HAPTIC FEEDBACK COMPARED WITH VISUAL FEEDBACK FOR BCI

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SUMMARY: Feedback plays an important role when learning to use a BCI. Here we compare visual and haptic feedback in a short experiment. By imagining left and right hand movements, six novice subjects tried to control a BCI with the help of either visual or haptic feedback every 1s. Alpha band EEG signals from C3 and C4 were classified. The classifier was updated after each prediction using correct class information. Thus feedback could be given throughout the experiment. Subjects got better at controlling the BCI during the experiment independent of the feedback modality. Haptic feedback did not present any artifacts to the classified brain signals. More research is required on haptic feedback for BCI-applications because it frees visual attention to other tasks.

INTRODUCTION

EEG signals associated to mental tasks can be classified accurately enough to be transferred into computer commands in a Brain-Computer Interface (BCI) [1,2]. Feedback plays an important role when subjects learn to control their brain signals. Nevertheless, just a few studies have addressed the role of feedback in BCIs (see. e.g. [3,4,5]), where only the effect of removing visual feedback from well-trained subjects [3], comparison of discrete and continuous visual feedback [4], and the use of auditory feedback has been examined [5]. To our knowledge the use of other feedback modalities, such as haptic feedback, has not been studied. The aim of this study was to compare haptic and visual feedback in a short experiment.

MATERIALS AND METHODS

Subjects: Six right-handed subjects (20-30 years).

Recordings: EEG was measured at 12 locations (international 10-20 system), in a shielded room. The reference was situated in the middle of Cz and Fz.

Experimental setup: Subjects were shown a visual target either on the right, left, or upper side of a small screen. The subjects were to imagine either left or right hand movements, or do nothing (target up). The targets were changed randomly every 10-15s. S1-S3 received haptic feedback in the first three sessions and visual feedback in the following three sessions. The order was reversed for S4-S6. Each session lasted ~7min.

Features: Movement-related activity (7-13Hz) from C3 and C4 was used. FFT components were calculated from a 1s time window, resulting in 2 channels x 7 frequencies = 14 features. The window was moved and features were re-calculated once the classifier function had finished with the previous sample (~ every 100ms)

Classification and Feedback: A linear model with logistic output function was used to classify the features. The model was re-trained after each new feature (~ every 100ms) using a maximum of 300 previous labelled samples from both classes (less in the beginning of the experiment). The iterative least squares algorithm was used to update the model parameters. Classification and training was done only when the subject was performing either the left or right task. Haptic feedback was delivered through a vibrotactile transducer driven by a custom board connected to the PC. It consisted of 100ms of 200Hz vibration either to the left or the right lower neck. The amplitude was set to a value that the subjects reported being clearly perceivable. Visual feedback showed for ~100 ms an arrow on the screen either to the left or right. Feedback was given every 1s if the averaged posterior probabilities of 10 previous predictions exceeded 70% (S1&S4) or 60% (others) for either of the two classes, i.e. feedback was not given in uncertain cases. Feedback was given from the beginning of the experiment.

RESULTS

Tab. 1 shows the mean classification accuracy averaged over three sessions with different feedback modalities. Even during a short 42-minute experiment high classification accuracies (means 56-80%) were possible.

Tab. 1: Mean classification accuracies for 3 sessions (%) (HF, VF: Haptic and Visual Feedback, respectively)

	S1	S2	S3	S4	S5	S6	**Mean±SD**
HF	77	71	56	71	64	67	**68±7**
VF	80	67	64	70	67	58	**68±7**

Tab. 2 shows how often the subjects received feedback. The best subjects got on average feedback every 2s and the worst subject every 6s. The posterior probability threshold was higher for S1 and S4, thus they had to perform better to get the same amount of feedback.

Table 2: Average feedback time interval (s) for subjects.

