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CONTRACTING ORGANIZATION: The Research Foundation For The SUNY Stony Brook University

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14. ABSTRACT

In this phase, we have significantly improved EyeCanDo for much improved accuracy and typing rates, and extended list of functionalities, and we also did preliminary studies on BCI EEG headsets. These include: 1) Integration of facial expressions and eye gaze to accelerate target selections; 2)Intelligent typing, 3) improved eye gaze estimation and target selection, 2) gaming functionalities, 5) Social media and ChatGPT integration, 6) adaption to iPhone; 6) evaluation of EEG headsets and 7) prototyping BCI interfaces.

15. SUBJECT TERMS

Assistive technology, eye tracking, facial expression, brain-Computer Interfaces, EEG speller, P300, SSVEP, Human-Computer Interaction, amyotrophic lateral sclerosis

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1. Introduction

One significant challenge for ALS patients is the lack of communication channels to express their needs, feelings, and thoughts and engage themselves with the outside world. There is little research-driven technical development to ensure all patients have access to effective communication and can participate to their greatest potential by taking advantage of various communication capabilities of individuals for maximizing human-computer interaction. The purpose of the research is to develop a lightweight, cost-effective, multi-modal-based assistive communication application EyeCanDo running on iPad Pro, with an optional consumer-grade wireless EEG headset, to take full advantage of the available capabilities of an ALS patient, including eye gaze, facial expressions, and brainwaves, to assist patients with communication. EyeCanDo will be the first application on iPad supporting ALS patients with both eye gaze and brain-computer interfaces.

2. Keywords

Assistive technology, eye tracking, facial expression, brain-Computer Interfaces, EEG speller, P300, SSVEP, Human-Computer Interaction, amyotrophic lateral sclerosis

3. Accomplishments

3.1 What were the major goals of the project:

The goal of the project is to develop an integrative multi-modal assistive communication application EyeCanDo, that supports eye gaze, facial expressions, and EEG brainwaves to achieve optimal communication for ALS patients using off-the-shelf devices. More specifically, we will focus on the following three major tasks:

1) Integrate facial expressions with eye gaze for advancing target selection and text entry and extend EyeCanDo for social support. This major task is ongoing; the percentage of completion is 90%.
2) Develop an EEG-based BCI speller to provide a complementary communication approach using a consumer-grade wireless EEG headset. This major task is ongoing; the percentage of completion is 30%.
3) Collaborate with Stony Brook University Hospital ALS Clinics on evaluating EyeCanDo and analyze the collected data. This major task is ongoing; the percentage of completion is 30%.

3.2 What was accomplished under these goals:

Our major activities include:

1) Facial expressions and eye gaze integration: We have explored facial expressions in ARKit and implemented facial expression-based operations with eye tracking for advanced target selection and text entry. We have tested over ten blend shape coefficients in Apple's ARKit framework ARFaceAnchor.BlendShapLocation. A user can now open their mouth (jawOpen) for instant target selection and use consecutive eye blinks (eyeBlinkLeft & eyeBlinkRight) for "undo" or "redo" when typing on a virtual keyboard.
2) Intelligent typing: We have designed and implemented multiple typing keyboards for users, such as a dwell-based gaze typing keyboard with auto-completion and auto-correction, and an Emoji keyboard that keeps track of the most recently used emojis (Fig 1a). We also implemented a system-level dwell-free gesture typing keyboard *GlanceWriter,* to improve typing speed and accuracy further.
3) Improved eye gaze estimation and target selection: We have fine-tuned the hit testing algorithm parameters for eye gaze estimation using Apple's ARKit framework. We also provided a calibration process to calibrate the user's gaze. Four filters (Window Average, Weighted Average, Saccade Detection, and Outlier Detection filter) have been implemented to improve eye-tracking accuracy and smoothness. We implemented *BayesGaze*, a Bayesian approach to determining selected targets, to improve the performance of gaze-based target selection.
4) New entertainment functionalities: We have implemented two gaze-based games: Pong and Tetris. In the Pong game (Fig 1b), a user moves his/her gaze to control the player paddle and plays against NPC. In Tetris (Fig 1c), a user moves their gaze to control the falling blocks by dwelling at the "left", "right", and "rotate" buttons.
5) Social media and ChatGPT integration: We have implemented web access and social network support with gaze and added a system keyboard for typing in web access. We also integrated ChatGPT (Fig 1e)

into EyeCanDo with a subscription to the OpenAI ChatGPT Plus version and access to its APIs. We launched a local server that hosts the GPT model, and a user could enter prompts via gaze and read the responses generated by the model in web access.

