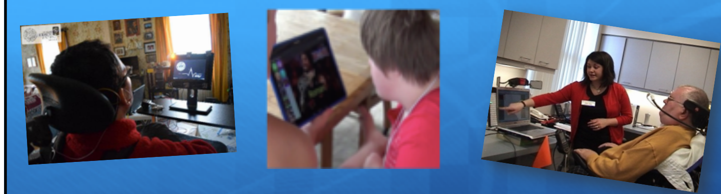

Research & Development Project
Update of the Rehabilitation
Engineering Research Center on AAC

D. Beukelman, S. Fager, M. Fried-Oken,
T. Jakobs, J. Light, & D. McNaughton

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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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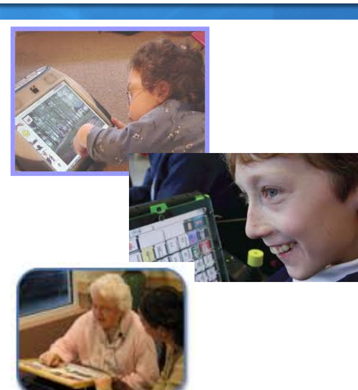
The need

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



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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

- **Team**
  - **OHSU:** Melanie Fried-Oken
    - Betts Peters
    - Brandon Eddy
    - Michelle Kinsella
    - Tab Memmott
    - **Northeastern:** Deniz Erdogmus
      - Cognitive Systems Laboratory students
- **The Problem**
- Individuals with Locked-In Syndrome have no reliable, consistent access method for communication.
- Visual typing BCI systems require skills including visual acuity and ocular motility, potentially creating barriers to effective use by people with CCN and visual impairments.

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Access R1: Investigating brain computer interface

Visual function is frequently impaired in people with LIS

- Mean visual acuity is 20/60
- Abnormal ocular motility skills present in 77%
- Diplopia present in 46%
- Nystagmus present in 46%
- Abnormal visual fields present in 17%
- Photophobia present in 22%

Graber, M., et al. "Evaluation of the visual function of patients with locked-in syndrome: Report of 13 cases." Journal Français d'Ophtalmologie 39.5 (2016): 437-440.

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Access R1: Investigating brain computer interface

- **Engineering solution**
- **SHUFFLE SPELLER**
- Typing interface
  - Used here with noninvasive SSVEP BCI, but could work with other access methods
- Integrated language model
- Multiple queries per selection
  - Greater uncertainty → more questions
  - Robust to errors

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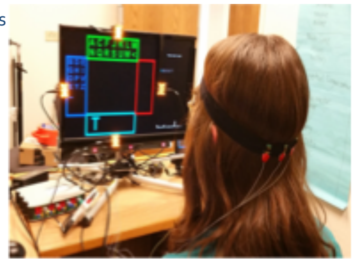
Access R1: Investigating brain computer interface

- Research question
  - How do simulated visual acuity and ocular motility impairments affect Shuffle Speller BCI performance in healthy adults?
- Design: Use SSVEP
  - Steady-state visually-evoked potential
  - Brain response to oscillating visual stimulus (e.g. flashing light)
  - Measured over visual cortex
  - Can be measured with noninvasive electrodes
  - High signal-to-noise ratio



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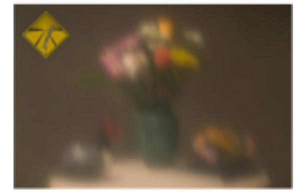
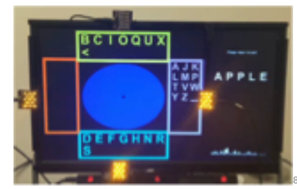
Access R1: Investigating brain computer interface

- Independent variable: CONDITION
  1. Unimpaired
  2. Simulated acuity impairment (20/200 goggles)
  3. Simulated motility impairment (fixation circle)
- Dependent variables
  1. Accuracy (correct selections/total selections)
  2. Typing speed (characters per minute)
  3. User experience
     - Comfort & Workload
     - Satisfaction





Access R1: Investigating brain computer interface

- Hypotheses
- Simulated visual acuity impairment will have little effect on Shuffle Speller BCI performance
- Simulated ocular motility impairment will significantly affect performance
  - Few people will be able to type
  - Those who can type will experience slower speeds

- Experiment
- Crossover design
- Each participant copy-spells 10 words with Shuffle Speller under each condition
- 3 data collection visits
- Randomized condition order