	S1	S2	S3	S4	S5	S6	**Mean±SD**
HF	3	2	3	6	3	2	**3.3±1.5**
VF	2	2	3	5	3	2	**3.8±0.9**

Fig. 1 displays the classification accuracies for the individual sessions for the different subjects. No clear differences can be seen between haptic and visual feedback. Subjects S2-S6 got tired towards the end of the experiment which explains the worse results in the last session. Three out of six subjects show a decrease in classification accuracy when the feedback modality was changed. Subjects got better during the experiment irrespective of feedback modality.

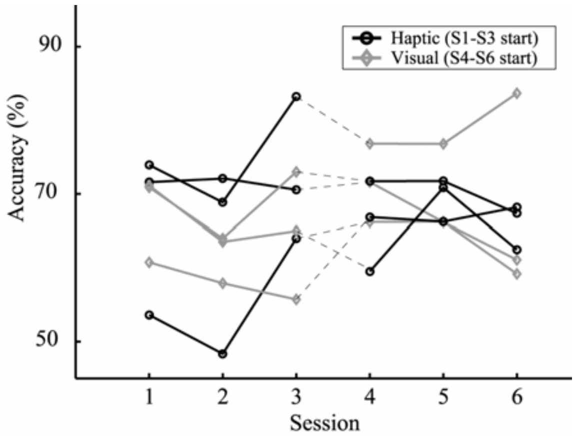

Fig 1: Classification accuracies in the different sessions.

The left side of Fig. 2 displays the event-related potentials for the visual (grey) and haptic feedback (black) from channel C3 and corresponding standard error. The slow somatosensory evoked potential (SEP) can be detected in all subjects at ~200ms. The visual feedback does not evoke any response. The right side of Fig. 2 displays the corresponding spectrum (calculated using FFT for 0.5s time window after stimulus onset). The haptic feedback does not show significant difference in the alpha band frequencies that could interfere with the classification of motor imaginary.

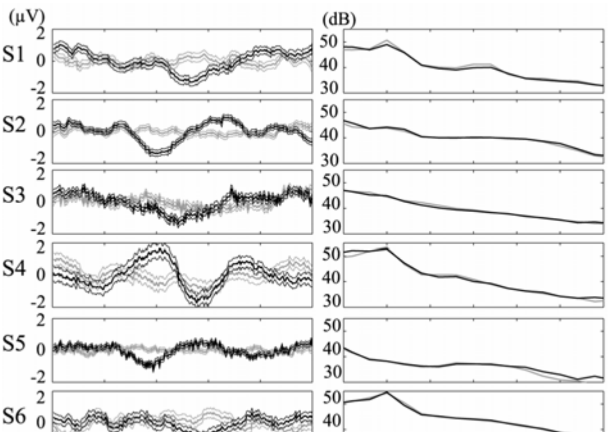

Fig 2: Left: Evoked-responses of feedback related activity (N=200-400). Right: Corresponding spectra.

DISCUSSION

No differences were found between training using haptic or visual feedback during the 42-min experiment. Even though SEPs can be detected in the averaged signals, the haptic feedback did not interfere with the classified brain signals in the 7-13 Hz range. When asked, most subjects thought haptic feedback felt more natural. However, one subject said that it sometimes, especially during misclassifications, interfered with the imagination of movements. Visual feedback was given discretely only once a second because continuous haptic feedback was not possible due to technical difficulties. Otherwise the different feedback modalities would not be comparable.

The preliminary results of this study show that haptic feedback could be used as an alternative to visual feedback if e.g. visual attention is needed for other tasks. Haptic feedback could also be used as additional information to visual feedback. For example, when controlling an intelligent application, haptic feedback could present the user with the output of the classifier and visual feedback the control of the application. For example, in a wheelchair simulator with intelligent assistance to avoid obstacles, the movement of the wheelchair does not directly describe the classification performance. These results should be verified with more subjects. Especially the long term effects when learning to use a BCI with the help of haptic feedback should be investigated as well as the effect of discrete and continuous feedback.

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