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Spectral Analysis of Category-specific Knowledge in the Intact Brain

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***Abstract*-----** **This paper implements spectral analysis of scalp--EEG recordings during a language naming and visualisation task. The method offers new frontier to explore spatio-temporal features of the organisation of conceptual knowledge in the intact brain. Our findings tallies with results reported in the literature using other techniques such as fMRI. The method introduced in this paper provides new perspective for understanding and possibly diagnosing category specific semantic deficits.**

***Keywords* ------** Knowledge representation, EEG analysis, spatio-temporal analysis, concept naming, language.

I. INTRODUCTION

Selective loss of category-specific knowledge may occur due to brain damage, see for example [1, 2]. This phenomenon has been studied extensively by neurologists and neurolinguists using functional imaging and/or behavioural tests. Few studies have used electroencephalography (EEG) to investigate cortical responses during different language tasks [3]. In [3], EEG was used to estimate current source densities (CSD) for all recording sites of the scalp during a lexical decision task. CSDs were then analysed to establish whether there are associations between visual or motor cortex responses and names and verbs presented as stimuli

We are unaware of any study that has investigated the spatio-temporal variations in the brain using scalp EEG during a category-specific naming task.

In this paper, we attempt to establish whether spectral analysis of recorded scalp EEG provides a new perspective in the understanding of the organization of conceptual knowledge in the intact brain that would complement findings using other techniques such as fMRI or PET and therefore would potentially assist in diagnosing category-specific semantic deficits.

II. METHOD

A. Subjects

Three subjects were paid for participating in the experiment. All three were male, right-handed, monolingual native speakers. They were of age range 20-30yrs with at least 13 years of formal education. Their vision was normal or corrected to normal. None had any history of neurological disease, language deficit or substance abuse.

B. Stimuli and Tasks

The stimuli consisted of ninety-four concepts of animals and tools. They were presented in the form of visual and audio stimuli in two different successive sessions. Visual stimuli were in the form of black and white line drawing from or similar to the Snodgrass and Vanderwart corpus [4], see figure 1. The visual stimuli were presented in the first session and the subject was asked to silently name the object in the presented image.

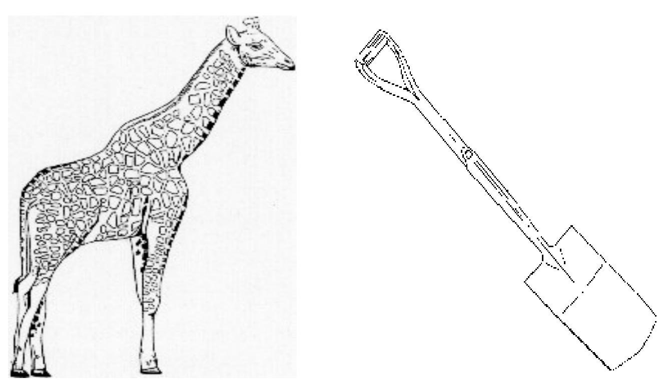

Figure 1 Examples of visual stimuli used in our experiments.

In a following session the audio stimuli were presented in the form of spoken words (representing the same concepts as in the naming task), the task was for the subjects to visualise the objects.

Stimuli were presented in random order. All visual stimuli were presented for 0.5s at the centre of a computer monitor with interstimulus periods of 4.5s. Audio stimuli presentation varied but did not exceed 1s with interstimulus presentation of 4s.

C. Experimental protocol and data collection

The experiments were conducted with the approval of the local ethics committee and the informed consent of the participants.

Multichannel digital EEG was recorded from the three subjects using 24-channel Mindset^{TM}. The scalp electrode placement was made in accordance with the 10-20 international system using Electrocap^{TM}.

EEG was recorded whilst the subjects sat in a relaxed but alert condition during the (silent) naming task. Following the EEG recordings, behavioural data were collected from the same set of images presented in the same way. Errors where the subject failed to find the correct name within the time limit were counted. An average score of approximately 98% was achieved.
EEG was recorded for the auditory-visualisation task which followed the naming task sessions.

D. Data Analysis

Eye blinks and movement artifacts were removed from the data. The EEG signals were then low-pass filtered at 60Hz. EEG data from the visual and auditory trials were epoched from -1s to +2s. Epochs related to each concept (animals and tools) were collated separately for analysis. Event related potentials (ERPs) were calculated by averaging the epochs. The baseline offset (-1 to 0s) was corrected after averaging.

Event related spectral perturbation (ERSP) was computed for the epoched data using EEGLAB [5]. ERSP measures the dynamic change in EEG frequency spectrum as a function of time relative to an event. It can be interpreted as event related synchronisation and desynchronisation.

III. Results and Discussion

Figures 2 and 3 show ERSP associated with the epoched signal recorded from electrode C3 while the subject is silently naming an animal compared to naming a tool and during visualising an animal and a tool when listening to the name of the animal or tool, respectively. Moreover, figures 4 and 5 show the ERSP associated with the epoched signal recorded from electrode O1.