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Access R1: Investigating brain computer interface

- Participants for Phase 1:
- 38 healthy controls
- Aged 37 ± 15
- Passing score on Telephone Interview for Cognitive Status
- Corrected visual acuity 20/40 or better
- Screening indicates no deficits in visual field or ocular motility

- Participants for Phase 2:
- Individuals with severe speech and physical impairments secondary to Locked-In Syndrome

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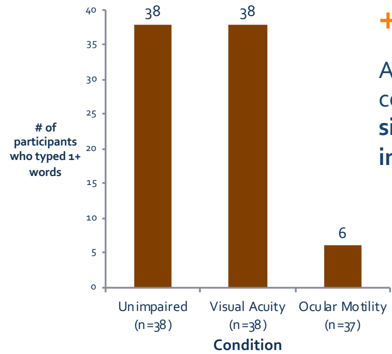
Access R1: Investigating brain computer interface



+ COPY-SPELL ABILITY

All participants could copy-spell with **simulated visual acuity impairment of 20/200.**

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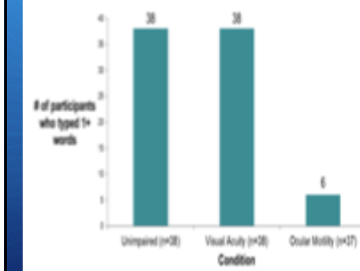
Access R1: Investigating brain computer interface



+ COPY-SPELL ABILITY

6 of 37* participants copy-spelled 1+ words with **simulated ocular motility impairment**

*eye tracker could not be calibrated for one participant

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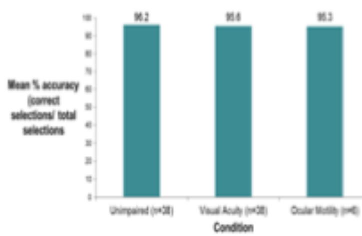
Access R1: Investigating brain computer interface



+SELECTION ACCURACY

Accuracy unaffected by simulated visual acuity impairment

Accuracy was high for 6 participants who could spell with reduced motility

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Access R1: Investigating brain computer interface

- **User experience (N=38)**
  - Unimpaired and acuity conditions:
    - Low workload
    - Low discomfort
    - High satisfaction
  - Motility condition (regardless of typing success):
    - Higher workload
    - Greater discomfort
    - Lower satisfaction

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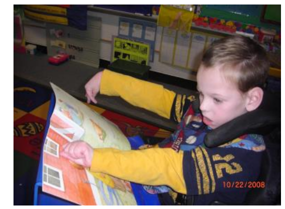
Access R1: Investigating brain computer interface

+ **Implications**
+ Acuity impairment of 20/200 (legal blindness) is not an obstacle to Shuffle use
+ Some people may be able to use Shuffle with reduced ocular motility

+ **Next Steps**
+ Test Shuffle Speller BCI with PSSPI
+ Conduct visual simulation experiment with PSSPI
+ Compare and add multi-modal access methods (eyegaze)

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



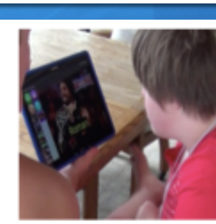
Transition to Literacy (T2L) Software Features

+ **Transition to literacy (T2L)** software feature
  + Individual selects a picture symbol from AAC display
  + Written word appears dynamically
  + Written word is spoken by the app

+ 2 apps
  + Grid-based T2L app developed by Saltillo (Hershberger)
  + VSD T2L app developed by InvoTek (Jakobs)
    + Incorporated into SnapScene by TobiiDynavox

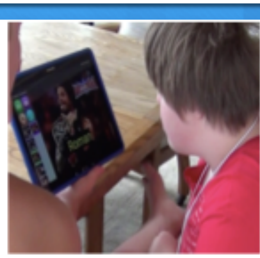
T2L feature for AAC apps
A first step in the transition to literacy

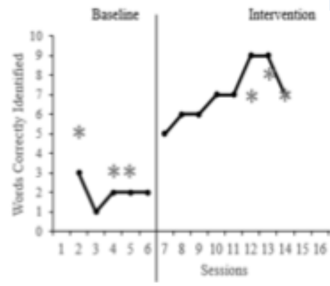
+ T2L apps are intended to **complement, not replace** literacy instruction



