

Research & Development Project Update of the Rehabilitation Engineering Research Center on AAC

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What is the RERC on AAC?

- The Rehabilitation Engineering Research Center on Augmentative and Alternative Communication
  - The RERC on AAC
  - http://rerc-aac.org
- Virtual center with a mission to improve outcomes for individuals with complex communication needs who require AAC and their families
  - Research to advance knowledge
  - Development to improve AAC technologies /apps
  - Training to build greater capacity in the field
  - Dissemination to effectively translate research & development to practice
- Funded through the U.S. National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR) through grant #90RE5017 (2014-19)

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The partners

- **InvoTek, Inc.**
  - Tom Jakobs, co-Investigator
- **Madonna Rehabilitation Hospital**
  - David Beukelman, co-Investigator
  - Susan Fager, co-Investigator
- **Oregon Health & Science University**
  - Melanie Fried-Oken, co-Investigator
- **Pennsylvania State University**
  - Janice Light, Principal Investigator
  - David McNaughton, co-Investigator

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Collaborations

- Inclusion of individuals with disabilities and family members in all RERC activities
  - Research
  - Development
  - Training & dissemination
- Active collaborations with AT manufacturers, mainstream industry, professional organizations, IHEs, educators/ rehab professionals to maximize impact

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The need

- There are millions who have severe disabilities resulting in complex communication needs (CCN)
  - Developmental disabilities
  - Acquired disabilities
  - Degenerative disabilities

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The challenge

- Many individuals with CCN are severely restricted in their participation in society
  - Education
  - Employment
  - Health care
  - Family
  - Community living

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Our vision

- Ensure that <u>all</u> individuals, including those with the most complex needs, have access to effective AAC to realize
  - the basic human need,
  - the basic human right, and
  - the basic human power of communication

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RERC on AAC

Research
- Access R1: Brain-computer interface (BCI) with enhanced language modeling
- LangTech R2: Technologies to support the transition from graphic symbols to literacy
- HCI R3: Visual cognitive processing demands of AAC interfaces

Development
- Access D1: Multimodal technologies to improve access
- LangTech D2: AAC technology to support interactive video visual scene displays
- LangTech D3: AAC technology with smart prediction
- HCI D4: Cognitive demands checklist for AAC technologies and apps

Training
- Mentored research and lab experiences, AAC webcasts and MOOC, AAC Incubator (Rehab Engineering Capstone and Hack-a-Thon) , RESNA Student Design Competition, Doctoral student Research ThinkTank

Dissemination
- Website, webcasts, YouTube channel, e-blasts, presentations, publications, consumer publications, blogs, technical assistance , exhibit booth, State of the Science conference

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Goals of the session

- To discuss the goals of the RERC on AAC and share our progress to date
  - 3 research projects
  - 4 development projects
  - 5 training and dissemination projects
- To seek input from you as stakeholders regarding our activities to date
- To brainstorm needs and directions for future research, development, training, and dissemination

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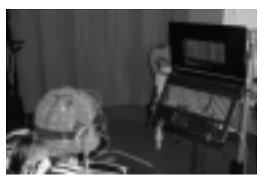
RERC on AAC Research projects

Advancing knowledge to improve outcomes

Access R1: Investigating brain computer interface (BCI)



- **Team**
  - Oregon Health and Science, Northeastern
- **The problem**
  - Brain-computer interface (BCI) provides a potential means for individuals to control a computer using only their brain waves, but limited information on
    - Safe, reliable and usable BCI systems in the home
    - Use with clinical populations
    - Support for effective use

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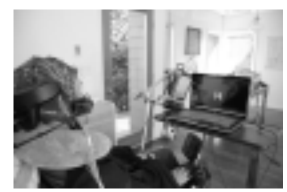
Access R1: Investigating use of a BCI with enhanced language modeling

HOW BCI WORKS



- You are fitted with an EEG cap that acquires your brain signals. You watch a screen with letters.
- When a letter that you want appears on the screen, your brain wave (the P300 event related potential) changes.
- This is averaged over time and is interpreted as a 'keystroke'.
- A language model confirms that the 'keystroke' is a statistically possible selection.

