The USSAAC Webinar Series

Clinical Considerations for Future Non-Implantable Brain-Computer Interface (BCI)

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LEARNING OBJECTIVES

1. Understand potential screening tools for gathering information to best inform AAC-BCI system configuration to support communication and computer control for people with SSPI.

2. Understand ways to elicit user preference related to AAC-BCI technology design and use.

3. Learn methods to incorporate end user input and feedback into an integrative design process for AAC-BCI systems.

CAMBI: Consortium for Accessible Multimodal Brain-Body Interfaces

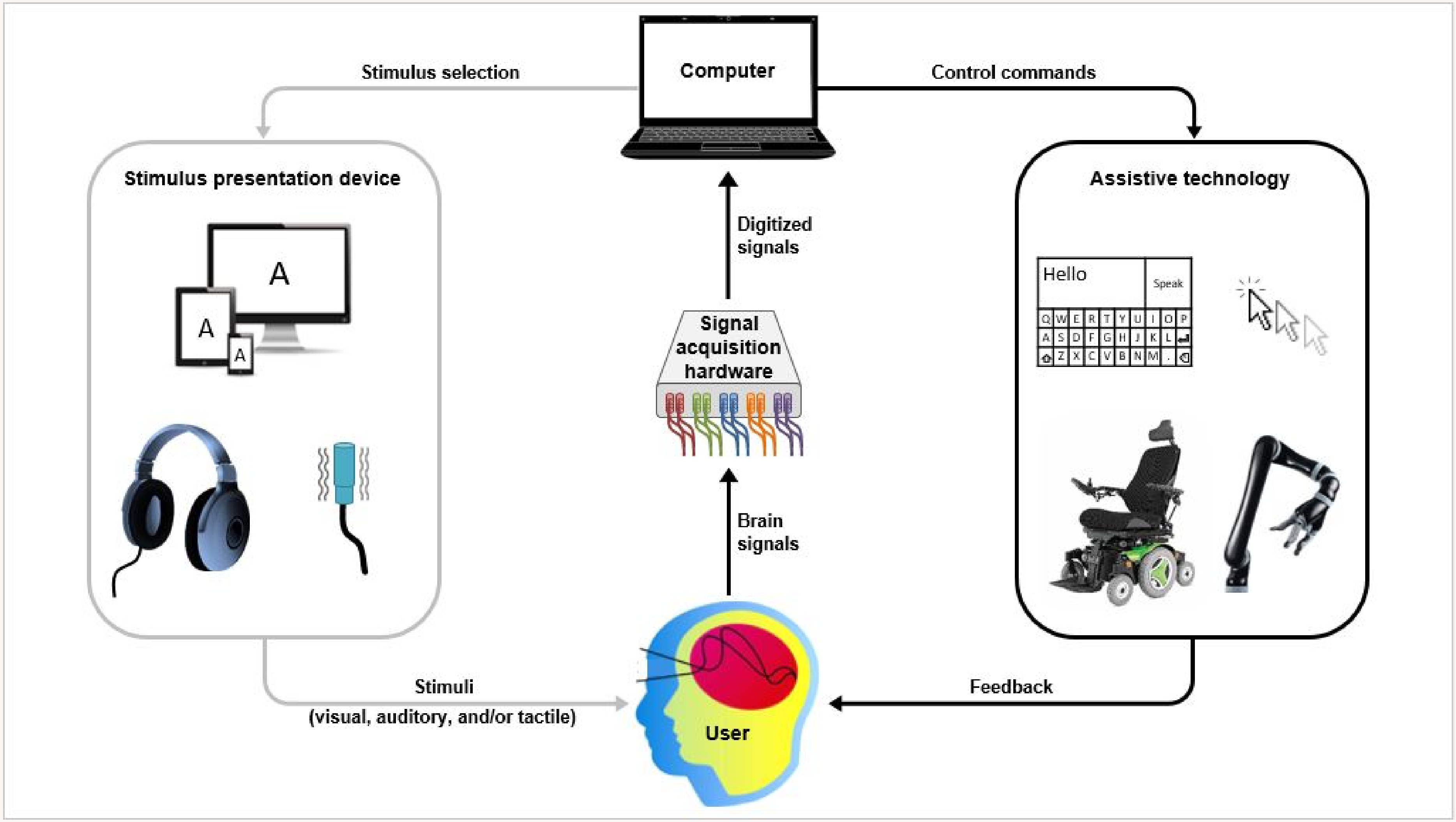
Introduction to non-implantable BCI systems

Brain-Computer Interface (BCI)

- Technology whereby a computer detects a ‘selection’ made by a person who does not rely on neuromuscular activity.

- The technology uses the person’s changes in brain waves as the intended action. This is our newest means to access an SGD or computer.

- Technology substitutes for the loss of typical neuromuscular outputs so that people can interact with their environments through brain signals rather than through muscle movement.



Computer
Stimulus selection
Control commands
Stimulus presentation device
A
A
A
Digitized
signals
Signal
acquisition
hardware
Assistive technology
Hello
Speak
Brain
signals
Stimuli
(visual, auditory, and/or tactile)
User
Feedback

Who would use a BCI for communication?

BCI is currently used in research studies with participants who present with incomplete or complete locked-in syndrome (LIS)

NOTE: BCI systems work best on individuals with minimal to no voluntary movement. It is very difficult to acquire brain signals from participants with extraneous or involuntary movement, for those with attention challenges, or those who cannot tolerate wearing a BCI cap.

We are working on better hardware and software to include more end-users.

Participants with common LIS diagnoses

- Advanced ALS
- Brainstem CVA
- High level spinal cord injury
- Traumatic brain injury

GOAL: Expand LIS by function instead of diagnosis: severe speech and physical impairment (SSPI)

- Cerebral palsy
- Rett Syndrome
- Muscular dystrophies
- Multiple sclerosis
- Parkinson’s disease
- Ataxia

GOAL: Include new populations as potential BCI users

- Children and adults who will not be spelling full sentences, but know first letters;
- Children and adults with IDD who want to meet the communication goal of participating in family life with pre-determined messages;
- Children and adults who rely on icons and pictures for communication.

Current BCI Research

Current human BCI research for communication & control

Implantable

Non-implantable or wearable

Most non-implantable BCI requires an EEG cap

Emotiv BCI headcap

Wet electrode cap

Dry electrode cap

Common brain signals acquired in BCIs for communication and computer control

- **P300-** the surprise evoked potential that can be acquired through multiple stimulus presentations
- **SMR-** sensory motor rhythm to detect movement (think right; think left)
- **SSVEP-** steady state visual evoked potentials- an averaged wave that occur in response to flashing stimulus presentations

RSVP Keyboard: CAMBI communication BCI

Our goal: Provide a means for individuals to communicate independent of neuromuscular output through EEG activity (P300 EPs) that is fused with language models.

