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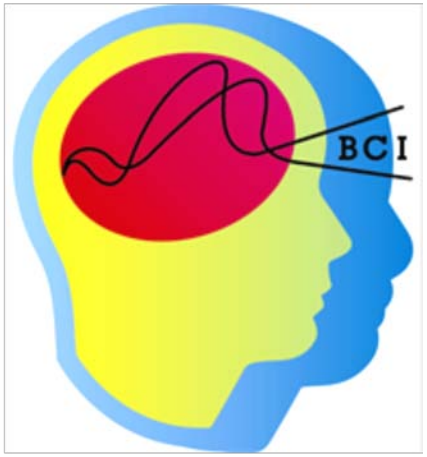
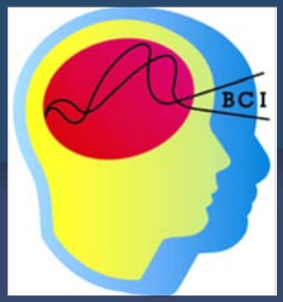


Brain Computer Interface for AAC Technology

Melanie Fried-Oken, D. Erdogmus, C. Gibbons, A. Mooney, B. Oken, B. Roark
Neurology, Biomedical Engineering and
Institute on Development and Disabilities
Portland, OR

ASHA Convention, session # 0913
Thursday November 18, 2011

Collaborators



- Deniz Erdogmus, Ph.D., Northeastern ECE
- Barry Oken, M.D., OHSU Neurology
- Brian Roark, Ph.D., OHSU BME
- Kenneth Hild III, Ph.D., OHSU BME
- Aimee Mooney, M.S., OHSU CDRC

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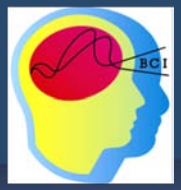
Translational R01 from NIDCD



Signal Processing Engineering

Northeastern U group:
Deniz Erdogmus, PhD
Umut O
Shalini P
Kenneth Hild III, PhD

Neurophysiology

Barry Oken, MD
Meghan Miller, BA
Roger Ellingson, MS

Computer Science
(language modeling)

Brian Roark, PhD
Andrew Fowler
Russ Beckley

Clinical team

Melanie Fried-Oken, PhD
Barry Oken, MD
Aimee Mooney, MS
GB, participant with LIS
HB, participant with ALS

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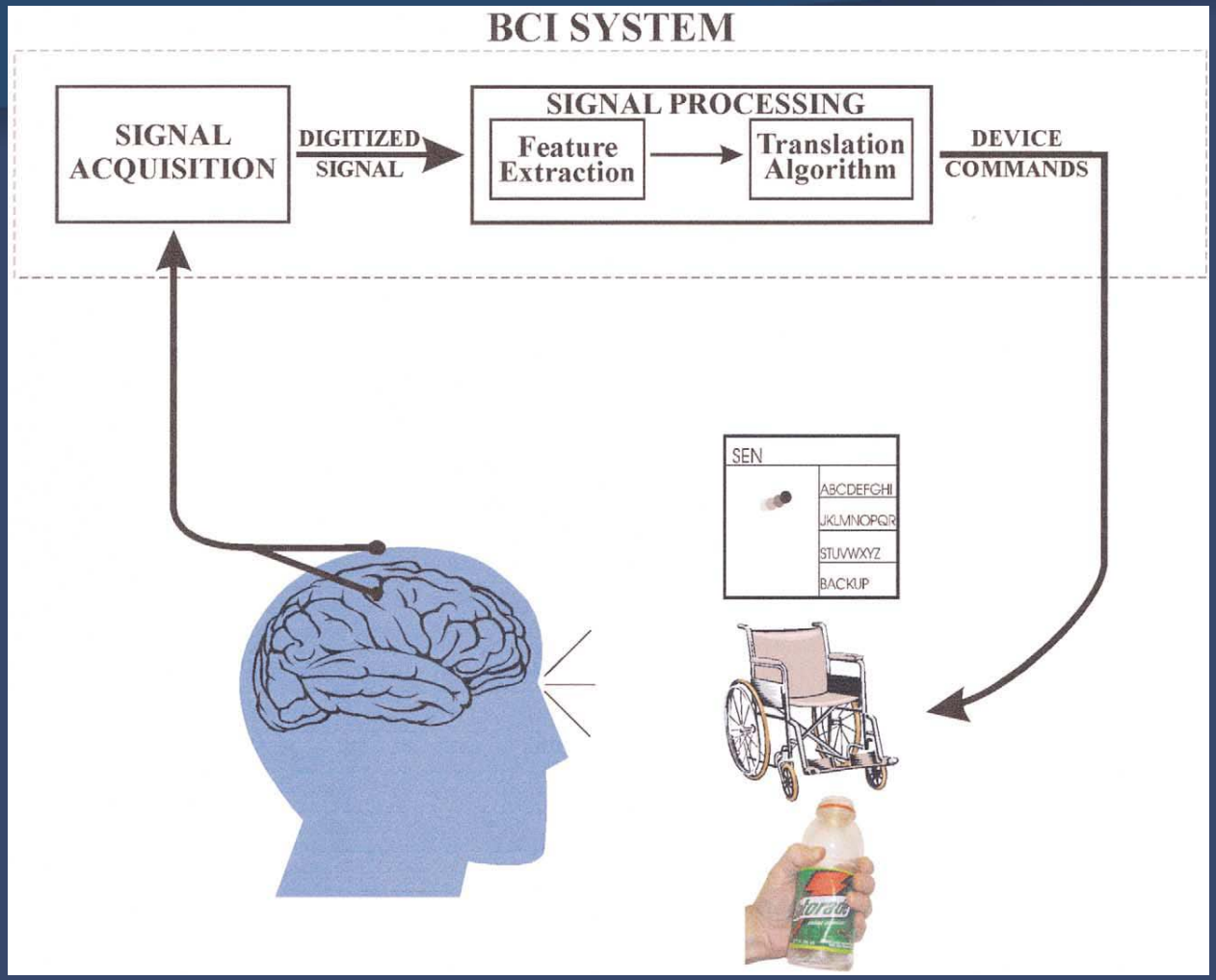
Brain- Computer Interface (BCI)

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



Wolpaw, et al (2002). Brain-computer interfaces for communication and control. *Clinical Neurophysiology, 113*. 767-791

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Locked In Sydrome:
American Congress of Rehab Med (1995)

- A syndrome characterized by preserved awareness, relatively intact cognitive functions, and ability to communicate while being paralysed and voiceless. This syndrome is defined by five criteria:

1. Sustained eyes opening and preserved vertical eye movement
2. Preserved higher cortical functions
3. Aphonia or severe hypophonia
4. Quadriplegia or quadriparesis
5. Primary mode of communication that uses vertical eye movements or blinking

Common Diagnoses Leading to LIS

- End stage ALS
- Brainstem CVA
- High level spinal cord injury
- Traumatic Brain injury

Functional LIS diagnoses

- End stage ALS
- Brainstem CVA
- High level spinal cord injury
- Traumatic Brain injury
- Cerebral palsy
- Muscular dystrophies
- Multiple sclerosis
- Parkinson’s disease (plus)
- Tumors

Classifications of LIS

- Complete or total LIS: Quadriplegia and anarthria. No eye movement
- Classic LIS: Preserved vertical eye movement and blinking
- Incomplete LIS: Recovery of some voluntary movements in addition to eye movements (Bauer et al, 1979)

Epidemiology of LIS

- Over 2 million people in the U.S. with some level of functional LIS;
- Less than 1% of CVA;
- More than 85% of individuals are still alive after 10 years;
- Average age range: 17 – 52 years;
- Younger patients have better px of survival.

