Augmenting Gaze Control With a Brain-Computer Interface

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Introduction

- A hybrid brain-computer interface (hBCI) is a system composed of a BCI and one other system [1].
- Eye-gaze or head-gaze based interfaces are good examples of interfaces that can benefit from an additional communication channel such as a BCI.
- Users often suffer from the Midas Touch Problem where objects are selected unintentionally, making it difficult to create the correct dwell time length [2].
- We present a hBCI composed of a head-tracker and a event-related desynchronization (ERD)-based BCI.
- We demonstrate our hBCI in a fully immersive virtual environment in the UCL CAVE.
- We compare the performance of our HBCI with that of using dwell time to select and move objects in a 3D virtual environment.

Methodology

- To compare the performance of the HBCI and DT conditions we created a spatial reasoning task based on rotation of 3D objects. The aim of the task was to select and manipulate the object matching the target object and drop it on top of the target object. There were four objects to choose from (Figure 1 left). The correct object was set to a different rotation angle from the target object.

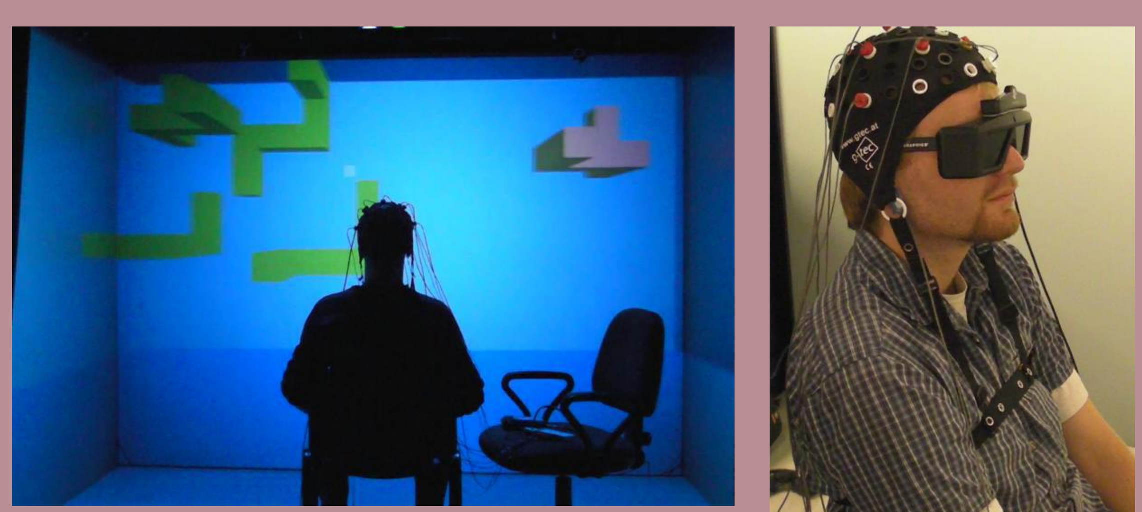

Figure 1: Set up of experiment. Left: Spatial reasoning task (target object is on right-hand side of screen). Right: Subject wearing electrodes and head-tracker.

- The white cursor seen in Figures 1 and 2 is the point at which the head-tracker is aimed.
- When the correct object was selected, its colour turned to purple. If an incorrect object was selected, its colour turned to red and it could not be moved.
- Participants had 45 seconds to complete each trial with 5 seconds rest between 9 trials.
- Dwell Time (DT) Condition: Users selected an object by gazing at it for 3.5 seconds. Once the object was selected they could move it on top of the target object by moving the head-tracker. To drop the object on top of the target object they had to gaze at the object for 3.5 seconds (length of DT was determined by pilot studies).
- Hybrid BCI Condition: Users selected an object by carrying out hand motor imagery. Once the object was selected they could movie it on top of the target object by moving the head-tracker. To drop the object on top of the target object they once again carried out hand motor imagery (Figure 2).

A

B

C

D

Figure 2: hBCI condition in the UCL CAVE. A: User is selecting correct object that matches target object using the hBCI. B: User has selected correct object and is moving it with the head-tracker. C: Object is now on top of the target object. D: User has dropped the target object using the hBCI.

Results

- Results showed that during most trials there were no significant differences between the hBCI system and the dwell time system.
- There were five timouts (unfinished trials) in the hBCI condition whilst there were zero timeouts for the dwell time condition.
- Four of the five timeouts resulted in extremely long pick up/drop off times. These 5 trials proved to be outliers when compared to the other 50 trials. Therefore, statistical analysis was carried out both with and without these timeouts.
- The Wilcoxon matched pairs test was used to compare the hBCI and dwell time conditions using three measurements:
  - Pick up and drop times
  - Error rates (when an incorrect object is selected)
  - Task completion times
- There were no significant differences in pick up and rop rates without the timed-out trials, however the hBCI condition was slower with timed-out data (Table 1 and Figure 3).

	Pick Up	Drop	Pick Up & Drop Off
Without Timeouts	0.4544	0.0610	0.0613
With Timeouts	0.5611	0.0095	0.0200

Table 1: P-values of Wilcoxon matched pairs test comparing the hBCI and DT systems (significant differences are highlighted in red).

