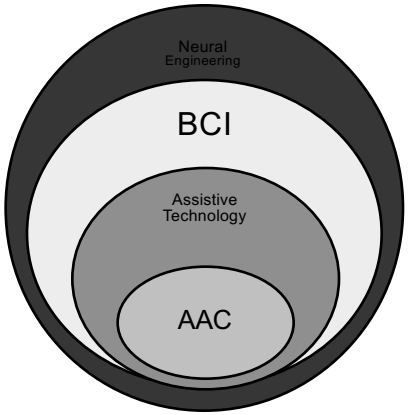
CREATING AN INTERNATIONAL COLLABORATION FOR SYNERGY BETWEEN AAC AND BCI

MELANIE FRIED-OKEN, PH.D.

AND THE NIH AAC-BCI WEBINAR TEAM:

LEIGH HOCHBERG, MD, PHD
JANE HUGGINS, PHD
MARY ANN ROMSKI, PHD
THERESA VAUGHAN

OUR GOAL: TO BRING AN IMPORTANT DISCUSSION TO THE INTERNATIONAL AAC COMMUNITY



What are our visions for the synergy between AAC (as an assistive technology) and BCI?

HOW DID WE GET HERE?

- NIH AAC Research Priorities (1994)
- NIH BCI for speech synthesis (2006)
- NIH Webinar sponsored Drs. Lana Shekim and Roger Miller in September 2015
  - https://www.nidcd.nih.gov/workshops/towards-augmentative-and-alternative-communication-and-brain-computer-interface-synergy/2015/summary
- International BCI Meeting, June 2016
- Rehabilitation Engineering and Assistive Technology Society of North America (RESNA) workshop July 2016

PREVIOUS NIDCD RESEARCH PRIORITIES ON AAC-BCI *AAC (1994)*

1.Study the impact of AAC technologies on the devtof communication in persons with severe disorders.

2.Study the influence of user variables on AAC system use.

3.Investigate the impact of AAC system features on comm competence of users.

4.Develop tools to validly measure communication competence of children and adults AAC users.

5.Investigate the effectiveness of AAC interventions by studying various user factors that are related to success and failure of AAC use.

6.Encourage academic development of researchers with a focus in AAC by establishing research and training opportunities..

PREVIOUS NIDCD RESEARCH PRIORITIES ON AAC-BCI

BCI for speech synthesis (2006)

1. **Further R&D in this area holds great promise for the development of a high bandwidth controller that could be used to benefit both paralyzed and locked-in individuals.**
2. **Progress needed in:**
   1. Creating software capable of extracting intention
   2. Algorithm devt. for controlled signals
   3. Access to shared software libraries that scale up according to quality of control signals.
   4. Shared data for raw data acquired from cortex neurons
3. **R&D needs input from interdisciplinary groups.**
4. **Use NIDCD translational and R01 funding mechanisms.**
5. **Continued meetings necessary..**

BEUKELMAN, D. (1993). AAC RESEARCH: A MULTIDIMENSIONAL LEARNING COMMUNITY. *AAC*. 9(1). 63-68.

1. **Identify the need and problem** ✓
2. **Define the need and problem** ✓
3. **Suggest the probable** ✓
4. **Demonstrate the possible** ✓
5. **Explain the processes**
6. **Document the effective**
7. **Prove the efficient**
8. **Implement the routine**
9. **Evaluate the system**

2015: CHALLENGES TOWARD AN AAC-BCI SYNERGY

AAC clinical perspective: M. Fried-Oken

Engineering perspective: J. Huggins

Developmental perspective: MA Romski

Adult user perspective: T. Vaughan

Neuroscience perspective: L. Hochberg

Participant discussion and contributions

CHALLENGES TOWARD AN AAC-BCI SYNERGY: CONSENSUS SURVEY

1. Define the population of potential AAC-BCI users
2. Improve BCI technology
3. Apply user-centered design
4. Plan for technology transfer and clinical implementation
5. Collaborate across disciplines
6. Establish a funding environment and academic culture for the present and future.