Options for restoring functional motor function

- Rely on capabilities of remaining pathways
  - Eye gaze communication system
  - Head mouse access to computer
- Detouring around neural pathway breaks
  - FES: Direct electrical stimulation of paralyzed muscles through EMG activity in muscles above lesion level.
- Provide the brain with a new, non-muscular communication and control channel: BCI.

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Current human BCI research for communication & control

- Invasive BCI: Braingate

http://www.youtube.com/watch?v=NIG47YgndP8&feature=player_embedded

- Non-invasive BCI: BCI 2000 with P300 speller

http://www.youtube.com/watch?v=4QxPR25DMAg&feature=player_embedded

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BCI 2000 with P300 speller

- Most commonly used spelling interface
- Uses a grid with randomly flashing rows/columns
- 3 passes of same response = selection

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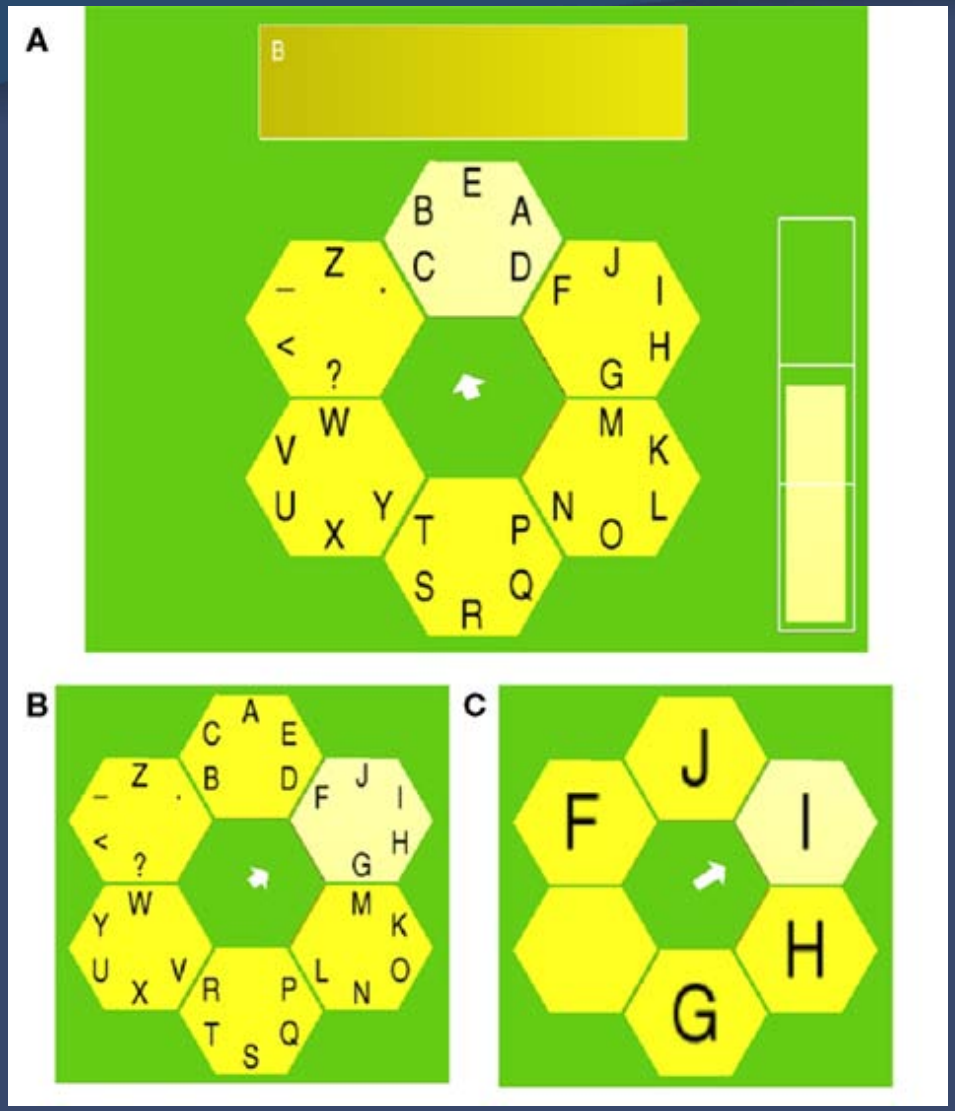
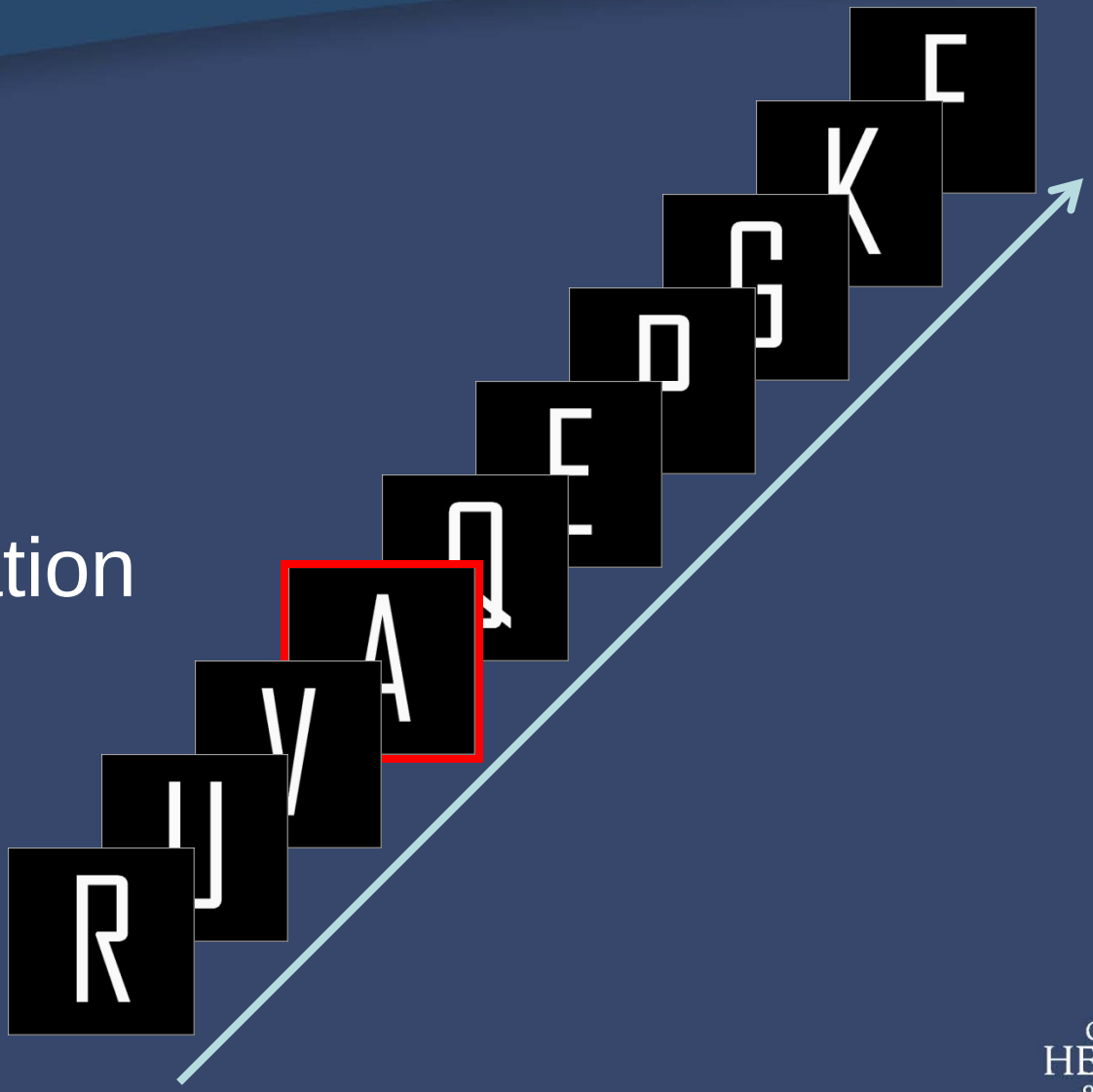
Berlin BCI: Hex-o-spell



RSVP Keyboard

- Rapid
- Serial
- Visual
- Presentation



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RSVP BCI Overall Goal

To integrate new engineering developments in EEG analysis with language models for people who are functionally locked-in to communicate and control their environments.