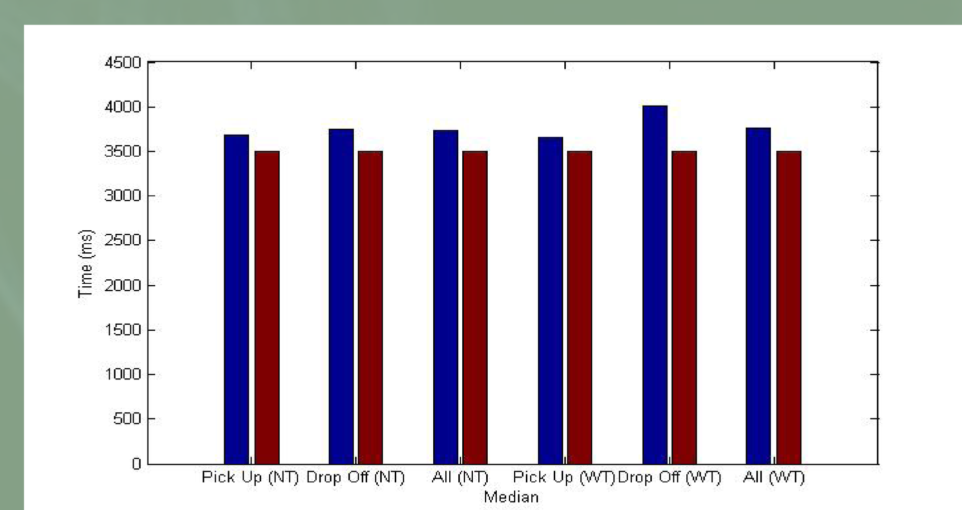

Figure 3: Median time taken to pick up and drop objects with no timeouts (NT) and with timeouts (WT) for the bBCI condition (blue) and the DT condition (red).

- There were no significant differences in error rates (p=0.1063) or in task completion times (p=0.8741) between the two conditions (Figure 4).

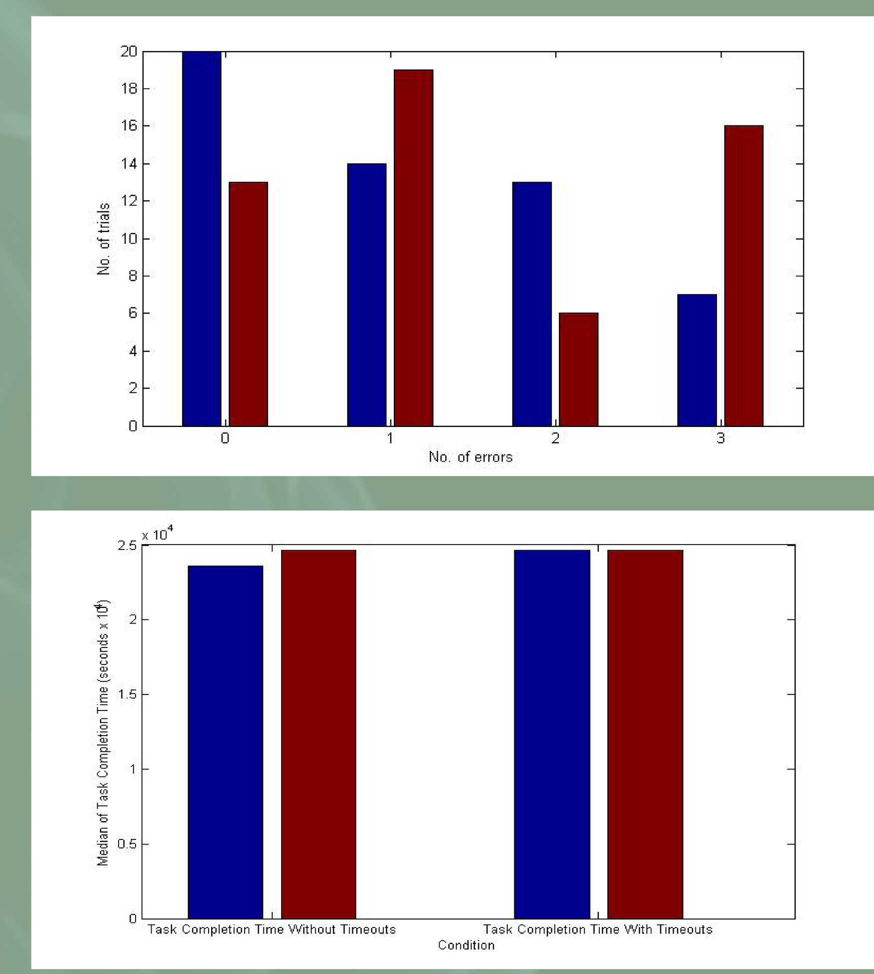

Figure 4: Top: Error rates (out of 54 trials) Bottom: Median task completion times for the bBCI condition (blue) and the DT condition (red).

Conclusions

- Most trials showed no significant differences between the two conditions which suggest that a hBCI can be used as an alternative to eye-gaze interfaces, or at least as an additional channel. This may be a solution to the Midas Touch Problem.
- We believe that it is possible to improve our hBCI in two ways and possibly surpass the performance of a pure eye-gaze technologies.
- Our hBCI could be made asynchronous. Users were at a significant disadvantage by having to wait for the cycle of the software to pick up their motor imagery.
- Participants could be given real-time feedback regarding the strength of their motor imagery in the form of an audio or visual bar in the CAVE.
- In conclusion, we present the beginnings of an alternative to dwell time interfaces. We feel that there is much potential in developing hBCIs within and outside virtual immersive displays.

References

1. Millan, J. d. R., Rupp, R., Muller-Putz, G., Murray-Smith, R., Giugliemma, C., Tangermann, M. , Vidaurre, C., Cincotti, F., Kubler, A., Leeb, R., Neuper, C., Muller, K-R. and Mattia, D. Combining braincomputer interfaces and assistive technologies: state-of-the-art and challenges. *Frontiers in Neuroscience*, 4:1-15, 2010.
2. Jacob, R. What you look at is what you get. *CHI '90 Proceedings*. 11-18, 1990.