# One-Dimensional Eye-Gaze Typing Interface for People with Locked-in Syndrome

Michael Cross\* Leping Qiu\* microccross@gmail.com qlp19@mails.tsinghua.edu.cn Tsinghua University Haidian, Beijing, China Mingyuan Zhong myzhong@cs.washington.edu University of Washington Seattle, WA, USA Yuntao Wang Yuanchun Shi yuntaowang@tsinghua.edu.cn shiyc@tsinghua.edu.cn Tsinghua University Haidian, Beijing, China

# ABSTRACT

People with Locked-in syndrome (LIS) suffer from complete loss of voluntary motor functions for speech or hand-writing. They are mentally intact, retaining only the control of vertical eye movements and blinking. In this work, we present a one-dimensional typing interface controlled exclusively by vertical eye movements and dwell-time for them to communicate at will. Hidden Markov Model and Bigram Models are used as auto-completion on both word and sentence level. We conducted two preliminary user studies on non-disabled users. The typing interface achieved 3.75 WPM without prediction and 11.36 WPM with prediction.

### **KEYWORDS**

Locked-in Syndrome, eye gaze typing, one-dimensional text entry

#### ACM Reference Format:

Michael Cross, Leping Qiu, Mingyuan Zhong, Yuntao Wang, and Yuanchun Shi. 2022. One-Dimensional Eye-Gaze Typing Interface for People with Locked-in Syndrome. In *The Adjunct Publication of the 35th Annual ACM Symposium on User Interface Software and Technology (UIST '22 Adjunct), October 29-November 2, 2022, Bend, OR, USA.* ACM, New York, NY, USA, 3 pages. https://doi.org/10.1145/3526114.3558732

## **1 INTRODUCTION**

Locked-in syndrome (LIS) is a severe paralysis that results in patients' loss of voluntary motor functions to communicate via speech or hand-writing while mentally intact [1]. It is common for them to retain voluntary vertical eye movements, providing interaction possibilities [1, 13]. Existing augmentative and alternative communication (AAC) include: 1) Communication board requiring caregivers to iterate through alphabets for the user to indicate confirmation with a yes/no blink, which is slow [13]; 2) Brain-computer interfaces that leverage the electroencephalogram (EEG) signals, which can also be slow (under 10 characters per minute [12]) and requires expensive setup [2, 3, 10]; 3) Eye tracking entry that utilizes user's gaze to control cursor on a keyboard and a confirm protocol to input (e.g., *EyeBoard* [11], *GazeTalk* [4], and *EyeSwipe* [6]), however they all

\*Both authors contributed equally to this research.

UIST '22 Adjunct, October 29-November 2, 2022, Bend, OR, USA

© 2022 Copyright held by the owner/author(s).

ACM ISBN 978-1-4503-9321-8/22/10.

https://doi.org/10.1145/3526114.3558732



require two-dimensional gaze motion, which is impossible for some people with LIS. One solution is to design one-dimensional key-

board layout, which has been explored on tablets [7], smart glasses

[14] and force sensitive touchscreens [16] via touch. In this work,

we present the implementation of one-dimensional interface that

relies solely on vertical eye movements and dwelling. We iteratively

designed the interface with the goal of achieving highest word per

minute (WPM) (the characters typed per second converted to WPM

by defining a typical English word length as five characters long);

Figure 1: Typing Interface: 1) A Tape with 26 English letters can be moved by gazing upwards and downwards; 2) The user dwells on the three-letter wide cursor to enter letters. The boarder outline builds up in green; 3) Previously entered letters move left; 4) Previously entered word is in white, and candidate words from language models are in gray; 5) User can move the tape down to select from candidate words; 6) The complete sentence is built on the top-right; 7) Delete, clear and pause buttons are located on either end of the tape.

#### 2 INTERACTION DESIGN

Figure 1 shows the interface of our proposed technique. A rectangular gray cursor is fixed to the center of the screen which highlights the selected letters in bold and the selected buttons with enlarged icons, and the user controls the tape's movement instead of the cursor's movement, so that the keyboard only requires minimal range of eye movement and moves in a more controllable speed.

Users move their eyes upwards or downwards to scroll through the tape and dwell upon their intended character or button covered

Permission to make digital or hard copies of part or all of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. For all other uses, contact the owner/author(s).

by the cursor to confirm an input. A green outline builds from the middle of the cursor to indicate dwelling is registered. Once selected, the letters move left to provide input history as reference, and a list of candidate words deduced from selected letters is shown on the right to present possible inputs. To select a word from that list, the user scrolls down to the candidate word selection buttons and dwell to confirm. All of the users' input words are stringed into sentence and displayed on the top-right corner of the screen for caregivers or other people to read.