OHSU RSVP BCI Project

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Using Brain-Computer Interface for Communication

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Unique aspects of OHSU BCI research

1. RSVP: stimulus presentation
2. Language modeling
3. Single event ERP goal
4. Functionally locked-in patients
5. Participatory Action Research

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- *“Through this research project, I have had the opportunity to assist the team in understanding things from a user’s standpoint. It has shaped my concept of what I think would be most helpful, not only for me, but for others who are locked-in. This has been, and continues to be, a wonderful experience for me.” GB*

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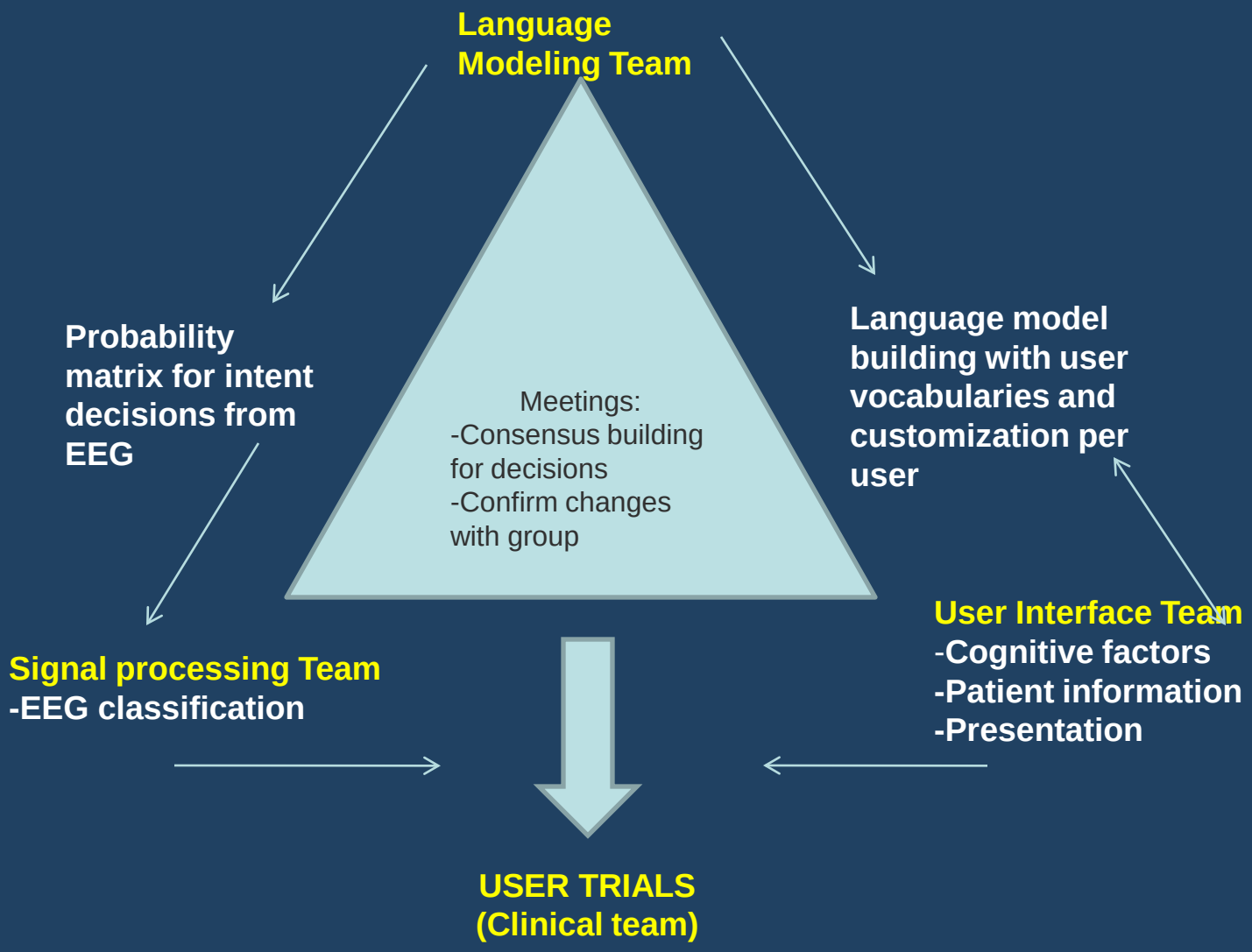
BCI Triangulated Collaboration

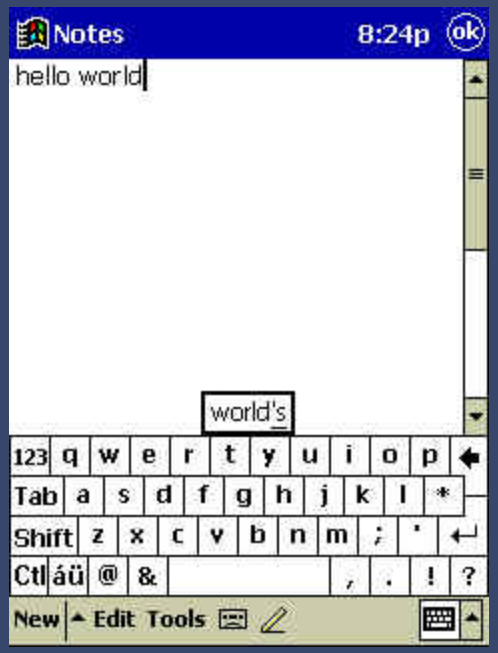


LANGUAGE MODELING

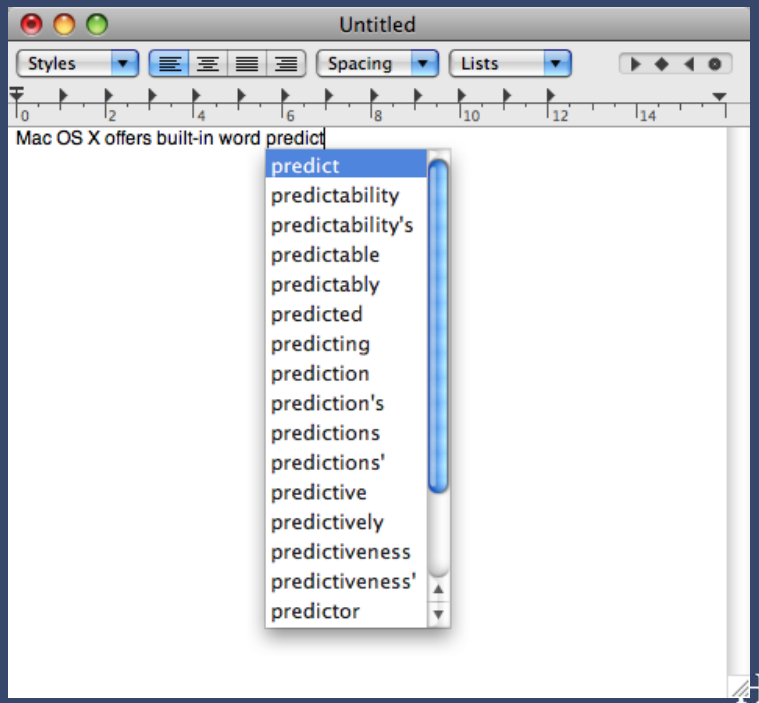
Word completion from language corpora

Technology-assisted spelling after # letters (n-gram prediction)

