GazeSync: Eye Movement Transfer Using an Optical Eye Tracker and Monochrome Liquid Crystal Displays

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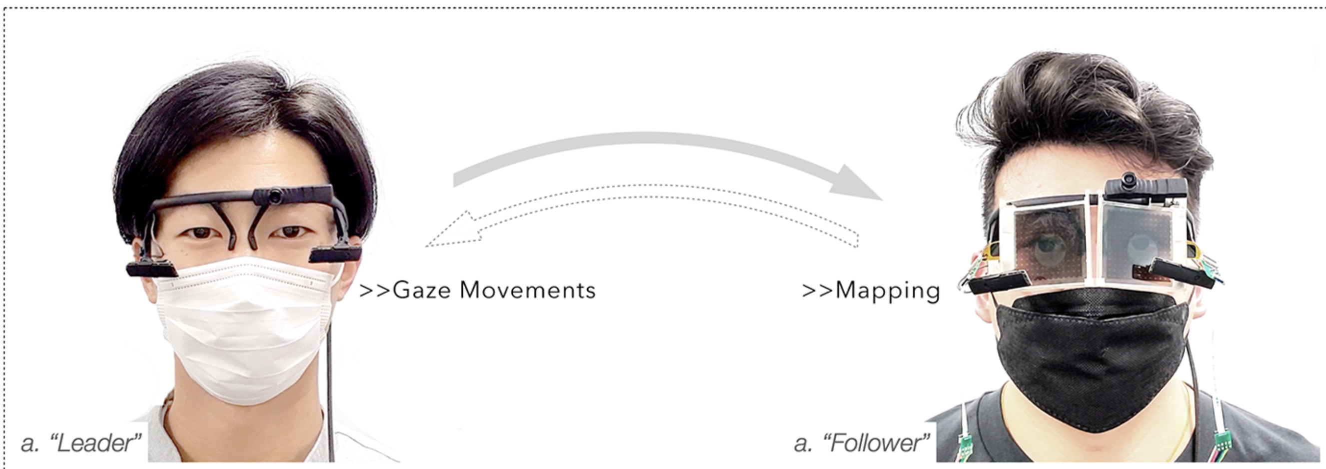

Figure 1: a. The Leader is the gaze input resource that we get two-dimensional x and y coordinates by having him wear a Pupil CORE eye tracker. b. The Follower follows the transparent circle that represents the gaze movements of the leader.

ABSTRACT

Can we see the world through the eyes of somebody else? We present an early work to transfer eye gaze from one person to another. Imagine you can follow the eye gaze of an instructor while explaining a complex work step, or you can experience a painting like an expert would: Your gaze is directed to the important parts and follows the appropriate steps. In this work, we explore the possibility to transmit eye-gaze information in a subtle, unobtrusive fashion between two individuals. We present an early prototype consisting of an optical eye-tracker for the leader (person who shares the eye gaze) and two monochrome see-through displays for the follower (person who follows the eye gaze of the leader). We report the results of an initial user test and discuss future works.

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CCS CONCEPTS

• **Human-centered computing** → *Empirical studies in ubiquitous and mobile computing*; *Collaborative and social computing systems and tools*; **Ubiquitous and mobile devices**.

KEYWORDS

gaze detection, gaze synchronization, eye tracking, gaze communication

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1 INTRODUCTION

The sclera, the white in our eyes, is more prominent compared to primates or other animals, enabling us to communicate and recognize gaze more efficiently [13]. We often rely on gaze information in social situations, from learning over coordination to guessing intentions [1, 12, 18, 23]. Yet, estimating the gaze of a person from just their eye position is difficult, especially when we are engaging in an unfamiliar task. Have you ever imagined seeing the world from another perspective or the eyes of somebody else? In our research, we aim at augmenting the social components of eye gaze and searching for ways of sharing, transferring, and extending gaze information.

