March 27, 2019
7:00 PM Eastern

An introduction to non-invasive brain-computer interface techniques for AAC

Presenter:
Kevin Pitt, MS, Doctoral Candidate
Webinar Logistics

ASHA CEUs – live webcast

- Included for USSAAC members;
  $25 – non-USSAAC members
- Participant form and instructions on USSAAC website
- Can only receive CEUs for live webinar
- NOTE: You need to scan and send participant form to smeehan8@ku.edu by April 10, 2019

- Archived webcasts https://www.isaac-online.org/english/news/webinars/
- Enter questions in the chatbox. We will answer as time permits.
WHAT WILL YOU LEARN?

1) Different non-invasive brain-computer interface techniques.
2) Various considerations for brain-computer interface assessment.
3) Future directions for integrating brain-computer interfaces into clinical practice.
An Introduction to Non-Invasive Brain-Computer Interface Techniques for Augmentative and Alternative Communication

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University of Kansas
Disclosures

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Nonfinancial: No relevant nonfinancial relationship exists.
Outline

1a) Emerging AAC access technologies
1b) What is a BCI?
2) What do stakeholders think about BCI?
3) Work on the translation of Brain-computer interfaces (BCI) into clinical practice
4) Future research directions

Focus:
- Communication impairment due to severe physical impairment (SPI)
- Cerebral Palsy
- Amyotrophic lateral sclerosis (ALS)
- Locked in Syndrome
1a) AAC access technologies

- Brain-computer interface (BCI)
- Movement sensing technology
- Electromyography (EMG)
- Eye-gaze
- Head tracking
- Multimodal: Eye-gaze +

- Besides BCI: oculomotor/motor control
- Environmental restrictions

- Need new access technologies along side existing methods
- Everyone has access method
1b) What is a BCI?

- **Focus**: Noninvasive BCI

- Record summed activity of thousands of neurons at the scalp using electroencephalography (EEG) – device control

- Common: For individuals unable to perform movements needed for conventional access

- Learning demands (e.g., Liberati et al., 2015)

- Support across life span

Non-invasive BCI overview

Image taken from: Wolpaw et al., 2002
2) What Do Stakeholders Think?

- Emerging research

- Overall, positive view of BCI technology individuals with neuromotor disorders (Liberati et al., 2015; Blain-Morales et al., 2012)

- Freedom, hope and connection, unlocking (Blain-Morales et al., 2012)

- 84% of individuals with ALS reported they were willing to wear an EEG cap (Huggins, Wren, & Gruis, 2011)

- Concerns noted by caregivers for long term wear ability (Liberati et al., 2015)
Stakeholder Opinions

- Impact of BCI on an individual’s life with advanced ALS...
- Use of P300-BCI for over 2.5 years

Figure taken from: Sellers, Vaughan, & Wolpaw (2010)
Limitations Noted

- Level of technology  
  (e.g., Blain-Morales et al., 2012)

- Cognitive load/maintaining focus  
  (e.g., Pasqualotto et al., 2015)

- Fatiguing  
  (Blain-Morales et al., 2012; Liberati et al., 2015)

- Frustrating/ effortful at times  
  (Blain-Morales et al., 2012)

- Set up is cumbersome  
  (e.g., Miralles et al., 2015; Liberati et al., 2015)

- Need for increased reliability (around 70%; <70-90%)  
  (e.g., Brumberg et al., 2017; Marchetti & Priftis, 2015)

Rate  
(for review see Brumberg et al., 2018)

- Current BCIs slower than existing AAC methods (e.g., 5-10 selections per minute).

- BCIs in development up to 33 characters/minute
  (e.g., Townsend & Platsko, 2016; Chen et al., 2015)
However, Different BCI Experiences

- Not everyone feels the same about existing AAC methods...