+ Current T2L apps
  + only support sight word acquisition
  + are a **first step** in technologies that provide a direct bridge from picture-based systems to literacy
+ Future developments are required to further support the full transition to literacy

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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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	96 sec
N	5	20	60 sec
W	6	24	72 sec
D	6	24	72 sec
T	6	24	72 sec

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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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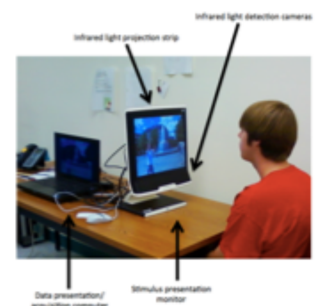
HCI R3: Investigating cognitive processing demands of AAC interfaces

- **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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Studies with adults with CCN

HCI R3: Investigating visual cognitive processing demands of AAC interfaces

Selecting Visual Scene Displays:

Personal relevance

Age and gender

Web-based Resources

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)

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

Procedures

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

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.

Results: Young Male Participants
Images of Women & Men

	Female	Male
Young Males	24%	76%

- Young men focused on male as compared to female images. Ongoing data collection for older men.

Results: Men and Women with Stroke

Participants	Female	Male
Males	0%	100%
Women	80%	20%

Ongoing data for men and women with stroke.

Eye-Gaze Plot Analysis of Visual Scene Displays with Vertical and Horizontal Menu Options

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- The purpose of this study was to investigate the eye tracking patterns of adults with and without disabilities to were cued to identify a VSD that represented activities in vertical and horizontal menu bars

Results: Young and Middle-aged Women, Individuals with Stroke- First Fixation on Top or Left Menu bar

Women	Top	Left
Young women	63%	37%
Middle-aged women	67%	33%
Young Men	72%	28%
Individuals with Stroke & TBI	60%	40%

Conclusions

- They tend to fixate initially on the top menu bar are leaving the main image.

Future Directions

- Focus on visual attention to symbols routinely used in patient provider care
- Use of video VSD for patient provider communication and staff training

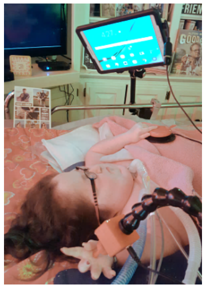
HCI R3: Investigating cognitive processing demands of AAC interfaces

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

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 advances 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
  - Some access methods require optimal set-up, positioning and environmental conditions to be relied on exclusively as an access method



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Access D1: Developing multimodal access technologies

+ **Goals of the project**
  - Design multi-modal technology so that the multiple access method are available.
  - Minimize the shortcomings of a single access method.

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Access D1: Developing multimodal access technologies

+ **Engineering solution**
  + Development of prototype eye tracking + switch scanning system

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Access D1: Developing multimodal access technologies – Eye tracking + Scanning Prototype

+ Eye tracking identifies "cluster" of letters
+ When target letter is in the highlighted "cluster", user activates a switch
+ All letters within the "cluster" are then scanned, user activates switch when target letter is reached
+ Letter is then inserted into message window

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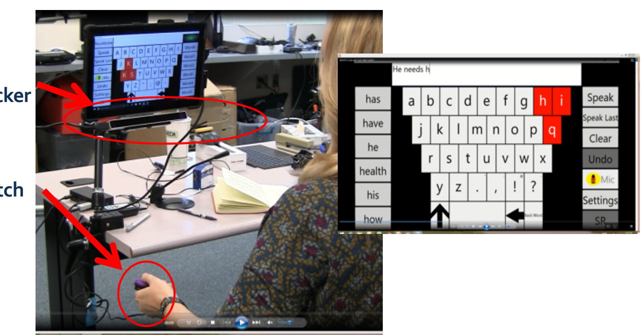
Eye Tracker

Switch



Access D1: Developing multimodal access technologies – Clinical Evaluation

- 2 primary groups
  - Group 1: Individuals with SCI and/or tetraplegia due to other conditions
    - Exploration of multimodal system as alternative access option due to challenges experienced consistently using eye tracking
    - Example: tech dependent group that is often highly mobile (multiple positioning environments that make eye tracking difficult) and often have medical complications (bed rest for wound healing is challenging position for successful eye tracking access through out the day)
    - Can eye track- only under optimal settings
  - Group 2: Individuals who rely on AAC (e.g., CP, brainstem stroke)
    - Exploration of multimodal system as alternative access option due to poor performance using eye tracking