Expand BCI for AAC uses

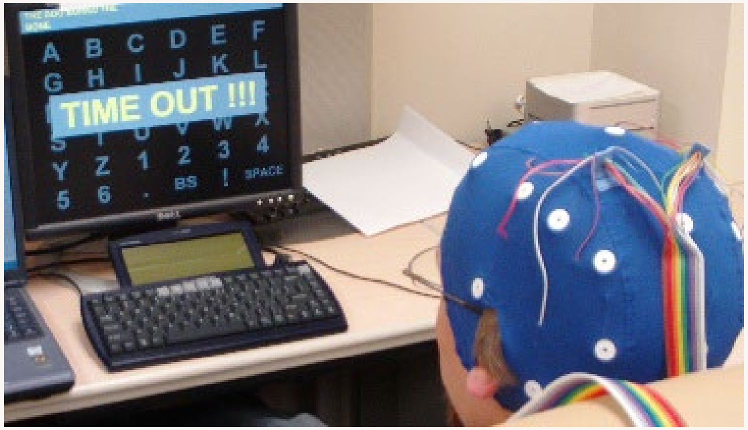
1. BCI as a switch (input)
2. BCI as a communication device
3. BCI as an assessment tool
4. BCI for AAC treatment
5. BCI for research

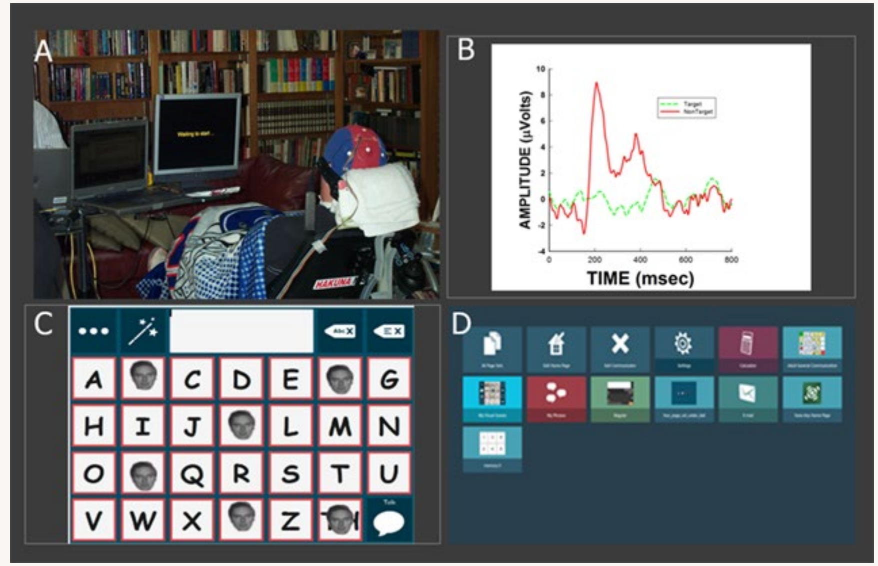
BCI as a switch

- Yes/no communication (binary choice) with binary switch using motor imagery (SMR)

- BCI as a plug and play device. P300 BCI as a switch to a marketed speech generating device

A plug-and-play brain-computer interface to operate commercial assistive technology
Thompson DE, Gruis KL, Huggins JE
Disabil Rehabil Assist Technol 2014;9(2):144-150





BCI as a switch to select letters for the DynaWrite speech generating device

Or with the TobiiDynavox Communicator 5 software

Gosmanova, K. A., Carmack, C. S., Goldberg, D., Fitzpatrick, K., Zoltan, B., Zeitlin, D. M., ... & Vaughan, T. M. (2017). Eeg-based brain-computer interface access to tobii dynavox communicator 5. Rehabilitation Engineering and AssistiveTechnology Society of North America, 4.

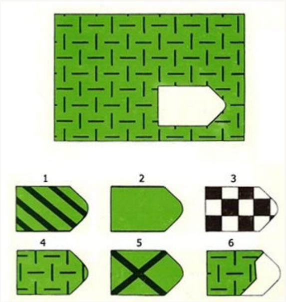
BCI as a communication device

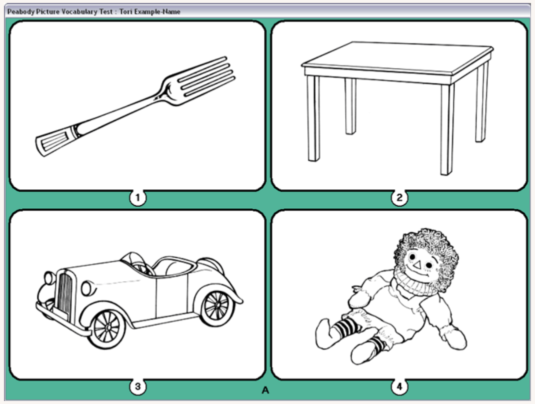
Matrix speller: Wadsworth BCI2000

RSVP Keyboard

BCI as an assessment tool

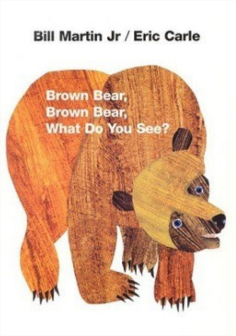
- BCI to determine cognitive status of patients with disorders of consciousness in the ICU
- Adapt standardized tests to measure cognitive or receptive language skills for people who cannot produce motor responses
- Use flashing stimuli for P300 or SSVEP signals, or binary choice motor imagery.
  - pALS
  - Rett syndrome
  - Severe spastic CP





BCI as an intervention tool

- Play: @BCI4kids at University of Calgary video game playing and painting



- Conversation and reciprocal

Communication: *pre-stored messages for interaction*

- Literacy: Learning to read and write- *repetitive line reading*

BCI as a research tool

- How does receptive and expressive language change with the use of BCI?
- Does brain development change with the introduction of BCI?
- How does interaction with a person with LIS change with the use of BCI?
- How can we improve neuroengineering developments for individuals with additional movement or attention challenges?

Clinical screening tools for user preferences, motor, visual, language, and cognitive function

Purpose of screening

- To assess adults
- To describe users and their abilities in a standardized way
- To inform modifications for technology design
- NOT to be exclusionary

The development of our screening

AJSLP

Clinical Focus

Guidelines for Feature Matching Assessment of Brain–Computer Interfaces for Augmentative and Alternative Communication

Kevin M. Pitt[a] and Jonathan S. Brumberg[b]

Purpose: Brain–computer interfaces (BCIs) can provide access to augmentative and alternative communication (AAC) devices using neurological activity alone without voluntary movements. As with traditional AAC access methods, BCI performance may be influenced by the cognitive–sensory–motor and motor imagery profiles of those who use these devices. Therefore, we propose a person-centered, feature matching framework consistent with clinical AAC best practices to ensure selection of the most appropriate BCI technology to meet individuals' communication needs.
Method: The proposed feature matching procedure is based on the current state of the art in BCI technology and published reports on cognitive, sensory, motor, and motor imagery factors important for successful operation of BCI devices.
Results: Considerations for successful selection of BCI for accessing AAC are summarized based on interpretation from a multidisciplinary team with experience in AAC, BCI, neuromotor disorders, and cognitive assessment. The set of features that support each BCI option are discussed in a hypothetical case format to model possible transition of BCI research from the laboratory into clinical AAC applications.
Conclusions: This procedure is an initial step toward consideration of feature matching assessment for the full range of BCI devices. Future investigations are needed to fully examine how person-centered factors influence BCI performance across devices.