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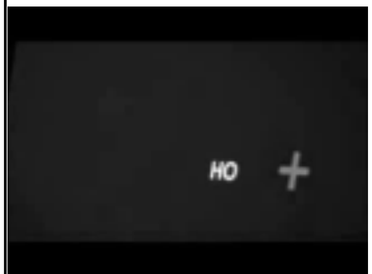
Access R1: The AAC technology problems



- BCI for communication is very slow.
- Spelling with BCI is often inaccurate.
- Language modeling has not been applied to an RSVP spelling paradigm previously.
- It is very difficult to attend to the BCI task for long periods of time.

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Access R1: Engineering solutions

- **Increase speed and spelling accuracy:** Change the language model probabilities and add an autotyping function.
- **Increase attention to the task:**
  - Provide cognitive training programs to people as they learn to use BCI

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Language Modeling

- A Language Model (LM) is a way of assigning *probability* to strings of symbols (words, letters, etc.)
- Using a large collection of real-world text, an LM learns patterns of language
- "President of the United _______"
- "FRED WAS Q_"
- Often we think of an LM in terms of conditional probability (Given X, what is the probability of Y)

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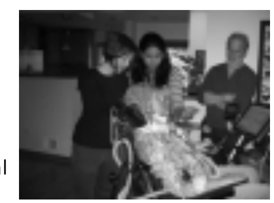
Access R1: Research hypotheses and design

- **Study 1:** Ps will attain better selection accuracy scores and spelling performance with enhanced LMs.
- **Study 2 and 3:** Ps' selection accuracy and spelling performance will improve after a 6-week training period.
- **Design**
  - Series of single subject experimental designs
    - 5 Individuals each with ALS, spinal cord injuries, brainstem stroke (N=15)



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Access R1: Independent and dependent variables; data analysis

Independent Variables

- Study 1: Enhanced language model
- Study 2 & 3: Training protocols
- **Data analysis**
- Single subject designs and compare level, trend, slope & variability of data at baseline to intervention

Dependent Variables

- Highest level completed on a copy-spelling task
- Selection accuracy score
  - Correct characters/minute
  - Total error rate

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Access R1: Expected outcomes

- Increased functionality of RSVP Keyboard™
- Increased user satisfaction with access method
- Reduced workload and fatigue
- Evidence-based training programs for all BCI users

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Lang Tech R2: Investigating AAC technologies to support literacy

- **Team**
  - Penn State/ InvoTek/ Saltillo
- **The problem**
  - More than 90% of individuals with CCN enter adulthood without literacy skills (Foley & Wolter, 2010)
  - Current AAC technologies do not support the transition from graphic picture symbols to literacy

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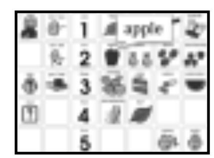
Lang Tech R2: Investigating AAC technologies to support literacy

- AAC apps to support the transition from graphic symbols to literacy
  - Individual selects a picture symbol from AAC display
  - Written word appears dynamically next to graphic symbol representation
  - Written word is spoken by the app
- Two apps
  - VSD app developed by InvoTek
  - Grid-based app developed by Saltillo



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Lang Tech R2: Investigating AAC technologies to support literacy

- App design is grounded in theory and research in visual cognitive processing, motivation, literacy learning
  - Dynamic presentation of text (rather than static)
    - Promotes visual attention
  - Pairing of text with graphic symbol & speech output
    - Promotes paired associate learning of link between written word & known referent (speech output/ AAC symbol)
  - Active selection of AAC symbol by individual with CCN to retrieve text
    - Promotes motivation, learning, functionality

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Lang Tech R2: Investigating AAC technologies to support literacy