CLINICAL AAC-BCI PERSPECTIVE

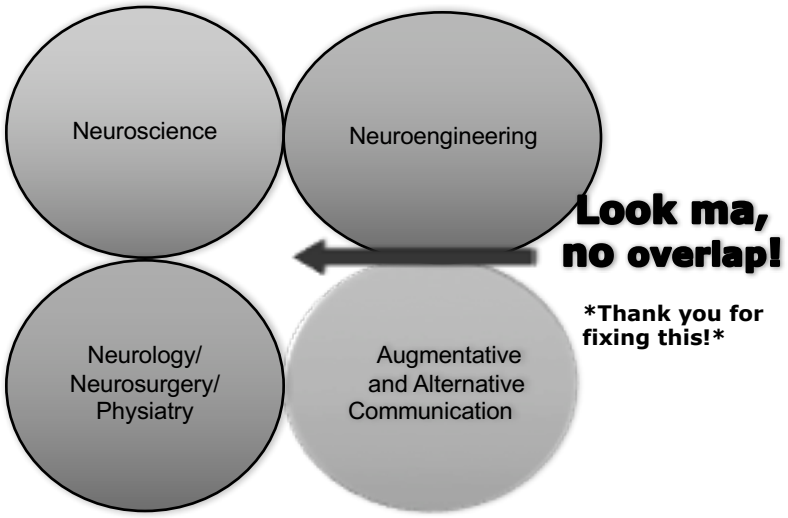
THE AAC PERSPECTIVE

1. **Expand on BCI for AAC clinical research**
2. **Increase the restricted experimental populations**
3. **Understand the process of language use & learning with BCI modalities**
4. **Collaborate across disciplines**

FOR BCI-AAC TECH TRANSFER TO OCCUR FROM CLINICAL PERSPECTIVE:

- Technical support
- Knowledgeable prescribers and therapists
- Training resources
- Health care reimbursement models
- AT purchasing models
- Outcomes measurement system
- Pre-service and in-service education in place to teach the next generation of researchers and providers.

NEUROSCIENCE PERSPECTIVE



NEUROSCIENCE CHALLENGES FOR AAC AND BCI

What are the indicators that an AAC-BCI device will work for a given user?

Once a user gains experience with an AABCI™, how can we augment the signal or teach the user to augment the signal so it works more quickly, more easily, more reliably?

What can we learn about the nervous system of someone using an AABCI?

What are the (neuroscience) questions that arise from AABCIs being used for *rehabilitation* rather than *replacement*?

A neuroethics quandary (perhaps for another time): What are the criteria by which a BCI could be used to convey requests that are only carried out when there is both capacity and competence?

NEUROSCIENCE CHALLENGES FOR AAC

How does the AAC interface affect (or effect) the signal?

Are some AAC interfaces easier to learn than others, and for whom?

Are users learning a motor skill? An interface? A language?

NEUROSCIENCE CHALLENGES FOR BCI

What information is there in the signal?

How does learning and cortical plasticity affect BCI use?

How stationary is the biological signal?

From where in the brain (or on the brain, or on the scalp) should signals be derived?

What dimensional space is the signal in? Phenomenon or epiphenomenon?

What approaches (neuroscience, not engineering) can be used to improve information content in the signal, enhance learning, increase stationarity?

What signal do we want? Salient response signal, visual attention, aural attention, somatosensory attention, movement intention signal, speech intention signal, "thought" signal?

How does the disease affect the signal (statically or dynamically)?

ENGINEERING PERSPECTIVE

ENGINEERING CHALLENGES

- Compatible terminology, performance metrics
- Acceptable daily brain signal recording
- Managing extremes of brain diversity
- Managing intra-subject variability
- Calibration of BCI as an input device
- Integration of BCI into AAC devices
- Providing appropriate feedback/ displays

CHALLENGE: COMPATIBILITY OF PERFORMANCE METRICS

Communication Rate

- Engineers: Bits per minute
- AAC: Words per minute

Handling time between letters

Multiple points in the cycle to measure performance

- Level 1: BCI accuracy/selection rate
- Level 2: Communication capacity
- Level 3: Communication effectiveness

Thompson, Blain-Moraes, Huggins. Performance assessment in BCI-based AAC, BioMedical Engineering OnLine, 12:43, 2013.

