First real-time study of a BCI based on quasi-movements: Comparison to the MI BCI within a new hybrid eye–brain–computer interface paradigm

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This poster

Introduction

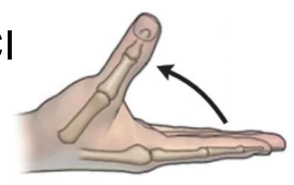
Motor imagery (MI) is widely used for BCI control. However, as an internally directed task, MI may compete for attentional resources with external interaction [1]. Attempted movements (AM) provide an alternative for patients with paralysis [2]. AM involve an effort to perform an actual movement without overt movement and induce EEG changes similar to those observed during MI. **Quasi-movements (QM)** – movements minimized until muscle activity disappears – have been proposed as an experimental model of AM in healthy individuals [3].
However, QM produce no natural sensory feedback, making them a potentially unnatural experience. Can BCI-mediated feedback make QM more natural and effective for control?
Here, for the first time, we investigated QM for controlling a hybrid eye–brain–computer interface (EBCI). Participants selected objects semi-passively with their gaze and then activated the BCI using either QM or MI, while visual feedback guided the precise timing of task termination.

Hypothesis: We expected QM to be more compatible than MI with gaze-based interaction requiring externally directed attention, resulting in better EBCI performance and greater subjective control success and comfort.

Methods

Participants: 18 healthy participants. All participants had prior experience with MI; 9 had prior experience with QM.

Conditions:
motor imagery BCI vs quasi-movements BCI



Movement: Abduction of the right thumb

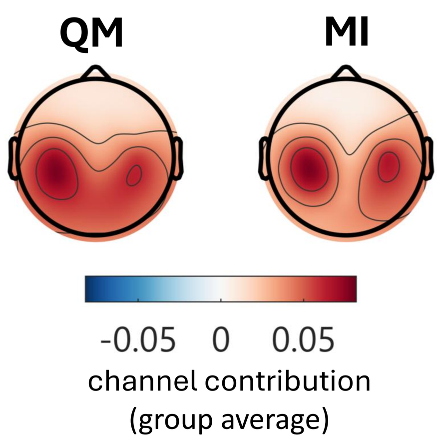
Equipment

Eye tracking: EyeLink 1000 Plus (SR Research), 500 Hz
EEG (64 channels) & **EMG**: NVX136, 1000 Hz

EEG Pattern Classification

MI/QM vs Rest*

Spatial filtering



Feature extraction:

1. CSP -> 2 manually selected μ-ERD components
2. Fourier Transform -> optimal frequency bins selected by Fisher's criterion

Features: power of selected CSP components within individual μ-bands [4].

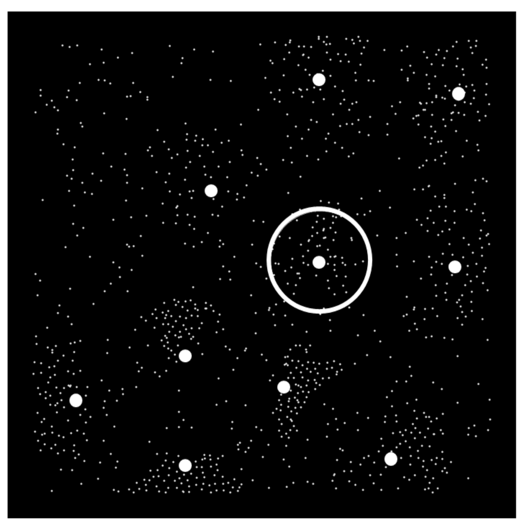
Classification: participant-specific Naïve Bayes classifier.

Real-time classification

Classifier output rate: 10 Hz
Command generation: based on 10 consecutive classifier outputs (i.e., one command per second).

AstroSync Game

Game field: 10 stars and mini-stars (reward points).

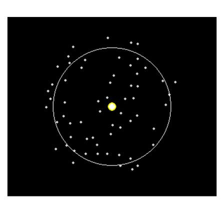
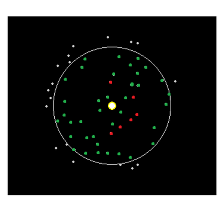
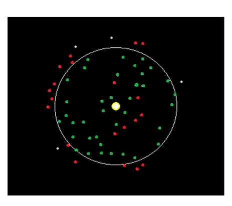


Circle – star selection indicator.

Goal: score as many points as possible.

Game interaction:
1. Select a star by gaze (500 ms dwell time).
2. Interact with the selected star by performing the MI/QM at the appropriate time.

