Creating an international collaboration for synergy between AAC and BCI

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Theresa Vaughan

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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
- 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 development of 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 communication 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.
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..

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.

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CLINICAL AAC-BCI PERSPECTIVE

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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 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?
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

Recording Brain Activity

- Safe
- Accurate
- Reliable
- Easily setup/available
- Inconspicuous/fashionable
- Compatible with other technology or devices

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Challenges of EEG Sensor Technology

- Rapid setup
- Remain stable despite uncontrolled movements
- Consistent placement
- Artifact rejection
- Amateur setup personnel
- Dry technology/containing gel

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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

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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

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PEDIATRIC PERSPECTIVE
Pediatric Challenges

- Related Research Advances
- Developmental Period
- Pediatric BCI Uses
- Considerations for Potential Uses
- Ethical Considerations

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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

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# Potential Pediatric BCI Uses

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<thead>
<tr>
<th></th>
<th>Acquired Disorders</th>
<th>Congenital Disorders</th>
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<tbody>
<tr>
<td>Replace</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>Restore</td>
<td>Y</td>
<td>N</td>
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<tr>
<td>Enhance</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>Improve</td>
<td>Y</td>
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<tr>
<td>Research</td>
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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

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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

BCI and Users

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2005: From the clinicians (Market study, AD Little 2005)

**2005 Market Study Description of BCI**

1. This BCI system records brain signals non-invasively using standard EEG electrodes and translates the signals into commands that select icons on a computer screen.
2. It consists of an electrode cap, a small EEG amplifier, a notebook computer, and a monitor.
3. The BCI system would operate in the patient's home up to 24 hours/day.
4. Each day a caregiver would put a simple cap containing several EEG electrodes on the patient and initialize the system using ordinary computer skills.
5. The system would cost about $5,000.

**Recommendations from Market Study**

- BCI technology is most useful for the severely disabled without voice.
  - It is critical the technology have a speech-generating component.
  - Interviewees state the current speech-generating software is reliable and effective.
  - The BCI Group should consider interfacing with current devices to overcome the hurdle of being novel.
- The aesthetics of the cap may be a limiting factor in enrolling patients who are mobile and visible.
  - A research study with actual wearers of the cap during development is recommended.
- Consistency in the operation of the technology is key; early failures will result in abandonment.
  - The technology should not be released until it is consistent.
- As an input device, $5,000 is an expensive price point, especially if it does not include training costs, maintenance costs, etc.
  - Consider integration with the speech-generating device in order to have the product covered by insurance.
  - Further explore pricing schemes in order to attract a larger user base.
- It is critical to do the design work with significant input from the disabled population targeted.
- It was highly recommended that the BCI Group bring the technology to the Closing the Gap conference (Oct. 2006).
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
<table>
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<tr>
<th><strong>Selection Criteria</strong></th>
<th><strong>Specifications, Examples</strong></th>
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<tbody>
<tr>
<td>Chronic disorder of voluntary movement</td>
<td>ALS, brainstem stroke, cerebral palsy, spinal cord injury</td>
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<td>Minimal remaining useful control</td>
<td>Single muscle, eye movement</td>
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<td>Conventional technologies not adequate</td>
<td>Single-switch EMG or eye-movement systems difficult, unreliable</td>
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<td>Stable environment</td>
<td>Strong medical, physical, social support</td>
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<tr>
<td>Technically capable caregivers</td>
<td>Able and willing to master BCI system operation</td>
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<tr>
<td>Realistic understanding of this BCI study</td>
<td>Research enterprise, success not assured</td>
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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.

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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 rehabilitation engineering 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

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