6) iPhone adaptation: We have been working on the iPhone adaptation as iPhone is more popular and widely used worldwide. We have adjusted Graphic User Interfaces (GUIs) on different screen sizes and re-fine-tuned eye-tracking parameters for iPhones.
7) Evaluation of EEG headsets: We have tested different commercial headsets, including EMOTIV EPOC+, Muse S, Muse 2, Neurosity Crown, OpenBCI Ganglion and Cyton. We found that OpenBCI provides the best signal quality (higher Signal-Noise-Ratio in EEG Signal) and is the best among others. However, it lacks support for iOS development and requires the use of dongles for data streaming. To overcome this limitation, we have explored utilizing the Raspberry Pi single-board computer, which offers an effective data streaming method and costs less than $100, as shown in Fig 2a.
8) Speller: We explored and compared two types of EEG signals: P300 and SSVEP. We designed and implemented different GUIs for both the P300 speller and SSVEP speller for PC using the PsychoPy package and provided a custom keyboard for the iOS app, as shown in Fig 2b and 2c.
9) IRB Approval: We worked with the SBU IRB board to get our IRB with EEG support approved.

3.3 What opportunities for training and professional development has the project provided:

From April 23-28, 2023, Dr. Xiaojun Bi attended CHI'23, the SIGCHI Conference on Human Factors in Computing Systems, to give a presentation on our work *GlanceWriter: Writing Text by Glancing Over Letters with Gaze*, to experts and researchers in this area.

3.4 How were the results disseminated to communities of interest:

- The software is publicly available at the Apple App Store. The technologies are presented in conferences.
- On February 28, 2023, at the Rare Disease Day Awareness & Networking Fair, Dr. Fusheng Wang demonstrated EyeCanDo to students at Stony Brook University and shared his experience to enhance public understanding of rare diseases.

3.5 What do you plan to do during the next reporting period to accomplish the goals:

1) We plan to combine the proposed release A and release B together and make a major release including all functionalities and features we have already completed in major task 1, as it takes months to negotiate with the Apple App Review team regarding the privacy policy, terms and conditions, data collection and usage, among others. We plan to upload the release for review in the coming month and complete major task 1 in the summer.
2) We plan to finish the data streaming and integration of open-source EEG data processing libraries in fall. After that, we can build a BCI speller prototype. We will then incorporate a large language model and explore interactive reinforcement learning to improve the typing speed and reduce the error rate. We plan to complete major task 2 no later than March 2024.
3) We will work on detailed instructions and procedures for both in-person and at-home patient evaluation. We plan to conduct our first round of patient evaluation later this year, including formal testing on eye gaze and facial expression integration and pilot testing on our BCI speller. After the first round of evaluation and completion of major task 2, we will conduct our second round of patient testing in spring 2024.
4) Meanwhile, we plan to improve the usability and user experience further iteratively based on the feedback from Apple App Store reviews and patients. We aim to do more research on large language models (including ChatGPT integration) and Intelligent typing (including BCI speller).
5) We plan to submit a paper on the app and its supporting technologies in next Spring.

4. Impact

4.1 What was the impact on the development of the principal disciplines of the project:

The gaze-based interaction technologies developed and deployed in the project are likely to impact the knowledge base in gaze-based gesture typing (shape writing) methods. Existing gaze-based gesture

typing decoding algorithms usually require users to deliberately mark the starting and ending positions of a gaze path and use shape-based template matching methods to calculate the spatial model score. In contrast, *GlanceWriter* removes such requirements by probabilistically determining the letters to be entered based on the dynamics of eye movements and gaze locations. Our user study demonstrated that *GlanceWriter* significantly improves the text entry performance over existing methods *EyeSwipe* and Tobii Communicator 5 keyboard, advancing gaze-based text entry one step further.

We have delivered our app EyeCanDo to Apple App Store for download. As of May 24, 2023, there has been a total of 482 downloads, most of which come from the United States (319), United Kingdom (42), and Canada (19), as shown in Fig. 3. We expect there will be a dramatic increase in downloads with our next release (which will also support iPhone).

4.2 What was the impact on other disciplines:

Our gaze based typing technologies will also provide a novel approach to support fast typing based on Virtual Reality (VR), such as Meta's Quest, which has a broad range of applications.

4.3 What was the impact on technology transfer:

The gaze-based interaction technologies developed and deployed in the project are likely to impact commercial technology in the industry, such as VR and AR. For example, Meta Reality Lab is exploring potential synergies with our project. We recently had our initial discussion with Meta.

4.4 What was the impact on society beyond science and technology:

The app will provide a new framework to support people with disabilities, including amyotrophic lateral sclerosis (ALS), multiple sclerosis (MS), cerebral palsy, spinal cord injury, traumatic brain injuries and stroke, as well as muscular dystrophy and other serious illnesses.