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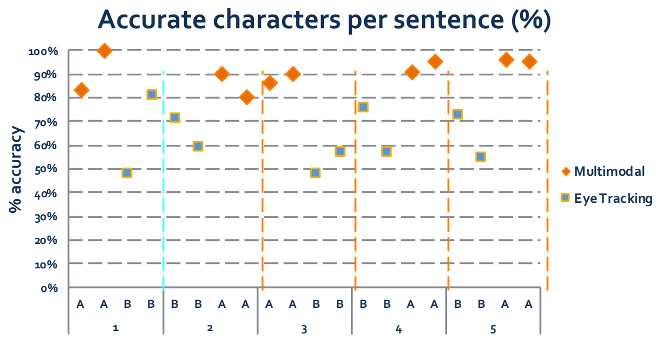
Preliminary Results: Case Illustration

- Participant description
  - Brainstem stroke (3 months post onset)
  - Tetraplegic with emerging hand movement
  - Significant occulomotor control challenges with spot patching on glasses required for diplopia
  - Challenges with eye tracking due to eye motor control deficits

Preliminary results: Accurate characters per sentence



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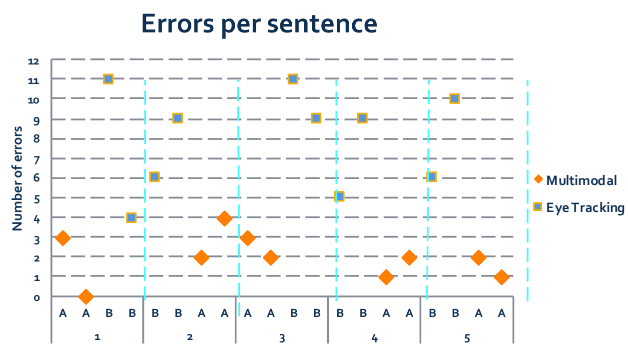
Preliminary results: Errors per sentence



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Future Directions

- Systematic studies comparing single vs. multimodal access strategies (alternating treatment design)
- Trials of other combinations of access methods
- Saturday, 9:20
- Bonaire 6

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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

- **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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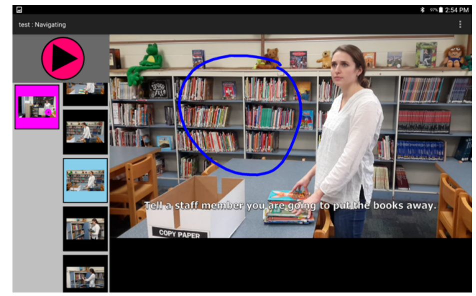
Lang Tech D2: Developing technologies with video visual scene displays

Babb, Gormley, Light, & McNaughton (2018)

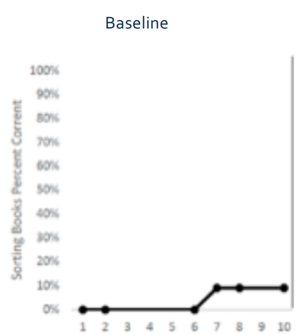
- 18 year old male with autism
- High school student
- No functional speech
  - A few signs – mostly yes/no, thank you
- Prompt dependent
- Local elementary school library
  - 3 tasks – Checking in books, putting away/sorting books, and making dye cuts

Task Analysis: Putting Books Away

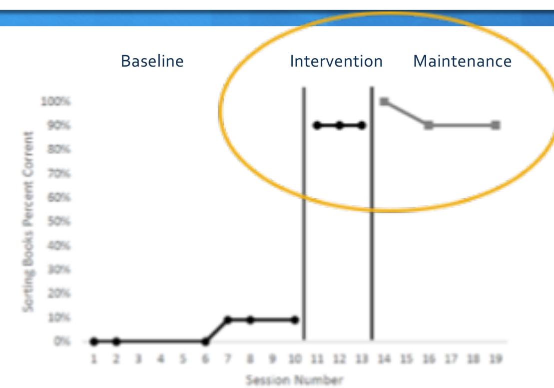
1. Ask to put the books away: **Can I put the books away?**
2. Pick up the box of books
3. Bring the box to the table
4. Empty the books on to the table
5. Sort the books into piles based on categories