RECORDING BRAIN ACTIVITY

Safe

Accurate

Reliable

Easily setup/available

Inconspicuous/fashionable

Compatible with other technology or devices

CHALLENGES OF EEG SENSOR TECHNOLOGY

Rapid setup

Remain stable despite uncontrolled movements

Consistent placement

Artifact rejection

Amateur setup personnel

Dry technology/containing gel

FEATURE EXTRACTION: PEOPLE ARE VARIABLE

Engineering methods assume consistent signals

High person-to-person variability

High intra-person variability

Congenital disability creates different developmental path

AAC speakers

- Don't match established norms
- Fatigue, spasticity issues
- Highly diverse

BCI CONFIGURATION

Handles person-to-person variability

Time-consuming

Configuration drift could be problematic

- Fatigue
- Mental workload
- Degenerative conditions

Challenges

- Managing variability
- Adapting to configuration drift
- Rapid configuration

PEDIATRIC PERSPECTIVE

PEDIATRIC CHALLENGES

Related Research Advances

Developmental Period

Pediatric BCI Uses

Considerations for Potential Uses

Ethical Considerations

INCLUDE RELATED RESEARCH ADVANCES

Cochlear Implants for Children with Significant Hearing Impairment

- Implanting very early leads to much better language and communication outcomes

Eye tracking research with Children who use AAC

- Special Issue of *Augmentative and Alternative Communication* (June 2014)

Baby Babble Blanket (BBB) for Children with Motor Disabilities

- A pad with pressure-sensitive switches linked to a computer that was developed to provide infants or developmentally delayed children with a communication/environmental control system.

DEVELOPMENTAL PERIODS: BROAD CHRONOLOGICAL AGE RANGE

Aspects of development across the developmental period

- Brain development
  - Plasticity of the developing brain offers a unique opportunity
- Social Emotional development
- Fine and Gross Motor development
- Cognitive development
- **Language and Communication development**

POTENTIAL PEDIATRIC BCI USES

	Acquired Disorders	Congenital Disorders
Replace	Y	Y
Restore	Y	N
Enhance	Y	Y
Improve	Y	Y
Research	Y	Y

CONSIDERATION FOR POTENTIAL USE

Assessment Mechanisms

- To assess speech (auditory) and symbol (visual) comprehension skills at all language levels (single word vocabulary, phrases, sentences, connected text) for a range of children with congenital and acquired disorders

Integrating BCI Technology into AAC Interventions

- For developing children, the technology must go hand in hand with the AAC interventions to develop language and communication skills
- Early intervention and exposure/experience may offer developmental enhancement
- may lead to using it for early literacy instruction as well

Enhancing learning including social uses (e.g., games) and environmental access

AAC RESEARCH

- Use BCI as an approach for assessing the effects of language and communication interventions.
  - Do we find changes in areas of the brain pre-post AAC interventions?
  - Are there changes over time?
- Consider perceptions of the child's communicative partners and others in the child's environment about BCI
- How will AAC-BCI change the communication interaction in the dyad?

ETHICS

Child assent

Developing ethical standards for children

Disseminate knowledge to providers, clinicians, parents, educators so they embrace, prescribe and teach BCI technology during developmental phases.

RECOMMENDATIONS TO AAC-BCI RESEARCHERS

Do not limit the children who could use and benefit from AAC-BCI

- Think broadly and think early

Do not constrain how AAC-BCI could be used with pediatric populations

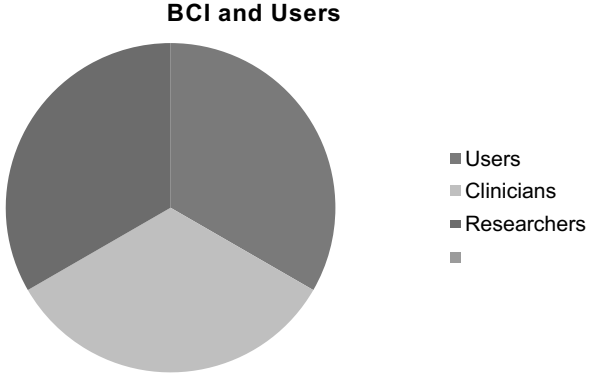
- The evidence base will evolve – be open to the possibilities