We iteratively designed the typing interface. First, we designed the cursor to select multiple letters at the same time, requiring less gaze precision. To realize this, we devised a descrambler that takes all possible permutations of a given multi-letter series, and match them against the top ten thousand results from the American National Corpus [5] with possessives, acronyms, onomatopoeias, apostrophes removed, and return the top matches as candidates.

Second, we ran simulations to evaluate the percentage of intended word missing from candidates under three factors: 1) dwellfree (SWYPE keyboard) and dwell-based selection; 2) different widths of the multi-letter cursor (2, 3); 3) different number of candidates (1, 5, 10). Based on that result, we adopted a dwell-based, 3-letter design with 5 candidates.

Third, we utilized prediction models to reduce number of letter selection per word entry. On a word level, we implemented a Hidden Markov Model (HMM) to auto-complete user's letter entry by evaluating the selected letters against the model. It was trained on the top ten-thousand words corpus plus words from the evaluation set (MacKenzie and Soukoreff's phrase set [8]). On a sentence level, we applied a Bigram Model to predict user's possible next words by computing the posterior probability of every word in the corpus given the user's most recent word input [15].

Finally, eye tracking uses a Tobii Eye Tracker 5 mounted at the bottom of a laptop screen. Users complete a three-point calibration (up, middle, down) prior to first time using.

### **3 PILOT STUDY: PARAMETER DISCOVERY**

We first conducted a pilot study on 8 non-disabled participants (4 male, 4 female, average age 28.4) to validate the keyboard UI and determine dwell-time (500 ms, 750 ms, 1000 ms based on [9]) and keyboard scrolling speed (20, 30, 40 letter-movement per second (LPS)) and test the effect of prediction algorithm on entry speed.

Participants were tasked to complete 9 blocks of 2 sentences where dwell and speed setting combinations were evaluated in random. All sentences were randomly selected from the MacKenzie and Soukoreff's phrase set, and were read out loud to the participants. They were given a short tutorial and up to 2 minutes of practice before the experiment, and a 1-minute break between blocks.

Results showed that the short dwell-time (500 ms) medium speed (30 LPS) combination yielded the highest average speed of 4.07 WPM. 5/8 participants performed best under this combination.

# 4 EVALUATION ON NON-DISABLED PARTICIPANTS

We then conducted preliminary evaluation on 9 recruited nondisabled participants (6 male, 3 female, average age 24.8) to evaluate and compare user performance and preferences with prediction absent and present.

Participants were tasked to input 4 blocks of 5 sentences using the short dwell-time and medium speed setting, alternating between prediction on and off. The sentences came from the same phrase set, and participants were given the same tutorial and rest as in pilot study. A seven-point survey was given between each block to collect user preferences. Users were allowed to revise the scores between blocks.

Participants achieved 3.75 WPM without prediction, and 11.36 WPM with prediction, gaining a 202.9% increase. One-way ANOVA yields statistical significance ( $F_{1,89} = 97.71, p < .001$ ). This result supports the keyboard design as a viable text-entry method.

The character selection error rate also had significant difference between prediction disabled (3.22%) and enabled (1.26%) ( $F_{1,17}$  = 12.07, p < .005). As we observed during the study, this was likely due to users needed to enter significantly more characters with prediction disabled, and produced more errors as their eyes become more fatigued. In contrast, the word selection error rate had no significant difference between prediction disabled (0.812%) and enabled (0.808%) ( $F_{1,17}$  = 2.90, p = .11).



Figure 2: Survey scores with and without prediction

Figure 2 shows the seven-point survey results when prediction is disabled and enabled. Lower scores for fatigue, efforts, and frustration (first four questions) are good, while high scores for feelings, satisfactions and performance (last three questions) are good. A Wilcoxon Signed Rank test found that all but mental and physical efforts exhibited statistical significance. Prediction enabled keyboard showed significantly better scores with lower eye fatigue, lower frustration and higher feeling of success, feeling of satisfaction with speed and overall performance.

#### 5 DISCUSSION AND FUTURE WORK

We successfully demonstrated the feasibility of a one-dimensional gaze keyboard on non-disabled participants, and achieved input speed that has surpassed some two-dimensional gaze keyboards [4, 11]. In the future, we plan to conduct user studies with locked-in patients and their caregivers to confirm usability. There are also opportunities in exploring different interface modifications such as changing the order of A to Z to frequency-based, and using other language models or taking users' own corpus with phrases including common caring needs and the names of family members and medications to further enhance input efficiency.

