THE HABITUALIZATION OF VOLUNTARY FORGETTING - THE NEURAL EVIDENCE FROM FAST PERIODIC VISUAL STIMULATION PARADIGM

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INTRODUCTION

- Contrary to memory, forgetting has often been overlooked despite its necessity. The motivated forgetting theory suggested that people can “intentionally” forget unwanted memories, either consciously or unconsciously[1].
- The think/no-think task (TNT) paradigm is frequently used as a major task to induce consciously voluntary forgetting in laboratory settings and it reflects people’s ability to voluntarily suppress unwanted memory[2].
- Recent research in cognitive neuroscience has pointed out that TNT can also affect the unconscious factor (habitualization) of memory control[3]. However, the nature of explicit measurement limited the interpretation and replication. A more sensitive paradigm that can directly reflect automatic memory repression is in demand.
- The fast Periodic Visual Stimulation (FPVS) paradigm[4] is a newly developed paradigm that is short (around several minutes) and no voluntary efforts are required. It is flexible and allows for capturing both the low-level perception and high-level executive functions.
- To investigate the automatic pattern of memory suppression and to provide direct evidence for the transition from voluntary forgetting to unconscious forgetting, we applied TNT and FPVS sequentially with the same materials. ERP (N2) of TNT was extracted as a conscious memory control index to evaluate the efforts the subjects paid, in order to explore the relationship between the conscious and unconscious components of memory control. The FPVS stimulation evoked potentials of each condition were conducted and used as indexes for unintentional memory control by the brain's top-down control system.

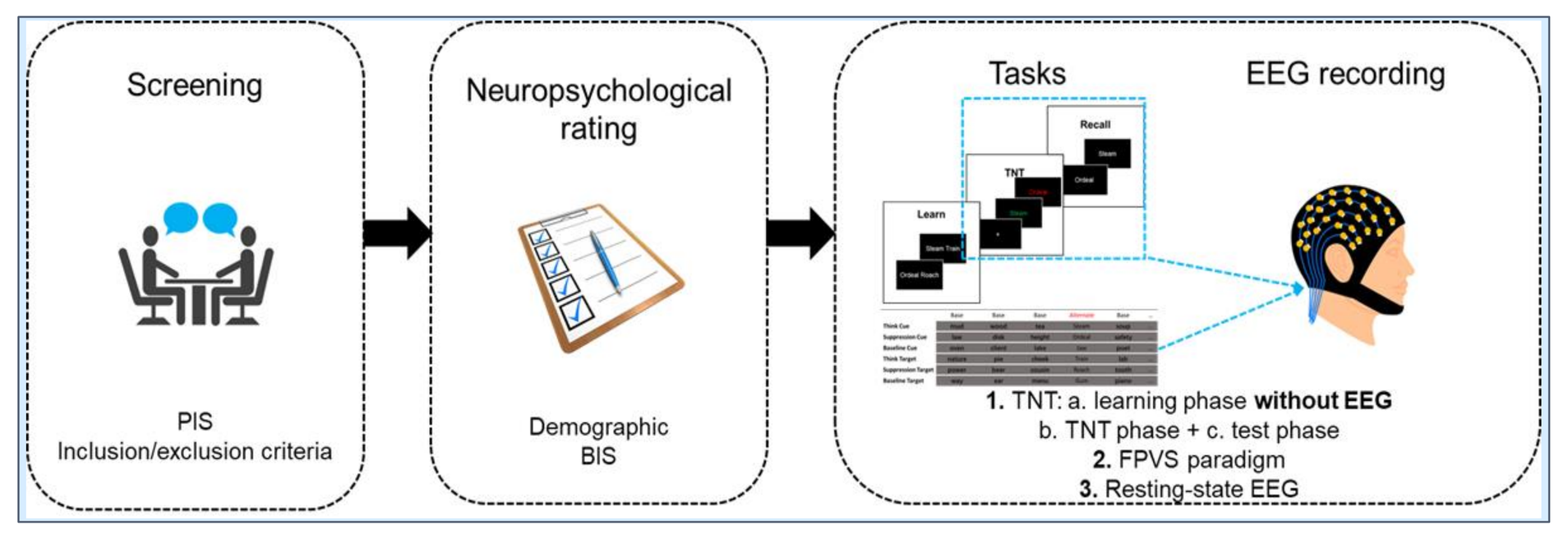
METHODS

Participants

- Eighteen normal healthy adults were recruited (age: 24.76 ± 5.59 years old; 8 males and 9 females).