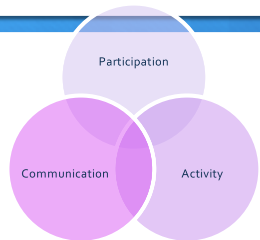


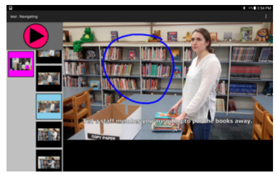
Results: Putting Away Books/Sorting



Results: Putting Away Books/Sorting







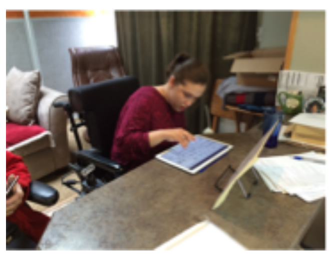
Salena Babb will present
Friday at 4:30 – 5:30 pm, Curacao 4

RERC on AAC Partner Disclosures

- Melanie Fried-Oken receives a salary from the Oregon Health Sciences University and has research grants from NIH and NIDILRR. She has no personal disclosure to report.
- Tom and Erik Jakobs are paid employees of InvoTek, Inc.

Access D3: Developing AAC technologies with smart prediction

- Team
- Invotek: T Jakobs
  - Erik Jakobs
- OHSU: M Fried-Oken
  - Michelle Kinsella
  - Rebecca Pryor



Access D3: Developing AAC technologies with smart prediction

- **Challenge**
  - Using an AAC spelling device to type out messages during spontaneous conversation is *very* slow. The rate of message production violates verbal interaction rules, leading to isolation or impoverished communication of AAC users.
- **Goal**
  - To increase the speed of message generation in an AAC spelling device and the engagement of communication partners by relying on the knowledge of a partner during conversation.

Access D3: Developing AAC technologies with smart prediction

- Research Question
  - Can we develop a novel dual-app AAC system that enables a person with severe speech and physical impairments to produce messages faster while still maintaining control over expression and increases engagement of the partner during conversation?
- Targeted Users
  - Literate individuals with severe speech and physical impairments who use AAC devices with single switch scanning, and their care or communication partners.
- Current Efforts
  - Improve SBIR CoConstruct prototype within RERC SmartPredict project. SBIR ended in May 2016.

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Access D3: Developing AAC technologies with smart prediction

- Engineering solution

CoConstruct apps SBIR funds to Invotek

(proof of concept)

SmartPredict

(current apps)

RERC on AAC project

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Access D3: Developing AAC technologies with smart prediction

Materials:
2 Samsung Galaxy tablets connected by Bluetooth®
- CoConstruct-AAC app for the AAC user
- Partner app for the familiar partner

CoConstruct-AAC app interface:
QWERTY keyboard with two lines above the keyboard:
- Message line
- Word prediction from language model system

Partner app interface:
QWERTY keyboard and 2 lines:
- Message line
- Word prediction line from CoConstruct-AAC app

CoConstruct-AAC app functionality:
- As an AAC user types with the CoConstruct-AAC app, the text appears in the message line AND in the partner's tablet message line.
- The partner can suggest a word or phrase started by the AAC user by typing in the partner app. The suggestions are sent to the word prediction line of the CoConstruct-AAC app.
- The AAC user does not know which words are from the CoConstruct-AAC word prediction system and which are from the partner suggestions to maintain user autonomy.

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Access D3: Developing AAC technologies with smart prediction

- Clinical Evaluation of CoConstruct
- Single case research ABAB alternating treatment design
- 5 subjects with CNN: 3 direct selectors; 2 scanners
- Subjects described 3 pictures with and without partner assistance
- DV: Words/minute; selections/minute; selections/word in 10 minutes

- Results

CoConstruct partner app shows *trends toward improving speed of message production* by:

- Slight increase rate of word production in 10 minute period.
- Slight decrease in number of selections needed in a 10 minute period for one picture.
- Slight decrease in number of selections per word needed with direct selection and scanning access.

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Access D3: Developing AAC technologies with smart prediction

Improvements to SmartPredict

1. Use the COCA language model to also predict trigrams.
2. Evaluate with users who rely on switch scanning.
3. Handle near-miss predictions and the creation of story prediction databases from text documents.
4. Add the option to always display the partner's prediction in the word prediction list.
5. Display the UI for the AAC user on the partner's app.
   - This provides a lot of information to the partner during scanning.
     - Words in the word prediction list that are not chosen
     - Letters during scanning that are passed up

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Access D3: Developing AAC technologies with smart prediction

Smart Predict:

AAC User Interface

Partner Interface

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Access D3: Developing AAC technologies with smart prediction

Add a new variable:

Partner engagement

Our work to date indicates that we need to learn more about the partner's experience.

