Combining Intuitive Gaze-Based Control with EEG-Based Detection of Motor Imagery and Quasi-Movements

This poster

Our website

Artem S. Yashin (1*), Yulia G. Shevtsova (1, 2), Evgeniy P. Svirin (1), Anatoly N. Vasilyev (1, 2) & Sergei L. Shishkin (1)

1 – MEG Center, Moscow State University of Psychology and Education; 2 – M.V. Lomonosov Moscow State University

Correspondence: yashinart1996@gmail.com

1 Introduction

- Gaze-based interaction allows users to control interfaces by looking at objects [Majaranta et al. 2019]. Hybrid eye-brain-computer interfaces (EBCIs) [Reddy et al. 2024] combine gaze with BCI control, typically using **motor imagery (MI)** – an internal task.
- MI-BCIs are used in assistive tech and neurorehabilitation [Villa-Berges et al. 2023], but gaze instructions can interfere with internal task performance [Walcher et al. 2023], potentially complicating feedback preception during MI.
- An external alternative to MI is attempted movements [Mansour et al. 2022], which could be modelled via **quasi-movements (QM)** – movements reduced to the point of no muscle activation [Nikulin et al. 2008]. QM have not yet been used for online BCI control.

2 Ideas & Hypotheses

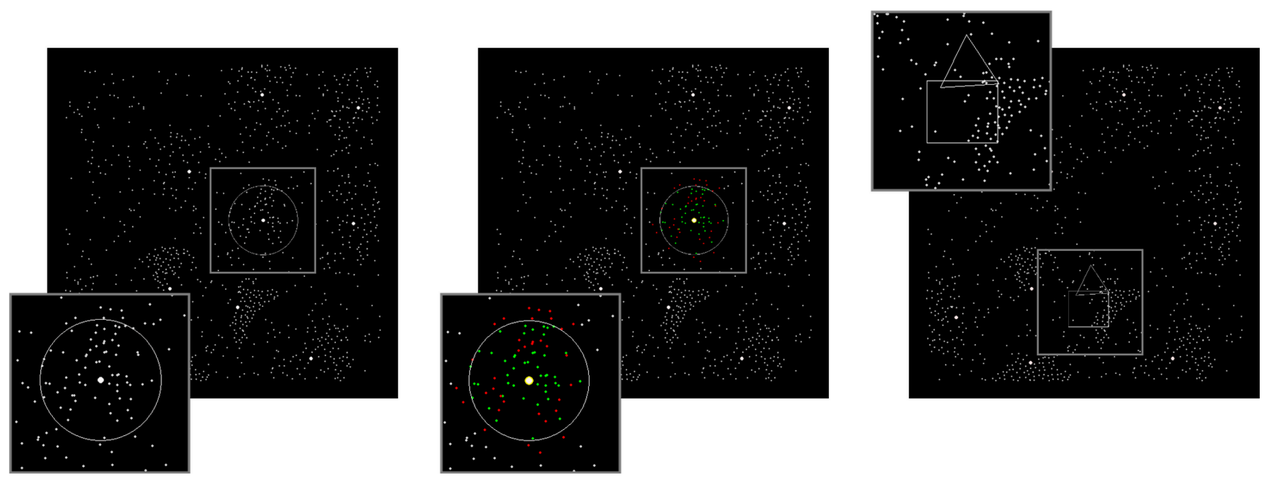
- We, for the first time, used QM in online BCI. We tested a complementary EBCI interaction model in which gaze ensures precise target selection, and the QM/MI-BCI frees gaze for continuous feedback monitoring. Gaze-based control in the setup was designed to reduce demands on gaze behavior.
- Hypotheses:

H1: QM-based EBCI control will be more efficient than MI-based control.

H2: User experience (UX) ratings will be more positive under the QM condition.