5. Changes/Problems

5.1 Changes in approach and reasons for change:

Nothing to report.

5.2 Actual or anticipated problems or delays and actions or plans to resolve them:

During the pandemic, all R&D team members worked remotely and off-campus, which made collaboration and user study less effective, and therefore caused a several months delay in major tasks. One anticipated problem we're facing is that, unlike Windows, on which tons of development tools are available, iOS is a closed community for developers, which makes it challenging to deploy existing EEG frameworks and libraries on iOS in a short time.

With the end of the pandemic and return to office, we expect the future work will be more productive in terms of collaboration and patient evaluations. We will also dedicate more effort on BCI speller development and patient evaluation as major task 1 has almost been completed.

5.3 Changes that had a significant impact on expenditures

Nothing to report.

5.4 Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents

Nothing to report.

5.5 Significant changes in use or care of human subjects

Nothing to report.

5.6 Significant changes in use or care of vertebrate animals

Nothing to report.

5.7 Significant changes in use of biohazards and/or select agents

Nothing to report.

6. Products

6.1 Publications, conference papers and presentations

Whezhe Cui*, Rui Liu*, Zhi Li, Yifan Wang, Andrew Wang, Xiao Zhao, Sina Rashidian, Furqan Baig, IV Ramakrishnan, Fusheng Wang, Xiaojun Bi: *GlanceWriter: Writing Text by Glancing Over Letters with Gaze*. In Proceedings of CHI 2023 - The ACM CHI Conference on Human Factors in Computing Systems (*: Co-first authors ordered alphabetically). April 23-28, Hamburg, Germany.
Presentation video: https://www.youtube.com/watch?v=6ialUJPhrd0.

6.2 Websites or other Internet sites

Our research project website is http://eyecando.org/.
There are six sections, including Home, Overview, Product (download link, app demo, terms & conditions, and privacy policy), Publications, News and About (team, history, and contact).
The EyeCanDo application is available to download at Apple App Store at: https://apps.apple.com/app/id1550932850. An iPad Pro is needed to run the app.

6.3 Technologies or techniques

Nothing to report.

6.4 Inventions, patent applications, and/or licenses

Nothing to report.

6.5 Other Products

Nothing to report.

7. Participants & Other Collaborating Organizations

7.1 What individuals have worked on the project?

1) Individual 1:

Name:	Fusheng Wang
Project Role:	PI
Research Identifier:	0000-0002-9369-9361 (ORCID)
Nearest person month worked:	2 months
Contribution to Project:	Dr. Wang leads the project
Funding Support:	This award

2) Table 2:

Name:	Xiaojun Bi
Project Role:	Co-Investigator
Research Identifier:	0000-0002-9716-7709 (ORCID)
Nearest person month worked:	1.5 months
Contribution to Project:	Dr. Bi co-supervises the project. His expertise in HCI helps both research and software development
Funding Support:	This award

3) Individual 3:

Name:	Nurcan Gursoy
Project Role:	Co-Investigator
Research Identifier:	
Nearest person month worked:	1 month
Contribution to Project:	Dr. Gursoy provides clinical guidance and coordinates ALS Clinic on recruiting patients

Funding Support:	This award

4) Individual 4:

Name:	Rui Liu
Project Role:	Project team member
Research Identifier:	0000-0001-3654-1645 (ORCID)
Nearest person month worked:	12
Contribution to Project:	Work on the development and release of EyeCanDo
Funding Support:	This award

5) Individual 5:

Name:	Fatemeh Aslan Beigi
Project Role:	Project team member
Research Identifier:	0009-0003-3967-7713
Nearest person month worked:	12
Contribution to Project:	Work on EEG and BCI speller
Funding Support:	This award

6. Individual:

Name:	Zhi Li
Project Role:	Project team member
Research Identifier:	
Nearest person month worked:	4
Contribution to Project:	Work human computer interactions
Funding Support:	This award

7. Individual:

Name:	Yan Ma
Project Role:	Project team member
Research Identifier:	
Nearest person month worked:	4
Contribution to Project:	Work human computer interactions
Funding Support:	This award

7.2 Has there been a change in the active other support of the PD/PI or senior/key personnel since the last reporting period?

The PI has a new active award, which has no overlap.