What can we learn about the partner's experience during conversation with a person who relies on switch scanning for message generation?

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Access D3: Developing AAC technologies with smart prediction

+ Research Questions

During conversations about a shared experience:

1. Are differences observed in level of **partner engagement** with and without the *Smart Predict* app?
2. Are differences observed in AAC user **message efficiency** with and without the *Smart Predict* app?
3. Are differences observed in AAC user & partner **workload and satisfaction** with and without the *Smart Predict* app?

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Access D3: Developing AAC technologies with smart prediction

+ **Design**
  + Single case ABAB withdrawal design
  + 5 literate adults with CCN who use switch scanning paired with 5 partners for 20 conversations
  + Watch videos and discuss topic for 15 minutes.
+ **Dependent Variables**
  + Partner engagement (on/off task behaviors)
  + Message efficiency (selections/turn)
  + User/partner satisfaction
  + User/partner workload

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Access D3: Developing AAC technologies with smart prediction

+ **Expected Tech Transfer Outcomes**
+ The SmartPredict co-construction concept should appear in every device as we harnass contextual information and vocabulary within new technologies for people who rely on SGDs.
+ Every SGD should have to capability of adding vocabulary options from a knowledgeable partner into the word prediction function. The person with CCN will always have the choice to select or ignore the vocabulary so autonomy and independence are maintained.
+ An accompanying device should provide additional vocabulary into the lexicon of every SGD.

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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
  + Limited research published regarding 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 Cognitive Demands Checklist for AAC (CDC4AAC)
+ Base this tool on evidence from AAC and cognition research
+ 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

- **Clinical evaluation and testing**
  - AAC: Examined feature lists for existing AAC devices and software/apps.
  - Validated 4 AAC categories through national consensus:
    - **Access** *(direct/indirect)*
    - **Display** *(navigation, color, grid size, use of VSD….)*
    - **Language** *(representation, organization, rate enhancement)*
    - **Output** *(visual, auditory, tactile)*
  - Cognition: Examined cognitive domains critical for AAC and validated through national consensus.
  - Chose to focus on 3 cognitive skills critical to AAC technologies:
    - **Attention**
    - **Memory**
    - **Executive Function**

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HCI D4: Developing a Cognitive Demands Checklist for AAC Technologies

1. **Conducted systematic literature review using guidelines**
   - **Key words:** Attention, Memory or Executive Function + designated feature. i.e.: memory and direct selection for AAC
   - **Recent evidence**: within past ten years UNLESS sentinel article
   - **Consensus:** Each article read independently by 2 team members, annotating relevant citations then verifying through consensus process
2. **Developed website and created an interactive tool**
   - Provide information about cognitive demands as user selects feature, based on current research evidence.
   - Produce a final synthesis report of identified features and their cognitive demands, substantiated by current evidence.

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Access D4: Developing a cognitive demands checklist

- **Progress to date**
  - CDC4AAC has been developed.
  - Completing systematic literature review for each feature.
  - Planning feedback survey to to administer to 60 stakeholders:
    - People who rely on AAC
    - Clinicians
    - Developers

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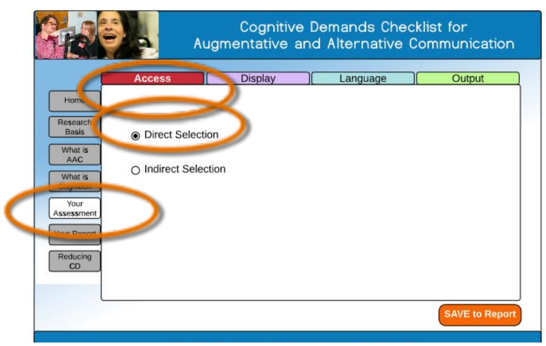
HCI D4: Developing a Cognitive Demands Checklist for AAC Technologies



