Comparisons of Auditory Brain-Computer Interfaces with Different Auditory Stimuli

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Abstract

- In this study, we investigated three different P300-based auditory BCI systems that present each different stimuli, which are beep, voice and animal sound.
- We studied how BCI performance and ERP patterns are differed in three different types of the auditory BCIs.
- The results showed that natural sound, which were the voice and animal sound, elicited better performance than the artificial sound, which was the beep, and the comparison between two different natural sound showed less differences in ERP components.

Introduction

- People with severe disabilities, such as the patients with late-stage ALS, have limitations on using the visual BCI due to unreliable visual functions.
- The developed technology of AR and VR has brought the idea that visual distractors should be considered for the visual BCIs.
- The auditory BCI was suggested as an alternative way of communication.
- Several studies have tried to develop the auditory BCI system by providing additional visual cues, spatial auditory stimuli, or both visual and auditory stimuli [1-3].
- To use the auditory BCIs that elicit better performance in daily lives, new design of auditory stimuli should be investigated.

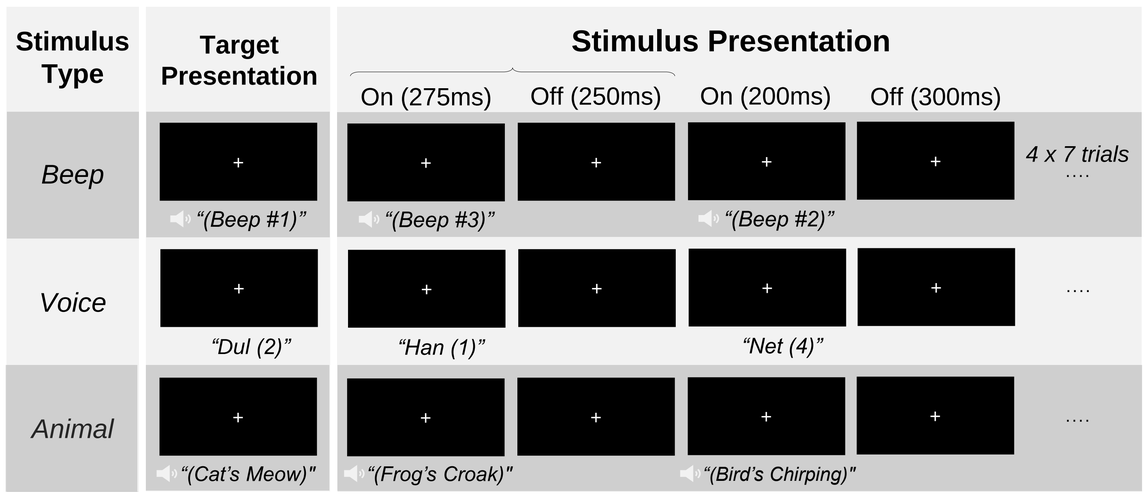
Research Objective

- In this study, we aimed to find the differences among three different types of the P300-based auditory BCIs, which provide vision-independent and non-spatial stimuli.

Methods

- Data collection
  - 30 healthy subjects (14 female, ages from 19 to 37 years old with mean 23.6 ± 3.83) participated in the experiment.
  - Three different types of the P300-based auditory BCI systems that present each different type of stimuli were used to control an electric light device.
  - In each system, four different stimuli with the same length set as 275ms were presented in an oddball paradigm with same length of inter-stimulus interval (IS) set as 250ms.

[Example of Stimulus]



  - 31 channels (FP1, FPZ, FP2, FZ, F3, F4, F7, F8, FT9, FC1, FC2, FC5, FC6, FT10, T7, C3, CZ, C4, T8, CP5, CP1, CP2, CP6, PZ, P3, P4, P7, P8, O1, OZ, and O2) were measured with sampling rate 500Hz.
- EEG Preprocessing
  - (1) 0.5Hz high-pass filter
  - (2) Bad channel rejection
  - (3) Common average reference (CAR)
  - (4) 50Hz low-pass filter (Butterworth, 4th order)
  - (5) Artifact subspace reconstruction (ASR)
  - (6) 12Hz low-pass filter
  - (7) Epoching
    - With training data, eight options of the post stimulus epoch length with same baseline were applied for cross-validation.
    - Eight options of the post stimulus epoch length were 0.8s, 0.9s, 1.0s, 1.1s, 1.2s, 1.3s, 1.4s and 1.5s.
    - Among eight options, the option with the biggest score of cross-validation was finally chosen to be applied on the classification for the online test.
  - (8) Obtain ERP for 1 target and 3 nontarget