- **Research hypothesis**
  - Individuals with CCN will increase their literacy skills as a result of using the T2L app
- **Design**
  - Series of single subject experimental designs
    - Children and adults with autism, cerebral palsy, Down syndrome/ IDD

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Lang Tech R2: Investigating AAC technologies to support literacy

- Independent variable
  - T2L app
    - VSD T2L app
    - Grid T2L app
- Dependent variable
  - Number of written words read accurately
- Data analysis
  - Comparison of level, trend, slope & variability of data across phases
    - Baseline, intervention, generalization/ maintenance

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Lang Tech R2: Investigating AAC technologies to support literacy

- 4 studies to evaluate effects of **VSD T2L app** in progress
  - Young preliterate children with ASD (Kelsey Mandak & Maggie Lamb)
  - Young preliterate children with IDD (Shelley Chapin & Ethen Richtsmeier)
  - Young preliterate children at risk and their peers in small groups (Suz Boyle & Ashley McCoy)
  - Adults with IDD (Christine Holyfield & Lauramarie Pope)

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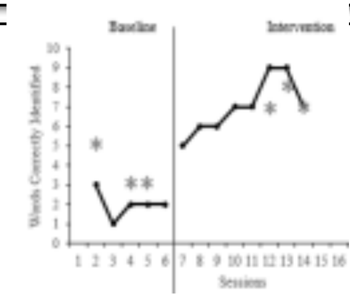
Results



Increased identification of words as a result of utilizing the VSD T2L app
Success reading single words generalized to novel photos

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Lang Tech R2: Investigating AAC technologies to support literacy

- 2 studies to evaluate effects of **grid-based T2L app**
  - School-aged nonliterate children with ASD (Jessica Caron & Clark Knudtson)
  - School-aged children with ASD with limited literacy skills (Jessica Caron, Christine Holyfield & Clark Knudtson)

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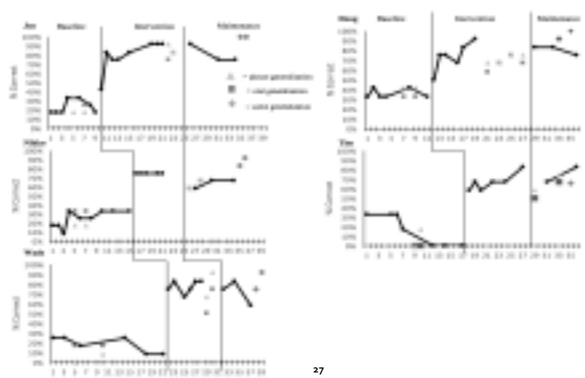
Effectiveness of T2L app with children with ASD who have some initial literacy skills (Caron et al., 2016)



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Efficiency of intervention (Caron et al., 2016)

Participant	# of intervention sessions	# of exposures to each written word	Total exposure time per word (in sec)
J	8	32	96s
N	5	20	60s
W	6	24	72s
D	6	24	72s
T	6	24	72s

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Lang Tech R2: Investigating AAC technologies to support literacy

- Preliminary evaluation data very positive
  - T2L supported acquisition of literacy skills
  - In minimal amount of time /exposures
  - Stay tuned for further results
- Implications
  - **Incorporate T2L supports in AAC apps to promote literacy development**
  - **T2L apps intended to complement not replace literacy instruction**

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HCI R3: Investigating cognitive processing demands of AAC interfaces

- **Team**
  - Penn State, Madonna, InvoTek/ Saltillo
- **The problem**
  - Most AAC displays are <u>not</u> research-based and are poorly designed
    - Impose significant visual cognitive processing demands
    - Impede communication performance

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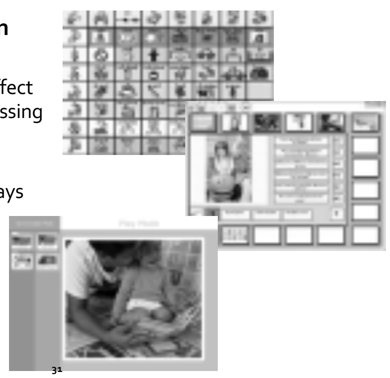
HCI R3: Investigating cognitive processing demands of AAC interfaces

