
Personalized Multimodal Computer Interfaces For The Motor Impaired

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Abstract

Severe motor disorders such as LIS and ALS are characterized by an inability to move or communicate effectively. Though it is essential to provide assistance to these groups, motor and cognitive function within these groups varies so widely that one static design cannot serve the group as a whole. Despite this variety, eye movements and brain functions are often under conscious control and can potentially be exploited for communication. We believe that to provide the most effective communication systems for individuals with progressive neurological disorders, it will be essential to create adaptive eye and biosignal computer interfaces that dynamically fit the changing abilities of the user as inexpensively as possible.

Author Keywords

Augmentative Communication; Eye Tracking;
Amyotrophic Lateral Sclerosis; Motor Impairment;
Locked-In Syndrome; Brain Computer Interfaces;

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous;

Introduction

Individuals with severe motor disabilities (SMD) such as Amyotrophic Lateral Sclerosis (ALS) or Locked-In Syndrome (LIS) can completely lose the ability to move or communicate effectively. Regaining communicative ability can result in a significant increase in quality of

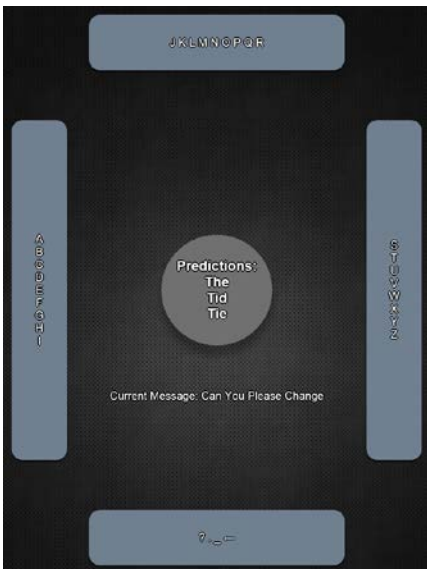


Fig 1: The EyeHome System showing a detail of our T9 keyboard implemented as part of the “Sides” layout.

life for these individuals, yet current assistive technologies have not reached this goal effectively. There is still a great need to develop new technologies to help individuals with SMD communicate as well as possible. In order for assistive technologies to reach their potential, researchers need to integrate techniques from ability-based design [3], text-input methods for motor-impairments [5], and gaze-independent brain computer interfaces [4]. Systems that implement these techniques also need to adapt to individual differences in oculomotor control [1] and cognitive ability, especially in neurodegenerative diseases like ALS [2].

Alternative Text-Input Design Space: The highest priority feature of an SMD assistive technology is to maximize communicative ability, usually by enabling the user to input text into a computer. Text input has been well studied in individuals with motor-impairments [5]. Text entry methods typically involve an interaction modality, a selection technique, and a character (or word) layout which may change dynamically based on the language context. The motor impaired usually need a reduced number of keys in a layout and this reduction can be accomplished with chording keyboards, ambiguous keyboards, and different kinds of encoding. For the motor impaired, ambiguous keyboards, such as the T9 keyboards seen on older cellphones, or encoding techniques such as Morse-code are more appropriate since chording can be difficult. Additionally, individuals who can only provide two commands (‘next letter’ and ‘select’) can use scanning techniques to move through letters one-by-one or in chunks to create messages.

Gaze Interfaces: Gaze can be used as the interaction modality for pointing on screen, as a mouse would, for some individuals. Dwell time, multimodal interaction, and gestural input are needed to make selections with gaze. Dwell time uses time in a region to determine selection, but comes with the *Midas touch* problem: people can often unintentionally trigger a dwell time selection. In multimodal interaction, a modality other than gaze, such as speech, facial movements, or brain

signals, can be exploited for selection. In gestural input, scan path patterns (drawing with gaze) can be used to select letters.