Take an offline visual creative activity as an example, namely, learning how to draw a sketch precisely and how to observe the motif systematically. In general, due to our limited visual memory, professional painters switch their gaze between their canvas and the motif quickly and frequently to carry as much visual information as they can observe [4]. That observational method enables professional painters to suppress perceptual (visual) constancy (color, size). However, beginners of drawing are less likely to switch their gaze from the motif and their canvas as many as experts do [4]. In this context, gaze imitation is a powerful mechanism for transferring knowledge from a well trained one to an unskilled one [11]. Thus, one of the original ideas is to design a method that can synchronize the professional instructor's gaze moving patterns and the beginners'. Those indicate the potential that real-time gaze synchronization can compensate or even enhance both online and offline communication experiences.

There are a lot of works dealing with gaze visualization in virtual reality, augmented reality, mixed reality, and real-world environments [17, 20, 22, 24]. Efficient visual guidance could contribute to reducing cognitive load while conducting visual search activities [15], as well as [3] used HoloLens for augmented collaboration under co-design scenarios in shared space. Shared gaze was used to improve robot performance as well [19]. It was also found that gaze information strongly reflects the human interest or their attention [8]. Hata et al. [9] proposed a method to guide their users' attention to the intended location without being noticed by using subtle blur effects. Shared attention between two parts is also used to modulate gaze following [2].

Researches regarding ocular activities such as saccadic eye movements and smooth pursuit suggest the potentials that we can leverage those inherent properties to build better or reshape our visual experience. The phenomenon that saccades can be triggered voluntarily or involuntarily [21] indicates the possibility to synchronize gaze explicitly or implicitly. Regarding leveraging smooth pursuit to build gaze interaction, [5] enables hands-free interaction while using smartwatches.

We propose GazeSync, a gaze movement transferring device that synchronizes gaze movements between the leader side and follower side, which will be described in detail in the following paragraphs. The contributions of this paper are as follows: (1) we present the concept of GazeSync which is using wearable smart eyewear to synchronize gaze movements from one user (leader) to another user (follower), (2) we present an initial, fully functional prototype using an optical eye tracker and 2 monochrome liquid crystal displays to share eye gaze unidirectional in real-time. (3) we report insights of an initial user test and present future directions for gaze-communication-related research.

2 IMPLEMENTATION

As the gaze synchronization material, we use two monochrome Liquid Crystal Displays (LCDs), similar to the ones used by [10] for the generation of a semi-transparent layer in between the real world and our eyes to suppress excessively bright illumination, see figure 2B. We design a pattern that can work as blurry effects [9] to induce the user to move their gaze to the unobscured area or the relatively high-resolution area, see figure 2C. To track the eye movements as well as to generate the corresponding data of eye activities, we use Pupil Core Eye Tracker [14, 16]. It is widely used in various studies such as [6, 7, 26] because of its robust eye-tracking performance. To have the eye movement tracking cameras detect eyeball movements successfully and stably through the LCD panels, we replaced the original camera arms with our re-designed 3D printed ones, which made sure that we can set the cameras at a relatively optimal angle to detect the pupils. To decide the appropriate interpupillary distance and the radius of the transparent circle, we follow [25] and set 8cm as the interpupillary distance and 30 pixels as the radius of the transparent circle.

3 INITIAL TEST

As an initial usability test, we recruit two male graduate students to test our gaze synchronization glasses, one of them assigned as the leader (white-mask male), the other as a follower (black-mask male). The leader wore a Pupil Core to obtain the data of his gaze movements. To generate a Cartesian coordinate system to get the x and y coordinates of gaze, we set four Apriltag Markers on a vertical 1.2m x 1.8m whiteboard in front of him, the distance between the front camera of his Pupil Core and the vertical whiteboard is 50cm. Then we conduct calibration of gaze movement, making sure we can obtain stable and reliable x and y coordinates from the leader. Meanwhile, the follower wears our customized Pupil Core with two transparent monochrome LCD attached on the Pupil Core frame as the lenses, in which we displayed a peripheral-black but center-transparent pattern, see figure 1b, for both left and right lenses.

We take two steps to test the synchronization. In the first step, the experimenter gives directional signs in Japanese to the leader (native Japanese), *e.g.,* slowly moving your gaze up, down, left, or right and back to the center. The follower is a non-Japanese student having little Japanese experience, which prevents him from being distracted by the language signal. Both the leader and the follower could not see each other so that the follower does not have access to the leader's gaze directly. To further make sure that the follower would not be affected by external visual stimuli, we require him to face a whiteboard that covers his entire field of view. As the step two, to test their synchronization performance over natural gaze patterns, we ask the leader to move his eye freely and observe the corresponding eye movements of the follower.

