Considering User-Centered Design in BCI Research and Development

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CAMBI

A little about me

- I am a speech-language pathologist and assistive technology researcher in Portland, Oregon USA
- I have worked in the area of AAC- augmentative and alternative communication – since 1979
- I have both clinical and research AAC experience with children and adults
- I joined BCI researchers worldwide in 2009 to design a non-invasive speller for literate adults
- I now lead a multi-disciplinary team and learn from them every day!

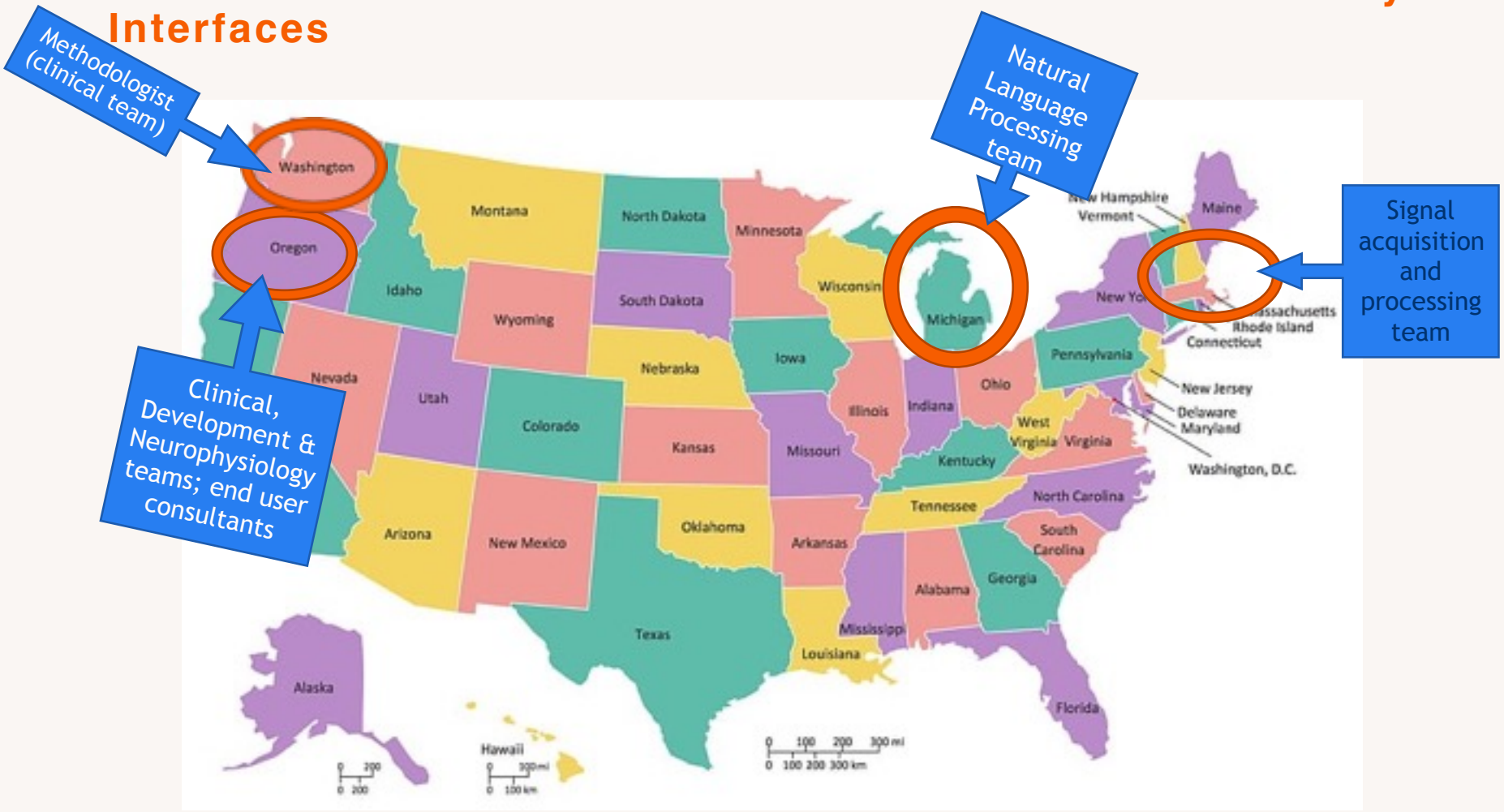
Mark and Melanie in 1980

Why BCI?

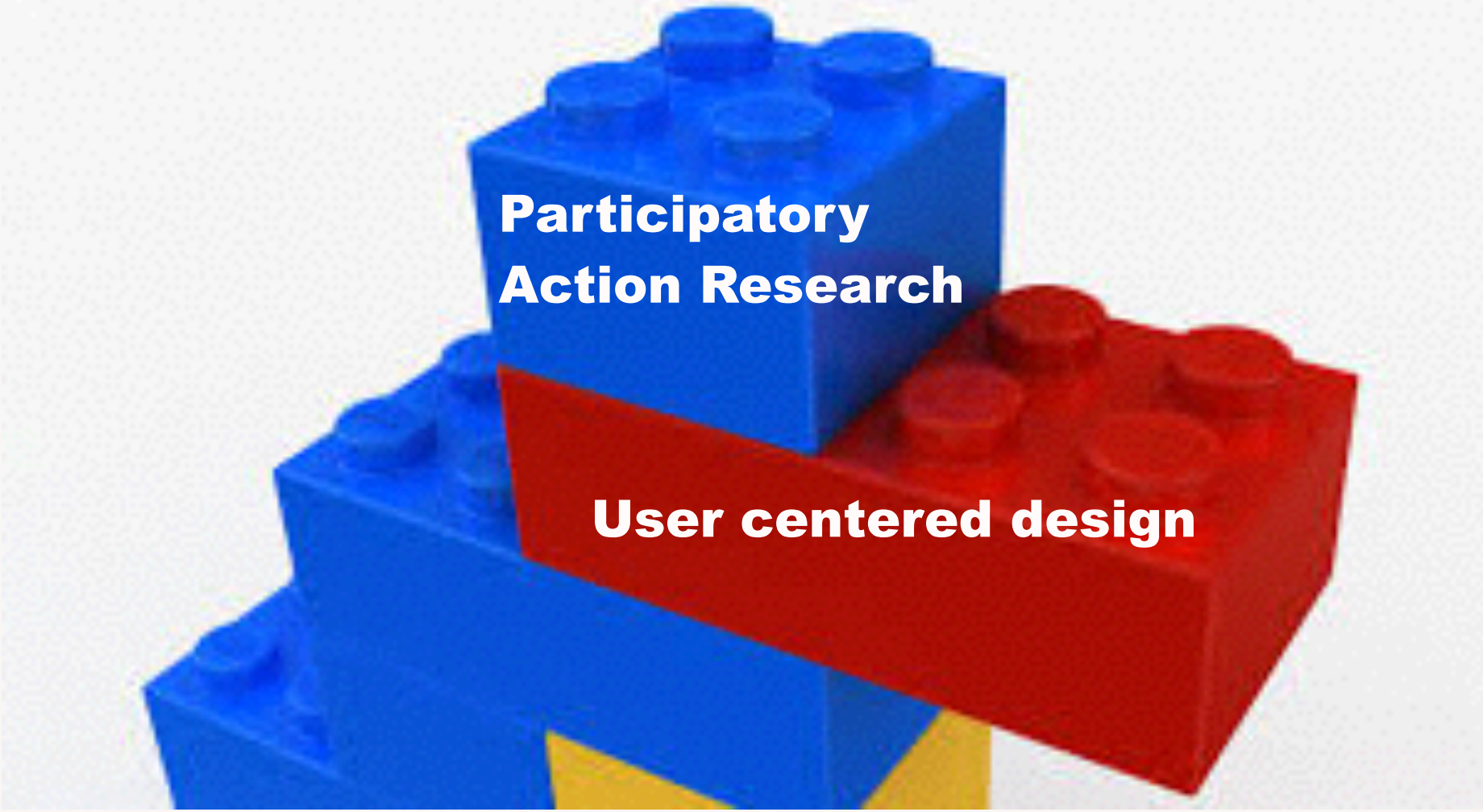
- In clinic, I evaluated one man with end-stage ALS and one man with locked-in syndrome from a brainstem stroke.
- Neither person had a reliable, consistent means of expression
- What was available?
- Started the OHSU BCI team!