Biosignal Interfaces: In addition to gaze, it is also possible to input text with biosignals: intentional muscle constrictions measured with EMG (electromyography) and brain signals measured with EEG (electroencephalography). EEG based systems are called brain computer interfaces (BCI), and represent the only modality that can assist individuals without any voluntary muscle control. EMG and BCI can be used as a multimodal selection technique if combined with gaze. Shifts of covert attention to visual, auditory, and tactile stimuli as well as mental commands can be used by BCI as the interaction modality for individuals who cannot move their eyes or as a multimodal selection technique for those that can.

Hybrid Gaze and Brain Interaction

In this paper, we present our ongoing work focused on the use of an array of screen-based interaction widgets, such as T9-like ambiguous keyboard, that uses gaze data from an inexpensive, consumer grade eye tracker (Tobii EyeX)¹ as the interaction modality and dwell time, eye brow lifts, blinks, and EEG data as the selection technique.

EyeHome: In our research we are targeting ALS and LIS and, although our goal is to design a system for many different people, we are specifically working with Bob, a severe case of LIS. Our interaction widgets are developed as part of prototype system, dubbed EyeHome (Fig. 1) which builds on the well-known “home-screen” paradigm used by most smart-phones. The EyeHome system links together various gaze-based apps to support communication.

¹ <http://www.tobii.com/xperience/>



Given Bob's limited ability to fixate small elements, EyeHome uses the "Sides" layout: four larger rectangles located on each side of the screen that can be used to interact with the EyeHome apps (Fig. 1). While testing the system, we discovered that effectively exploiting the eye tracking data was difficult: Bob (shown in Fig. 2) struggled to operate the Sides apps and control his eyes, even when calibration was successful. He was able to gaze in all four directions, but his eye movements were sometimes highly unstable and would saccade in random directions and random times, making it difficult to infer his intentions. Importantly, Bob could control his eyes best in the morning, but as the day progressed and he became fatigued, his ability to control his eyes declined and the system became unusable.

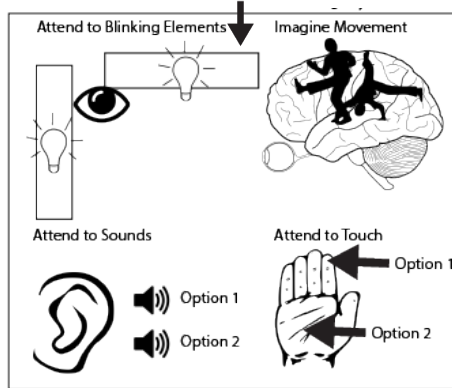


Fig 3: Workflow for integrating gaze and BCI methods. First, an ambiguous gaze selection is detected and then, depending on user ability and preferences, four different BCI techniques are used to decide between the two best options. In sight, sound, and touch, the user may attend to different stimuli or locations that correspond to different options. In movement imagination, the user selects options by imagining movement or not.

Integrating BCI: To address these challenges, we set out to explore the feasibility of integrating BCI and eye tracking. We designed a system that could resolve ambiguity in gaze selection with BCI. The key idea is to exploit the noisy gaze data to determine which of the UI elements are most likely to be desired. Then, we prompt the user to select between the two most likely options using BCI. Making this selection can be accomplished with gaze-independent BCI techniques [4]. These techniques are able to detect the imagination of motor imagery, which can be used as a mental command, as well as covert shifts attention to different sounds, vibrations, skin taps, and flashing objects on screen (see Figure 3). Different selection options found via gaze can then be discriminated by pairing multisensory stimulation or mental commands to the options. If the user attends to sound 1, then the system would select option 1. If the user is imagining movement and therefore giving mental command 2, then the system selects option 2. We tested the Emotiv Insight's² ability to detect mental commands while the eyes were moving to investigate the feasibility of