1: Automatic completion



2: Self-select from a list



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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 trained using large language databases:
  - *Wall Street Journal* and *New York Times* databases
  - Enron e-mails
  - User-provided previous conversations and vocabulary lists

Language Model Comparisons

- **Row/column scanning**

  (uses optimized grid frequency layout)

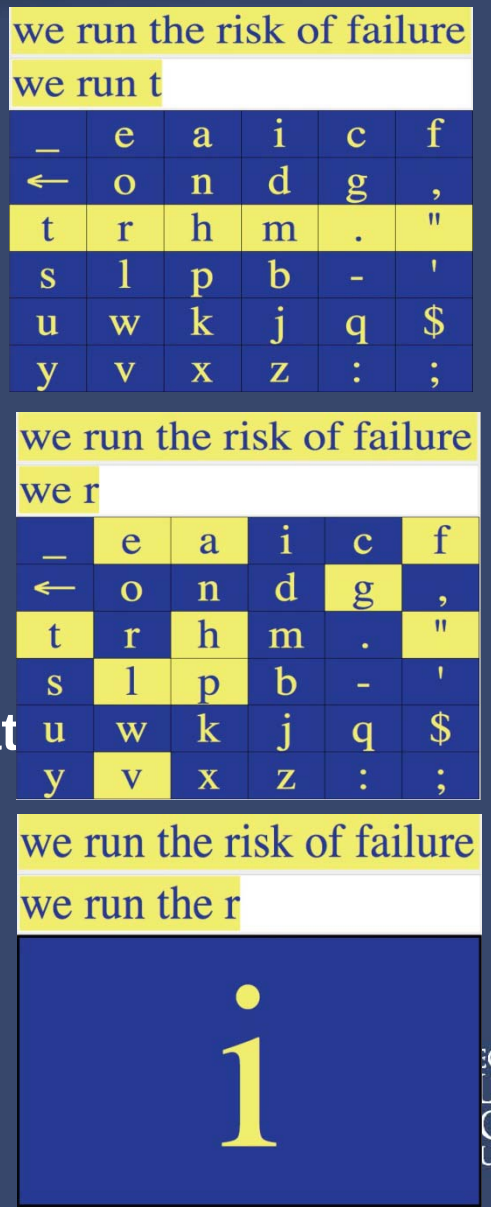
- **Huffman scanning**

  (uses an 8-gram language model and a Hoffman code)

- **RSVP (Rapid Serial Visual Presentat**

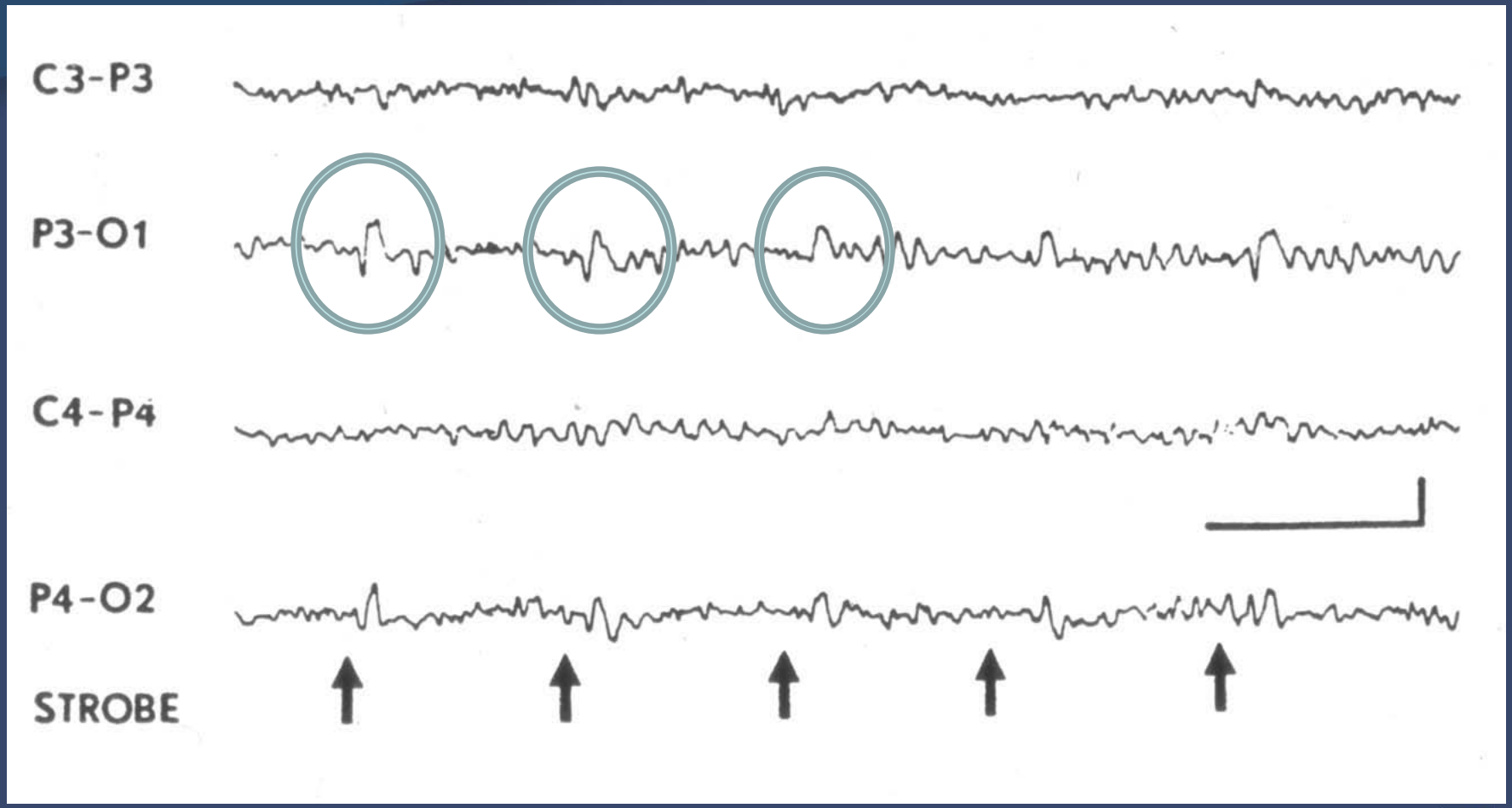
  (uses an 8-gram language model and Displays in rank order)

(Models trained using NYT data)