About the CAMBI 2022 team

CAMBI: Consortium of Accessible Multi-Modal Brain-Body Interfaces



AAC and BCI Design Principles



AAC and BCI Design Principles

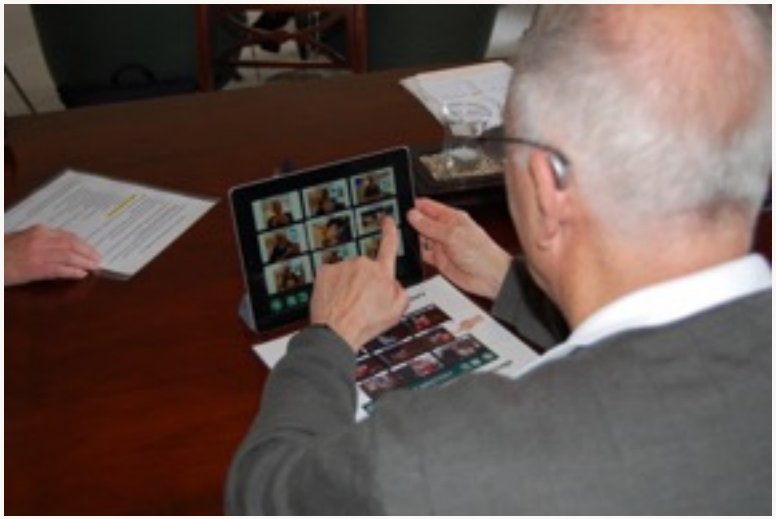
Participatory Action Research

Individuals with disabilities are included in every phase of research

Individuals with disabilities are the experts……

Research is conducted in the participant's residence or location of choice

Research materials are customized to individuals with disabilities



Input comes directly from people living with disabilities

Peters, B., Bieker, G., Cach, M., Do, A., Fritz, A., Guger, C., Spataro, R., Vuckovic, A., & Fried-Oken, M. (2016) What does BCI stand for? The 2016 Virtual Forum of BCI Users. Presentation at the Sixth International Brain-Computer Interface Meeting. Pacific Grove, CA.

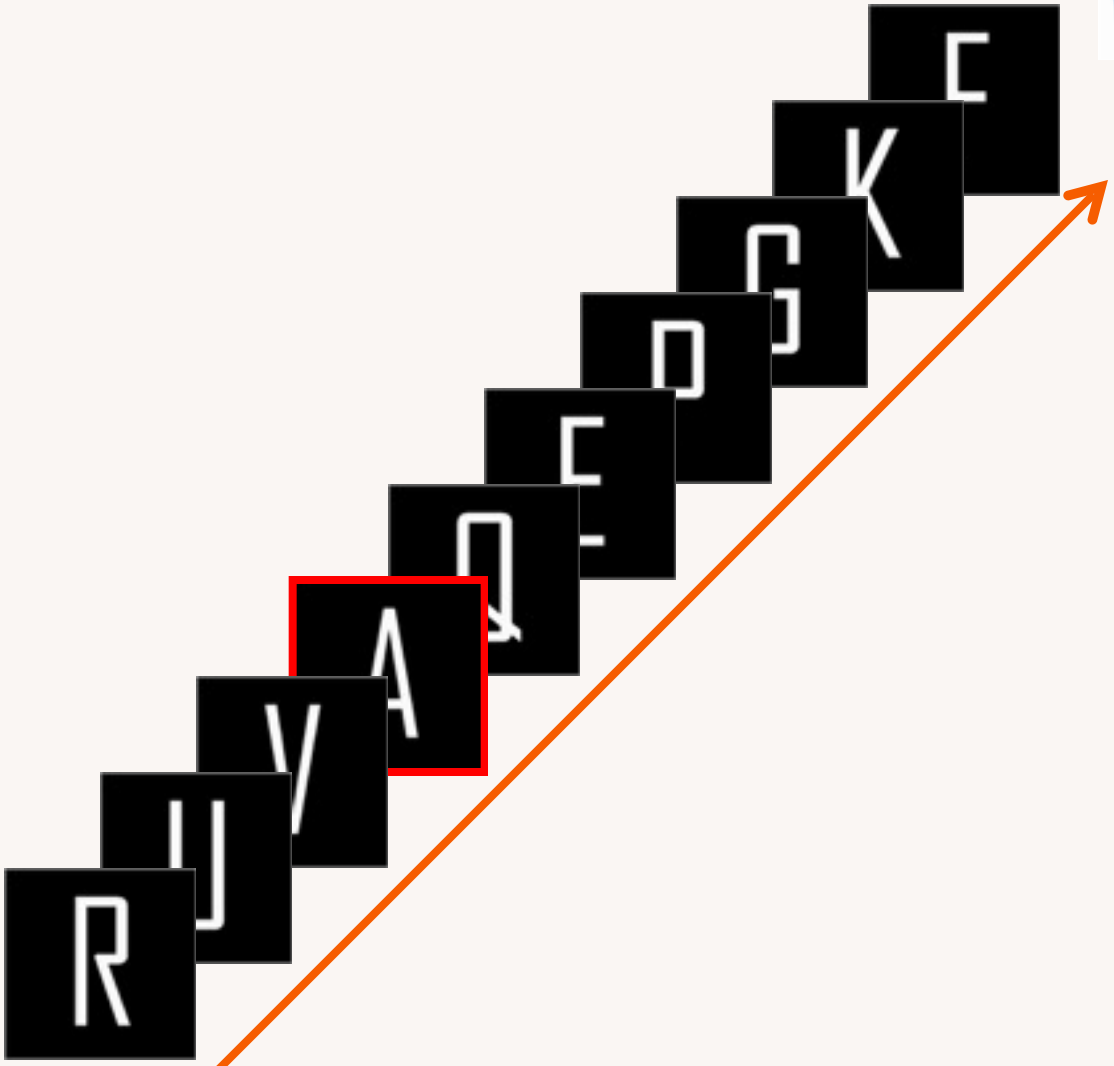
Development is based on patients' ideas

"I wish there was a way that he could just use thoughts to communicate."