Pitt, K. M., & Brumberg, J. S. (2018). **Guidelines for feature matching assessment of brain–computer interfaces for augmentative and alternative communication**. *American Journal of Speech-Language Pathology*, *27*(3), 950-964.

The development of our screening

Technology and Disability 14 (2002) 125–131
IOS Press

Matching Person & Technology (MPT) assessment process

Marcia J. Scherer[a,*] and Gerald Craddock[b]
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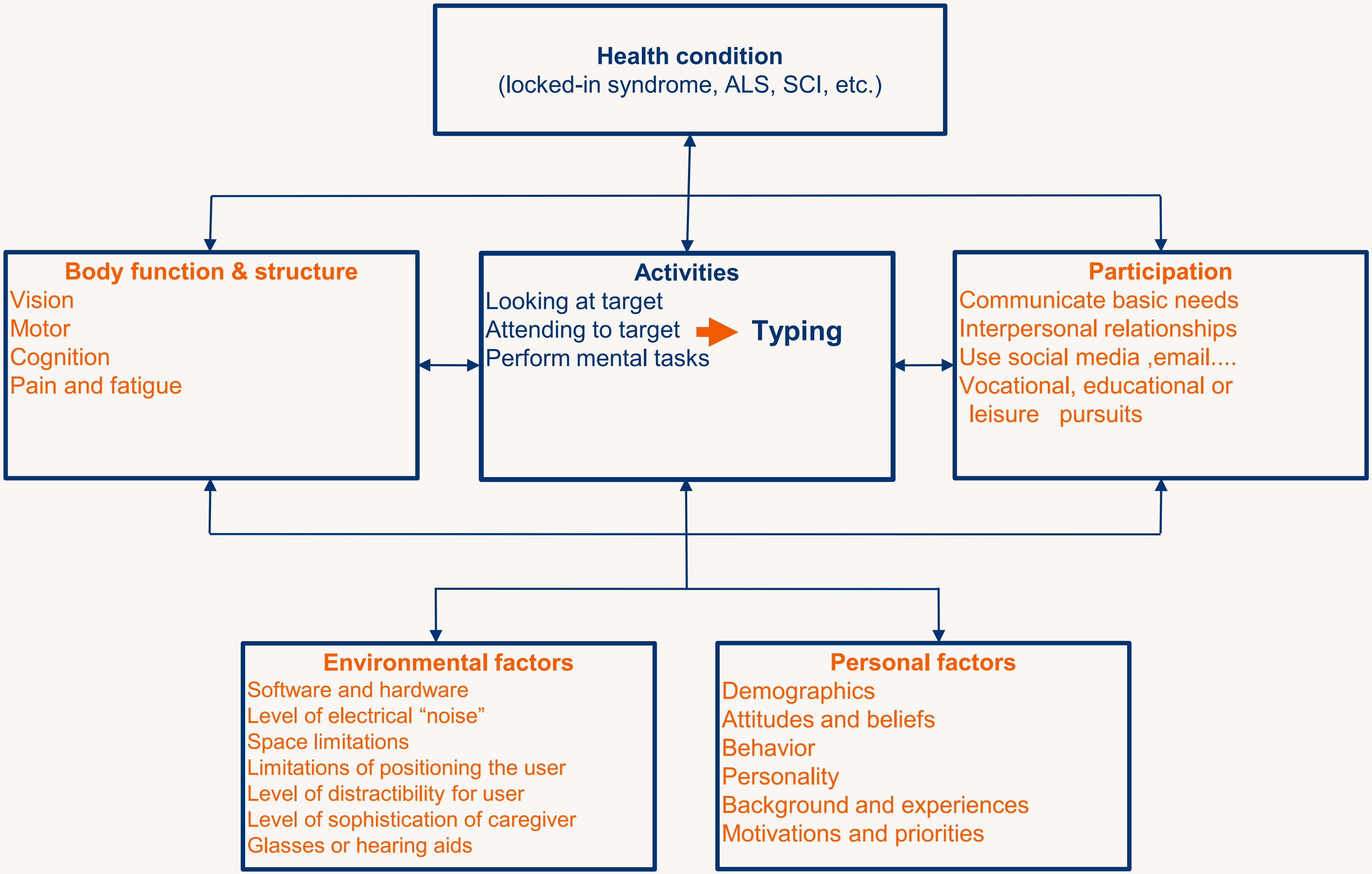
[b] *Client Technical Services, Central Remedial Clinic, Vernon Avenue, Clontarf, Dublin 3, Ireland*

Abstract. The Matching Person & Technology (MPT) assessment process is a set of person-centered measures, all of which examine the self-reported perspectives of adult consumers regarding strengths/capabilities, needs/goals, preferences and psychosocial characteristics, and expected technology benefit. There are separate measures for general, assistive, educational, workplace, and healthcare technology use; in Ireland, the measures were used to assess outcomes of assistive technology (AT) provision for (a) people throughout the country participating in a new localized AT service delivery process and (b) students transitioning from secondary education. There are companion provider forms so that consumer-provider shared perspectives can be assessed and to ensure that the matching process is a collaborative one; the Irish version assumes collaboration from the start. Each measure can be used when evaluating a person for technology use and as person-centered, ideographic, outcomes measure. The measures have been determined to have good reliability and validity.

Scherer, M. J., & Craddock, G. (2002). **Matching person & technology (MPT) assessment process**. *Technology and Disability*, *14*(3), 125-131.

The development of our screening



Clinical screening tool

Part 1: **Telephone Pre-screening**

Questions for caregiver prior to initial visit:

- User's communication method
- Optimal time of day for participation
- Types of medications
- Medical history/status related to sensory and physical and cognitive functioning

Part 2: **Hearing, Auditory Comprehension**

Beginning of in person screening process

Completed *prior* to consent process

Auditory Verbal Comprehension subtest of WAB

Complex Ideational Material section of the BDAE

Part 2: **Informed Consent**

Comprehension questions asked related to the consent form:

1. Will the study take 3 to 6 months to complete?	Y	☐ Correct ☐ Incorrect
2. Will you come to our office at OHSU?	N	☐ Correct ☐ Incorrect
3. Does the study involve testing a new medication?	N	☐ Correct ☐ Incorrect
4. Does the study involve testing a new typing interface?	Y	☐ Correct ☐ Incorrect
5. Will you wear a headband to hold electrodes on your head?	Y	☐ Correct ☐ Incorrect
6. Will each data collection session last 5 hours?	N	☐ Correct ☐ Incorrect
7. Is there a risk of mild discomfort or eye strain?	Y	☐ Correct ☐ Incorrect
8. Will we make your personal data available to the public?	N	☐ Correct ☐ Incorrect
9. Will you receive a $1 gift card for each study visit?	N	☐ Correct ☐ Incorrect
10. Do you have the right to quit the study at any time?	Y	☐ Correct ☐ Incorrect

Vansteensel, M. J., Branco, M. P., Leinders, S., Freudenburg, Z. F., Schippers, A., Geukes, S. H., ... & Ramsey, N. F. (2022). **Methodological Recommendations for Studies on the Daily Life Implementation of Implantable Communication-Brain–Computer Interfaces for Individuals With Locked-in Syndrome**. *Neurorehabilitation and Neural Repair*, *36*(10-11), 666-677.