² <https://emotiv.com>

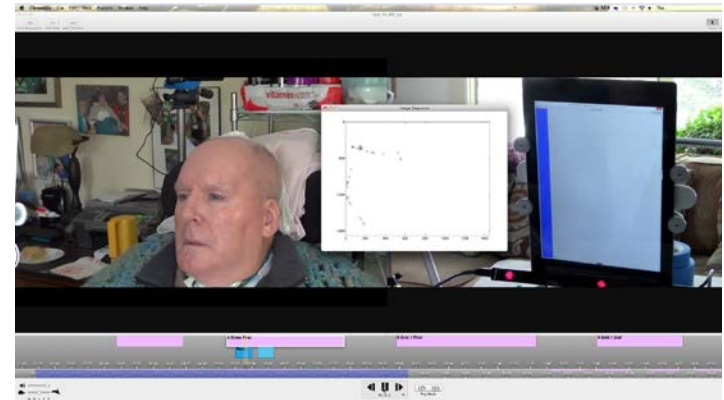


Fig.2: Analysis session showing the videos from two cameras focused on Bob's interaction with an early prototype of EyeHome and a plot of his gaze data.

integrating these eye and brain interfaces with consumer grade equipment, but found that the Insight lacked sufficient signal quality for eye and BCI integration and its headset design would be impractical for long term use.

Portable EEGs: Given the Insight's limitations, we tested another, slightly more expensive, dry electrode portable headset: the Cognionics Quick20.³ Though our long term goals are to incorporate the strengths of both BCI and gaze control to interact with adaptive interfaces, our short term experience with these headsets has revealed the importance of headset size flexibility, electrode shape, comfort, signal quality, and ease of setup. In our lab experiments, we found that the Insight was comfortable for 30 minutes whereas the Quick20 was comfortable for 1-2 hours because the Quick20 distributes pressure across larger electrodes and more pads. Even the Quick20, possibly the best headset on the market, cannot be worn all day. We expect that reducing the number of sensors based on users' needs will not only reduce headset cost, but will

³ <https://cognionics.com>

also enable headset designs that significantly increase comfort for hours of use.

Dynamic Hybrid Interfaces: Given the current limitations of BCI and the challenges we faced with Bob's changing ability to control his eyes, we are perusing ability-based design techniques, which involve dynamically adapting the interface to what a user can accomplish rather than what they cannot [3]. Instead of designing systems for ALS or LIS disabilities, we are designing systems for a range of oculomotor abilities that can change overtime. We are incorporating assessment of eye fixation, smooth pursuit, and blinking, as in Kumar [1], as a key system feature. With those assessments, we are directing users to different apps within EyeHome that best fit their current abilities. We are supporting a wide range of input techniques, from ambiguous keyboards, encoding, and scanning approaches. Within each of those input apps, the layouts can dynamically adjust UI element size and position to better match a user's oculomotor ability. We believe this ability-based approach will be the most cost effective way to bring high performance communication systems to the widest range of users with motor impairments.

Conclusion

There is no one best technique for motor-impaired communication. Rather, all available techniques, from text-input, gaze, and biosignal interfaces, should be made available in one system that automatically selects the best option given the user's current ability. Especially in individuals with neurological disorders, abilities may vary widely over the course or hours, weeks, and years. Designers should expect this variability and create their systems accordingly. Researchers should measure ability and report the effectiveness of their experimental techniques in relation to each individual's capabilities, not just based on group membership defined by disability.

In our current research and development, we are prioritizing features that adapt to the user's ability and exploit the least expensive techniques, such as eye tracking. Yet, more studies on the integration of gaze and BCI will be essential to provide the best service to all users. Importantly, BCI will be required to reach users without any voluntary muscle control. Bringing BCI to the masses will require optimizing headset cost and comfort by determining the fewest number of sensors required for an individual's communicative needs. Even with BCI, ability-based design is essential, and user's neurocognitive function should be assessed and interfaces should adapt accordingly. With proper integration of these diverse approaches, the personalized multimodal gaze and BCI communication system we have described has the potential to make best use of every user ability.

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