BCI: Vision and project goals

Vision: To make an AAC-BCI available for independent communication so that individuals with the most severe disabilities can return to their families, live in the community, and contribute to decision-making and medical management.

One Solution:
RSVP Keyboard™



- Oken, B., Orhan, U., Roark, B., Erdogmus, D., Fowler, A., Mooney, A., Peters, B., Miller, M., & Fried-Oken, M. (2014). Brain-computer interface with language model-EEG fusion for locked-in syndrome. Neurorehabilitation

RSVP Keyboard:
Spelling stimuli for a P300 signal

- RSVP:
  - Rapid
  - Serial
  - Visual
  - Presentation of letters
- 400ms per letter

RSVP Keyboard™

- RSVP Keyboard™ is a BCI typing system
  - Letters are typed one at a time
  - A rapid sequence of individual letters is shown to the user
  - EEG measurements are made and processed
  - This evidence is *combined* with a character-based language model
- This combination is called fusion
- When the EEG/LM evidence points strongly to a specific letter, we type it and begin again

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Using Brain-Computer Interface for Communication

RSVP Keyboard™: Fusing Language Model & EEG Evidence

- RSVP Keyboard makes letter selections based on *joint evidence* from an n-gram language model and EEG signals.

- Language model is a letter and word based algorithm trained using large language databases.

Language Models for BCI

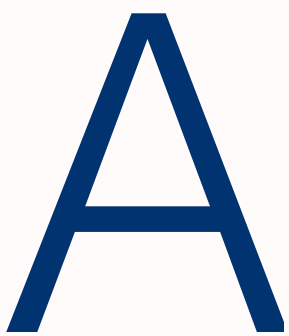
- BCI is a very good place to use LMs
  - Communication is often text-based
  - Speed is essential
  - Brain signal measured by scalp EEG sensors is noisy and relatively weak, often not enough on its own
- A language model can not only make a BCI typing system faster, it can make it usable

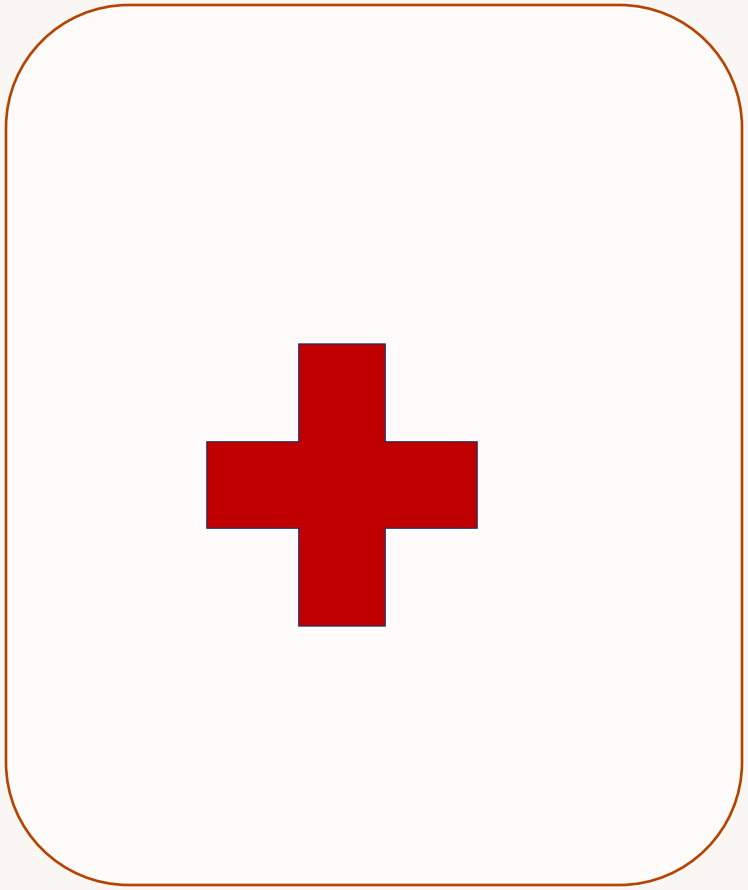
- RSVP Keyboard is trained with people with disabilities, rather than graduate students or research staff.

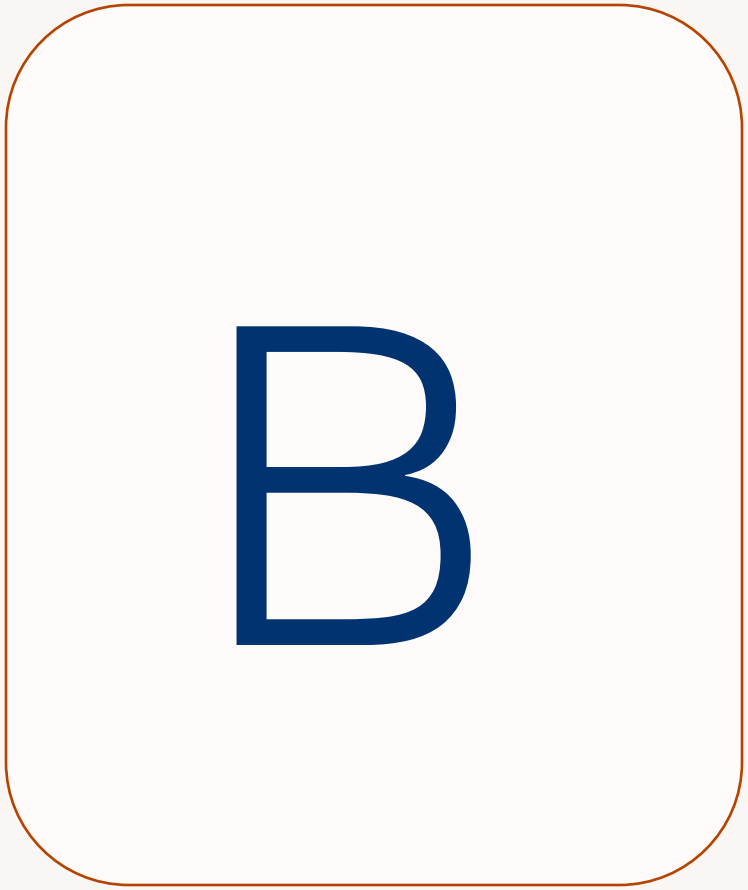
- We develop the system within a clinical translational setting, in homes and then in laboratories, and back to homes.