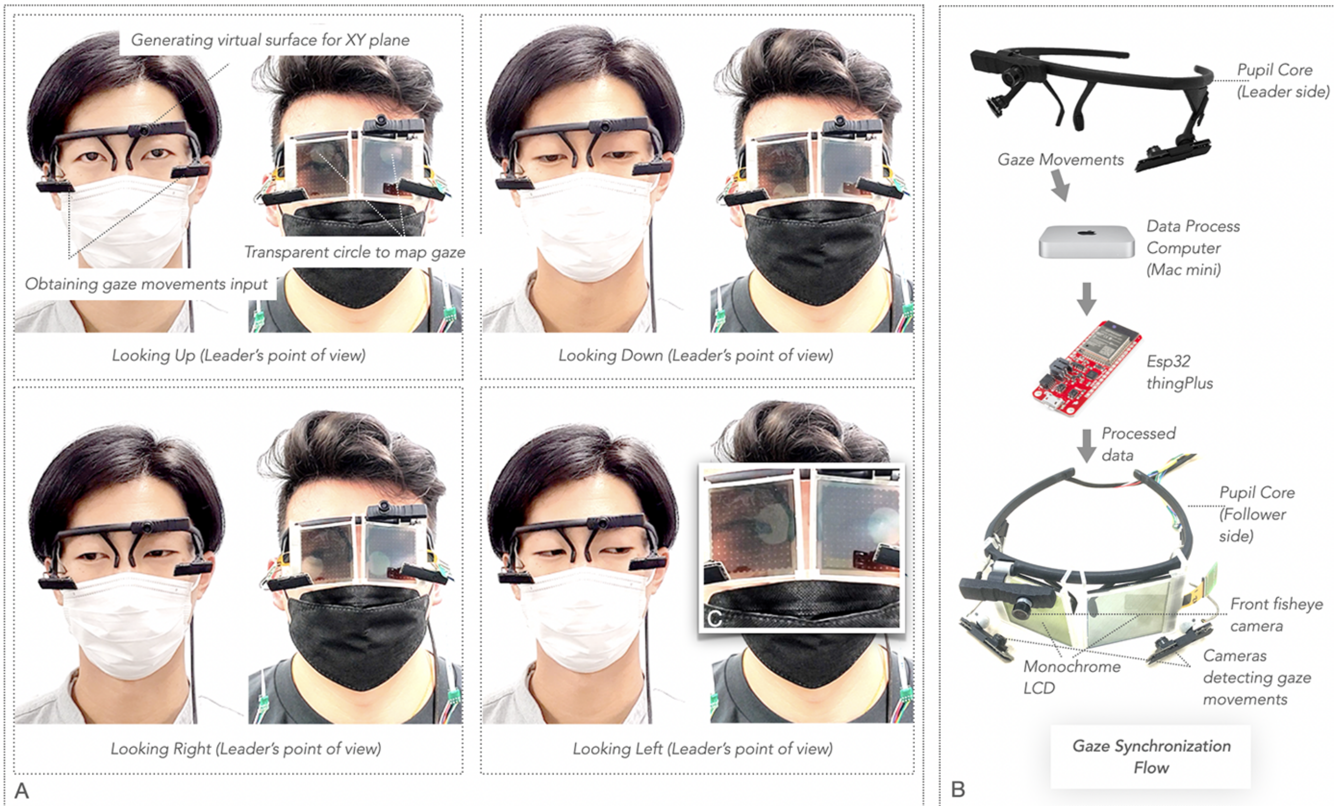

Figure 2: Demonstration of gaze Sync and its Configuration. A. indicates how we map the leader's gaze to the follower, such as the directional signs that the experimenter gave to the leader, slowly looking up, slowly looking down, slowly looking right, and slowly looking right, meanwhile, the follower reacted as the corresponding directions. B. demonstrate the gaze synchronization working flow.