Project/Proposal Title: Project Title: 3D Multiscale Biomolecular Human Reference Atlas Construction, Visualization and Usage [4 of 5]
Proposal/Award Number: 1OT2OD033756-01
Role: Co-Investigator (PI: Katy Borner)
Person-Month(s) (or Partial Person-Months) Per Year: 1
Total Award Amount (including Indirect Costs): $ 611,096
Supporting agency: National Institutes of Health
Grants Officer: Tyler Kory Best, Program Officer, Health Science Administrator, Office of Strategic Coordination, Division of Program Coordination, Planning, and Strategic Initiatives; Office of the Director National Institutes of Health, Bethesda, MD
Performance period: 08/01/2022-07/31/2026
Goals: Develop 3D modeling, management, and queries for the Human BioMolecular Atlas Program.
Specific Aims:

1. Constructing a multiscale, multimodal, and open Human Reference Atlas.

2. Diverse ingestion, processing, and curation of both HuBMAP and community partner datasets.
3. Comprehensive mapping of new datasets to the Human Reference Atlas.
4. Scalable tools to query, visualize, and explore biomolecular data.
5. Community engagement, education, and outreach serving diverse perspectives.

Overlap with proposed project? No

7.3 What other organizations were involved as partners?

Nothing to report.

8. Special Reporting Requirements

8.1 Collaborative Award

Nothing to report.

8.2 Quad Charts

Nothing to report.

9. Appendices

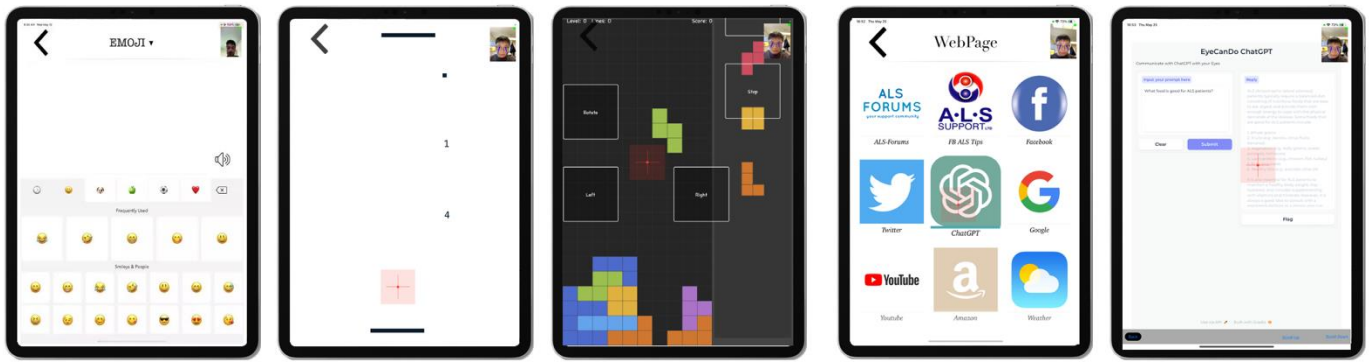

Figure 1 New Functionality Added to EyeCanDo

Figure 2. BCI streaming and speller GUI

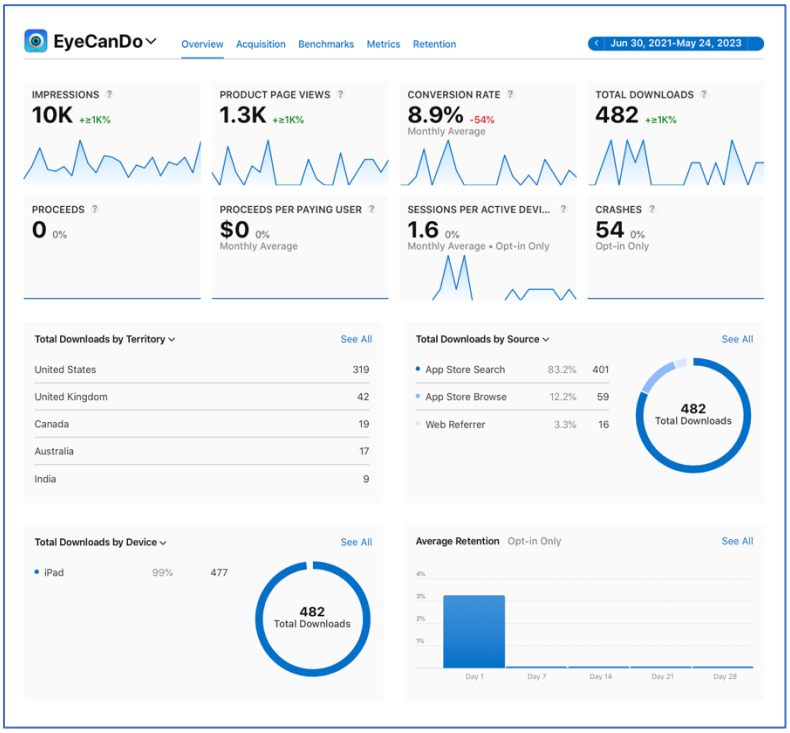

Figure 3. EyeCanDo App Analytics Overview