- This system does not read thoughts or read minds. It is detecting changes in brainwaves that form choices, like a mouse click.

TARGET



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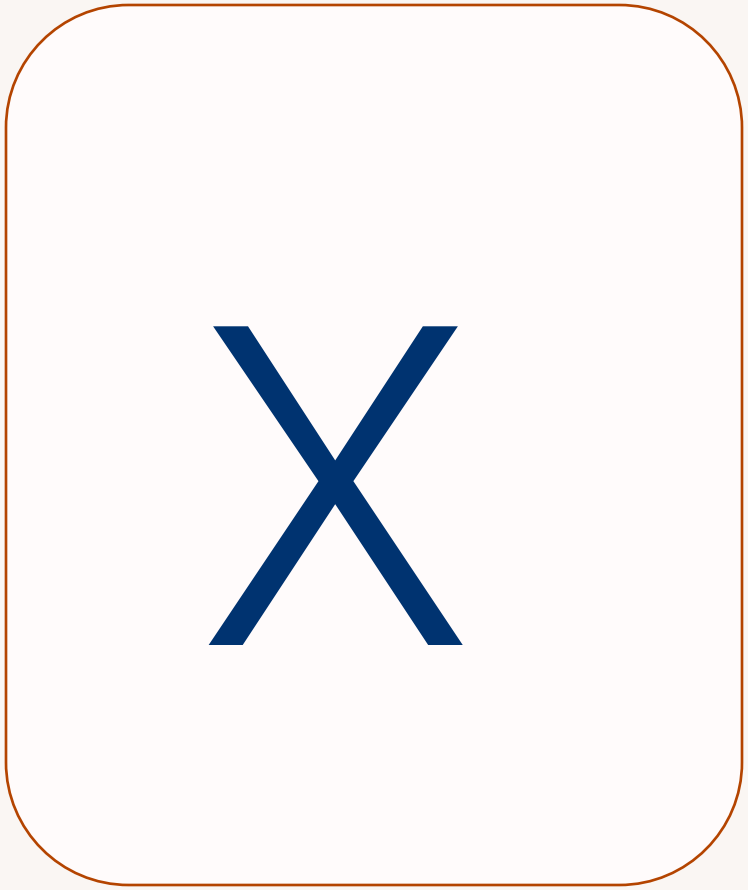