Feedback — mini-star color:
green: points awarded;
red: points deducted.

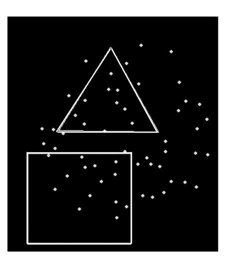




Game challenges:

• MI/QM must be initiated at the correct time, as a premature start blocks interaction with the star.

• MI/QM must be terminated at the correct time, as continuing the task after the "end" signal results in penalty points.

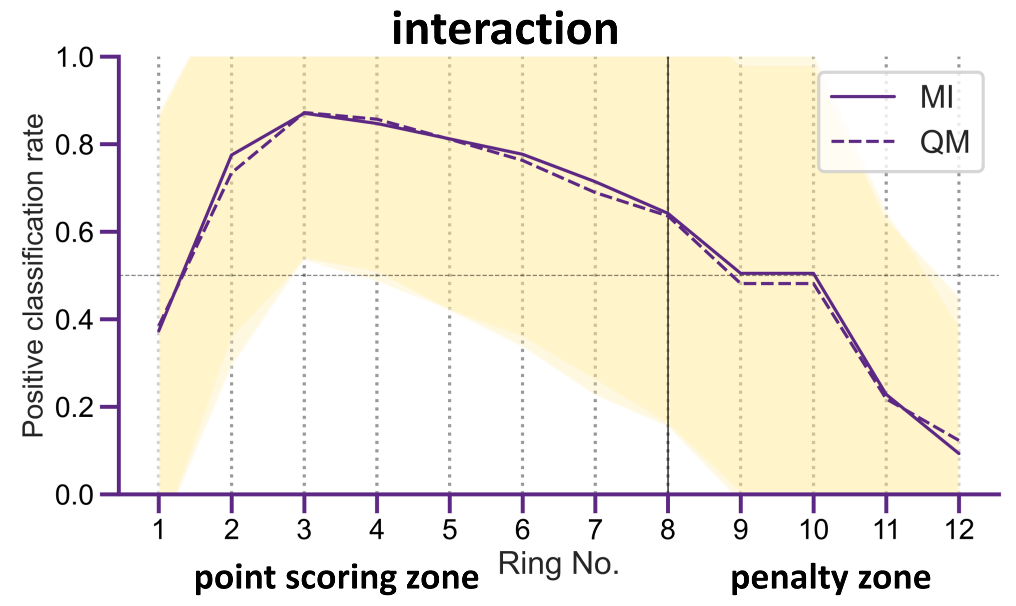
*For **rest** trials, participants performed a distractor task, counting small stars within geometric shapes.



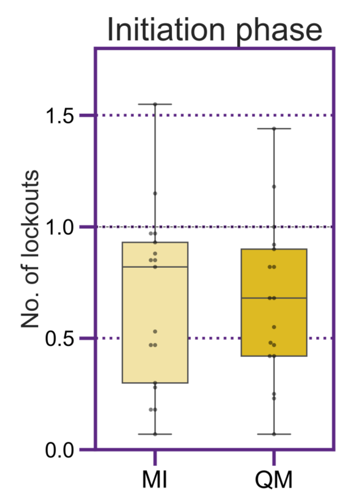
Results

Classification accuracy

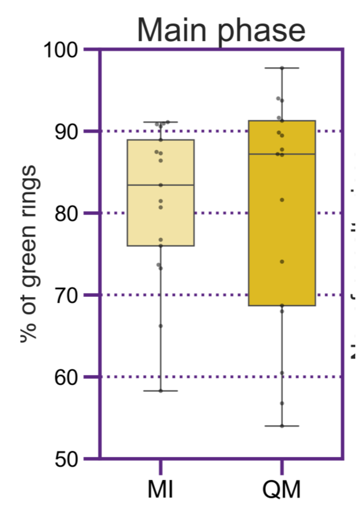
Mean QM/MI classification accuracy over the entire interaction