Stimuli and Materials

- Word stimulations were randomly selected from the SUBTLEX-UK word base, matching the words’ frequency and length.
- All stimuli were presented using PsychoPy (version v2021.1.4).

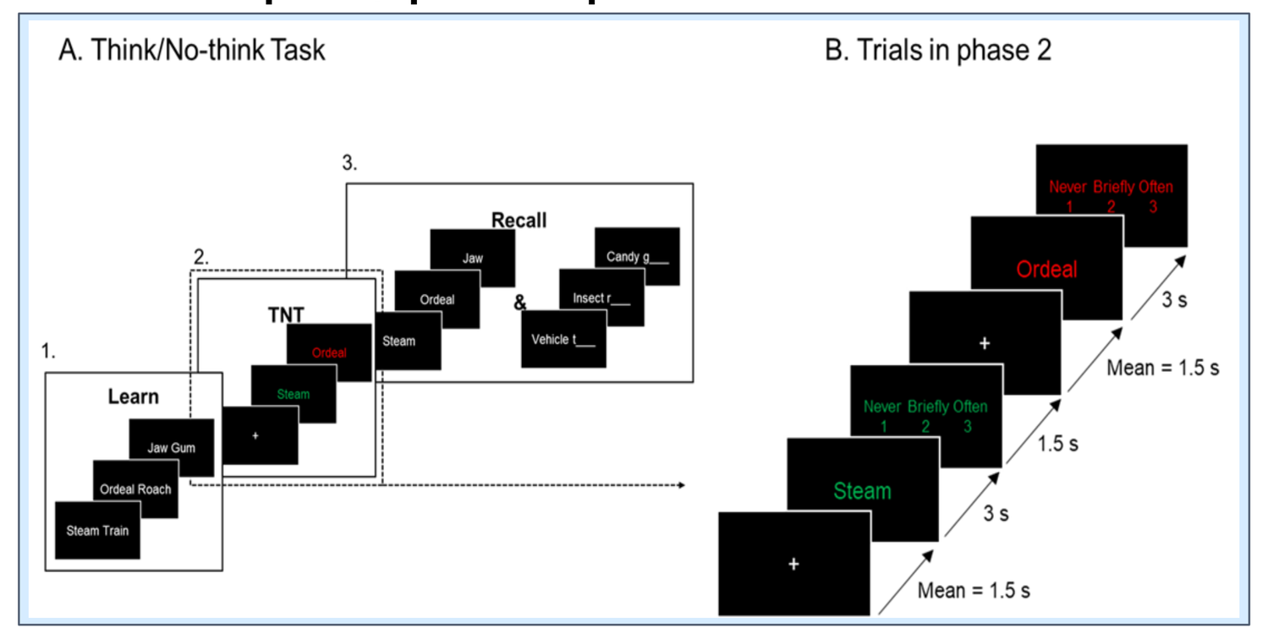


The flow chart of experiments.

METHODS

Procedure

- After completing questionnaires and the first learning of 58 word-pair, participants were trained for TNT phase.



Schematic diagram of TNT task.

- In TNT phase, one word in previously learned pairs turned to red/green, suggesting an instruction for the subject to block/recall the associate paired word.

This was followed by the FPVS task, which was passive viewing a sequence of word stimuli presenting at a fixed frequency, using the same word - stimuli as TNT. Alternate words are present 1 time in each second (1 Hz) and mixed with base unseen words (4 Hz, 4 times per second).

EEG was recorded during TNT phase and FPVS task.