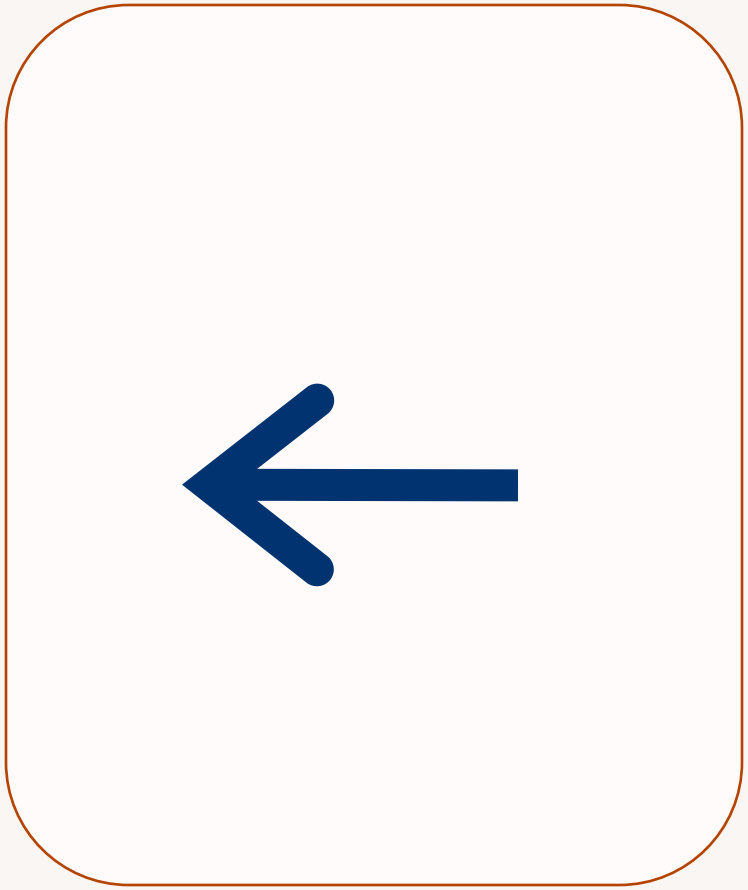

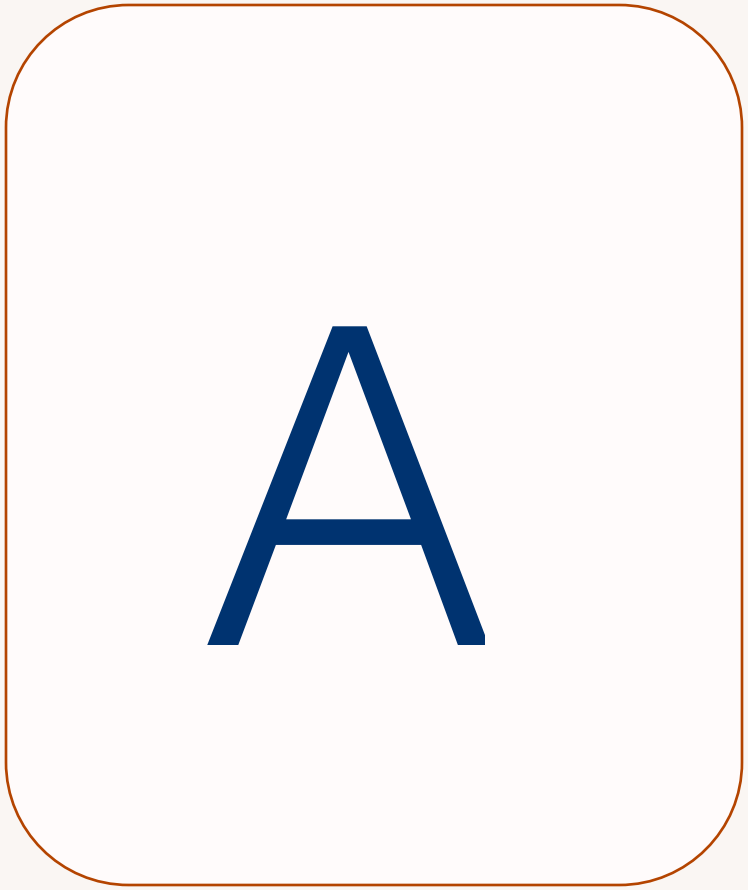
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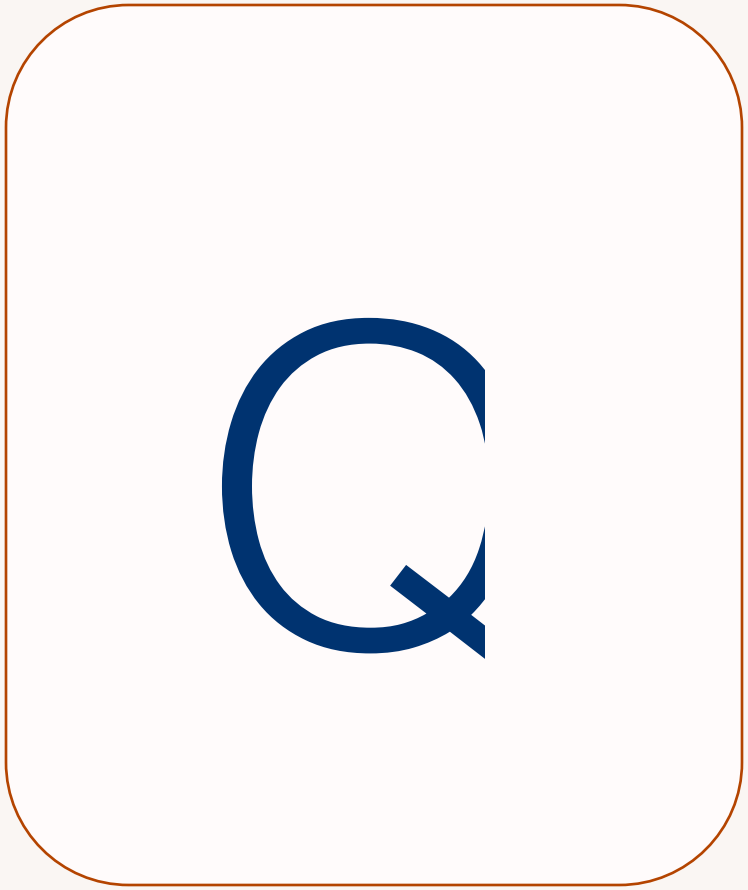
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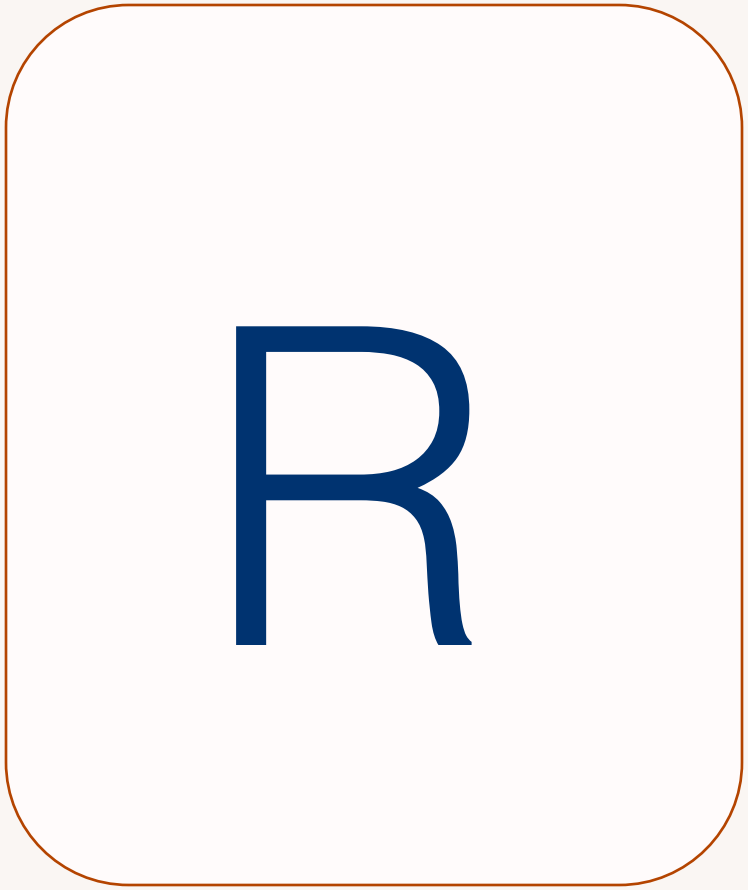
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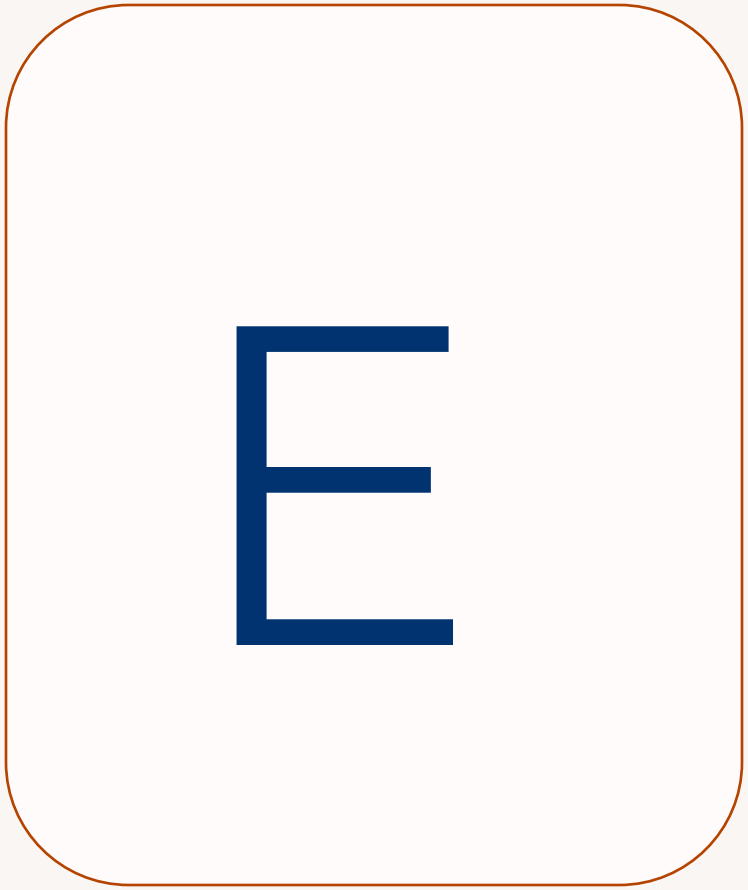
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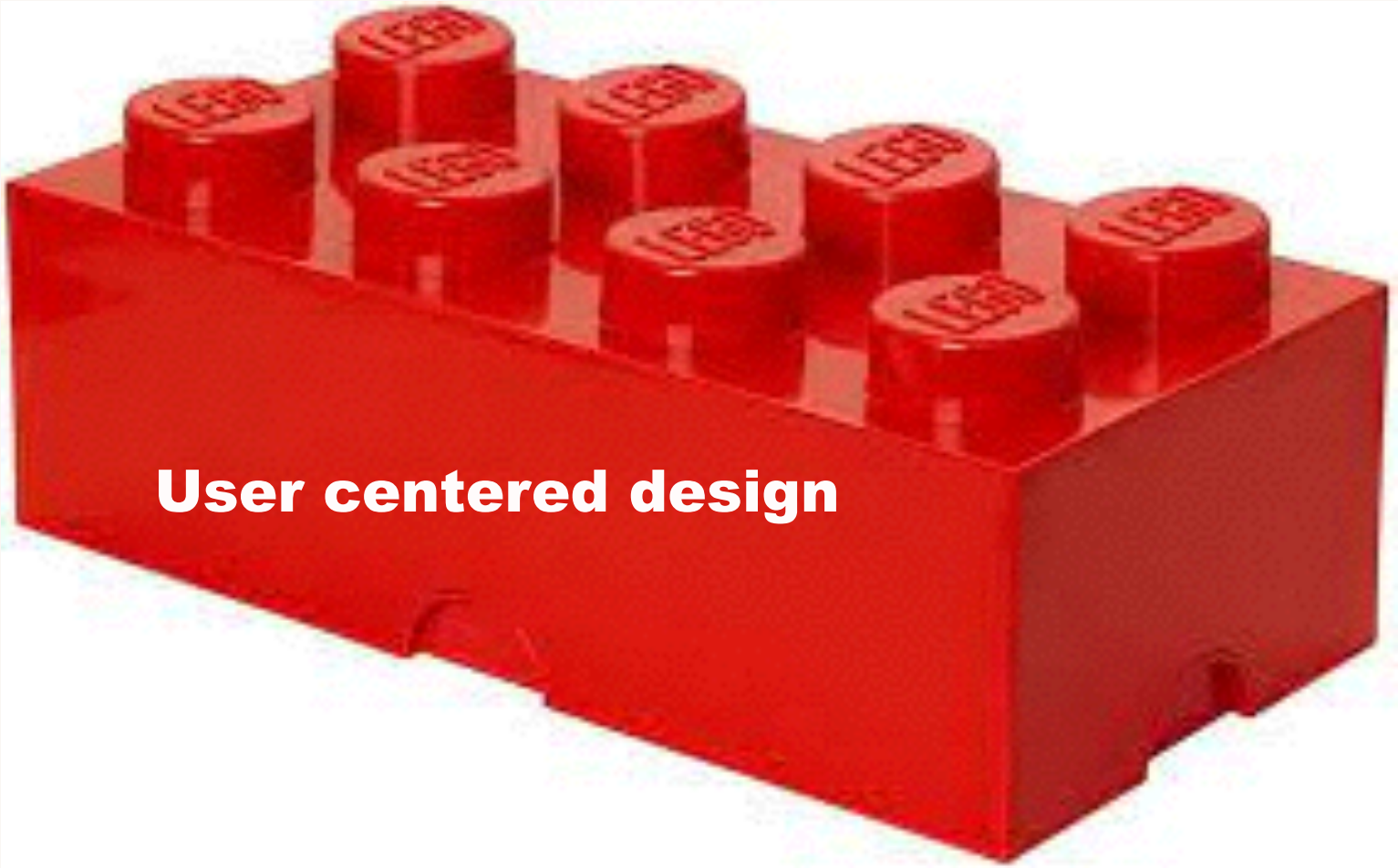
Congratulations! You created a P300 wave!