Acknowledgment

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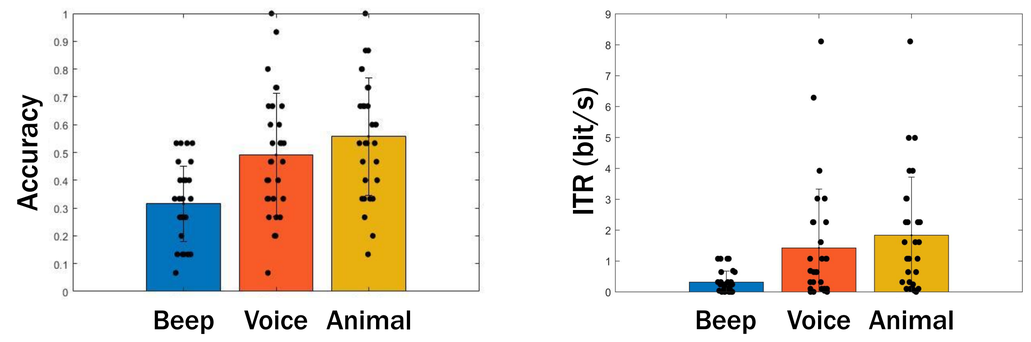
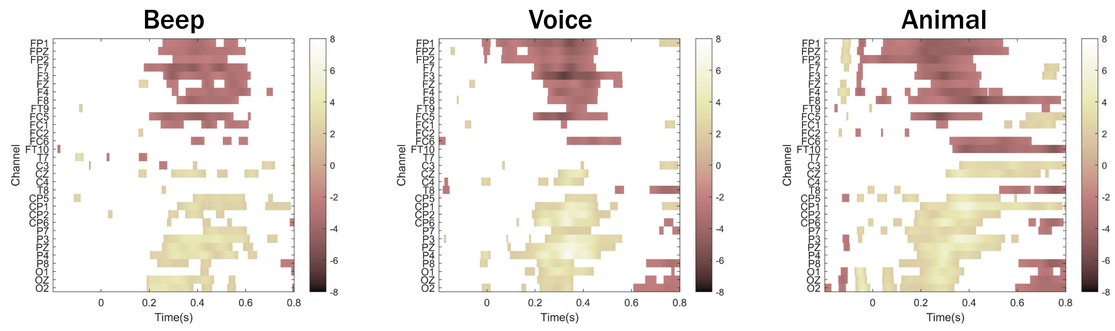
Results

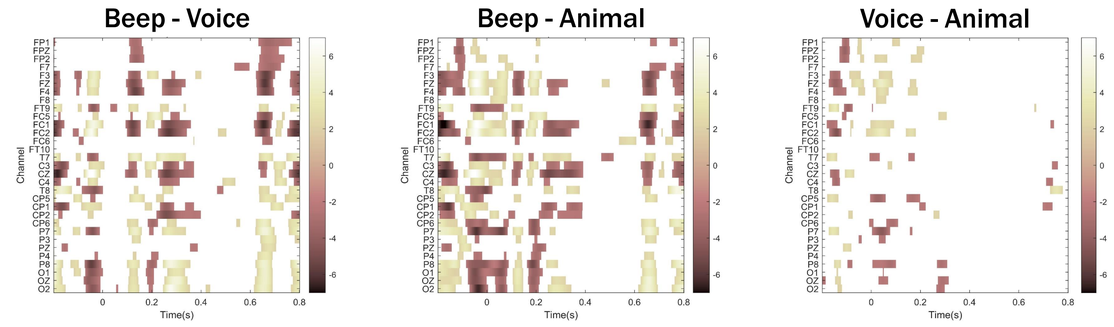
- BCI Performance
  - The average accuracy of control when using the beep, voice, and animal sound were 31.56%, 49.11%, and 55.78%, respectively.
  - The system with the beep yielded the lowest performance and the lowest information transfer rate (ITR) among three online BCI systems.



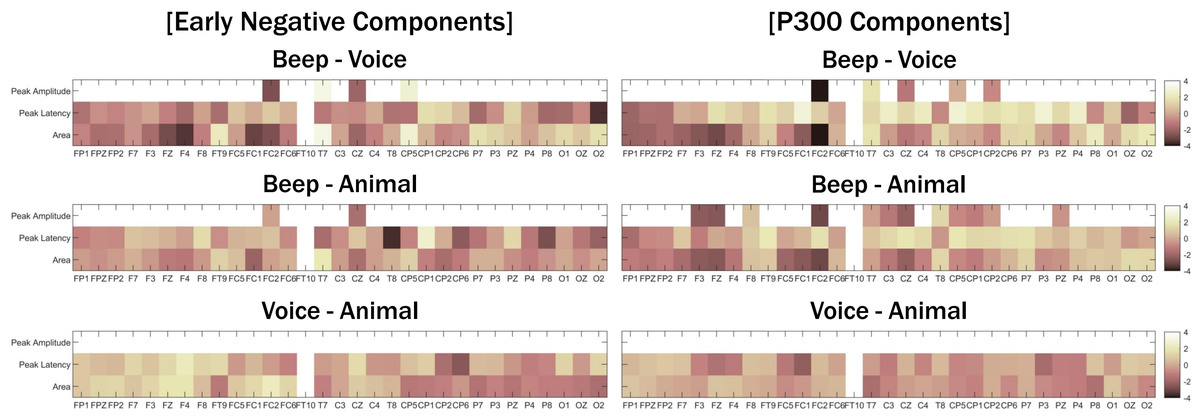
  - Among 30 subjects, 10 subjects showed the best performance with the voice stimuli and 20 subjects yielded the biggest accuracy with the animal sound. When considering only this best performance, the average accuracy of online auditory BCI control, regardless of the stimuli type, was 64.22%.
- ERP Patterns
  - When the beep was presented, there were the smallest number of the features that showed significant differences between the target and nontarget after conducting two-sample t-tests ($p<0.05$).



  - When comparing the features of the target in pair among three conditions using two-sample t-tests, there were the smallest number of the features that showed significant differences in the comparison of two different natural stimuli, which are the voice and animal sound ($p<0.05$).



  - Less differences were found in early negative components and the P300 components between two different natural stimuli, compared to the differences between the artificial and natural sound.



Discussion

- The natural stimuli should be used in the auditory BCI system for better performance, rather than the artificial stimuli.
- However, each subject showed each different optimum natural stimuli that showed the best accuracy of BCI control.
- There were less differences found in ERP patterns when comparing between the conditions of two different natural stimuli.

Reference

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