Design and Data Analysis

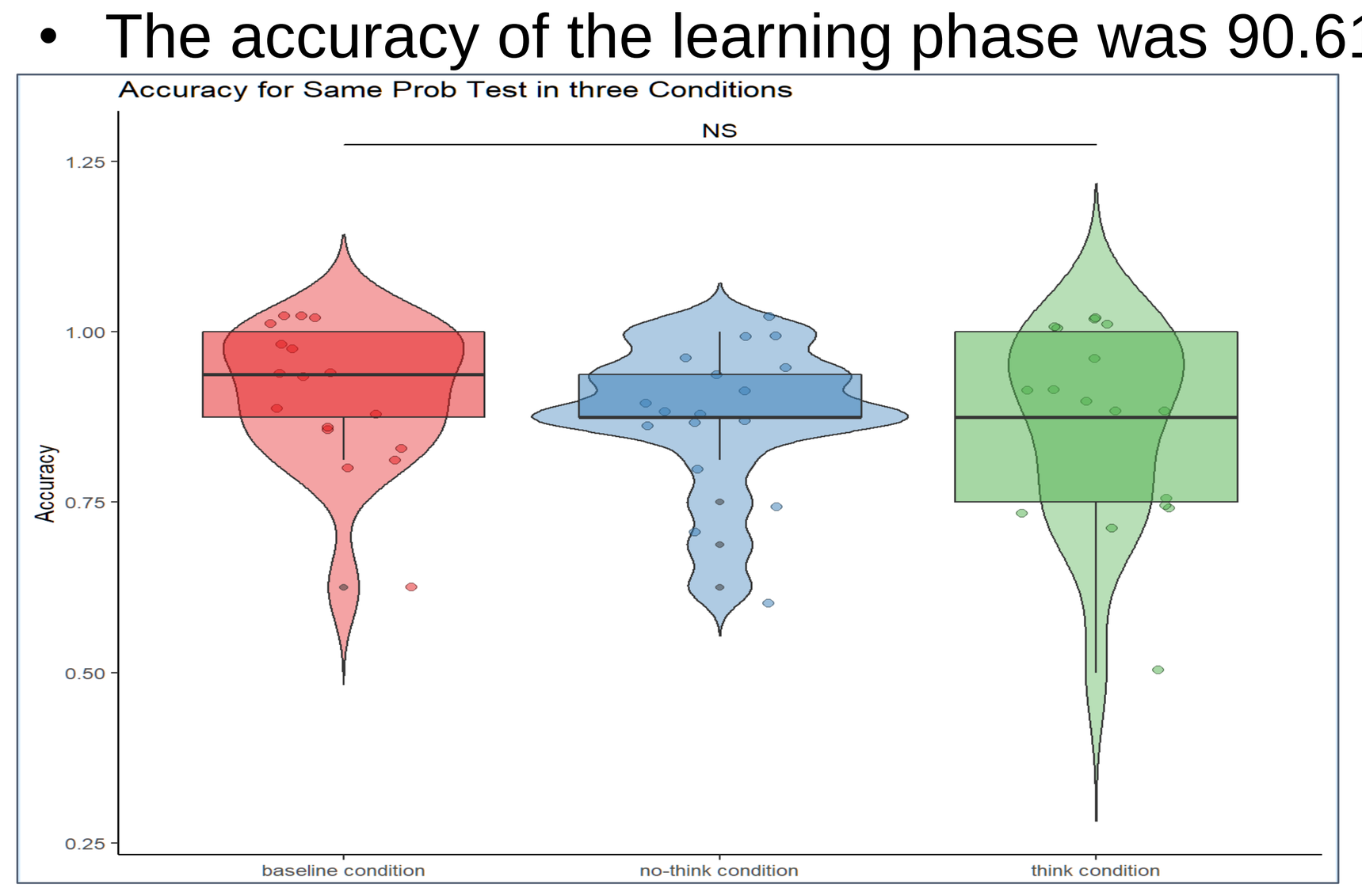
ERP from TNT, signal noise ratio (SNR) / corrected amplitude induced by words from TNT calculated from FPVS results, and behavioral data were analyzed. Repeated-measure ANOVAs or paired-sample *t*-tests were conducted for each index.