AAC and BCI Design Principles



User Centered Design

Users of a proposed product influence how it takes shape (ISO 9241-210:2010)

International Standards Organization 9241-210:2010

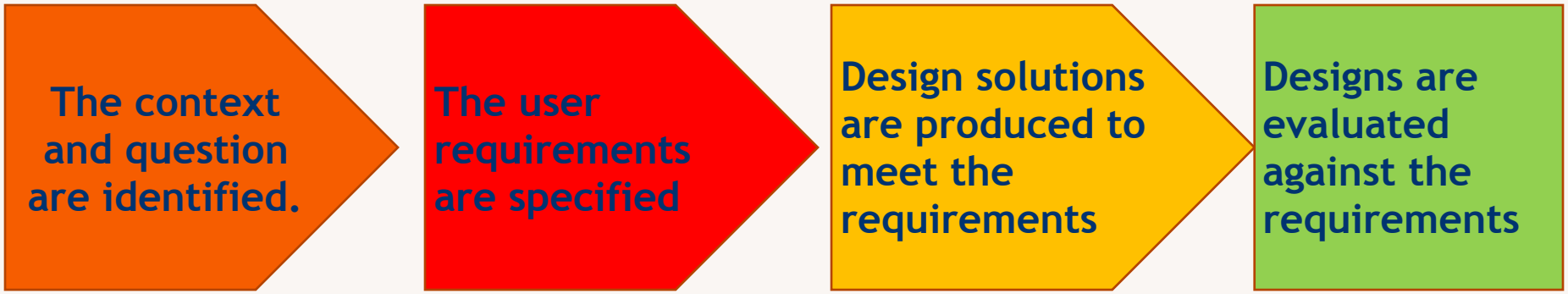
- Ergonomics of human-system interaction -- Part 210: Human-centred design for interactive systems

- Provides requirements and recommendations for human-centred design principles and activities throughout the life cycle of computer-based interactive systems. It is intended to be used by those managing design processes, and is concerned with ways in which both hardware and software components of interactive systems can enhance human–system interaction.

Three Groups of Users

1. **End-users** (primary): People who actually use the product (i.e., individuals with disabilities)
2. **Secondary users:** People who may occasionally use the product or use it through an intermediary (i.e., family members, caregivers)
3. **Tertiary users:** People who will be affected by the use of the product and make decisions about its usefulness in order to fund or purchase the product (i.e., speech-language pathologists, occupational therapists, special education teachers)

User centered design process



AAC-BCI user-centered design

- The target users of brain computer interfaces for AAC (AAC-BCI) are people who experience severe speech and physical impairment (SSPI)
- People who experience SSPI are often not included in the design or testing of AAC-BCI as team members or research participants (Eddy et al., 2019)
- For 14 years, our research team has partnered with people with SSPI to guide AAC-BCI system development
    - Peters, B., Mooney, A., Oken, B., & Fried-Oken, M. (2016). Soliciting BCI user experience feedback from people with severe speech and physical impairments. *Brain-Computer Interfaces*, *3*(1), 47-58.

CAMBI examples of end-user input for design

1. Preferences
2. Values and ethical considerations

Team Goal

To integrate switch activation as an additional control signal in our EEG-based non-invasive AAC-BCI spelling system.

How should we use a switch in our AAC-BCI spelling system?

Consultants for Switch Integration

Four individuals with SSPI who had participated in previous AAC-BCI studies and had experience using assistive technology acted as consultants.

They shared their opinions about potential features that could be controlled using switch activation.

McLaughlin, D., Peters, B., Memmott, T., Kinsella, M., & Fried-Oken, M. (2020). User-centered design influences the integration of multimodal access in an AAC-BCI system. Poster presented at ISAAC Connect virtual conference.

Opinions on Switch Integration

All consultants identified the following features as potentially useful:

- Backspace *(Oops, I chose the wrong letter.)*
- Pausing stimuli presentation *(My brain and eyes need a break!)*
- Switching to stored phrases *(I can type that faster with my phrases.)*
- Activating text-to-speech *(Let's say that out loud.)*

All consultants emphasized the importance of ease of use, flexibility, and customizability to meet the needs of individual users.