3 Methods

- 19 healthy volunteers (median age 24) participated in this study.
- 64 channel EEG and EMG (NVX136 amplifier) were recorded, gaze was tracked at 500 Hz (EyeLink 1000 Plus).
- Participants played AstroSync, a custom game involving gaze-based selection and BCI feedback monitoring during QM/MI in separate conditions. Fixating on large stars **(Fig. 1A)** initiated 8s constellation interaction **(Fig. 1B)**. Early execution of QM/MI blocked interaction **(Fig. 1C)**; delayed cessation triggered red activation of outer star bands.
- BCI efficacy was measured by: (1) % of green bands, (2) blocked interactions per star, (3) outer bands per star.
- UX was assessed using NASA TLX [Hart and Staveland 1988] and the System Usability Scale (SUS) [Brooke 1996].



(A) Constellation selection

(B) Interaction with a constellation

(C) Blocked interaction

Fig. 1 AstroSync gameplay situations. Large hitboxes and long selection times were used to reduce gaze strain. EEG classification determined success (green star bands) or failure (red).

5 Results

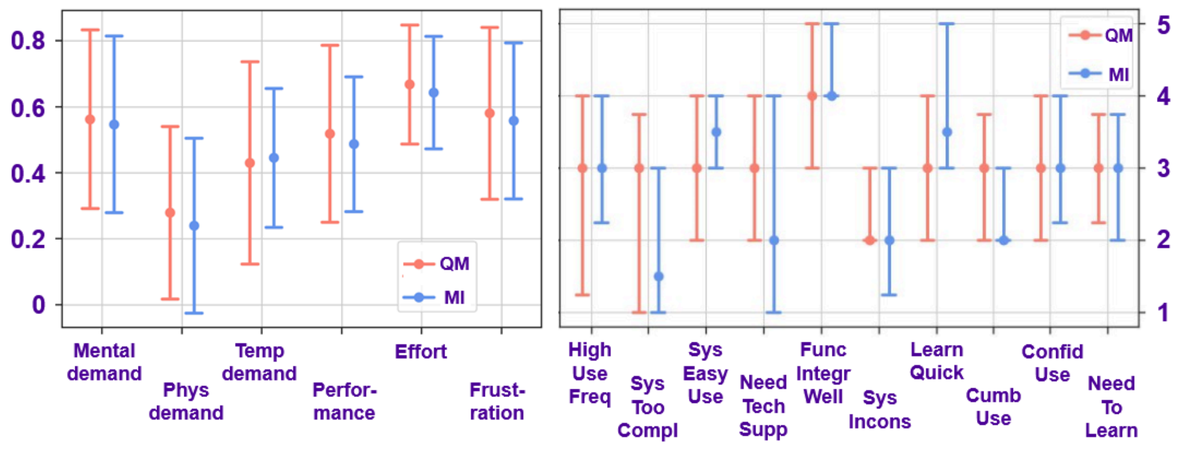
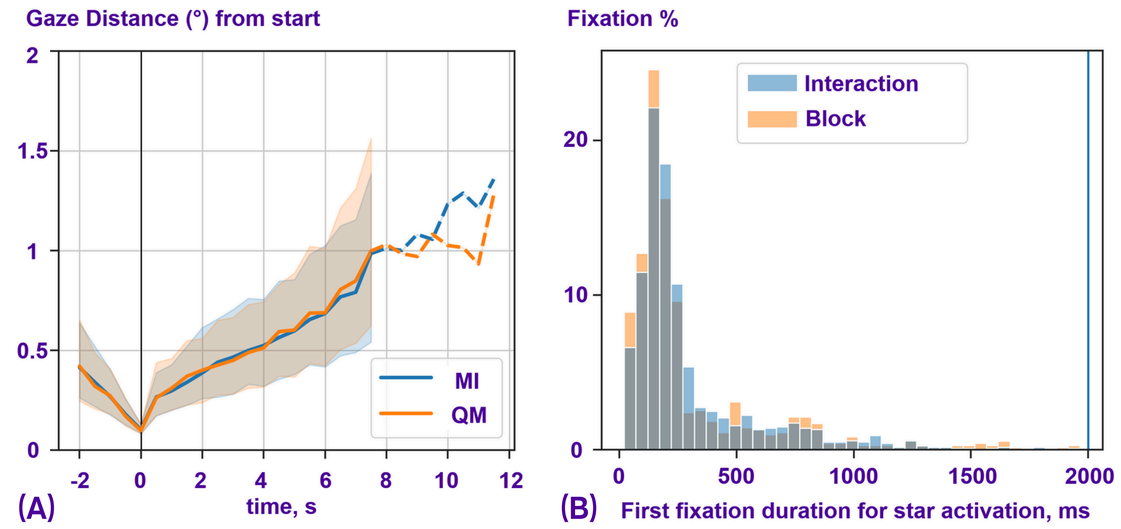