Part 3: **Trial of electrode cap**

DSI 24 dry electrode cap

Flexible DSI dry electrode cap

Part 4: **Visual skills screening procedures**

Visual acuity

Broken Wheel Acuity test

Near acuity cards

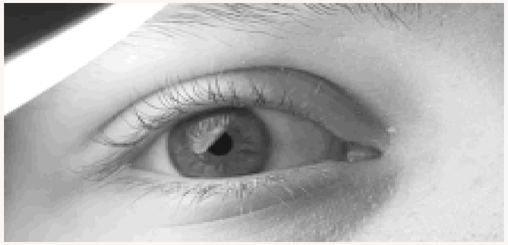
Distance acuity cards

Part 4: **Visual skills**

Visual fixation

Visual Fixation screening

Observing for:



Nystagmus

Ptosis

Light sensitivity/photophobia

Part 4: **Visual Skills**

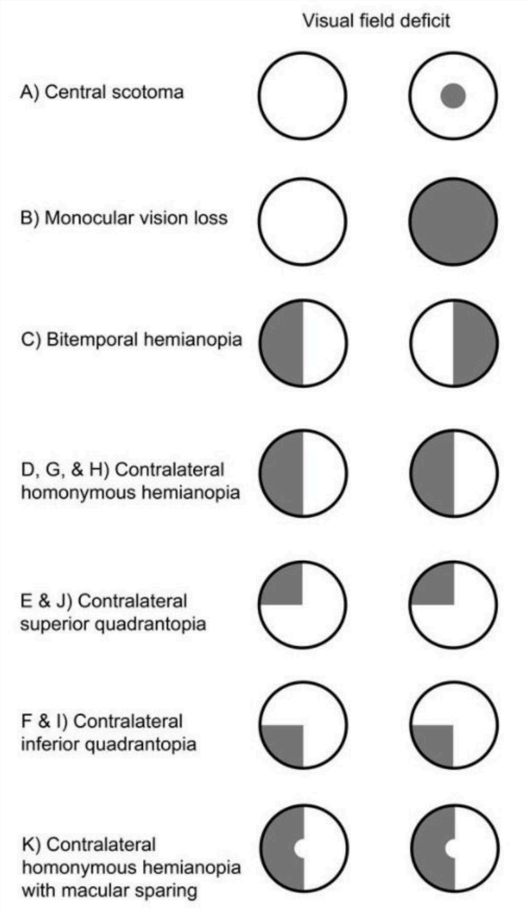
Ocular Motility

NSCUO Ocular Motility test

- Pursuits: accurately following moving targets
- Saccades: accurately shift gaze between targets

Part 4: **Visual Skills**

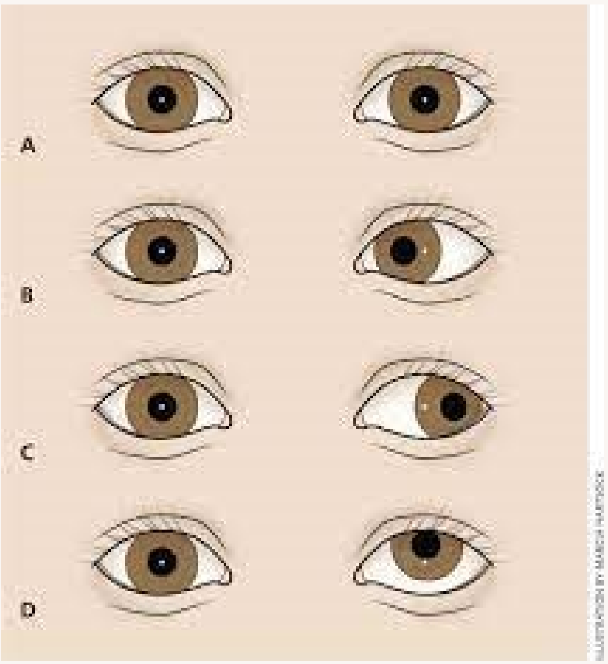
Visual field test: Rapid confrontation screening .