Individuals with ALS experience P300 BCIs differently
- Workload ratings
- Comfort ratings
- Ease of use ratings
- Satisfaction ratings

(Peters, Mooney, Oken, & Fried-Oken, 2016)

- Performance linked?  (e.g., Miralles et al., 2015)

- Consider factors on an individual basis
3) Translation of BCI into Clinical Practice

Research looking to support the transition of BCI into clinical practice

A. Feature matching assessment framework for BCI
   • Overview of different BCI paradigms
B. Development of BCI Screening tools
C. BCI access to commercial AAC devices and paradigms
A) Feature matching

AAC Serves Heterogenous Populations:
- 40% mild impairment
- Varied: executive function defects (e.g., attention)
- Frontotemporal dementia, approximately 5 to 14%
- Differing BCI/AAC perspectives

Feature match an individual to a device
1. Current and future profile
2. Cognitive
3. Linguistic
4. Sensory
5. Motor
6. Trial based preference

New concept for BCI  (e.g., Pitt et al., in press)
Different BCI paradigms

1. P300 overview
   - Feature matching considerations

2. Steady state visually evoked potentials
   - Feature matching considerations

3. Motor (imagery) based systems
   - Feature matching considerations
Visual Sensory BCIs: P300 Spellers

- All items randomly flash & generate a brain response when attending to desired item
- Repeat sequence many time (> 1, < 15) - select item with greatest response
- Auditory-based

Image taken from Perseh & Kiamin (2013).

P300 Grid Speller

Donchin et al. (2000)

RSVP Speller

Acqualagna & Blankertz (2010)
Orhan et al. (2012)
P300 Grid Video

Guger Technologies
https://www.youtube.com/watch?v=tl_CoJ8ICPA

RSVPKeyboard
https://www.youtube.com/watch?v=4cxaNXe9rVI&t=3s
### Considerations

<table>
<thead>
<tr>
<th><strong>Degree of oculomotor control for overt attention</strong></th>
<th><strong>Working memory</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>(Brunner et al., 2010)</td>
<td>(Fried-Oken, et al., 2013; Sprague et al., 2015),</td>
</tr>
</tbody>
</table>

**Selective attention/ temporal filtering:**  
Ability to attend to relevant stimuli amongst a stream of irrelevant or distracting stimuli) (Riccio et al., 2013)

**Literacy**

**Positioning** – headrest impedance (e.g., Fried-Oken, et al., 2013)

### Concerns

- Severe visual acuity impairment
- Severe oculomotor impairment
- History of seizures (less than those associated with steady state visually evoked potential, due to moving stimuli)

**Severe visual acuity impairment**

**Severe oculomotor impairment**

**History of seizures** (less than those associated with steady state visually evoked potential, due to moving stimuli)
### Auditory P300

<table>
<thead>
<tr>
<th>Considerations</th>
<th>Concerns</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Auditory perception</strong> and stream segregation abilities are needed</td>
<td><strong>Currently,</strong> normal visual acuity supports BCIs with visual feedback over auditory despite normal hearing (more mature methods).</td>
</tr>
<tr>
<td>Tones may be modified to match hearing acuity/range.</td>
<td></td>
</tr>
<tr>
<td>Engages <strong>attention, working memory</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Increased level</strong> of attention and short term memory capacity for navigation. (Klobassa et al., 2009; Kübler et al., 2009).</td>
<td></td>
</tr>
</tbody>
</table>

*Traditional view of BCI grid spellers*
- Tactile (left vs right hand)
- Less mature
Steady State Visual Evoked Potential (SSVEP) & Auditory Steady State Response (ASSR)

• SSVEP - Attending to a flicker stimuli ``tagged'' with a unique strobe frequency, generates recordable brain oscillations that contain the same frequency components.

• ASSR – **TWO** sound streams that containing different frequency modulations.