Fig. 3 NASA TLX and SUS ratings



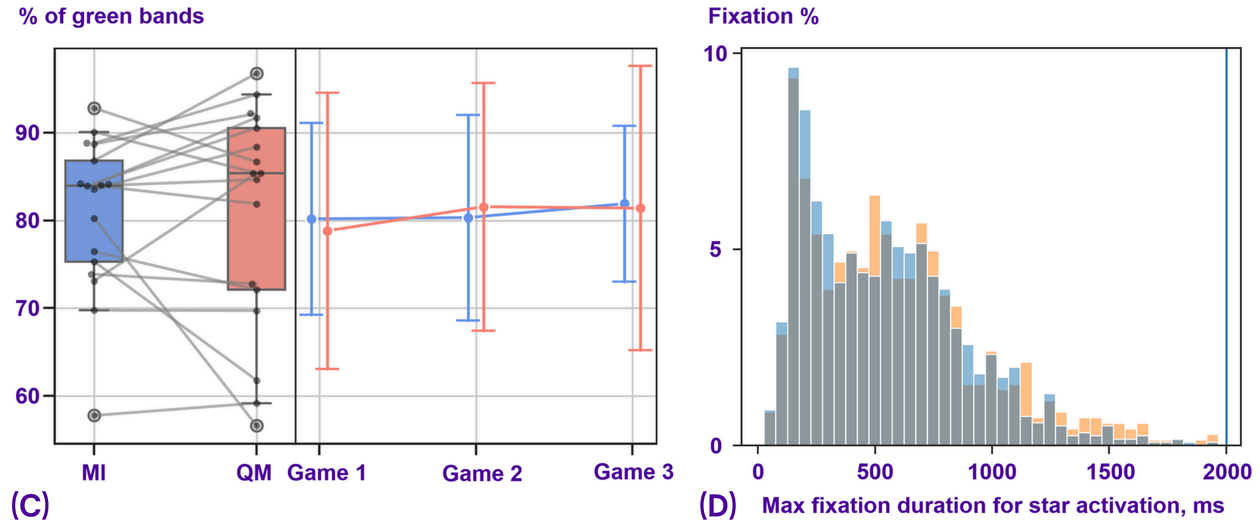


Fig. 4 EEG classification and gaze results

[Performance] The average % of green bands was ~80 in both QM and MI modes **(Fig. 4C)**. Overall, BCI control was successful, but H1 was not confirmed across all metrics.

[UX] NASA TLX: Physical demand ratings were significantly below the midpoint (QM: $t(17)=-3.59$, $p=.002$; MI: $t(17)=-4.17$, $p=.001$), while overall effort was significantly above it (QM: $t(17)=3.95$, $p=.001$; MI: $t(17)=3.57$, $p=.002$). SUS (MI condition): System complexity ($W=6$, $p=.002$) and function integration ($W=4.5$, $p=.001$) were rated positively. No significant differences were found in pairwise comparisons. See **Fig. 3**.

[Gaze] Participants monitored the constellations for visual feedback **(Fig. 4A)**, but used prolonged gaze fixations to initiate interaction **(Fig. 4B, 4D)**.

6 Conclusion

- The results confirmed the feasibility of using QM for BCI control in combination with gaze-based control, however, our hypothesis of QM superiority was not confirmed. Future work should explore the system's viability in real-world settings, including clinical applications.

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