Correlation analyses were conducted to investigate the relationship between these indexes.

RESULTS

Behavioural Results

- The accuracy of the learning phase was 90.61% (±8.13%).



For the explicit measurement of final test, there were no significant difference ($F(2,32) = 1.774$, $p = .186$) among conditions (fig. 1).

Fig. 1. the accuracy of memory test after TNT training.

ERP Results

- The paired-sample *t* test demonstrated no significant of averaged N2 amplitude ($t(1,17) = 0.766$), $p = .454$) between no-think trials relative to think trials.

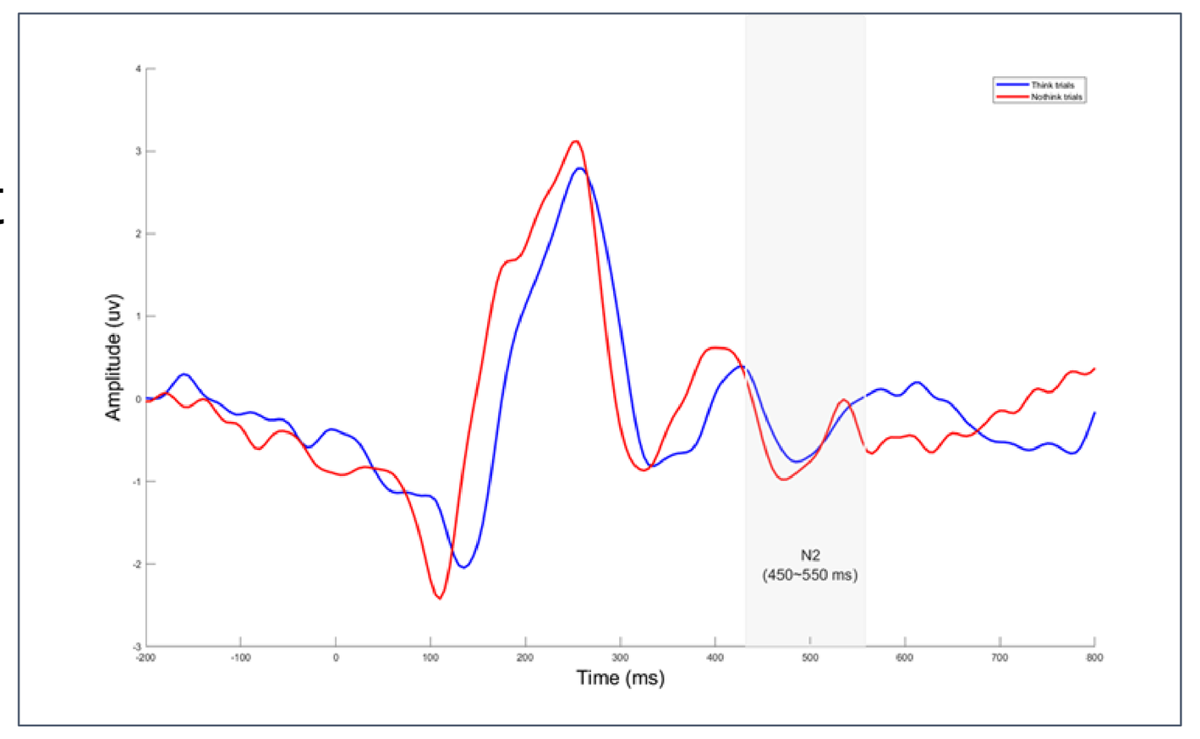


Fig. 2.. The time series plot of N2 component

RESULTS

FPVS induced response

- The spectrum plots (fig. 3) indicated the 3, 5, 6, and 7 Hz were most sensitive, which were used in following analysis.