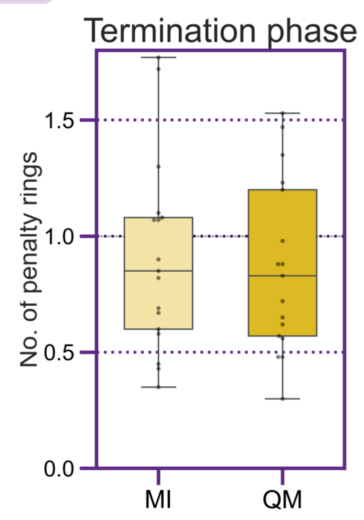
BCI Control Performance



Mean Number of Lockouts per Star



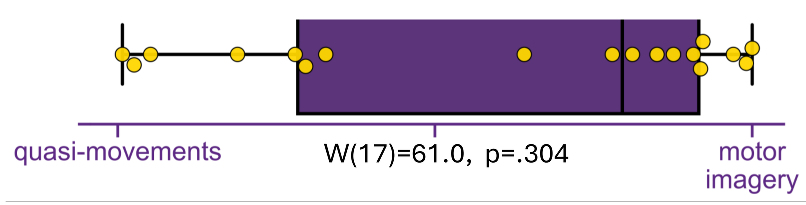
Percentage of Rings Correctly Activated in Point Scoring Zone



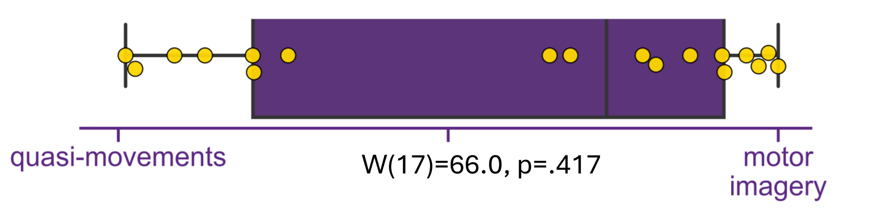
Mean Number of Penalty Zone Rings per Star

Subjective Assessment of Control Quality

Which condition allowed you **to perform better** in the game?



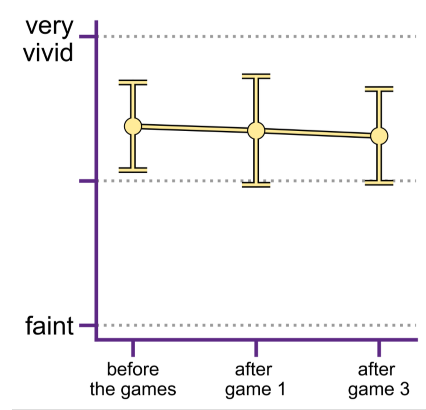
Which condition did you find **more comfortable**?



Preference for ...	
MI	QM
11	7

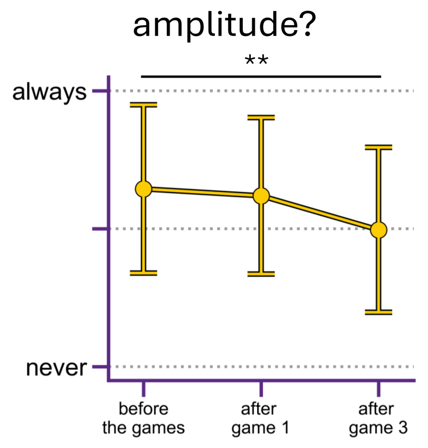
Real-Time BCI Experience Effects

(MI) How vivid was the imagined movement?



F(2, 34) = .747, p = .481

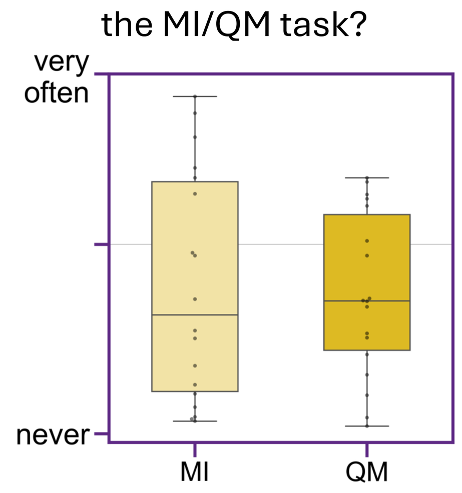
(QM) How often did you have to pay attention to the movement amplitude?