SIGNAL PROCESSING
AND
INTERFACE DESIGN

Photic stimulation at 1 Hz during routine EEG



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P300 is a variable waveform

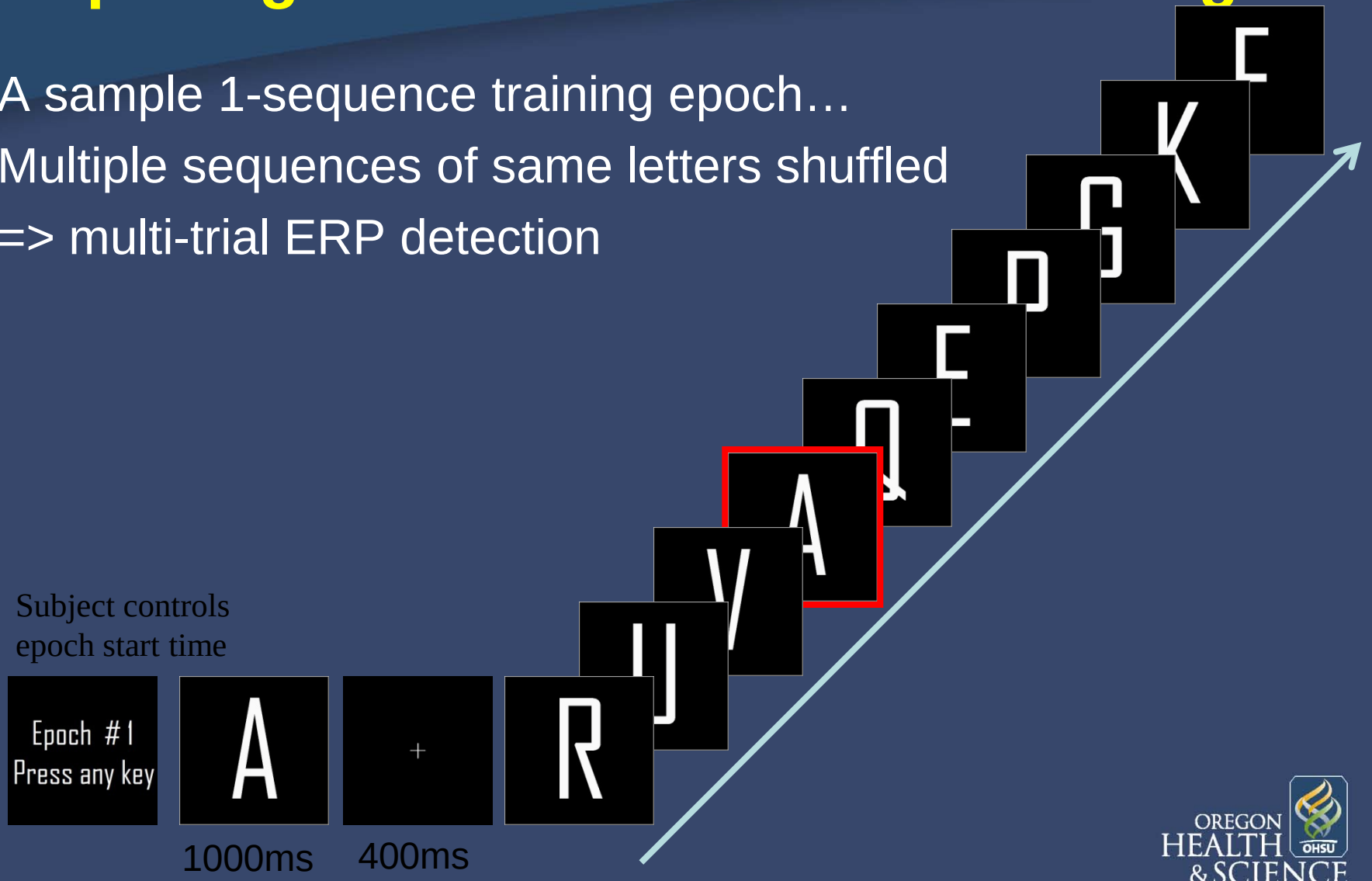
- Sensitive to alertness and attention
- Amplitude increased by stimulus infrequency and stimulus salience
- Latency affected by target detection difficulty and age

RSVP Keyboard: Spelling stimuli for a P300 sign

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

RSVP Keyboard:
A Spelling Interface based on the P3 Signal

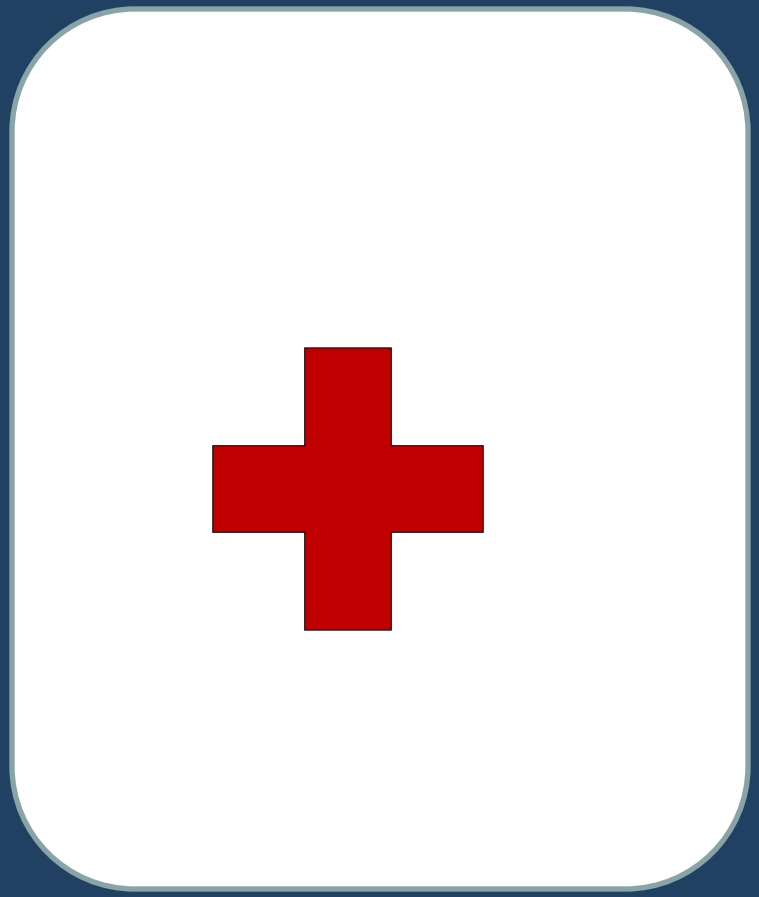
- A sample 1-sequence training epoch…
- Multiple sequences of same letters shuffled
  => multi-trial ERP detection



