N-009, 430 10th Street, Atlanta, GA 30318
Phone: 404-872-5757, email: kim.adams@neuralsignals.com