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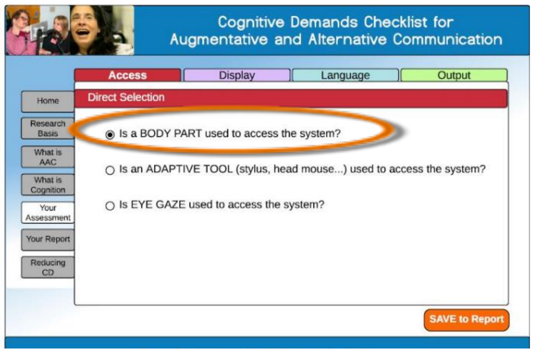
HCI D4: Developing a Cognitive Demands Checklist for AAC Technologies



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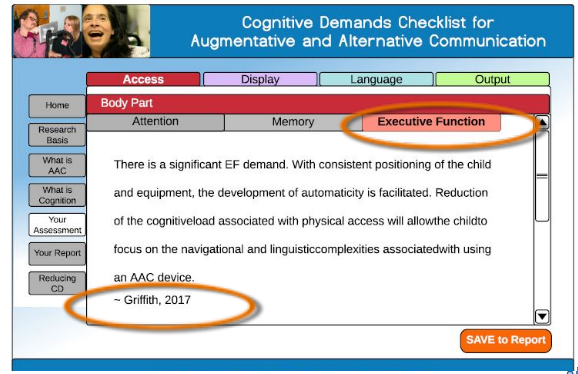

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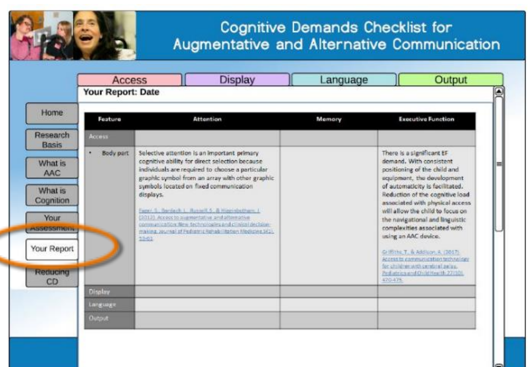
HCI D4: Developing a Cognitive Demands Checklist for AAC Technologies

- Final report;
- Links to references and comprehensive bibliography



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HCI D4: Developing a Cognitive Demands Checklist for AAC Technologies

- **Expected outcomes of the CDC4AAC**
  - 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
  - Broad accessibility (universal design)

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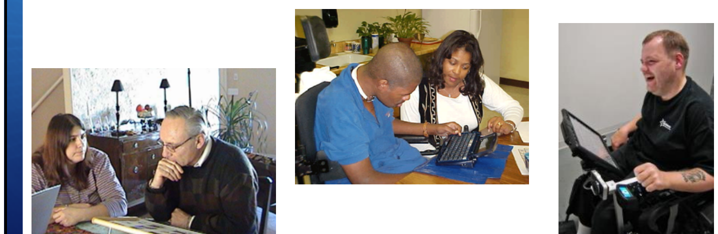
RERC on AAC
Training & dissemination