One-Dimensional Eye-Gaze Typing Interface for People with Locked-in Syndrome

UIST '22 Adjunct, October 29-November 2, 2022, Bend, OR, USA

## REFERENCES

- [1] 2021. Locked-in syndrome | Genetic and Rare Diseases Information Center (GARD) – an NCATS Program. https://rarediseases.info.nih.gov/diseases/6919/locked-in-syndrome#ref\_13005
- [2] Újwal Chaudhary, Ioannis Vlachos, Jonas B Zimmermann, Arnau Espinosa, Alessandro Tonin, Andres Jaramillo-Gonzalez, Majid Khalili-Ardali, Helge Topka, Jens Lehmberg, Gerhard M Friehs, et al. 2022. Spelling interface using intracortical signals in a completely locked-in patient enabled via auditory neurofeedback training. *Nature communications* 13, 1 (2022), 1–9.
- [3] Janis J. Daly and Jane E. Huggins. 2015. Brain-computer interface: Current and emerging rehabilitation applications. Archives of Physical Medicine and Rehabilitation 96 (3 2015), S1–S7. Issue 3. https://doi.org/10.1016/j.apmr.2015.01. 007
- [4] John Paulin Hansen, Kristian Tørning, Anders Sewerin Johansen, Kenji Itoh, and Hirotaka Aoki. 2004. Gaze typing compared with input by head and hand. Eye Tracking Research and Applications Symposium (ETRA), 131–138. https: //doi.org/10.1145/968363.968389
- [5] Nancy Ide and Keith Suderman. 2004. The American National Corpus first release.. In LREC.
- [6] Andrew Kurauchi, Wenxin Feng, Ajjen Joshi, Carlos Morimoto, and Margrit Betke. 2016. EyeSwipe: Dwell-free Text entry using gaze paths. Conference on Human Factors in Computing Systems - Proceedings, 1952–1956. https://doi.org/ 10.1145/2858036.2858335
- [7] Frank Chun Yat Li, Richard T. Guy, Koji Yatani, and Khai N. Truong. 2011. The 1Line keyboard: A QWERTY layout in a single line. UIST'11 - Proceedings of the 24th Annual ACM Symposium on User Interface Software and Technology, 461–470. https://doi.org/10.1145/2047196.2047257
- [8] I. Scott MacKenzie and R. William Soukoreff. 2003. Phrase sets for evaluating text entry techniques. Conference on Human Factors in Computing Systems -

Proceedings, 754-755. https://doi.org/10.1145/765891.765971

- [9] I. Scott MacKenzie and Xuang Zhang. 2008. Eye typing using word and letter prediction and a fixation algorithm. *Eye Tracking Research and Applications Symposium (ETRA)*, 55–58. https://doi.org/10.1145/1344471.1344484
- [10] Dennis J. McFarland and Jonathan R. Wolpaw. 2011. Brain-computer interfaces for communication and control. *Commun. ACM* 54 (5 2011), 60–66. Issue 5. https://doi.org/10.1145/1941487.1941506
- [11] Prateek Panwar, Sayan Sarcar, and Debasis Samanta. 2012. EyeBoard: A fast and accurate eye gaze-based text entry system. 4th International Conference on Intelligent Human Computer Interaction: Advancing Technology for Humanity, IHCI 2012. https://doi.org/10.1109/IHCI.2012.6481793
- [12] Aya Rezeika, Mihaly Benda, Piotr Stawicki, Felix Gembler, Abdul Saboor, and Ivan Volosyak. 2018. Brain-computer interface spellers: A review. *Brain Sciences* 8 (4 2018). Issue 4. https://doi.org/10.3390/brainsci8040057
- [13] Eimear Smith and Mark Delargy. 2005. Locked-in syndrome. British Medical Journal 330 (2 2005), 406–409. Issue 7488. https://doi.org/10.1136/bmj.330.7488. 406
- [14] Chun Yu, Ke Sun, Mingyuan Zhong, Xincheng Li, Peijun Zhao, and Yuanchun Shi. 2016. One-dimensional handwriting: Inputting letters and words on smart glasses. Conference on Human Factors in Computing Systems - Proceedings (5 2016), 71–82. https://doi.org/10.1145/2858036.2858542
- [15] Xuebai Zhang, Xiaolong Liu, Shyan Ming Yuan, and Shu Fan Lin. 2017. Eye Tracking Based Control System for Natural Human-Computer Interaction. Computational Intelligence and Neuroscience 2017 (2017). https://doi.org/10.1155/ 2017/5739301
- [16] Mingyuan Zhong, Chun Yu, Qian Wang, Xuhai Xu, and Yuanchun Shi. 2018. ForceBoard: Subtle text entry leveraging pressure. *Conference on Human Factors in Computing Systems - Proceedings* 2018-April (4 2018), 1–10. https://doi.org/10. 1145/3173574.3174102