McLaughlin, et al., 2020

Co-Designs of Selected Features

Session 1: Stored Phrases

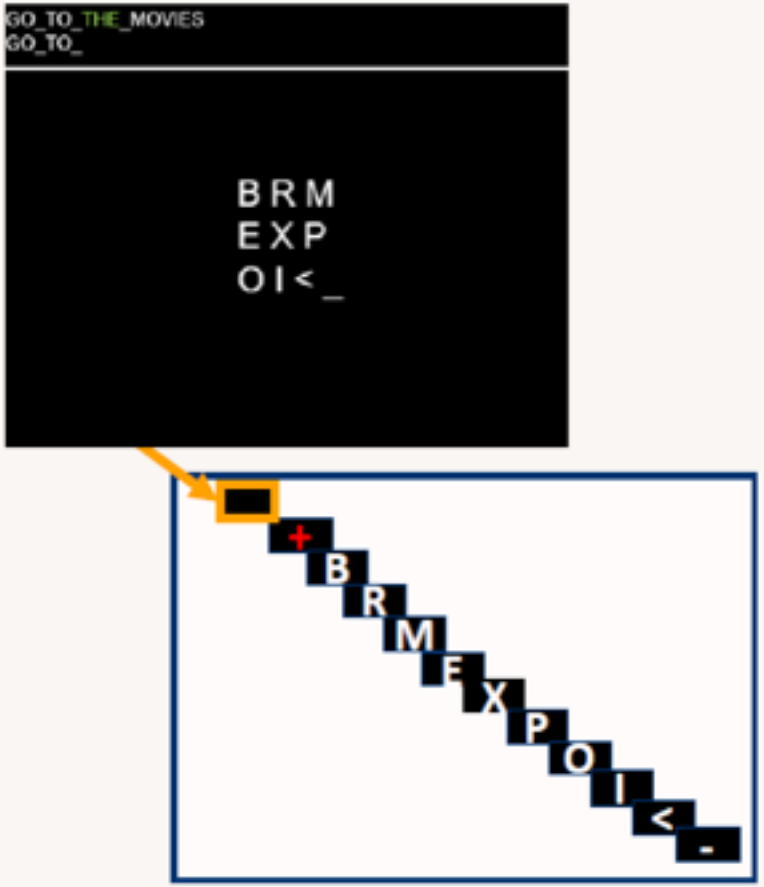
Session 2: Advanced Editing

McLaughlin, et al., 2020

Session 3:

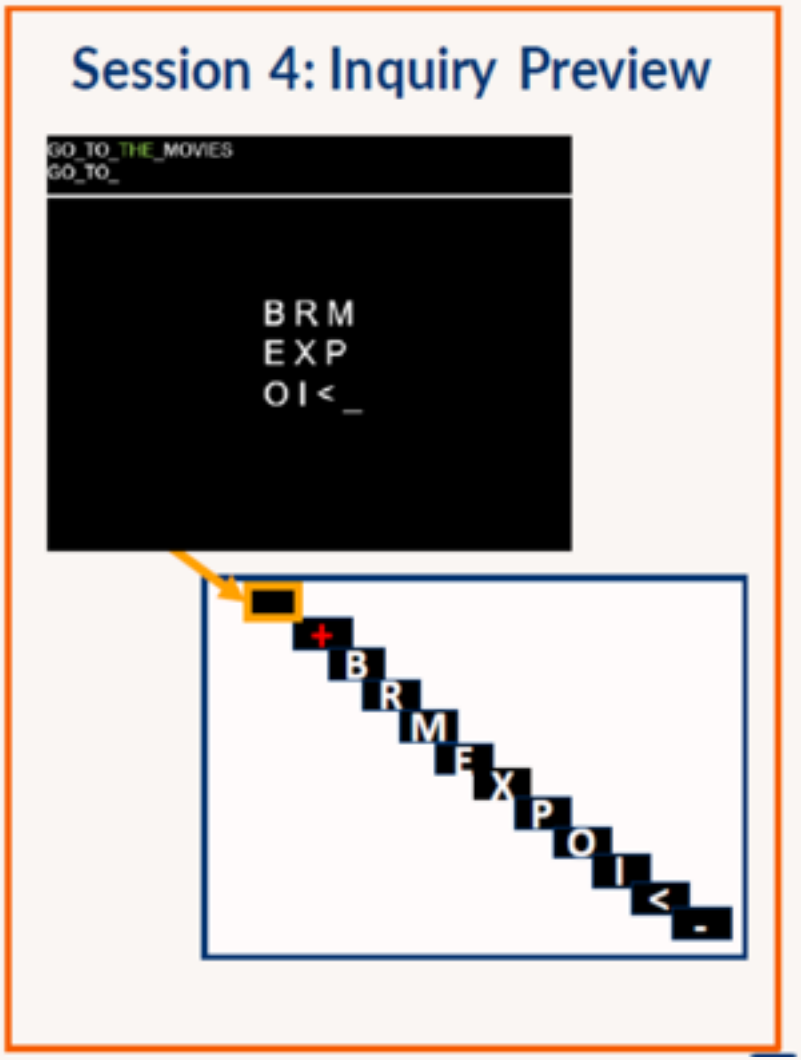
Delete & Pause Mode

Session 4: Inquiry Preview



McLaughlin, et al., 2020

Inquiry Preview was selected for switch access



Video of IP with switch

Peters, Vertanen, Wade, Gibbons, Fried-Oken (2023). Examining alternative keyboards and language modeling software for message generation by BCI end-users. A workshop to be presented at the BCI Society meeting. Brussels, Belguim.

Is Inquiry Preview with switch access a good interface for RSVP Spelling?

We are currently analyzing the data! Stay tuned for results!

User values and ethical perspectives shape design and adoption

What are your values around storing your personal vocabulary in an AAC-BCI?

Klein, Kinsella, Stevens & Fried-Oken. (2022). Ethical issues raised by incorporating personalized language models into brain-computer interface communication technologies: a qualitative study of individuals with neurological disease. *Disability & Rehabilitation: Assistive Technology*. DOI:10.1080/17483107.2022.2146217

Whom did we ask?

- 15 semi-structured interviews (in person or videoconferenced during pandemic)
- 51 online free response surveys
- Participants presented with:
  - ALS or PLS
  - Multiple sclerosis
  - Parkinson's disease
  - Multiply system atrophy
  - Spinal muscular dystropy

What did we ask?

- Beth is a 62-year-old woman with Multiple Sclerosis (MS). She is a strong advocate and has lobbied in Congress for MS funding and has led a local support group. As Beth's speech worsened, she decides to work with a research team that is developing a BCI device for communication. They suggest, "personalizing" her device using her emails to supplement the language model for autocorrection or word/phrase suggestion to speed up her communication.
- A year later when she is using the device like an expert, she invites family and friends over for her annual holiday party. When an old boyfriend unexpectedly makes an appearance at the party, the BCI voice blurts out "jerk!" (Rather than "Jerry!"). She protests to all at the party that she did not intend this insult, but others who know their history are doubtful. She wonders whether she was trying to say "Jerry!" and misinterpreted via auto-correct or whether her instinct was just to say "jerk."

