Beyond Eye Gaze: Alternative Access for Adults with Severe Speech and Physical Impairments

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The Problem:

- People with severe physical impairments may be unable to use commonly available AAC and computer access methods.
  - Minimal movement
  - Inconsistent movement
- Can design help?
- How about math?

Shuffle Speller

- Typing interface
- Can be used with various access methods
- Adapts to user input characteristics
- Aggregates evidence from multiple queries

Adaptation to the user

- Character presentation
  - Based on:
    - Language model probabilities
    - User-specific calibration data
  - Uses boxes that will get the most information from a user
- Multiple queries
  - Keeps asking “smart” questions until confidence threshold is reached
Access methods

• So far:
  – Eye tracking
  – SSVEP brain-computer interface

• Potential:
  – Switches
  – Joystick
  – Headmouse
  – Trackball
  – Etc.

User Interface

Electrode setup

Experiment 1: SSVEP BCI Typing with Simulated Visual Impairments
Participants

- Healthy controls
- Ages 21-80
- Normal or corrected-to-normal hearing and vision
- Passing score on Telephone Interview for Cognitive Status

Variables

- Independent variable: condition
  - Unimpaired
  - Simulated visual acuity impairment (VAI)
  - Simulated ocular motility impairment (OMI)

Variables

- Dependent variables
  1. Typing accuracy (correct selections/total selections)
  2. Typing speed (characters per minute)
  3. User experience
     1. Comfort
     2. Workload
     3. Satisfaction

Tasks

- Copy-spelling
  - 10 words per session (different each time)
  - 5-7 letters each
  - Balanced for language model support

- Stoppage criteria (for motility condition)
  - Stop if no letter selections within 5 minutes
  - Stop after 20 minutes regardless of performance
Analysis

• Unimpaired vs. VAI
  – paired t test of mean equivalence
• Descriptive statistics for OMI

Results

• 38 participants
  – Aged 37.2 ± 15.47 years
  – 26 women
  – 17.3 ± 2.41 years of education
  – Mostly 20/20 vision both near (n=35) and
distance (n=31)

Results: unimpaired and VAI

• All participants could spell under
unimpaired and VAI conditions
  – VAI performance was not inferior for either
accuracy or speed

Results: OMI

• 6/37 spelled word(s) under OMI condition
  – Accuracy comparable to other conditions,
speed greatly reduced
  – Longer trial lengths
• 31/37 could not spell under OMI condition
Results: unimpaired and VAI outliers

- 6 participants had low accuracy (<80%) and/or failed to complete 10 words under unimpaired or VAI conditions
  - Color blindness (difficulty seeing correct & incorrect selections)
  - Fatigue
  - Confusion about backspace character
  - Misreading of target word

Results: UX

- Unimpaired and VAI
  - Low ratings for workload and discomfort
  - High ratings for overall satisfaction
- OMI
  - Higher ratings for workload
  - Similar ratings for discomfort
  - Lower ratings for overall satisfaction

Discussion

- 20/200 acuity impairment (legal blindness) is not an obstacle to Shuffle use
- Some people may be able to use Shuffle with reduced motility
- High user satisfaction (unimpaired and VAI)
- Adaptive trial length
  - May support accurate typing

Experiment 2: Eyegaze and EEG Access for Participants with SSPI
Research Questions

• Is the Shuffle Speller interface, accessed with eyegaze or SSVEP-BCI, a viable option for people who have difficulty with traditional grid-based eyegaze systems?

• How do eyegaze access and SSVEP-BCI access compare?

Participants

• 3 adults with SSPI who have difficulty with commercially-available eyegaze systems
Design

- Single-case alternating-treatments research design
- Baseline: Two-step keyboard in Communicator 5 (similar to existing multi-step, large-button keyboards)
- Alternating treatments:
  - Shuffle Speller BCI
  - Shuffle Speller eyegaze
- 6 boxes used for all conditions

First attempt...

Learning From Failure
What we learned

Shuffle data for Participant 1

Condition
- baseline
- eye gaze
- avg

What we learned

Shuffle data for Participant 2

Condition
- baseline
- eye gaze
- avg

What we learned

Shuffle data for Participant 3

Condition
- baseline
- eye gaze
- avg
Second attempt
- Switch from 6 boxes to 4 for all conditions
  - Equipment failure
  - Possible easier for some participants
- Baseline: Three-step keyboard in Communicator 5 (1.2 second dwell)
- Alternating treatments:
  - Shuffle Speller BCI
  - Shuffle Speller eyegaze: New algorithm!
  - Three-step keyboard in Communicator 5 (2.5 second dwell)

Alternating treatments conditions: Potential advantages
- Shuffle Speller (Eyegaze or SSVEP BCI)
  - Smart querying
  - Aggregated evidence
  - Adapted to user input characteristics
  - Modified eye tracking is more forgiving
  - BCI option may work for some users when eye tracking won't
- Multi-step Communicator keyboard with 2.5 second dwell
  - Longer dwell allows more time to move

Baseline condition
- 3-step eyegaze spelling in Communicator

Shuffle conditions
- Eye tracking for Shuffle Speller
**Tasks**

- Copy-spelling
  - 5 words per session
  - 5 letters each
  - Balanced for language model support

**Variables**

- Independent variable: condition
  - Baseline: 3-step Communicator keyboard
  - Alternating treatments:
    - Shuffle Speller eyegaze
    - Shuffle Speller BCI

**Variables**

- Dependent variables
  1. Typing accuracy (correct selections/total selections)
  2. Typing speed (characters per minute)
  3. User experience
     1. Comfort
     2. Workload
     3. Satisfaction

**Preliminary results**

- Graph showing participant 1's results across sessions.
Preliminary results

Next steps

• Finish data collection
  – 5+ sessions with each condition
• Bonus round!

Research Challenges

Well, it didn’t work. Now what?
What are some obstacles to adopting a new access method, and what can we do about them?