4 INSIGHTS AND DISCUSSION

According to the observational result and the oral feedback from the follower, if the movement of the transparent circle (corresponding to the leader's eye movement) is too fast, the follower was not able to chase it. On the other hand, if the speed of the movement is moderate and smooth, it is relatively easy for him to follow the transparent region. Besides, this current prototype is somewhat heavier than ordinary glasses and its design did not distribute well the pressure on his nose. Also, we observed an obvious delay between the leader and the follower despite the devices being controlled over the RS-232 link via USB cables. Besides, to generate a virtual surface as the x and y coordinate plane, this current prototype requires a front camera which is somewhat sensitive regarding privacy when using it in public space.

5 CONCLUSION AND FUTURE WORKS

We expect that to leverage this device with the visual clues we can better react to the auditory information or vice versa in terms of both online and offline learning, teaching, and co-working scenarios. For future works, since this current initial test could not clarify whether the gaze following movements of the follower is active or passive, we will conduct a different study that covers voluntary smooth pursuit and involuntary subtle gaze guiding. Nevertheless, based on the feedback and visual observations, our device is performing reasonably well and does allow a certain level of eye movement synchronization. In the future, we will work on reducing the system latency and evaluate the synchronization levels in a more quantifiable way.

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REFERENCES

[1] Simon Baron-Cohen, Sally Wheelwright, Jacqueline Hill, Yogini Raste, and Ian Plumb. 2001. The "Reading the Mind in the Eyes" Test revised version: a study with normal adults, and adults with Asperger syndrome or high-functioning autism. *The Journal of Child Psychology and Psychiatry and Allied Disciplines* 42, 2 (2001), 241–251.
[2] Anne Böckler, Günther Knoblich, and Natalie Sebanz. 2011. Observing shared attention modulates gaze following. *Cognition* 120, 2 (2011), 292–298.
[3] Yoonjeong Cha, Sungu Nam, Mun Yong Yi, Jaeseung Jeong, and Woontack Woo. 2018. Augmented collaboration in shared space design with shared attention and manipulation. In *The 31st Annual ACM Symposium on User Interface Software and Technology Adjunct Proceedings*. 13–15.

[4] Dale J Cohen. 2005. Look little, look often: The influence of gaze frequency on drawing accuracy. *Perception & Psychophysics* 67, 6 (2005), 997–1009.

[5] Augusto Esteves, Eduardo Velloso, Andreas Bulling, and Hans Gellersen. 2015. Orbits: Gaze Interaction for Smart Watches Using Smooth Pursuit Eye Movements. In *Proceedings of the 28th Annual ACM Symposium on User Interface Software & Technology* (Charlotte, NC, USA) *(UIST '15)*. Association for Computing Machinery, New York, NY, USA, 457–466. https://doi.org/10.1145/2807442.2807499

[6] Augusto Esteves, Eduardo Velloso, Andreas Bulling, and Hans Gellersen. 2015. Orbits: Gaze interaction for smart watches using smooth pursuit eye movements. In *Proceedings of the 28th annual ACM symposium on user interface software & technology*. 457–466.

[7] Kunal Gupta, Gun A Lee, and Mark Billinghurst. 2016. Do you see what I see? The effect of gaze tracking on task space remote collaboration. *IEEE transactions on visualization and computer graphics* 22, 11 (2016), 2413–2422.

[8] Aiko Hagiwara, Akihiro Sugimoto, and Kazuhiko Kawamoto. 2011. Saliency-based image editing for guiding visual attention. In *Proceedings of the 1st international workshop on pervasive eye tracking & mobile eye-based interaction*. 43–48.

[9] Hajime Hata, Hideki Koike, and Yoichi Sato. 2016. Visual guidance with unnoticed blur effect. *Proceedings of the Workshop on Advanced Visual Interfaces AVI* 07-10-June-2016, 28–35. https://doi.org/10.1145/2909132.2909254

[10] Yuichi Hiroi, Yuta Itoh, Takumi Hamasaki, and Maki Sugimoto. 2017. Assisting Eye Adaptation Via Occlusive Optical See-Through Head-Mounted Displays AdaptiVisor.