- **Engineering solution**
  - Define display characteristics that affect visual cognitive processing demands
  - Determine optimal designs for AAC displays to maximize communication



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HCI R3: Investigating cognitive processing demands of AAC interfaces

- **Research methods**
  - Series of studies to investigate visual cognitive processing demands of different display characteristics with individuals with CCN
  - Eye tracking research methods

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HCI R3: Investigating cognitive processing demands of AAC interfaces

- Eye tracking research technology
  - Rapidly samples position of eye in relation to AAC display
    - Latency of fixation
    - Duration
    - Sequence of visual fixation

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HCI R3: Investigating visual cognitive processing demands of AAC interfaces

3 studies with children with CCN

- Goal
  - Evaluate effect of menu layouts on visual attention & navigation accuracy & latency
    - Top horizontal, bottom horizontal, right vertical, left vertical
  - Children with ASD, IDD, DS
- Procedures
  - Free viewing of VSDs
    - Determine elements of displays that capture visual attention
  - Cued viewing
    - Location of target VSD for navigation

Eye tracking data during navigation for participant with Down syndrome using VSDs

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Studies with adults with CCN

HCI R3: Investigating visual cognitive processing demands of AAC interfaces

Selecting Visual Scene Displays:

Personal relevance

Age and gender

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Rationale

- Visual Scene Displays (VSD) are increasing used to support communication for children and adults with complex communication needs.
  - Mobile technology contains cameras to capture "the moment"
  - Many SGDs can efficiently manage VSDs by onboard cameras, access to the web, and memory files
  - Web-based image resources (Google Image)

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Web-based Resources: Google Images

—Search based on an image

Examples of the 503 images identified by Google Images

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Purpose

- The purpose of this study was to investigate the eye tracking patterns of adults with and without disabilities who were cued to identify a VSD that represented activities such as:
  - Sleeping
  - Eating
  - Drinking
  - Writing
  - Reading

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Examples of Visual Scene Displays

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Procedures

- Equipment: Eye-Tracking with T-60 (Tobii)
- Stimuli: Screens containing 4 VSDs with adults of 3 age groups engage in an activity
  - Young female adults
  - Middle-aged female adults
  - Older female adults

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Heat Map

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Results: Women Participants
Images of Young and Senior Women & Men

Women	Female	Male
Young	90.9%	9.1%
Middle-aged	59.9%	40.1%
Older (Senior)	85.5%	14.5%

- Young and older women fixated primarily on women of their age group. Middle-aged women were influenced by lack of images of their age group.

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Conclusions

- People without complex communication needs tend to select VSD images based on gender and age range.

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Future Directions

- Future research will complete ongoing investigations of typical males as well as males and females with neurological conditions.
- Future research will investigate the influence of race on VSD selection.

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HCI R3: Investigating cognitive processing demands of AAC interfaces

- **Expected outcomes**
  - Scientifically-based design specifications for AAC displays for children & adults with CCN
    - Minimize cognitive demands
    - Maximize communication

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RERC on AAC Development projects

Access D1: Developing multimodal access technologies

- **Team**
  - InvoTek, Inc., Madonna, Penn State, Saltillo
- **The problem**
- Focus has remained on single access methods despite advanced in access technologies (eye/head tracking, touch interfaces, specialty switches).
- Challenges with focusing on a single access method
  - Fatigue due to over-use
  - Inefficiency
  - Heavy reliance/focus on methods such as dwell that require vigilance and precise motor execution

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Access D1: Developing multimodal access technologies

+ **Goals of the project**
  - Design multi-modal technology so that the best access method is always available.
    - E.g., Use a head tracker with dwell for accessing an onscreen keyboard; use an eye-blink for desktop selections.
  - Min. the shortcomings of an access method.
    - E.g., Use an eye tracking for large cursor movements and head tracking for small, corrective cursor movements.
  - Unintentional movements don't cause errors.
    - E.g., Thumb movement causes a switch closure only when the hand is still.