Probes related to language models in AAC-BCI devices

- Privacy
- Agency
- Identity
- Disability

Summary of take-aways

- The experience of a neurodegenerative disease shapes preferences for personalized language models.
- An individual's identity will be affected by their ability to personalize the language model.
- The motivation for personalization is tied to how relationships can be helped or harmed.
- Privacy is important to people who may need BCI communication technologies.
- People who may rely on BCI one day care about the usability of the technology and that the technology supports their values and priorities.

Speed versus accuracy trade-off

1. How likely would you be to use a device that worked faster but also revealed things you did not plan on sharing about your personality?

2. How likely would you be to use a device that worked faster but also made more mistakes?

Fried-Oken, Kinsella, & Klein (in progress). Potential end user values on the speed-accuracy trade-off in brain-computer interface systems for communication. *Brain Computer Interfaces.*

What did they tell us?

“I obviously spend more time being accurate and I know I could be a lot faster in typing with my eyes if I didn’t care as much about it, if I look at the misspelling and say, oh, they’ll know what I mean. But I still don’t wanna do that.”

“I don’t type as fast as I used to before PLS, but I would much prefer to type each word than have my sentences completed for me and take a chance that it’s wrong.”

“[Using a slow BCI device] I might get frustrated with the limitation of trying to get the words out, which might make me cut short what I'd like to say or affect my word choice. I might become less conversational, and I think that could make me feel sad and isolated.”

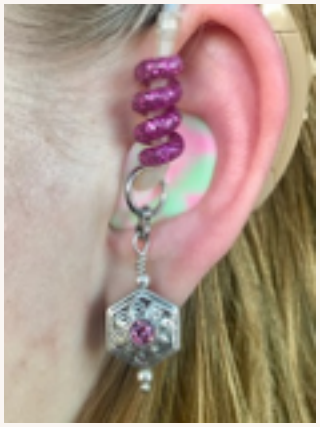
“The person using this device already has the disadvantage of little body language helping to create meaning and the slower the method of communicating the less others will be able or willing to listen”.

Design suggestions

- *"I think it's important to have that ability to control – to control the technology a little bit".*
- Users could have access to a *"command button"* to turn off accuracy features at times.
- A BCI device could be designed to adapt to communication partners (e.g., identify an intimate or a stranger) or social context (e.g., health care, work, or home setting).
- Have the ability to *"double check"* or *"correct or edit"* or *"cancel"* communication acts before going out.
- Have a device feature that signals the intent to speak *("Give me a moment")* in order to allow a user more control over a conversation.
- Disclaimer statement when starting a conversation.

Other assistive technology adaptations based on user-centered designs

Hearing aid designs



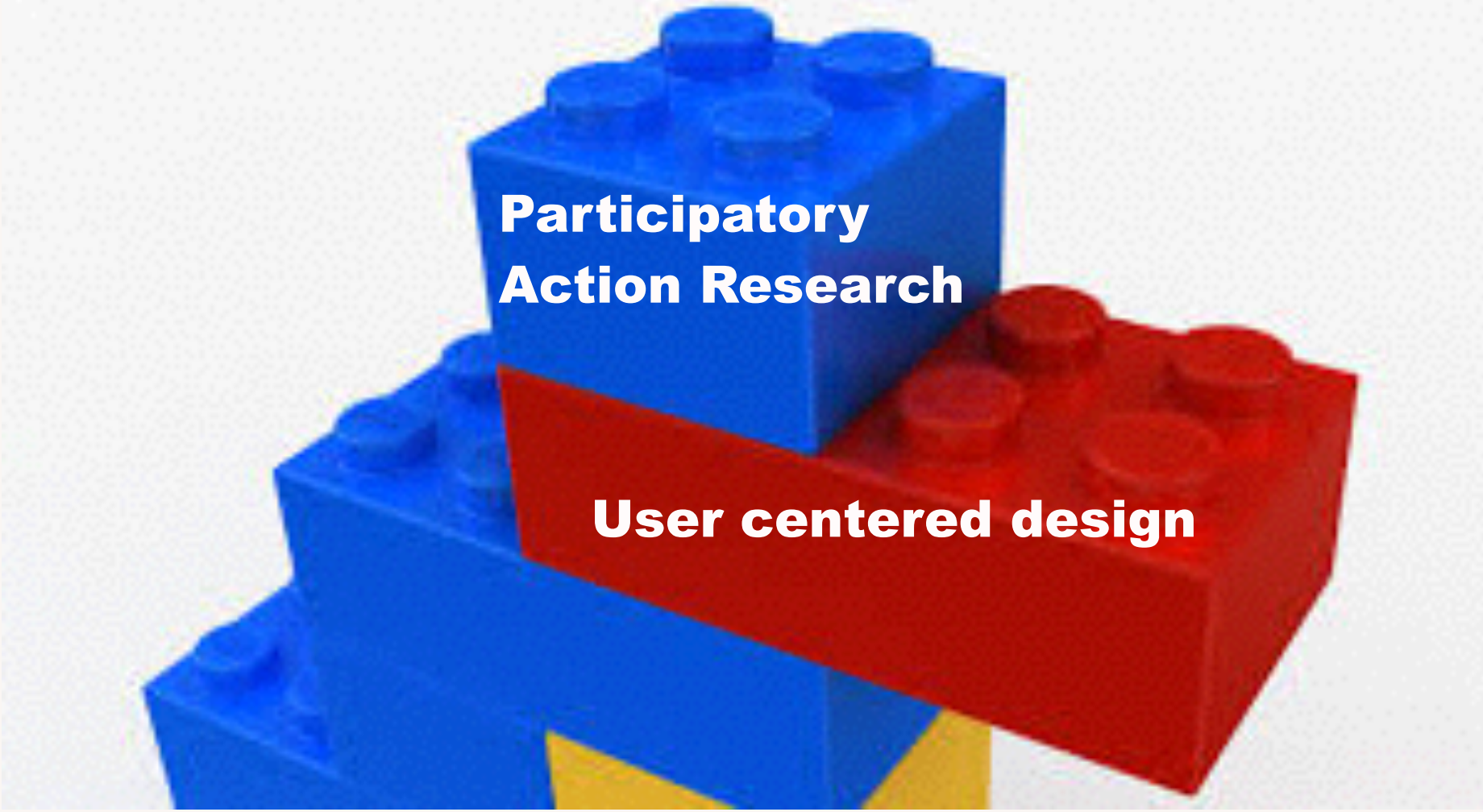
Cochlear implant designs

Colors for speech generating devices

Wheelchair designs

What are some of *your* ideas and values for user-centered design?

AAC and BCI Design Principles



Thank you

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