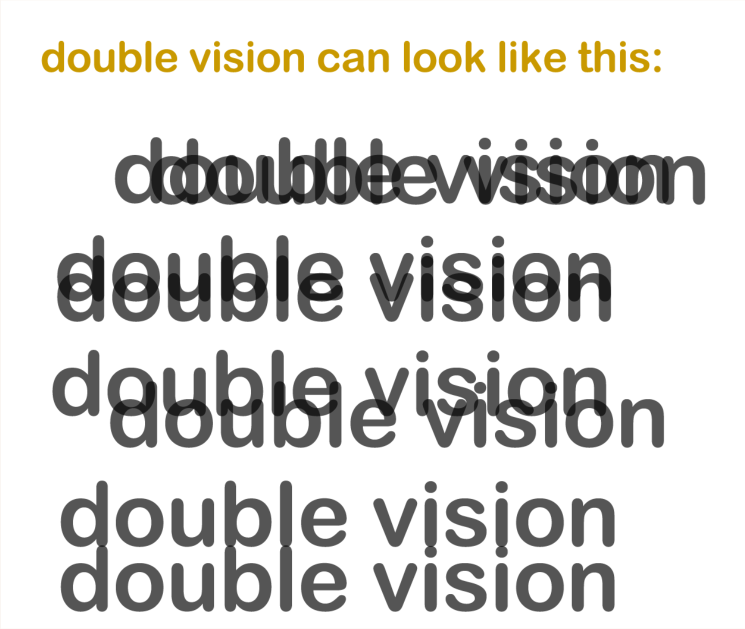


Part 3: **Visual Skills**

- Binocular skills

Medical history; participant report and observation

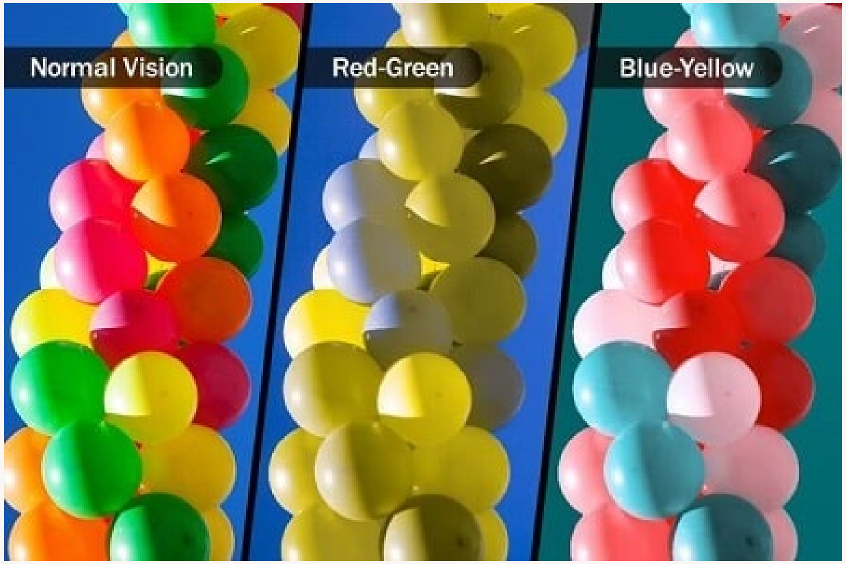




Part 4: **Visual skills**

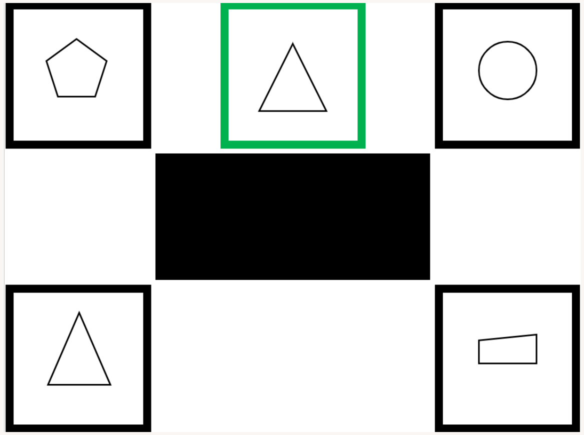
Color discrimination

Medical history; observation

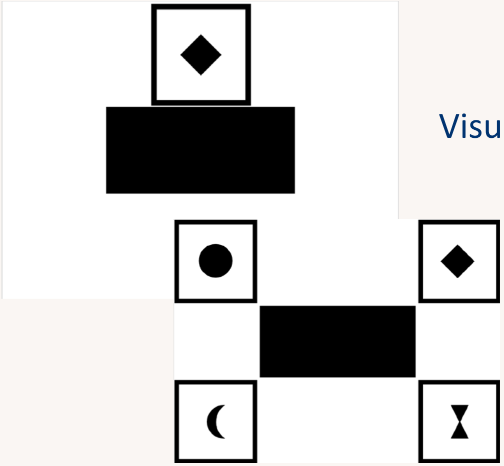


Part 4: **Visual skills**

Visual Perception



Form Constancy



Visual Memory

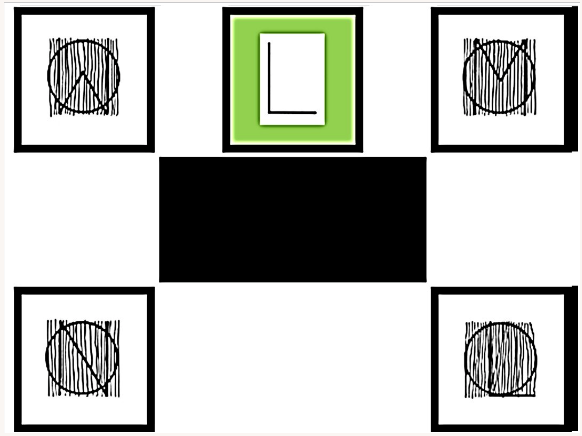


Figure Ground

Modified templates from Motor-Free Visual Perceptual test

Visual Screening Resources

DISABILITY AND REHABILITATION: ASSISTIVE TECHNOLOGY
2020, VOL. 15, NO. 7, 799–809
https://doi.org/10.1080/17483107.2020.1754929

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REVIEW ARTICLE

Human visual skills for brain-computer interface use: a tutorial

Melanie Fried-Oken[a,b], Michelle Kinsella[b], Betts Peters[b], Brandon Eddy[b,c] and Bruce Wojciechowski[d]

[a]Departments of Neurology, Pediatrics, Biomedical Engineering, and Otolaryngology, Oregon Health & Science University, Portland, OR, USA; [b]Institute on Development and Disability, Oregon Health & Science University, Portland, OR, USA; [c]Department of Speech and Hearing Sciences, Portland State University, Portland, OR, USA; [d]Northwest Eye Care Professionals, Clackamas, OR, USA

ABSTRACT

Background and objectives: Many brain-computer interfaces (BCIs) for people with severe disabilities present stimuli in the visual modality with little consideration of the visual skills required for successful use. The primary objective of this tutorial is to present researchers and clinical professionals with basic information about the visual skills needed for functional use of visual BCIs, and to offer modifications that would render BCI technology more accessible for persons with vision impairments.
Methods: First, we provide a background on BCIs that rely on a visual interface. We then describe the visual skills required for BCI technologies that are used for augmentative and alternative communication (AAC), as well as common eye conditions or impairments that can impact the user's performance. We summarize screening tools that can be administered by the non-eye care professional in a research or clinical setting, as well as the role of the eye care professional. Finally, we explore potential BCI design modifications to compensate for identified functional impairments. Information was generated from literature review and the clinical experience of vision experts.
Results and conclusions: This in-depth description culminates in foundational information about visual skills and functional visual impairments that affect the design and use of visual interfaces for BCI technologies. The visual interface is a critical component of successful BCI systems. We can determine a BCI system for potential users with visual impairments and design BCI visual interfaces based on sound anatomical and physiological visual clinical science.

ARTICLE HISTORY
Received 14 November 2019
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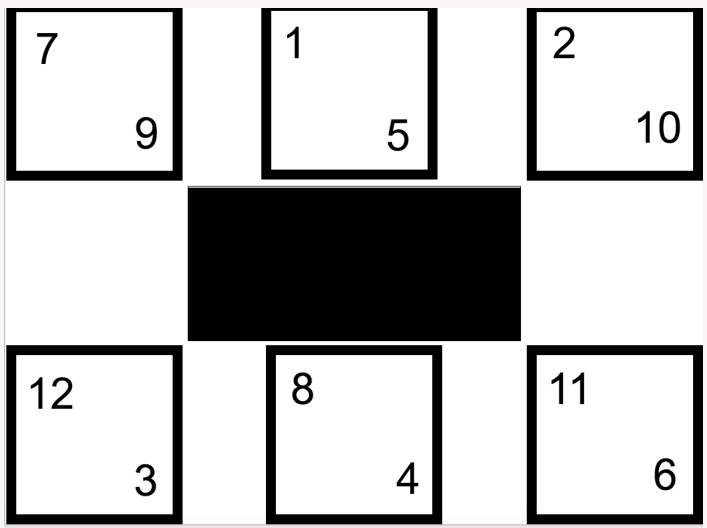
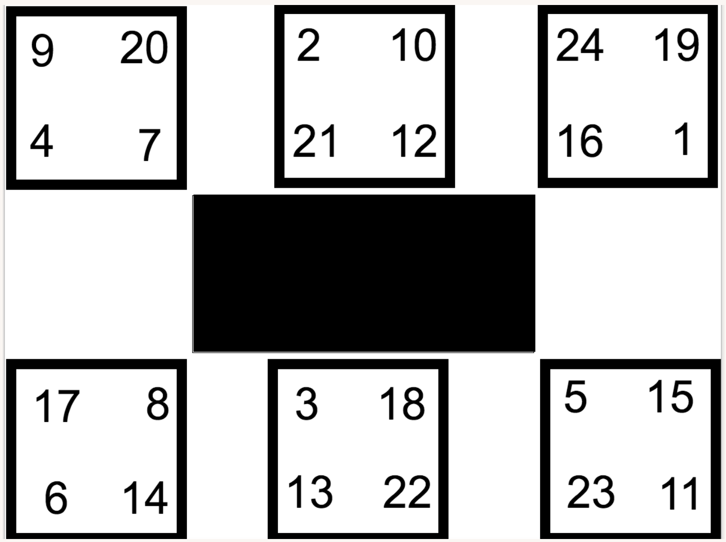
KEYWORDS
Brain-computer interface; vision; visual impairments; severe disabilities; assistive technology