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Access D1: Developing multimodal access technologies

+ **Engineering solution**
  + Develop multi-modal solutions specific to individual with SSPI
  + Develop 3-D movement tracking system capable of measuring eye, head, and gestures (e.g., jaw or finger movement)
    + Proposed system will provide universal access to wide range of computer and smart/mobile technologies
    + SDK (Software Development Kit) to integrate this technology into AAC devices

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Access D1: Developing multimodal access technologies – Clinical Evaluation

+ **Preliminary Investigations:**
  + Document current multi-modal use by persons with CCN (what technology is used, why, challenges associated, impact on participation)
  + Evaluate custom solutions through case study series

+ **Systematic evaluation of movement tracking system**
+ 45 participants (15 children with CP, 15 adults with CP, 15 adults with cervical SCI)
+ Alternating treatment design (5 single access and 5 multimodal access counterbalanced sessions)
  + Target acquisition task
  + Dependent measures- accuracy, rate and movement across tasks
  + Individual feedback and personal preference/potential benefit of 3-D multimodal system

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Access D1: Developing multimodal access technologies

+ **Progress to date**
  + Survey of multi-modal use by individuals with CCN
    + currently data collected on
      + 5 with SCI
      + 2 with ALS
      + 3 with CP

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Preliminary survey results

	1	2	3	4	5
TouchScreen		X		X	
Keyboard		X			
Standard Mouse					
Adapted Mouse					
Eye gaze	X	X	X		X
Head tracking					
Switch scanning	X		X	X	X

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	Eye gaze	Scanning	Touch Screen	Keyboard
Typing/Writing	XXXX		X	X
Opening Programs	X	XXX	X	
Scrolling	X	XXX	X	
Clicking on small buttons	X	XXX	X	

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	Eye gaze	Scanning	Touch Screen	Keyboard
F2F communication	XXXX	X	X	
Email	XXXX	XXX	X	X
Managing medical appts	XXXX	XXX		
Social networking	XXX	X	X	X
Reports/letters	XX			

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Developing multimodal access technologies

- Case study illustrations:
  - Alison, Tiffany
- Two 3-D tracking systems in design
  - 1st gen 9-axis sensor system completed. Seeking funding to create robust movement learning system
  - 1st gen camera-based hardware design completed. Firmware and software underway.
- Expected outcome: New genre of access technology

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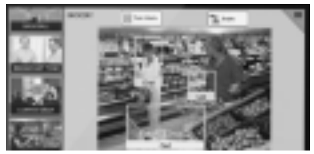
Lang Tech D2: Developing technologies with video visual scene displays

- **Team**
  - Penn State, InvoTek
- **The problem**
  - Many individuals with CCN benefit from visual scene displays (VSDs)
  - Current AAC apps with VSDs are limited to static photo VSDs; fail to capture dynamic events
  - Video offers potential to capture dynamic events but current AAC technologies only support passive video viewing



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Lang Tech D2: Developing technologies with video visual scene displays

- **Goals of the project**
  - To develop a mobile technology AAC app that supports video visual scene displays
  - To investigate the effects of the video VSD app on communication by individuals with CCN

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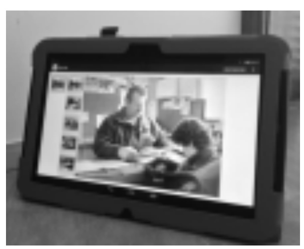
Lang Tech D2: Developing technologies with video visual scene displays

- **Engineering solution**
  - Capture video of daily routines
    - Via built in cameras & wireless import
  - Allow pause of video
    - Create VSDs at these junctures
    - Create hotspots with speech output



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Lang Tech D2: Developing technologies with video visual scene displays

- **Clinical evaluation**
  - Series of single case studies
  - Investigate the effects of the video VSD app on the communication & participation of individuals with CCN
    - Children and adults with autism, IDD, cerebral palsy