(Brumberg et al., 2018) (Hwang et al., 2012)
SSVEP Videos

Shuffle Speller
https://www.youtube.com/watch?v=JNFYSeIIOrw&t=6s

https://www.youtube.com/watch?v=uunf3FDfEno&t=11s
Steady State Visual Evoked Potential (SSVEP)

<table>
<thead>
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<th>Concerns</th>
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</table>
| **Degree of oculomotor control for overt attention** (Brumberg, Nguyen, Pitt, & Lorenz, 2018; Peters et al., 2018)  
Selective attention  
However, the individual is **not required to make active decisions** about when a novel target is highlighted (versus P300).  
**Positioning** - Headrest impedance | **User history of seizures** (due to flickering stimuli).  
Visual Impairments  
- Interfaces can be **adapted** to suit user strengths (Brumberg et al., 2018)  
- Simulated visual impairment (legal blindness) able to use BCI comparably (NT; Peters et al., 2018). |
Motor & motor-imagery

• Provide access to AAC using changes in brain rhythms associated with:
  - Physical motor movements
  - Attempted movements (paralysis)
  - Motor imagery (mental simulation without movement; e.g., making a fist)

• Versatile
• Does not depend on external stimuli

(Brumberg et al., 2018)
Motor-Imagery Video

https://www.youtube.com/watch?v=R-tNE-y2QU0&t=63s

Berlin BCI:
https://www.youtube.com/watch?v=yhR076duc8M
e.g., Blankertz et al., (2006a; 2006b)
Motor Imagery

Considerations

**Task: 1st versus third person** (e.g., Vuckovic & Osuagwu, 2013)

Does not rely on sensory stimuli

Support: poor selective attention, adaptations

Motor imagery vs overt motor learning (Wander et al., 2013):
- Feedback/Practice
- Executive function related to motor learning (e.g., task switching, working memory, abstract reasoning skills, self reflection.)
- Increased training times vs P300 and SSVEP

Concerns

No presence of the sensorimotor rhythm during covert task performance (reported as **approximately 15 to 30%** of the population by Blankertz et al., 2010)

**Increased training time/ initial preference** (Geronimo et al., 2014)

Congenital paralysis?
Lesions over motor cortex
- Utilize ‘other’ tasks (e.g., mental tasks, word association, rotation)?
Extrinsic Factors

Environmental noise
- Ventilators
- Distractors/ movement

(Sellers, Kubler, & Donchin, 2006)

Caregiver support
- BCI set up, trouble shooting, monitoring device use, training

(Brumberg et al., 2018; Wolpaw et al., 2018)

Influence of intrinsic and extrinsic factors
<table>
<thead>
<tr>
<th>Unique profile/ features of the client</th>
<th>Check rows that match their profile</th>
<th>Attention Modulated Visually based BCIs</th>
<th>Attention Modulated Auditory Only</th>
<th>Motor Imagery based BCIs</th>
</tr>
</thead>
<tbody>
<tr>
<td>No-mild imp: visual acuity</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Mod-severe imp: visual acuity</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>No-mild imp: hearing</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Mod-severe imp: hearing</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Without a history of seizures</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>With a history of seizures</td>
<td>-0.5</td>
<td>-0.5</td>
<td>-1</td>
<td>1</td>
</tr>
<tr>
<td>No-mild imp: eye movement</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Mod-severe imp: eye movement</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>No-mild imp: 1st person motor imagery</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Mod-severe imp: 1st person motor imagery</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<tr>
<td>No-mild imp: audio and/or visually based selective attention tasks</td>
<td>1</td>
<td>1</td>
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<td>1</td>
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<tr>
<td>Mod-severe imp: audio and/or visually based selective attention tasks</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No-Mod imp: working memory</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Severe imp: working memory</td>
<td>0</td>
<td>0</td>
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<tr>
<td>No-mild imp: cognitive motor learning/ performance factors (e.g. task switching, self monitoring, abstract reasoning, etc)</td>
<td>1</td>
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<tr>
<td>TOTAL number of feature matches</td>
<td>Yes/ No</td>
<td>Yes/ No</td>
<td>Yes/ No</td>
<td>Yes/ No</td>
</tr>
</tbody>
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**Figure & following cases taken from:** Pitt, K., & Brumberg, J. S. (2018a).
Clinical application case study

Following a brainstem stroke, Mrs. Holden (a 70 year old female) received a diagnosis of locked-in syndrome. An AAC evaluation revealed:

- **Strengths in** visual acuity, literacy, and selective attention / working memory skills.
- **Weaknesses in** cognitive-motor learning tasks (e.g., task switching, problem solving), low self-ratings on first person motor imagery, and an absent sensorimotor rhythm.
- Limited range of eye (oculomotor) movement.
- No history of seizure activity
- Posterior electroencephalography electrode recordings were largely unimpeded by her wheelchair headrest.