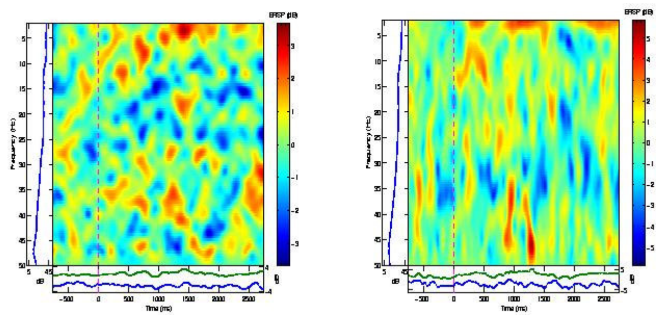

Figure 2 ERSP associated with the epoched signal recorded from electrode C3 while the subject is silently naming an animal (left) compared to naming a tool (right).

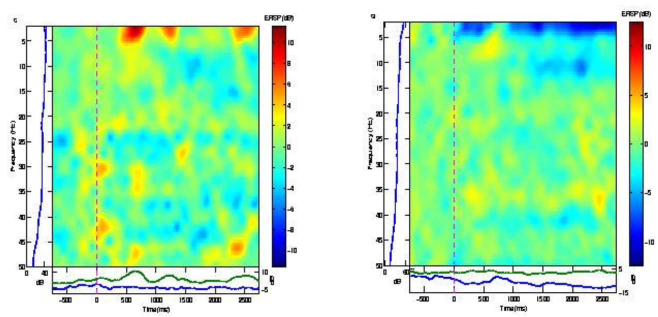

Figure 3 ERSP associated with the epoched signal recorded from electrode C3 while the subject is visualising an animal (left) compared to a tool (right) during the auditory-visualisation task

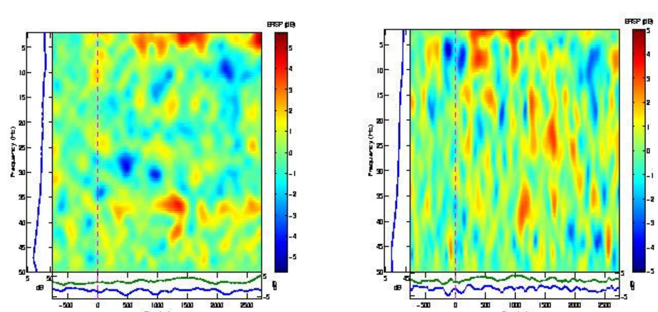

Figure 4 ERSP associated with the epoched signal recorded from electrode O1 while the subject is silently naming an animal (left) compared to naming a tool (right).

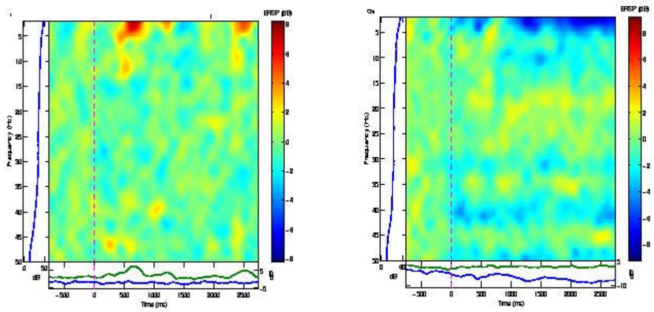

Figure 5 ERSP associated with the epoched signal recorded from electrode O1 while the subject is visualising an animal (left) compared to a tool (right) during the auditory-visualisation task.

In some studies (e.g. [3], it was suggested that brain activations are elicited based on the modalities of the categories of the stimuli (in our experiment motor/visual for tools/animals respectively). Therefore, we have chosen to start investigating the ERSPs associated with channels C3 and O1 which are positioned on the left anterior temporal and occipital lobes respectively.

From the figures, we can observe the desynchronisation occurring in C3 in the gamma band when naming tools and occurring in the alpha band when visualizing them. This desynchronisation is similar to that seen in the human brain during attempting an imaginary movement [6].

However with O2, we could not see any association with the modality of the stimuli.

It is obvious from the ERSP patterns, that different category stimuli exhibit different spatio-temporal mappings in the brain and one needs to further explore and investigate these patterns.

IV. CONCLUSIONS AND FUTURE WORKS

A. Conclusions

We have presented a study in which using ERSP to explore the frequency-time spectrum of scalp-EEG provided insight into the organisation of conceptual knowledge in the intact brain. We conclude that using spatio-temporal analysis would give neurologists and neurolinguists a new perspective in exploring and understanding the representation of category-specific semantics in the brain.

B. Future Works

Our future works include establishing our current findings in a larger population when using different categories. We also aim to carry out similar experiments and acquire EEG recordings for subjects with category-specific deficits and compare the spatio-temporal features extracted from ERSP to that of the intact brain.

References

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