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Lang Tech D2: Developing technologies with video visual scene displays

- Study #1 (Tara O'Neill)
  - Investigate effects of video VSD app on independent participation in community-based activities / employment by adolescents with CCN
  - Preliminary case study results demonstrate significant increases in successful independent participation

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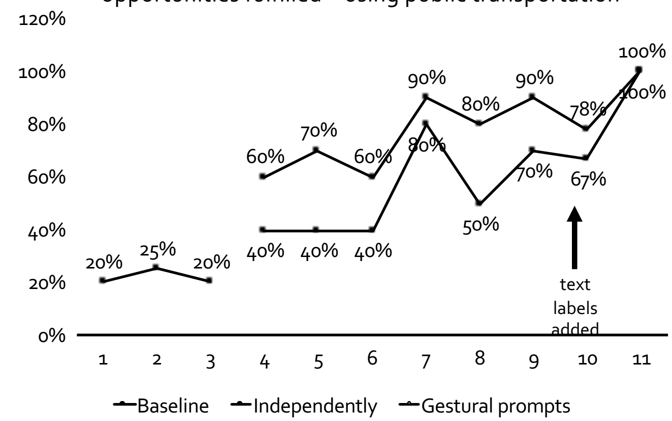
Percent of steps completed and communication opportunities fulfilled – using public transportation



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Lang Tech D2: Developing technologies with video visual scene displays

- Study #2 (Jessica Caron)
  - Investigate the effects of video VSD app on frequency & effectiveness of social interactions by school-aged children with ASD
  - Preliminary results demonstrate substantial increases
    - Frequency of turns
    - Initiations

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Lang Tech D2: Developing technologies with video visual scene displays

- Study #3 (Ashley McCoy)
  - Investigate effects of video VSD app on successful transitions & challenging behaviors of school-aged students with ASD

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Lang Tech D2: Developing technologies with video visual scene displays

- Output
  - New research-based video VSD app that
    - integrates communication into video
    - enhances communication and participation of children & adults with CCN

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Access D3: Developing AAC technologies with smart prediction

- **Team**
  - Oregon Health & Science University, InvoTek, Saltillo
- **The problem**
  - Slow communication speed violates conversation rules and isolates people who rely on AAC.
  - Communication partners have contextual knowledge, but no way to support written AAC message construction.

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Access D3: Developing AAC technologies with smart prediction

- **Goals of the project**
  - Develop a unique AAC system that incorporates the communication partner's knowledge into the AAC device prediction list.
  - The end result:
    - increased speed and informativeness of face-to-face conversations,
    - More control for AAC user in social interactions.

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Access D3: Developing AAC technologies with smart prediction

- **Engineering solution**
  - Develop a unique AAC system that incorporates the communication partner's knowledge into the AAC device prediction list.
  - The end result:
    - increased speed and informativeness of face-to-face conversations,
    - More control for AAC user in social interactions.

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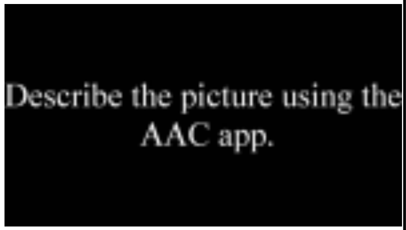
Access D3: Developing AAC technologies with smart prediction

- **Clinical evaluation**
  - The study will evaluate impact of Smart Prediction on conversation (rate, informativeness, satisfaction) compared to standard prediction
  - Testing will occur in the community, in Oregon.



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Access D3: Developing AAC technologies with smart prediction

- **Progress to date**
  - Prototype apps have been designed and tested.
- Data collected using an alternating treatment single case design from
  - 3 adults with CP using direction selection
  - 1 adult with ALS using single switch scanning
- *Improvements in speed of message production* with input from knowledgeable partner and system's word prediction:
- Increases rate of word production in 10 minute period.
- Increases in number of CIUs and amount of information produced in a 10 minute period.