Tackle ethical issues as they emerge

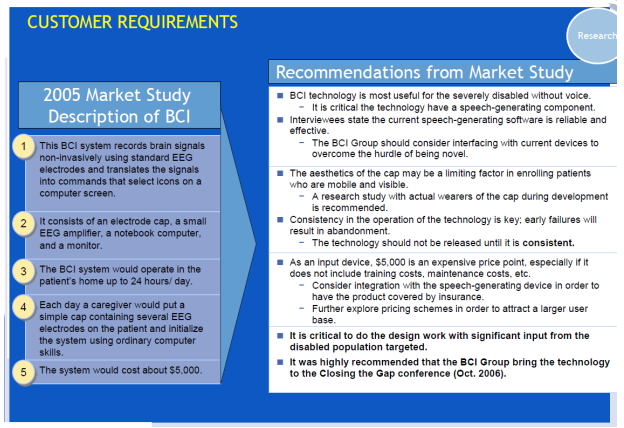
Begin seeding the knowledge base now

ADULT USER PERSPECTIVES: BCI INDEPENDENT HOME USE

PERSPECTIVE FROM 3 GROUPS



2005: FROM THE CLINICIANS
(MARKET STUDY, AD LITTLE 2005)



IS BCI SUITABLE FOR LONG TERM USE?

Who are the people who need the BCI system, and can they use it?

Can the BCI design be implemented in a form suitable for long-term independent use?

Can their home environments support their use of the BCI, and do they actually use it?

Does the BCI improve their lives?

Adapted from Wolpaw & Wolpaw 2012

THE FIRST BCI HOME USERS

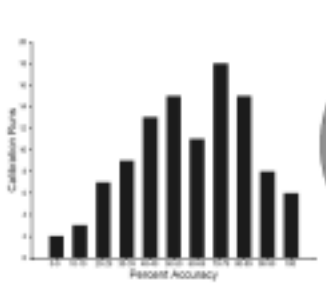
ADAPTED FROM VAUGHAN ET AL, 2006

Selection Criteria	*Specifications, Examples*
Chronic disorder of voluntary movement	ALS, brainstem stroke, cerebral palsy, spinal cord injury
Minimal remaining useful control	Single muscle, eye movement
Conventional technologies not adequate	Single-switch EMG or eye-movement systems difficult, unreliable
Stable environment	Strong medical, physical, social suppo
Technically capable caregivers	Able and willing to master BCI system operation
Realistic understanding of this BCI study	Research enterprise, success not assured

PROGRESS TO DATE

- Established evaluation procedure for people with ALS
- Installed 40 systems
  - 39 ALS patients
  - 22 individuals have used the system independently in their home
  - 8 have used it as their sole source for computer access.

IS THE BCI USEFUL?



Accuracy distribution for one Home User for calibration (copy spelling) on 107 days.

His average use of BCI applications.

FEEDBACK FROM HOME USERS

Eight BCI Home Users diagnosed with ALS (1 female)
Average ALSFRS-R* =5.6 (SD 8.4); (range 0-26)
Age: 30 - 76 yrs

Four relied on partner Assisted Scanning/four others had multiple strategies.

Five of the eight reported that they were satisfied with their current communication method.

The three who were not relied solely on partner-assisted scanning.

The same participants who found partner-assisted scanning inadequate rated the BCI as relatively easy to use (average=2.3 (Likert Scale of 7).

All participants rated speed and accuracy as important, average of 1.8 and 2.0 respectively (range 1-4).

Four of the six caregivers who completed their survey question rated the BCI setup as somewhat easy (average=3.3, range 1-7).

SPECIFIC REQUESTS

Researchers should list to BCI user feedback

Improve the BCI: wireless cap without gel

More portable system

Greater Internet access

Try different approaches

Make more home visits

And not ‘give up, keep refining’ the BCI.

IN THEIR OWN WORDS

- * H2 “Don’t let the dog pee on the rug.”
  “It hurts when you rub my eyes at night.”
  And to the evaluator “Speak louder.”
- * X1 asked to have his power of attorney changed and “I want a divorce”
- H3 participated in an online users forum.
- * H1 ran a lab with three employees (watched his favorite TV shows).
- * H71 asked for personal care, made appointments and organized the his social and house.

YOUR INPUT IS NEEDED

What is the international AAC perspective?

What have we left out?

What are your recommendations?

How can I represent your perspective and vision?

FOR FURTHER INFORMATION

WWW.RERC-AAC.ORG
WWW.REKNEWPROJECTS.ORG

The contents of this presentation were developed under a grant from the National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR #90RE5017) to the Rehabilitation Engineering Research Center on Augmentative and Alternative Communication (RERC on AAC).

NIDILRR is a Center within the Administration for Community Living (ACL), 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.

NIH grant #2R01DC009834

RERC on AAC