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Single trial classification of perceived and imagined music from EEG

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Summary

We have carried out two experiments to investigate imagined music as a possible paradigm for a brain-computer interface (BCI). In a first experiment, we found that although all participants showed above-chance classification for heard musical phrases, only three out of six showed classifiable imagery. We used a sequence method to use multiple trials, which increased the rates for these participants and led to rates above 80% (in a 4-class problem) for the best participant. To investigate multitrial results in a continuous sequence, a second experiment was carried out. This time, actually perceived music was detectable up to 98% correct, but for imagery again the results were varied. The sequence method for the continuous epochs did increase the rates, but not more so than for the alternating stimulus sequences. Imagined music is shown to be an effective BCI task, at least for a subset of users. As development is still in an early stage, more work is necessary to fine-tune the paradigm.

Background

In searching for a mental task suitable to drive a BCI, several types of imagery have been explored. After encouraging results for imagined rhythm [2]. we wanted to further investigate musical stimuli. Music imagery has previously been reported as a task for BCI [1]; however in this case it was contrasted with completely dissimilar tasks. Here, we investigate the possibilities of distinguishing between different imagined musical phrases. We used self-selected musical phrases that were well known to the participants, on the supposition that not only does this reduce the memory load and exertion as compared to more effortful tasks, but it would also evoke a stronger brain response as the participants selected their own personal choice of music they like and respond to.

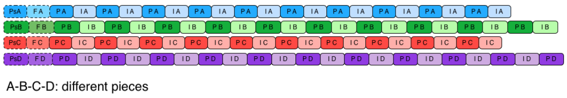

Figure 1: A schematic overview of the stimulus sequences used in experiment 1

Experiment 1: EEG was measured in 6 participants, listening and imagining 4 different musical phrases, by alternating perception and imagery (see Fig. 1) and thus keeping the timelock. One second of data was taken from each musical phrase and classified per task (perception/imagery).

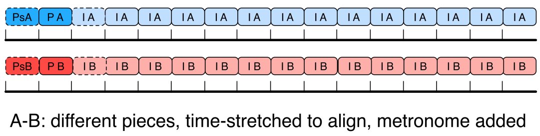

Figure 2: A schematic overview of the stimulus secuences used in experiment 2

Experiment 2: The current sequences did not allow for concatenation with continuous data, and additionally were not suitable for a real-time implementation. Thus, in a subsequent experiment, the alternating sequences were replaced by only imagery, with a metronome to give the time-lock and two perception trials as instruction and the music time-stretched to yield equal-length phrases (see Fig 2).

Method

For Experiment 1, 1s-epochs were taken (musical phrases had different lengths) with a 200 ms timelag to prevent carryover from the perception epochs just before. For Experiment 2 the whole segment was used. After some preprocessing steps, the multi-class problem was split into binary subproblems and a linear logistic-regression classifier trained and applied. The multi-class results are an average of these binary rates. To look at the effect of using multiple trials, a 'maximum-likelihood' decoding technique was used to combine per-epoch classifier predictions to both generate a multi-class prediction and to generate sequence predictions.

Results

Figure 3 shows the results for Experiment 1. It shows that increasing the number of epochs used raises the rates for all participants except one (S4). Perception signals are clearly stronger than imagery and go up to 90% and above for the best two participants after two seconds of data.

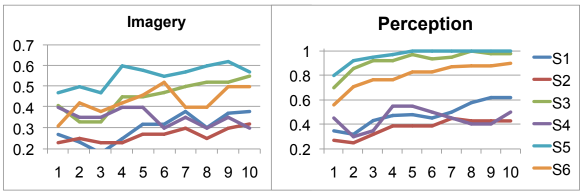

Figure 3: Classification rates for Experiment one, using an accumulating number of 1s- epochs up to ten. The colored lines indicate the subjects, and as this is a 4-class problem chance level is at 0.25.

Figure 4 shows the results for Experiment 2, with imagery results showing the best binary pair, and perception showing the results of a 5-class problem (as most binary problems went up to 100% fairly quickly). It shows that again, increasing the number of used epochs generally raises the rates for all participants, although it is not a straightforward increase as the stimuli were self-selected and epoch length thus varied.

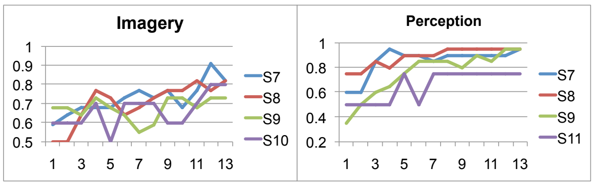

Figure 4: Classification rates for experiment two, using an accumulating number of epochs. The colored lines indicate the subjects, and the left graph shows the best binary pair in imagery (chance level at 0.5) and the right shows the 5-class results for detecting perceived music (chance level at 0.2).

Discussion

Generally, participants in Experiment 2 showed a better performance, and this may be due to the changed stimulus sequences, but this may also be caused by interpersonal differences. Even so, as the results are preliminary, more work in this direction is needed to make more solid conclusions. We are currently developing this paradigm for a real-time setting, cutting off the sequence once a good rate is reached with a reasonable probability. The reported classifications indicate that not much is gained after 5 seconds of data, but this may change in an online setting.

Imagined music is shown to be a promising paradigm for BCI, but also has to tackle problems of illiteracy. However, for participants that show useful brain signals, the performance is comparable to other popular BCI tasks. Future work will show the feasibility in a real-time set-up.

References

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