F(2, 34)=3.301, p=.049;
post-hoc 1-vs-3: p=.008

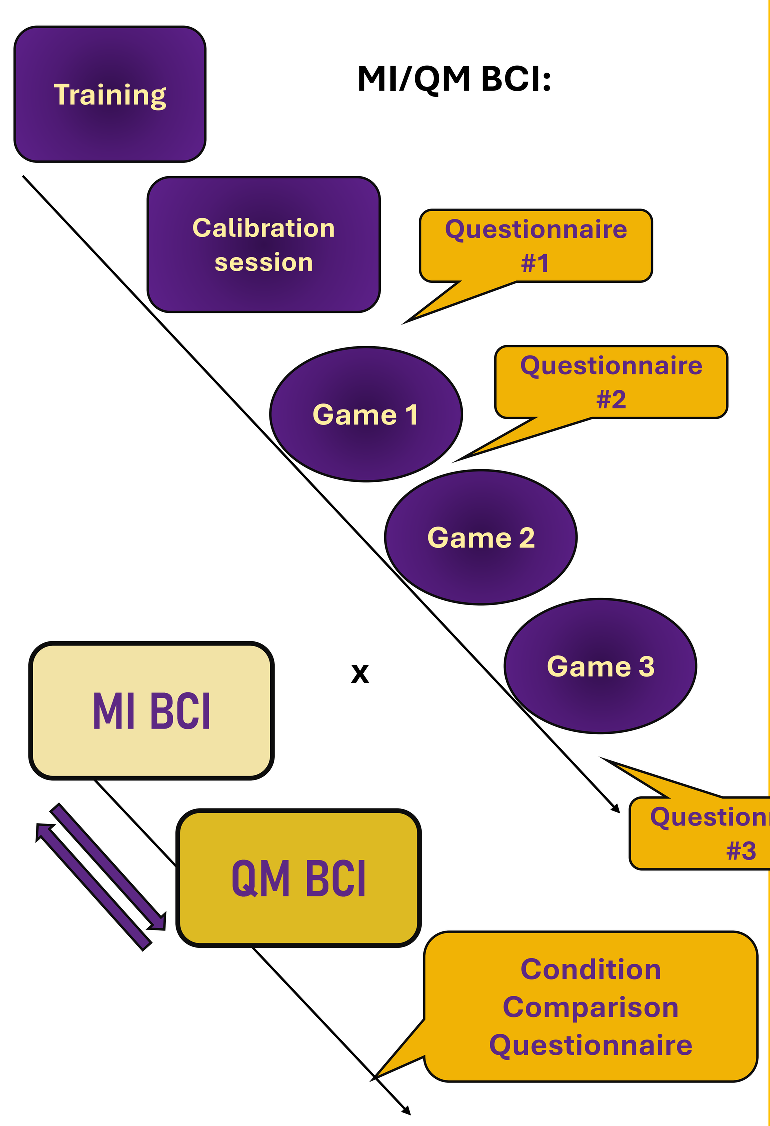
Automaticity of the MI/QM

How often were you able to explode a star without shifting your attention to performing the MI/QM task?



t(17) = –1.584, p = .132 **t(17) = –2.598, p = .019**

Experimental Design



Conclusion

- For the first time, QM were successfully implemented for the real-time BCI control with feedback.
- Both QM and MI enabled effective control of the hybrid eye–brain–computer interface.
- Contrary to our hypothesis, QM did not outperform MI in either objective BCI performance or subjective experience.
- Participants who preferred MI reported that QM were more difficult to perform, requiring continuous control to avoid overt movement.
- QM provide a feasible alternative to MI, but their effectiveness may depend on individual strategy and training.

Future Directions

- Optimize QM instructions and feedback (faster, more congruent feedback).
- Provide more extensive QM training.
- Evaluate QM-based BCI control in clinical populations (for a pilot clinical study with a rehab BCI exoskeleton, see [5]).
- Investigate the effects of long-term BCI training.

Literature

[1] Shishkin S.L., Yashin A.S., Shevtsova Y.G., Vasilyev A.N. Should attempted movements replace motor imagery in BCI? The issue of compatibility with gaze use. Proc. of the 9th Graz Brain-Computer Interface Conference 2024. Verlag der Technischen Universität Graz. Pp. 455-460.

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[3] Nikulin, V. V., Hohlefeld, F. U., Jacobs, A. M., & Curio, G. Quasi-movements: A novel motor–cognitive phenomenon // Neuropsychologia, 46(2), 2008, P. 727-742.

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[5] Yashin A.S., Ivanov L.A., Kondur A.A., Bobrov D.A., Slyunkova E.V., Gabuzov G.G., Lukyanov E.S., Shevtsova Y.G., Vasilyev A.N., Bobrov P.D., Kotov S.V., Shishkin S.L. First real-time use of quasi-movements for exoskeleton control: Comparison with MI-BCI in healthy participants and pilot application in stroke rehabilitation. 10th Graz Brain-Computer Interface Conference 2026.

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