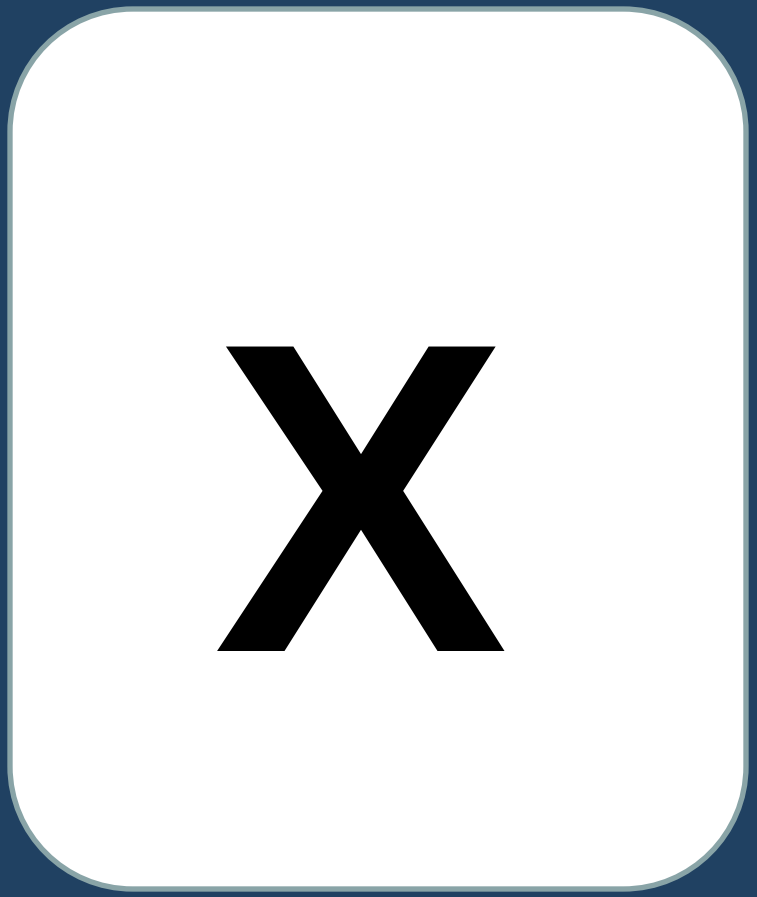
Deniz Erdogmus, Cognitive Systems Laboratory, Northeastern University