BCI images from Brumberg et al., (2018)
# Case Study (trials)

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<td>1</td>
</tr>
<tr>
<td>No-Mod imp: working memory</td>
<td>X</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Mod-Severe imp: cognitive motor learning/performance factors (e.g. task switching, self-monitoring, abstract reasoning, etc)</td>
<td>X</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

**TOTAL number of feature matches**
Add all values in each column matching their profile

|                              | 6 | 7 | 7 | 6 | 6 | 6 | 5 | 4 | 5 |

Literacy (reading and spelling) impairment? Yes/No

---

**Figure taken from:** Pitt, K., & Brumberg, J. S. (2018a). Guidelines for Feature Matching Assessment of Brain-Computer Interfaces for Augmentative and Alternative Communication. *American Journal of Speech-Language Pathology, 1*–*15.*
B) Development of BCI Screening tools

- Little standardization in BCI research for assessment

Lab Expansion:
- **Multidisciplinary:** PT, SLP, OT, Neuroscientist, BCI engineer
- Feature matching across devices
- Sensory-cognitive-motor imagery domains (e.g., attention, working memory, following directions, cognitive motor learning, motor-imagery)
- Binary/yes no response, <60 mins, minimal fatigue
- N=12, feasible for completion.
- Both screeners are a **first step**, skill presence
- Ongoing assessment + EEG

C) BCI access to commercial AAC devices

- BCI custom made paradigms and software
- Utilization of AAC advances over past 40 years.
- Learn a whole new system (modularity)
- Across life span/course (e.g., Pitt et al., in press)
D) BCI access to commercial AAC devices

Early efforts to access commercial AAC/AT paradigms and software

1) **Row/column scanning via BCI ‘switch’**
   - Adults with CP, and Neurotypical adults and those with ALS
   - Tobii-Dynavox AAC device (Brumberg et al., 2016)
   - Promising results
   - e.g., 62.2% *single session* offline accuracy (Brumberg et al., 2016)
   - Continuing research

2) **Assistive technology software**
   - QualiWorld, QualiLife Inc. Paradiso-Lugano, CH (e.g., Zickler et al., 2011)
   - Dynawrite text-to-speech (Thompson, Gruis & Huggins, 2013)

A heightened focus on utilizing commercially available technology:
- Promote collaborations and help navigate barriers to funding
4) Future Research Directions

A) BCI access for children

B) Engaging displays for children and adults

C) Technical barriers to BCI implementation (e.g., set up)

D) BCI availability and funding
A) BCI access for children

- Emerging

- Need more data EEG and developing brain. (e.g., Huggins et al., 2017)

- EEG signals for individuals with congenital paralysis
  - Muscle artifacts

- Literacy and symbols

- Design (‘cool’, motivating themes, functions, social image)
  - Play, artistic expression, colors, characters (Light & Drager, 2007)
B) Engaging displays for children and adults

- Sterile
- Task Engagement (e.g., Pitt et al., in press)
  - Look to learn (https://thinksmartbox.com/product/look-to-learn/)
  - Timocco (https://www.timocco.com)
- BCI-AAC generalization?
- Feedback effects on performance/boredom/fatigue

Brumberg & Pitt (2019)  
Zhang et al., (2019)  
Image from Look to Learn; Smart Box Assistive Technology
C) Technical barriers to BCI implementation

- Set up (gel application)
- Dry electrode technology
- Toward wireless systems
- Number of electrodes
- BCI processing algorithms (reliability)
- Artifact removal (e.g., muscle) in real time