Fried-Oken, M., Kinsella, M., Peters, B., Eddy, B., & Wojciechowski, B. (2020). **Human visual skills for brain-computer interface use: a tutorial.** *Disability and Rehabilitation: Assistive Technology*, *15*(7), 799-809.

Part 5: **Cognitive Skills Screening Procedures**

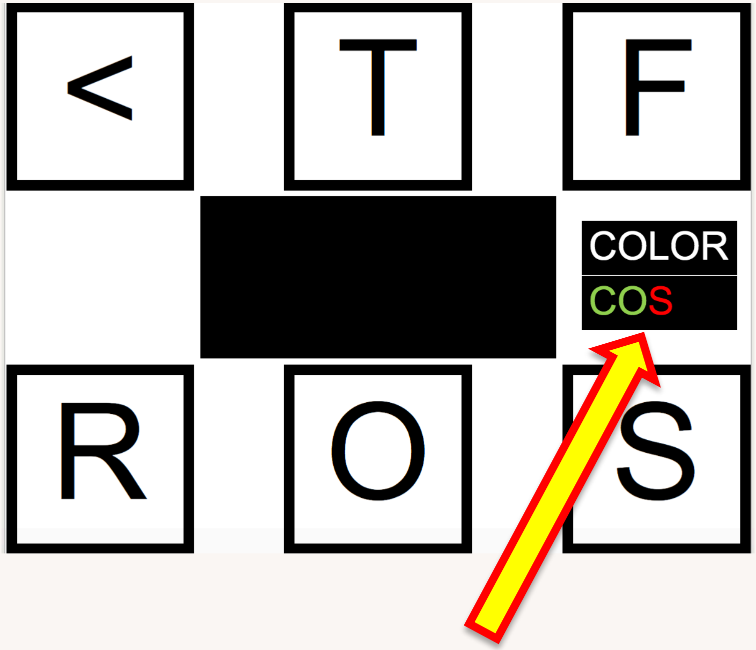
Attention and Working Memory



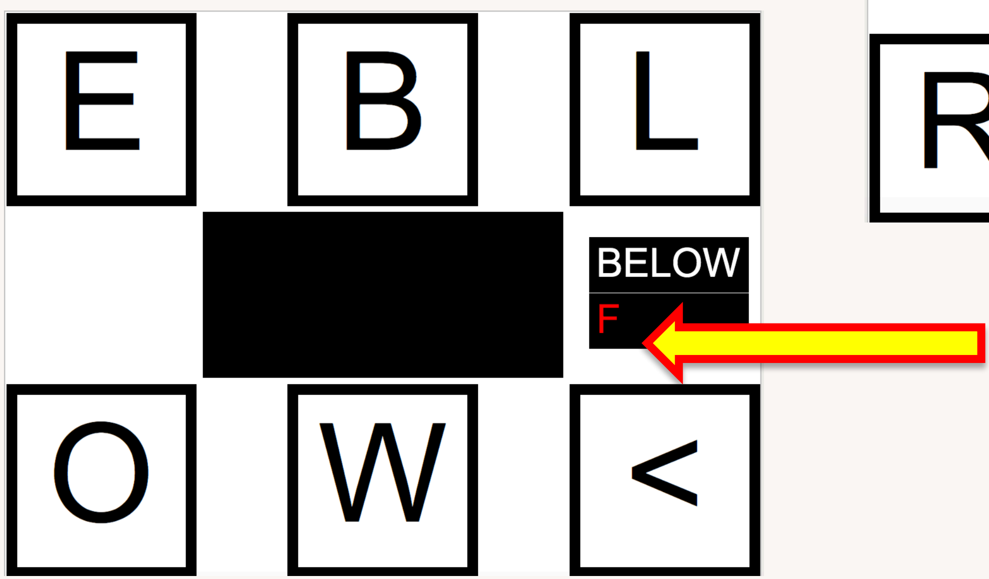


Modified Trails B test

Executive Function



Error Awareness



Red=error

Cognitive Screening Resources

Disability and Rehabilitation Assistive Technology

http://informahealthcare.com/idt
ISSN 1748-3107 print/ISSN 1748-3115 online

Disabil Rehabil Assist Technol, 2015; 10(1): 11–18
 DOI: 10.3109/17483107.2013.836684

informa healthcare

ORIGINAL RESEARCH

A clinical screening protocol for the RSVP Keyboard brain–computer interface

Melanie Fried-Oken[1], Aimee Mooney[1], Betts Peters[1], and Barry Oken[2]

[1]*Institute on Development & Disability and* [2]*Department of Neurology, Oregon Health & Science University, Portland, OR, USA*

Abstract

Purpose: To propose a screening protocol that identifies requisite sensory, motor, cognitive and communication skills for people with locked-in syndrome (PLIS) to use the RSVP Keyboard™ brain–computer interface (BCI). *Method*: A multidisciplinary clinical team of seven individuals representing five disciplines identified requisite skills for the BCI RSVP Keyboard™. They chose questions and subtests from existing standardized instruments for auditory comprehension, reading and spelling, modified them to accommodate nonverbal response modalities, and developed novel tasks to screen visual perception, sustained visual attention and working memory. Questions were included about sensory skills, positioning, pain interference and medications. The result is a compilation of questions, adapted subtests and original tasks designed for this new BCI system. It was administered to 12 PLIS and 6 healthy controls. *Results*: Administration required 1 h or less. Yes/no choices and eye gaze were adequate response modes for PLIS. Healthy controls and 9 PLIS were 100% accurate on all tasks; 3 PLIS missed single items. *Conclusions*: The RSVP BCI screening protocol is a brief, repeatable technique for patients with different levels of LIS to identify the presence/absence of skills for BCI use. Widespread adoption of screening methods should be a clinical goal and will help standardize BCI implementation for research and intervention.