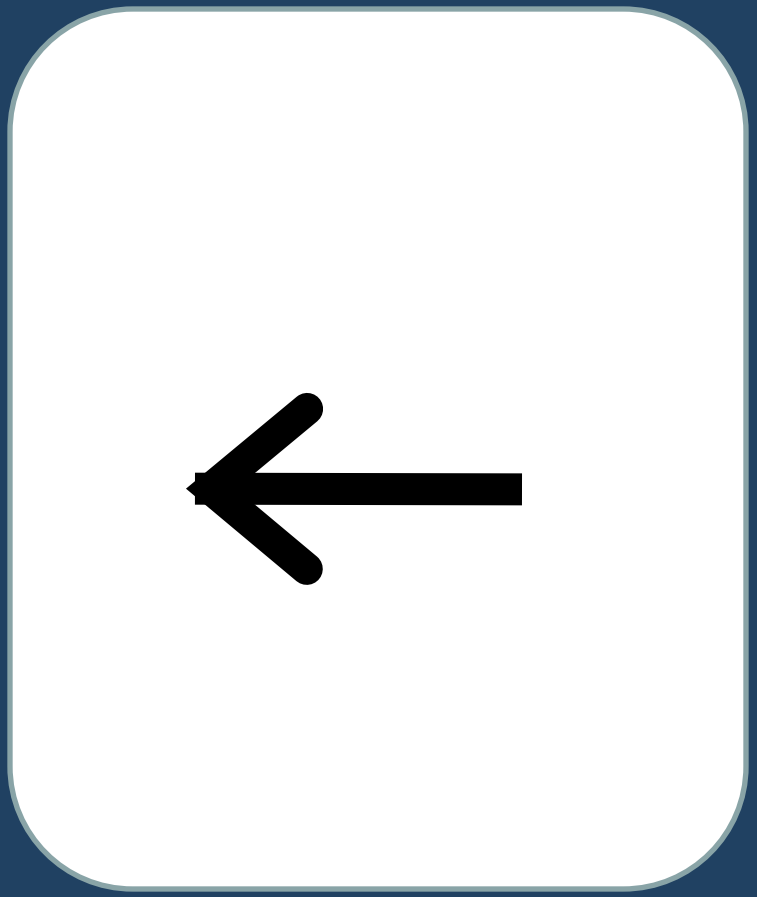
TARGET

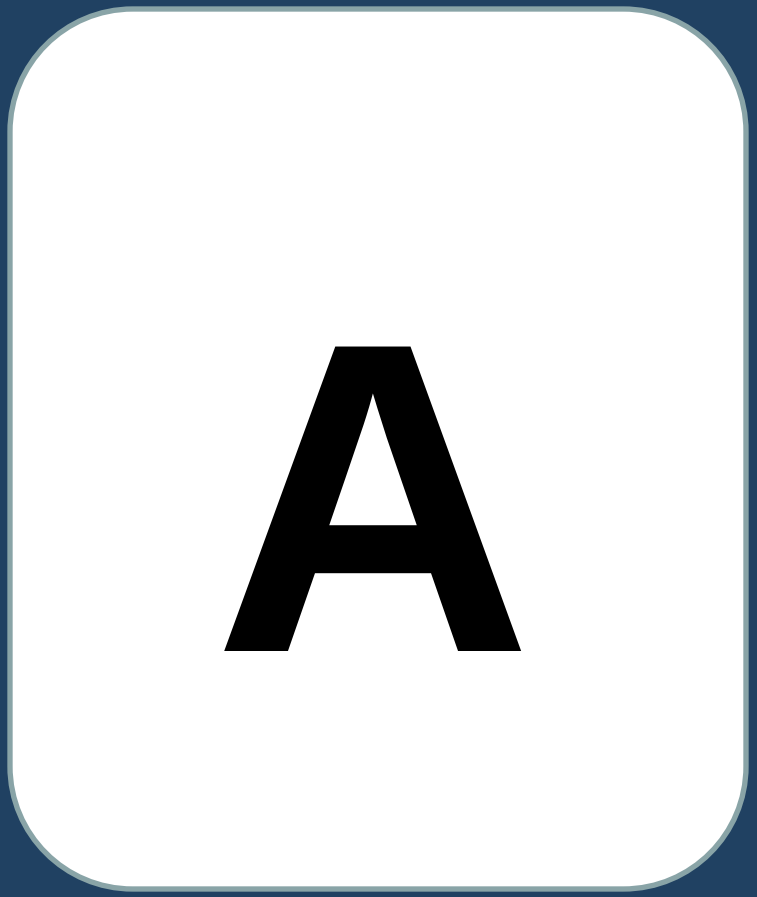
A

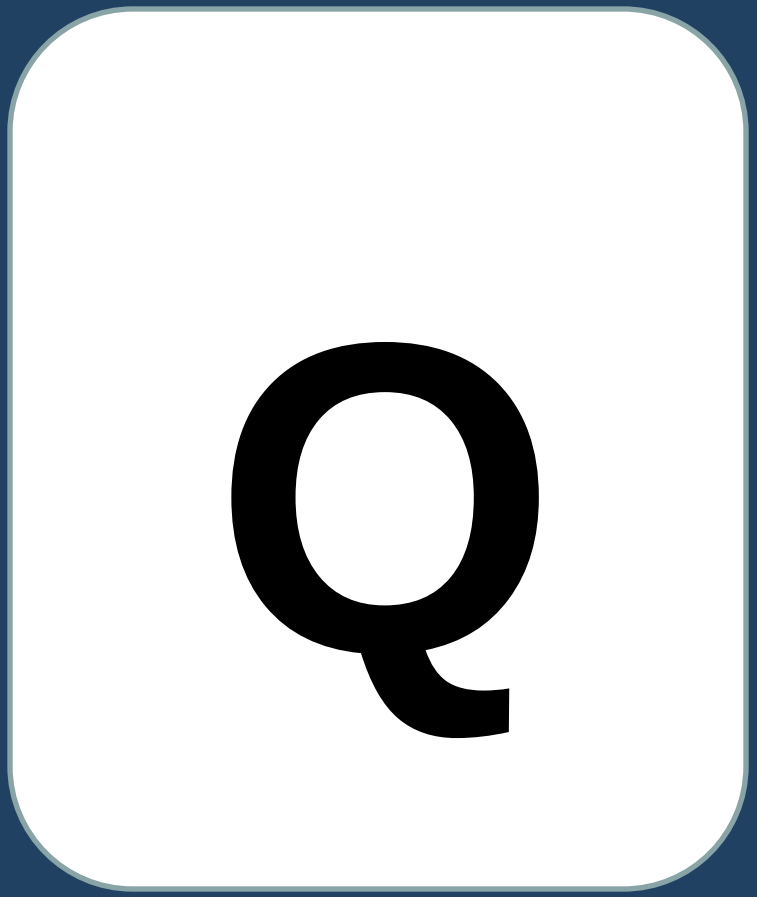


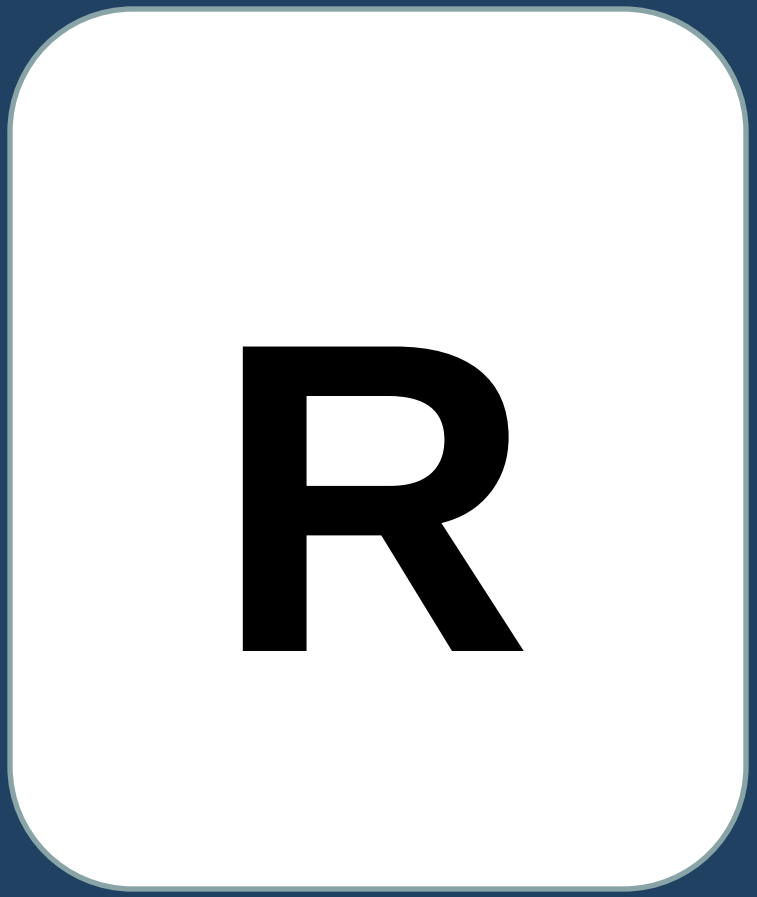
B


X




A


Q


R

E

Training Mode

Gathering Data to Train Classifier
(about 15 minutes)

- Subject instructed to look for a specific letter
- 50 series containing 2 sequences that present 30 characters (26 letters and 4 symbols)

Machine Learning
(about 15 minutes)

Learning Algorithm + **EEG**

Creation of the EEG/P3 Classifier

Free Writing Mode

Sentence Formulation

Subject presented with sequences of possible letters and attempts to write whatever they wish.

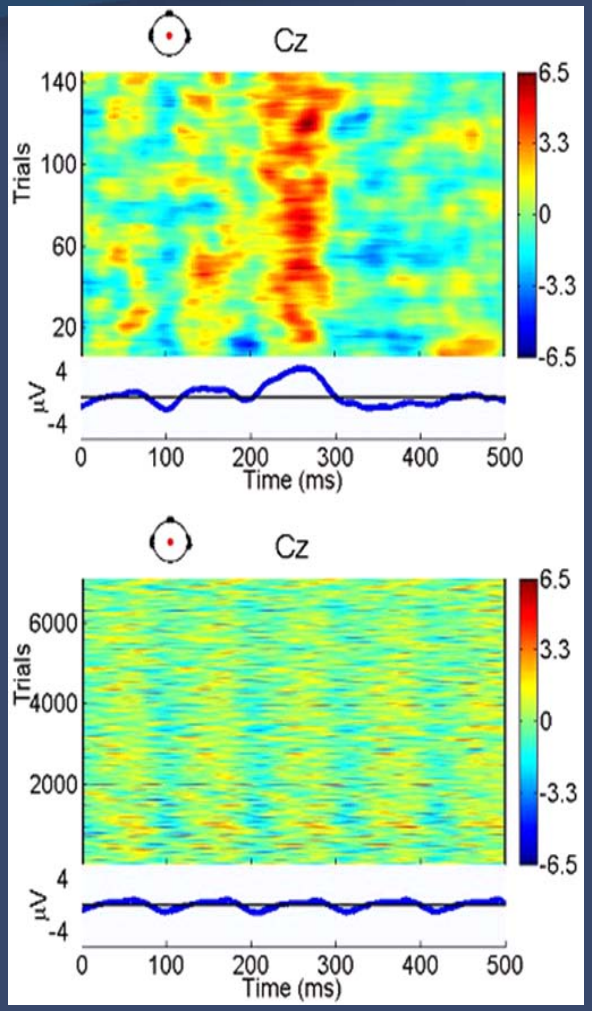
Hybrid Classifier

EEG/P3 Classifier

Language Model

Prediction and typing of intended letter

RSVP and P300



Target

Non-target
(distractor)

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CLINICAL ASSESSMENT OF FUNCTIONALLY LOCKED-IN SUBJECTS FOR RSVP BCI

4 Participants

Gender	Age	Dx	S/P	LIS	Education	Prof	Residence
Male*	42	BS CVA	16 yrs	Incomplete	16 yrs	landscaper	Home with parent
Male*	42	ALS	2 yrs	Incomplete	19 yrs	architect	Home with wife & daughter
Male	41	BS CVA	2 yrs	Complete	18 yrs	engineer	ICF
Male	30	TBI	16 mos	Incomplete (emerging)	16 yrs	musician	ICF

*Team member participant: consults on research design and use

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Screening tool criteria*

1. Assess *requisite skills* for RSVP Keyboard
    1) Vision
    2) Hearing
    3) Language (Auditory & Reading Comprehension; Spelling)
    4) Sustained Visual Attention
2. Easy to administer
3. Less than 45 minutes total time
4. Completed at participant's residence, at bedside or wheelchair

*Cannot use for *Complete LIS* participants

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Sources for Assessment Design

- Boston Naming Test, Kaplan, Goodglass, and Weintraub, 1983
- Functional Linguistic Communication Inventory, Bayles and Tomoeda, 1994
- Boston Assessment of Severe Aphasia, Helm-Estabrooks, Ramsberger, Morgan, Nicholas, 1989
- Coma Recovery Scale-Revised, Giacino, Kalmar, 2004
- Western Aphasia Battery-Revised, Kertesz, 2006

Ergonomic information regarding computer monitor distance and angle taken from: *The United States Department of Labor; Occupational Safety & Health Administration OSHA.*

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Confirm consistent & reliable YES/NO

- Binary code:
  - Eyes (up/down; left/right)
  - Eye blink
  - Thumb up/down
  - Smile/pucker

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Screening: Vision

A. Questions to care providers

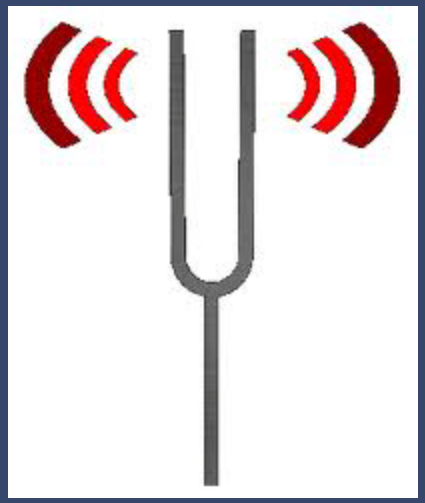
1. Does patient wear glasses? Recent prescription?
2. Do they see well enough to read?
3. Any other visual problems (cataracts, macular degeneration, field cut)?