(Guger et al., 2012, Zander et al., 2011)

(e.g., Brumberg et al., 2018; Miralles et al., 2015; Blain-Moraes et al., 2012; Nijboer, 2015)

Image taken from:
D) BCI availability and funding

BCI mostly in laboratory setting though undergoing in home trials with promising results (e.g., Wolpaw et al., 2018)

Availability of commercial/portable systems:
- g.tec P300 Intendix speller: ~$12,500

Funding
- Unknown
- Commercial partners/ documented need
- Increased reliability

(Huggins & Kovacs, 2018)
Some labs performing BCI research

1) East Tennessee State University; Johnson City, Tennessee.
https://www.etsu.edu/cas/psychology/bcilab/

2) Oregon Health & Science University; Portland, Oregon.
https://www.ohsu.edu/xd/research/centers-institutes/institute-on-development-and-disability/reknew/

3) Penn State Hershey Medical Center; Hershey, Pennsylvania.
https://alsadotorg.wordpress.com/2016/06/02/bringing-brain-computer-interface-home/

4) Speech and Applied Neuroscience Lab; Lawrence, Kansas.
https://sanlab.ku.edu/

5) University of Michigan; Ann Arbor, Michigan.
http://www.umich.edu/~umdbi/

6) University of Pittsburgh; Pittsburgh, Pennsylvania.
http://www.herl.pitt.edu/node

7) Wadsworth Center and the National Center for Adaptive Neurotechnologies; Albany, New York.
Thank you!

- All our study participants!
- United States Society for AAC
- Dr. Stephanie Meehan
- Franklin Smith and ISAAC
- Dr. Jonathan Brumberg and Chavis Lickvar-Armstrong

Questions?

Email: kmp4@ku.edu
https://sanlab.ku.edu/


Supporting people who use AAC and their families affected by disasters: https://aacdisasterrelief.recovers.org/
SAVE THE DATE! May 8, 2019, 7:00 Eastern
Dr. Kathy Howery, Mental Health and Students with Complex Communication Needs: Let’s Talk About It!
Check back at https://ussaac.org/news-events/webinars/ for additional details and registration information. Follow USSAAC on Facebook for up-to-date and “breaking” news.

Please consider joining USSAAC! Check out https://ussaac.org/membership/ for benefits!
ISAAC is excited to announce that the 19th Biennial Conference of the International Society for Augmentative and Alternative Communication, ISAAC 2020, will be held on the RIVIERA MAYA, QUINTANA ROO, MEXICO.

AUGUST 1-2
AAC Camp, Pre-Conference Workshops, Executive and Council Meetings

AUGUST 3-6
Main Conference, Riviera Maya, Quintana Roo, Mexico

JOIN US for AAC events and perspectives, the latest in research and clinical innovations, workshops, seminars, exhibits, social events, entertainment - everything you have come to expect from an ISAAC conference, and more!

Mark your calendar today, and save the date for ISAAC 2020 in Mexico!

For more information, visit us at www.isaac-online.org and follow #ISAAC2020 on Twitter.

www.isaac-online.org
ISAAC se complace en anunciar que el próximo XIX Congreso de la Sociedad Internacional de Comunicación Aumentativa y Alternativa, ISAAC 2020, se llevará a cabo en la RIVIERA MAYA, QUINTANA ROO, MÉXICO.

1-2 DE AGOSTO
Campamento CAA, Talleres Preconferencia, Juntas Ejecutivas y del Consejo

3-6 DE AGOSTO
Congreso Principal, Riviera Maya, Quintana Roo, MÉXICO

ÚNETE Y PARTICIPA en eventos de CAA, perspectivas, lo último en investigaciones e innovaciones clínicas, talleres, seminarios, exhibiciones, eventos sociales, entretenimiento y todo lo que esperas de un congreso de ISAAC ¡y mucho más!

Anótalo en tu calendario y aparta la fecha para ISAAC 2020 en México

Para mayor información consulta nuestro sitio web www.isaac-online.org y siguenos en #ISAAC2020 en Twitter