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Access D4: Developing a Cognitive Demands Checklist for AAC Technologies

- **Team**
  - Oregon Health & Science U.
- **The problem**
  - Communication technology should be matched to the cognitive needs and abilities of the user
  - Current feature matching tools do not address the cognitive demands of AAC use
  - We have not examined the cognitive demands of AAC technologies and apps

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HCI D4: Developing a Cognitive Demands Checklist for AAC Technologies

- Our goal: Develop, evaluate, and distribute the AAC Cognitive Demands Checklist (CDC) to
- Assist clinicians with person-technology matching
- Help developers understand the cognitive demands of AAC technologies and design improved products

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HCI D4: Developing a Cognitive Demands Checklist for AAC Technologies

- **Engineering solution**
  - Examine feature lists for existing AAC devices and software/apps
  - Identify requisite cognitive skills and propose checklist items
  - Determine domain and content relevance of features for a range of AAC technology
  - Develop scale to rate the cognitive load of each feature
  - Launch web-based checklist

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HCI D4: Developing a Cognitive Demands Checklist for AAC Technologies

- **Clinical evaluation and testing**
  - Validate checklist content with national AAC stakeholders for cognitive domains and AAC features
  - Revise checklist based on stakeholder feedback
  - Conduct survey with different stakeholder groups to develop a cognitive rating scale
  - Researchers complete checklist for features of existing AAC technologies to establish intra-rater reliability
  - AAC stakeholders complete checklist for features of existing AAC technologies to establish inter-rater reliability

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Access D4: Developing a cognitive demands checklist

- Progress to date
  - Cognitive domains for the AAC-CDC have been identified
  - Feature list for AAC devices/apps has been compiled
- Survey to determine cognitive rating scale for each feature has been developed and is ready to administer to 60 stakeholders:
  - People who rely on AAC
  - Clinicians
  - Developers

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HCI D4: Developing a Cognitive Demands Checklist for AAC Technologies

- **Expected outcomes of the AAC-CDC**
  - Web-based application
  - Available on multiple websites
  - Free of charge to AAC stakeholders
  - Marketed through AAC stakeholder groups and industry conferences
  - Added to GPII shelf of Raising the Floor Consortium
  - Eventually available in multiple languages and in Braille format
  - Broad accessibility (universal design)

RERC on AAC
Training & dissemination

Training & Dissemination

- Professionals (pre-service and in-service)
- Persons with complex communication needs
- Family members

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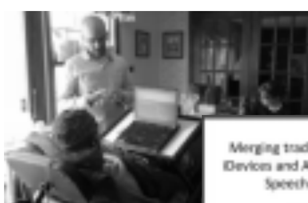
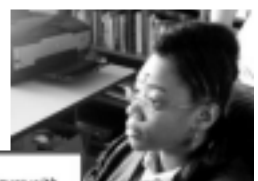
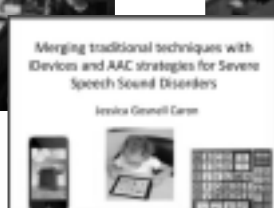
T1: Mentored Research and Lab experiences
- 59 students in 2015/16







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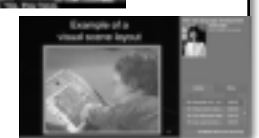
T2. Webcasts & MOOC

- 12 webcasts on AAC
  - Quizzes for preservice training
  - CEUs for inservice education
  - Research to practice
  - First person narratives



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MOOC: Massive Online Open Course

- Modules on range of AAC topics
  - E. g., early intervention, transition, funding, literacy, access for individuals with minimal movement
- Materials
  - Readings: Open access articles, summaries
  - Webcasts: presentations, "first person" accounts
  - Activities: Answers to FAQs, think/pair/share activities
- Assessment
  - Quizzes, AAC materials
    - CEUs, course credit (at home institution)