Keywords

Augmentative and alternative communication, brain–computer interface, cognition, locked-in syndrome, screening

History

Received 28 March 2013
Revised 9 August 2013
Accepted 17 August 2013
Published online 23 September 2013

Fried-Oken, M., Mooney, A., Peters, B., & Oken, B. (2015). **A clinical screening protocol for the RSVP keyboard brain–computer interface**. *Disability and Rehabilitation: Assistive Technology*, *10* (1), 11-18.

Part 6: **Motor demands to consider with BCI use**

Involuntary movement will impact the quality of signal acquisition:

- Tremors
- Increased spasticity
- Athetosis
- Coughing/swallowing
- Eye blinks

Part 7: **Environmental factors**

- Level and sophistication of caregiver support
- Amount of electrical "noise"
- Challenges involved with positioning of user
- Challenges involved with available space in room
- Glasses and hearing aids

Part 8: **Personal factors**

- Age, level of education
- Comfort with technology use
- Socio-economic factors
- Personal thoughts or preferences of interface design or access methods
- Level of motivation and frustration tolerance

Part 9: **EEG signal quality**

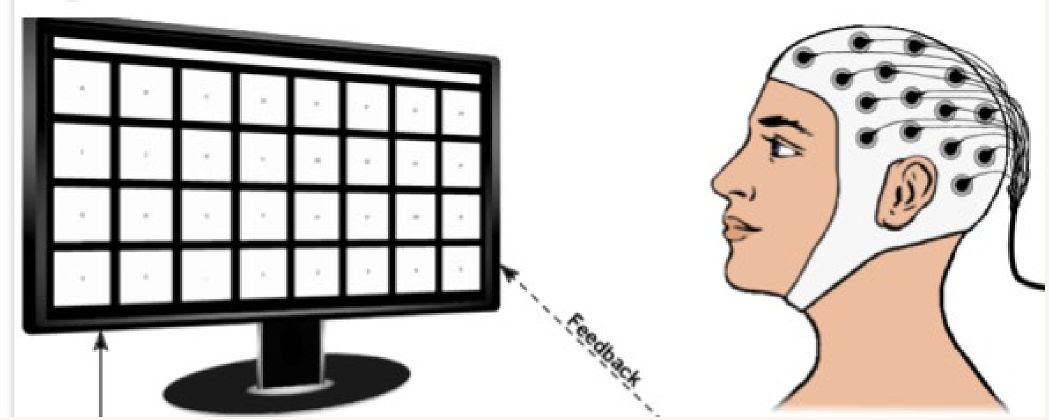
How to use this information to inform an optimal AAC-BCI configuration

Significant findings for PJ

User Skill	User performance	Implications for BCI-AAC configuration
Visual skills	Nystagmus, light-sensitivity and poor perceptual skills	Use simple to recognize targets; increase contrast target size avoid flashing bright lights
Cognitive skills	Poor performance Trails A	Possible problems with visual search
EEG signal quality	Poor quality SMR signal	Use P300 signal acquisition
User preferences	Limited technology use in past with low comfort level	Simplify instructions, allow for repeated practice and errorless learning

Design configurations to consider for Brandon

RSVP interface with P300

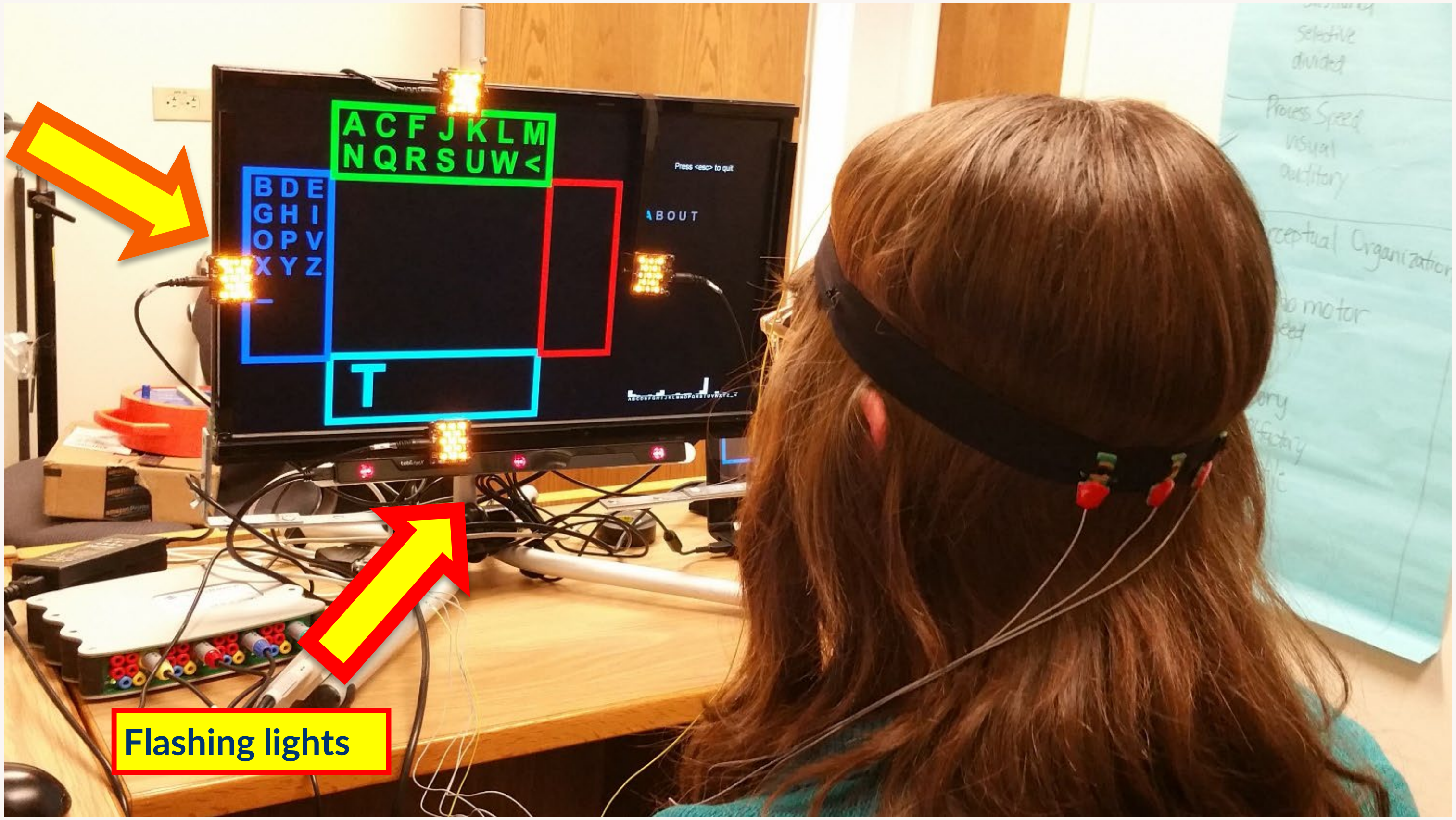


Matrix interface with P300

Significant findings for Alice

User Skill	User performance	Implications for BCI-AAC configuration
Visual skills	Reduced acuity	Increase contrast and target size
Cognitive skills	Poor performance error awareness	Use auditory or visual cues for errors
EEG signal quality	Poor quality of P300 signal	Use display interface with VEP or SMR signal access