B. Diplopia: present?

C. Visual Perception: Computer-based task for central accuracy and peripheral accuracy

Screening: Hearing

1. Questions about hearing function to participant (y/n response)
2. Questions to care provider about participant's hearing function
3. Tuning fork test



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Screening: Language: Auditory comprehension

A. Object Related Eye Movement Commands

Look at the *(object) X4*

B. Non-Object Related Eye Movement Commands

Look away from me

Look up/down *(at ceiling/floor)*

C. Visually based Situational Orientation (yes/no response)

Am I touching my ear/nose right now? X4

D. Personal Orientation

Name, age, history

E. Yes/No to Complex Sentences

“Does a stone sink in water?”

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Screening: Language
Reading Comprehension and Spelling

1. Object-picture matching X4
2. Picture-word matching from field of 4
3. Letter identification X4
4. Eye pointing to first letter of a word X4

   Bed J M B A
5. Spelling words with eye gaze boards (want, ball, stop)

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Screening: Cognition: Sustained Visual Attention

- RSVP Task created on EPRIME software
- Yes/no response to identify when a certain letter is present on the screen.
- Correct target and 3 foils/trial
- Must respond accurately in 9/10 trials

Input from participants with LIS

Harper and Greg as expert consultants

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"Giving people with LIS the option to use a BCI in their daily life can provide so many benefits. It has the potential to give us a sense of control, the ability to communicate independently, and a sense of depth. The challenges of designing a BCI system for people who are social and intelligent are making it user friendly, reliable, just as easy and fast as our current communication method, and low-profile."

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"At the very least, I am hoping to get aid in communication from a BCI system. I want to be able to express myself without the help of others at all times. If the system were able to predict text based on how my sentences are formed, that would be helpful. I want to be able to write emails and use Facebook independently. For people like me who are completely locked-in, it would also be nice to be able to control simple things in my environment like my wheelchair and the lift on my van. I would like to turn on lights, the thermostat, the radio, and my television. As I work more with the BCI system, I feel that it has the potential to do an unlimited amount of things in the future."

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Progress to Date

1. 8 Participants (4 enrolled)
2. Clinical protocol completed for inclusion criteria and subject description
3. Working styles of teams are compatible
4. The RSVP keyboard BCI exists and…

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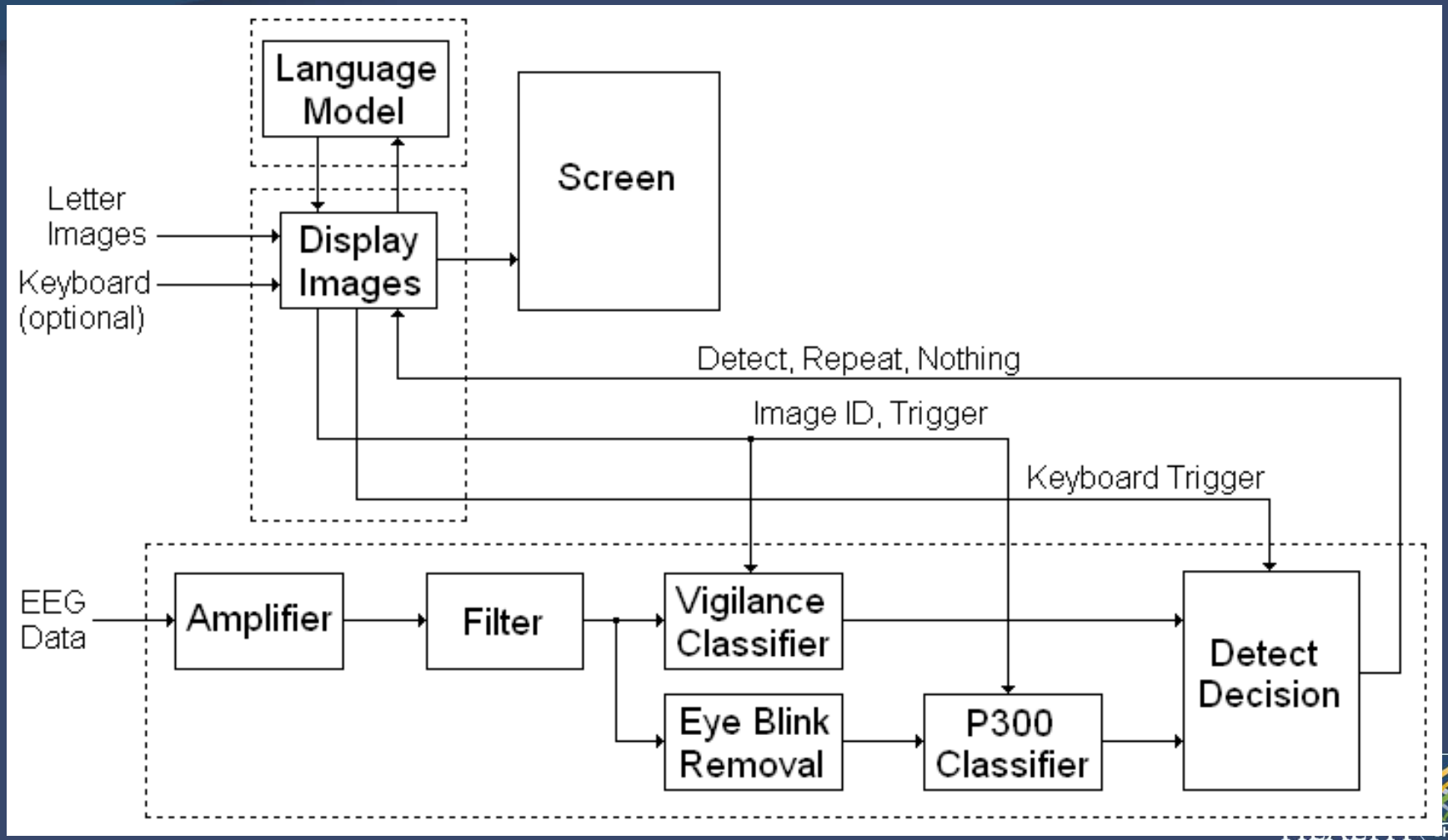
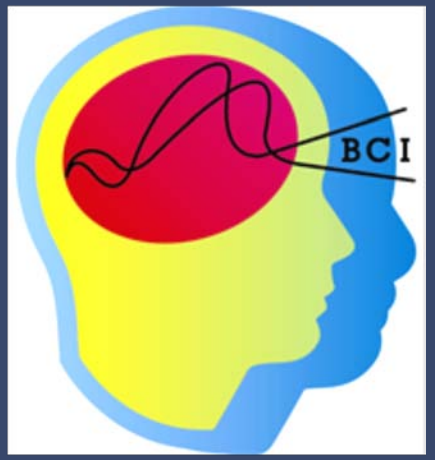
….and works



"BCI also can open new doors, which is hard to do when you're literally locked-in." GB



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