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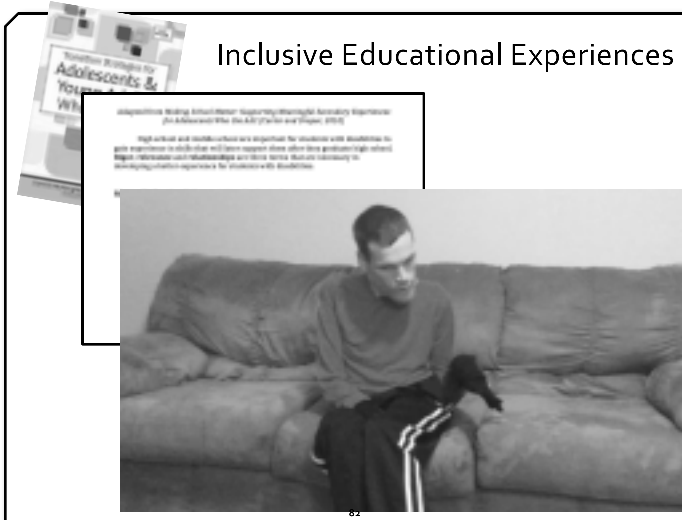
Inclusive Educational Experiences



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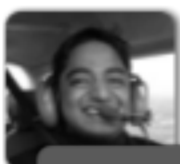
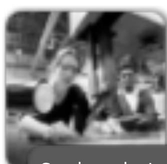
T3. AAC Incubator

- Persons with ALS who use AAC (2016)



Focus groups of persons who use AAC to identify needs /priorities



Student design teams
- Learning Factory
- RESNA competition

RESNA SDC
- Prototypes
- Feedback to manufacturers
- Presentations, publications

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T4. AAC Student Design Competition

- 2016: Tone of voice in AAC systems

2016 Student Research & Design Competition: Tone of Voice in AAC Systems

by David McNaughton on January 16, 2016 in News

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2017 AAC Student Design Competition
- AAC use in hospital settings

+ Deadline: May 12, 2017
+ Up to $3,000 in award money
+ *Entries for this competition should advance our understanding of engineering solutions to the challenge of AAC use in hospital settings*

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T5. Doctoral Student AAC Research Think Tank
- Summer 2017




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Doctoral Student AAC Research Think Tank

+ 3 days in May, 2017
+ Penn State University
  + State College, PA
+ Presentations and activities for Doctoral students with strong interest in AAC
+ Please complete survey at rerc-aac.org

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Dissemination
rerc-aac.org

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Outcomes of the RERC on AAC to date

- Initiated 17 new research studies to advance knowledge and improve outcomes for individuals with CCN, including both children and adults with a diverse range of disabilities
- Developed 5 new engineering solutions to advance AAC technologies and improve outcomes for individuals with CCN, including individuals with a wide range of needs and skills
- Mentored a total of 59 students in our labs, including 31 engineering students and 28 rehab scientists
  - 10 of these students recognized with national /international awards this year

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Outcomes of the RERC on AAC to date

- Published 19 peer-reviewed publications
  - 12 papers in peer-reviewed journals
  - 7 peer-reviewed conference proceedings
- Completed more than 13 presentations in the past year at state, national, and international conferences to disseminate results and build capacity in the field
- Organized a virtual forum of individuals who use BCI at an international conference
- Submitted several new grant proposals and continued work on 4 other grants to extend our RERC work even further

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Our vision

- Ensure that all individuals, including those with the most complex needs, have access to effective AAC to realize
  - the basic human need,
  - the basic human right, and
  - the basic human power of communication

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Discussion

- How can we enhance our current research, development, training, and dissemination activities?
- What are the priorities for future
  - Research
  - Development
  - Training and dissemination?

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RERC-AAC.ORG

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- NIDILRR is a Center within the Administration for Community Living (ACL), U.S. Department of Health and Human Services (HHS). The contents of this presentation do not necessarily represent the policy of NIDILRR, ACL, HHS, and you should not assume endorsement by the Federal Government.

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