Training & Dissemination

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



AAC-Learning-Center.psu.edu

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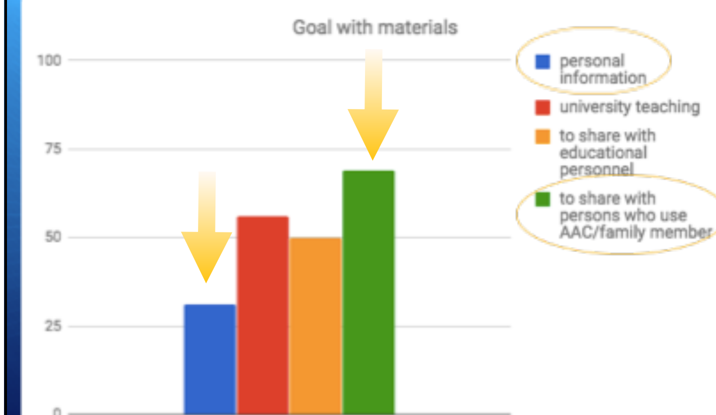
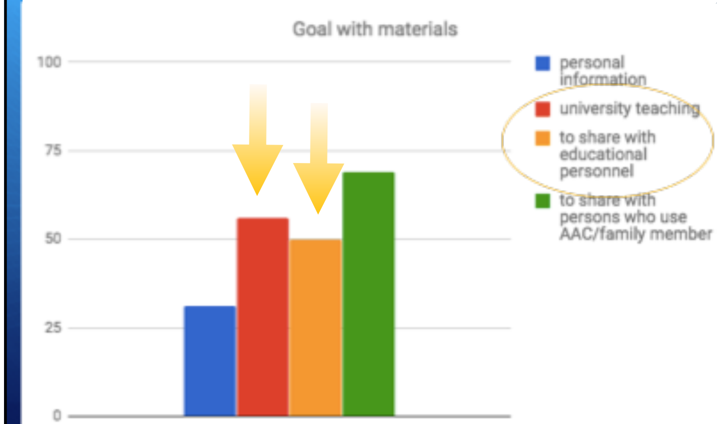
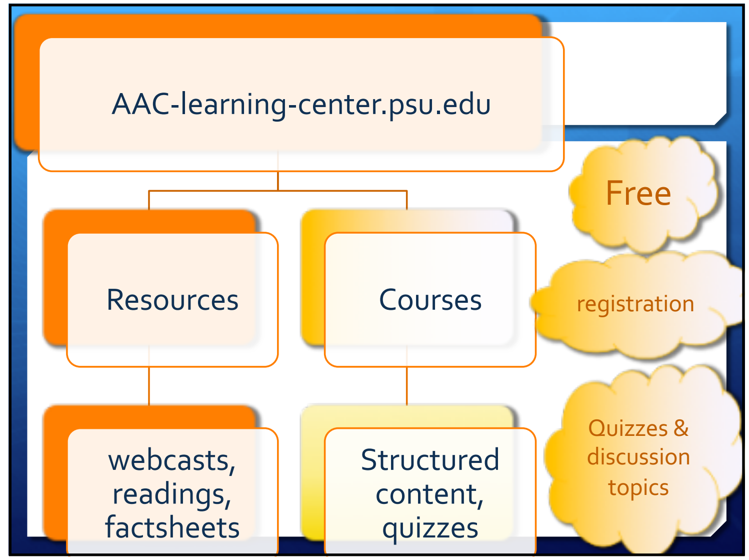
Who are the materials for?



Who are the materials for?





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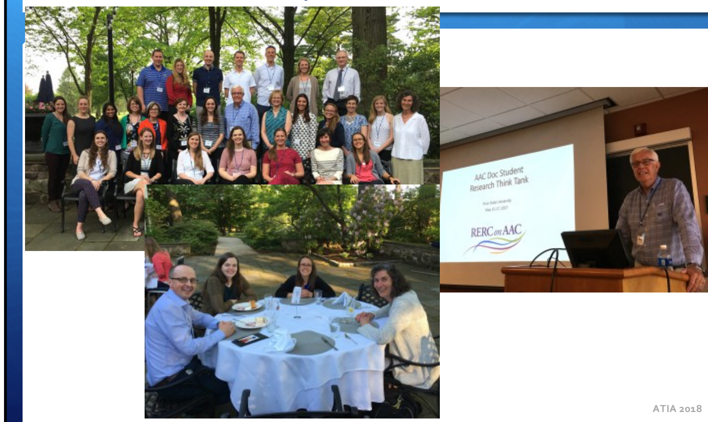
Topic	Contributors	Target date
Funding - Overview - Funding requests	David McNaughton Dana Brinkel Lew Golinker Rachel Weintraub	Fall 2018
Alternative Access	Jessica Gormley David McNaughton Naima Bhana	Fall 2018
Literacy - Instruction in early reading skills	Janice Light David McNaughton Jess Caron Grace Chang	Fall 2018
AAC in schools - Family centered practices	Kelsey Mandak Janice Light David McNaughton	Summer 2018
Transition - Building Community	David McNaughton Chris Klein	Summer 2019
AAC and in-patient settings	Jessica Gormley	Summer 2019

AAC Doctoral Student Think Tank
Penn State - May 16-18, 2017



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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
- Developed **5** new engineering solutions to advance AAC technologies and improve outcomes for individuals with CCN
- Mentored a total of **89** students in our labs, including 58 engineering students and 31 rehab scientists
  - **10** of these students recognized with national /international awards

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Outcomes of the RERC on AAC to date

- Published over **20** peer-reviewed publications
- Completed more than **44** presentations at state, national, and international conferences
- 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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Please visit our booth at 617!

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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.

RERC on AAC

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