[11] Matthew W Hoffman, David B Grimes, Aaron P Shon, and Rajesh PN Rao. 2006. A probabilistic model of gaze imitation and shared attention. *Neural Networks* 19, 3 (2006), 299–310.

[12] Roxane J Itier and Magali Batty. 2009. Neural bases of eye and gaze processing: the core of social cognition. *Neuroscience & Biobehavioral Reviews* 33, 6 (2009), 843–863.

[13] Sarah Jessen and Tobias Grossmann. 2014. Unconscious discrimination of social cues from eye whites in infants. *Proceedings of the National Academy of Sciences* 111, 45 (2014), 16208–16213. https://doi.org/10.1073/pnas.1411333111 arXiv:https://www.pnas.org/content/111/45/16208.full.pdf

[14] Moritz Kassner, William Patera, and Andreas Bulling. 2014. Pupil: an open source platform for pervasive eye tracking and mobile gaze-based interaction. In *Proceedings of the 2014 ACM international joint conference on pervasive and ubiquitous computing: Adjunct publication*. 1151–1160.

[15] Tiffany CK Kwok, Peter Kiefer, Victor R Schinazi, Benjamin Adams, and Martin Raubal. 2019. Gaze-guided narratives: Adapting audio guide content to gaze in virtual and real environments. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. 1–12.

[16] Pupil Labs. 2014. *Pupil Core Eye Tracker*. https://pupil-labs.com/products/core/

[17] Yuan Li, Feiyu Lu, Wallace S Lages, and Doug Bowman. 2019. Gaze direction visualization techniques for collaborative wide-area model-free augmented reality. In *Symposium on spatial user interaction*. 1–11.

[18] Christine E Looser and Thalia Wheatley. 2010. The tipping point of animacy: How, when, and where we perceive life in a face. *Psychological science* 21, 12 (2010), 1854–1862.

[19] AJung Moon, Daniel M Troniak, Brian Gleeson, Matthew KXJ Pan, Minhua Zheng, Benjamin A Blumer, Karon MacLean, and Elizabeth A Croft. 2014. Meet me where i'm gazing: how shared attention gaze affects human-robot handover timing. In *Proceedings of the 2014 ACM/IEEE international conference on Human-robot interaction*. 334–341.

[20] Zahar Prasov and Joyce Y Chai. 2008. What's in a gaze? The role of eye-gaze in reference resolution in multimodal conversational interfaces. In *Proceedings of the 13th international conference on Intelligent user interfaces*. 20–29.

[21] Dale Purves and Stephen Mark Williams. 2001. *Neuroscience. 2nd edition*. Sinauer Associates 2001. http://lib.ugent.be/catalog/ebk01:3450000000002013

[22] Ben Steichen, Giuseppe Carenini, and Cristina Conati. 2013. User-adaptive information visualization: using eye gaze data to infer visualization tasks and user cognitive abilities. In *Proceedings of the 2013 international conference on Intelligent user interfaces*. 317–328.

[23] Hiroki Tanaka, Sakriani Sakti, Graham Neubig, Tomoki Toda, Hideki Negoro, Hidemi Iwasaka, and Satoshi Nakamura. 2015. Automated social skills trainer. In *Proceedings of the 20th International Conference on Intelligent User Interfaces*. 17–27.

[24] Vincent Van Rheden, Bernhard Maurer, Dorothé Smit, Martin Murer, and Manfred Tscheligi. 2017. LaserViz: Shared gaze in the Co-located physical world. In *Proceedings of the Eleventh International Conference on Tangible, Embedded, and Embodied Interaction*. 191–196.

[25] Qing Zhang, Hiroo Yamamura, Holger Baldauf, Dingding Zheng, Kanyu Chen, Junichi Yamaoka, and Kai Kunze. 2021. Tunnel Vision–Dynamic Peripheral Vision Blocking Glasses for Reducing Motion Sickness Symptoms. In *2021 International Symposium on Wearable Computers*. 48–52.

[26] Xucong Zhang, Yusuke Sugano, Mario Fritz, and Andreas Bulling. 2017. Mpiigaze: Real-world dataset and deep appearance-based gaze estimation. *IEEE transactions on pattern analysis and machine intelligence* 41, 1 (2017), 162–175.