Design configurations to consider for Alice



Shuffle interface with SSVEP

Peters, B., et al (2018). **Effects of simulated visual acuity and ocular motility impairments on SSVEP brain-computer interface performance: an experiment with Shuffle Speller**. *Brain-Computer Interfaces*, *5*(2-3), 58-72**.**

Including people who use AAC in BCI design and evaluation

User-centered design

- Goals
  - Focus on user needs and preferences
  - Involve users at all stages of design
  - Iterative process

User-centered design: Switch input

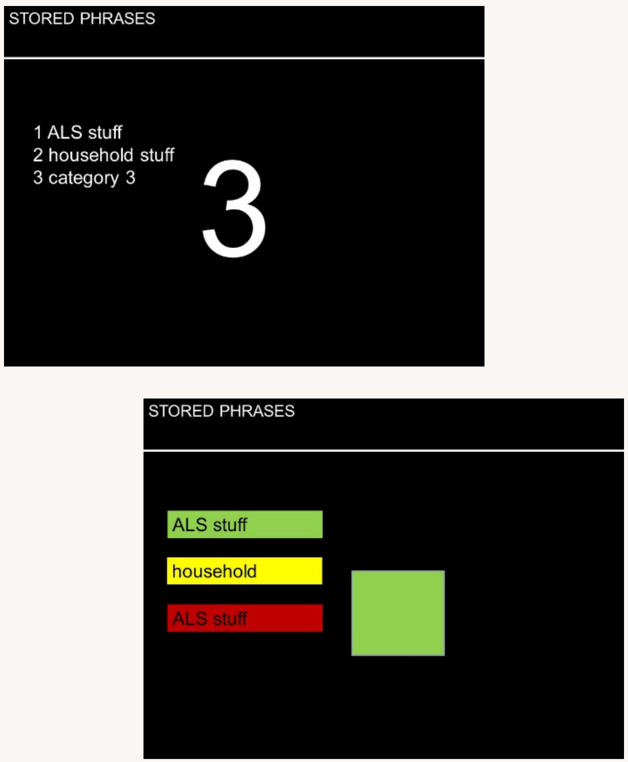
- Goal: identify a useful and desirable function for switch input in RSVP Keyboard
- Consultants: 4 people who use AAC and have participated in AAC-BCI research
- Procedure: Interviews & co-design sessions via videoconference & screen sharing

User-centered design: Switch input

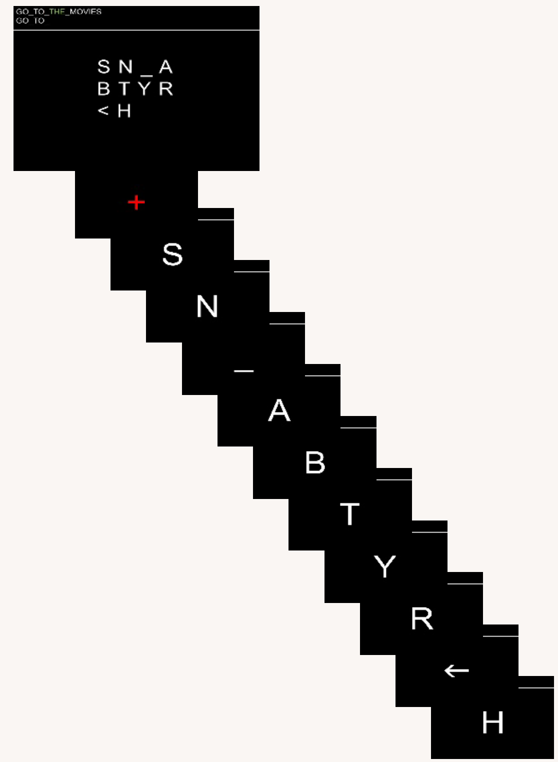
- Feedback on switch functions proposed by research team
  - Would you use it?
  - Would it be helpful for someone else?
  - How would you want it to work?
  - Do you have other ideas?
- Rank your top 3 choices

User-centered design: Switch input

- Co-design of user interface for a desired function



Stored phrases



Inquiry preview

User experience (UX) feedback

- Goal: elicit feedback on workload, comfort, satisfaction, etc.
- Part of iterative user-centered design

- Challenge: traditional questionnaires can be difficult, time-consuming, or inaccessible for people with severe speech and physical impairments

Soliciting UX feedback from people with SSPI

- Keep it focused
- Partner-assisted scanning and yes/no questions
- Questions in both visual and auditory format
- Extra time for narrative feedback

How much *physical* effort or activity was required to operate the system?

7	Extremely high
6	Considerably high
5	Somewhat high
4	Neither high nor low
3	Somewhat low
2	Considerably low
1	Extremely low

Overall, how hard did you have to *work* during the task?

7	Extremely hard
6	Really hard
5	Considerably hard
4	Moderately hard
3	A little hard
2	Scarcely hard
1	Not at all hard

Soliciting UX feedback from people with SSPI

Brain-Computer Interfaces, 2016
http://dx.doi.org/10.1080/2326263X.2015.1138056

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Soliciting BCI user experience feedback from people with severe speech and physical impairments

Betts Peters[a], Aimee Mooney[a], Barry Oken[b] and Melanie Fried-Oken[a,c]*

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Brain–computer interface (BCI) researchers have shown increasing interest in soliciting user experience (UX) feedback, but the severe speech and physical impairments (SSPI) of potential users create barriers to effective implementation with existing feedback instruments. This article describes augmentative and alternative communication (AAC)-based techniques for obtaining feedback from this population, and presents results from administration of a modified questionnaire to 12 individuals with SSPI after trials with a BCI spelling system. The proposed techniques facilitated successful questionnaire completion and provision of narrative feedback for all participants. Questionnaire administration required less than 5 minutes and minimal effort from participants. Results indicated that individual users may have very different reactions to the same system, and that ratings of workload and comfort provide important information not available through objective performance measures. People with SSPI are critical stakeholders in the future development of BCI, and appropriate adaptation of feedback questionnaires and administration techniques allows them to participate in shaping this assistive technology.

Keywords: Brain–computer interfaces; user feedback; communication aids for disabled; patient outcome assessment; quadriplegia; assistive technology; augmentative and alternative communication

CONCLUSION

- BCI systems show promise for:
  - Communication
  - Assessment
  - Intervention
  - Research
- But we're not there yet!

CONCLUSION

- BCI systems must be designed & configured to meet the needs & preferences of users
  - Clinical screening
  - Personal factors, preferences
  - Environmental factors
  - Input & feedback on system design
- BCI users must play a central role in technology development!

Questions?

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