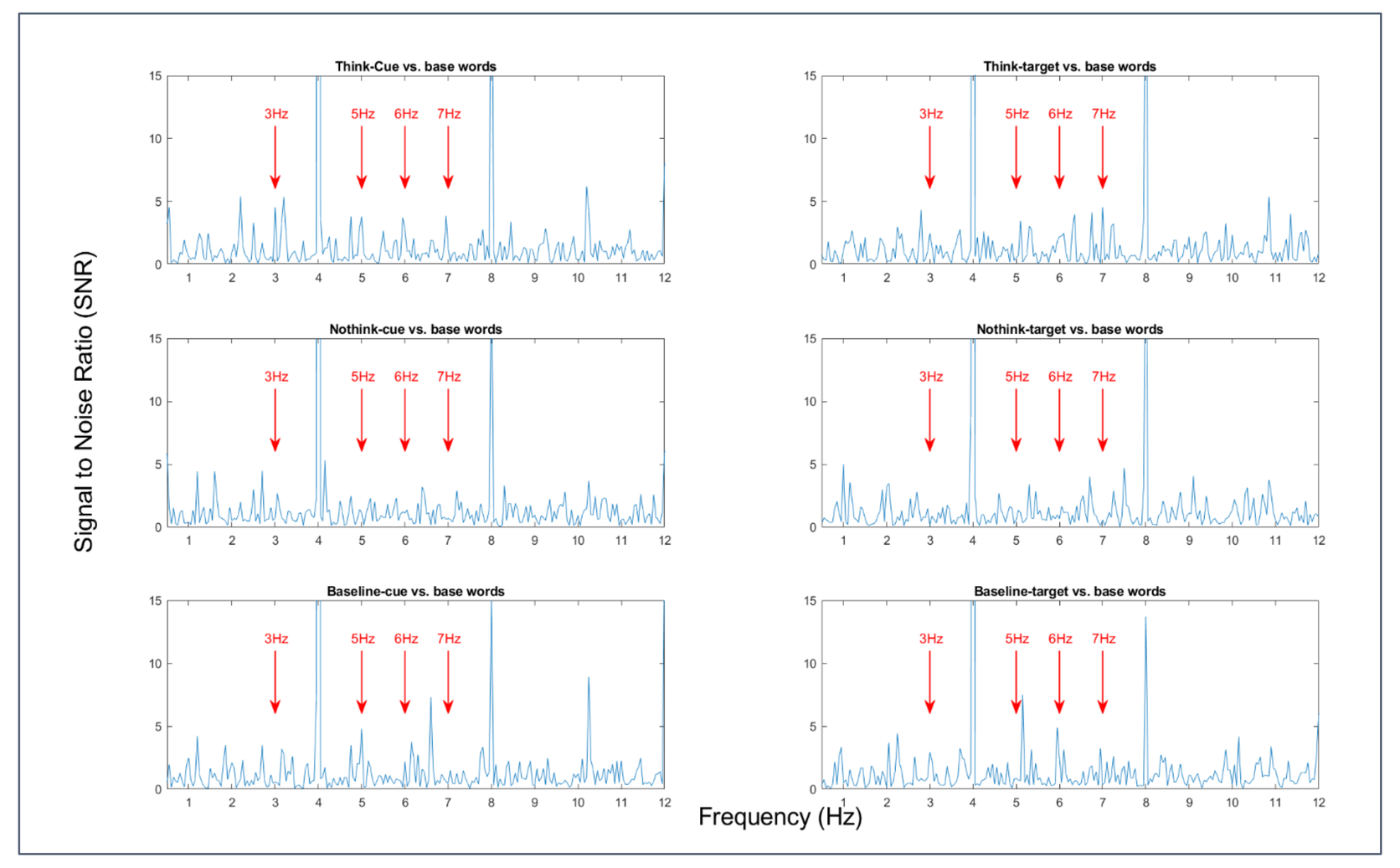


Fig. 3.. Singal to noise (SNR) of FFT spectrum of EEG responses .

- This distribution of Z-score(fig. 4) suggested the activity of all harmonics mainly located in left occipitoparietal areas.

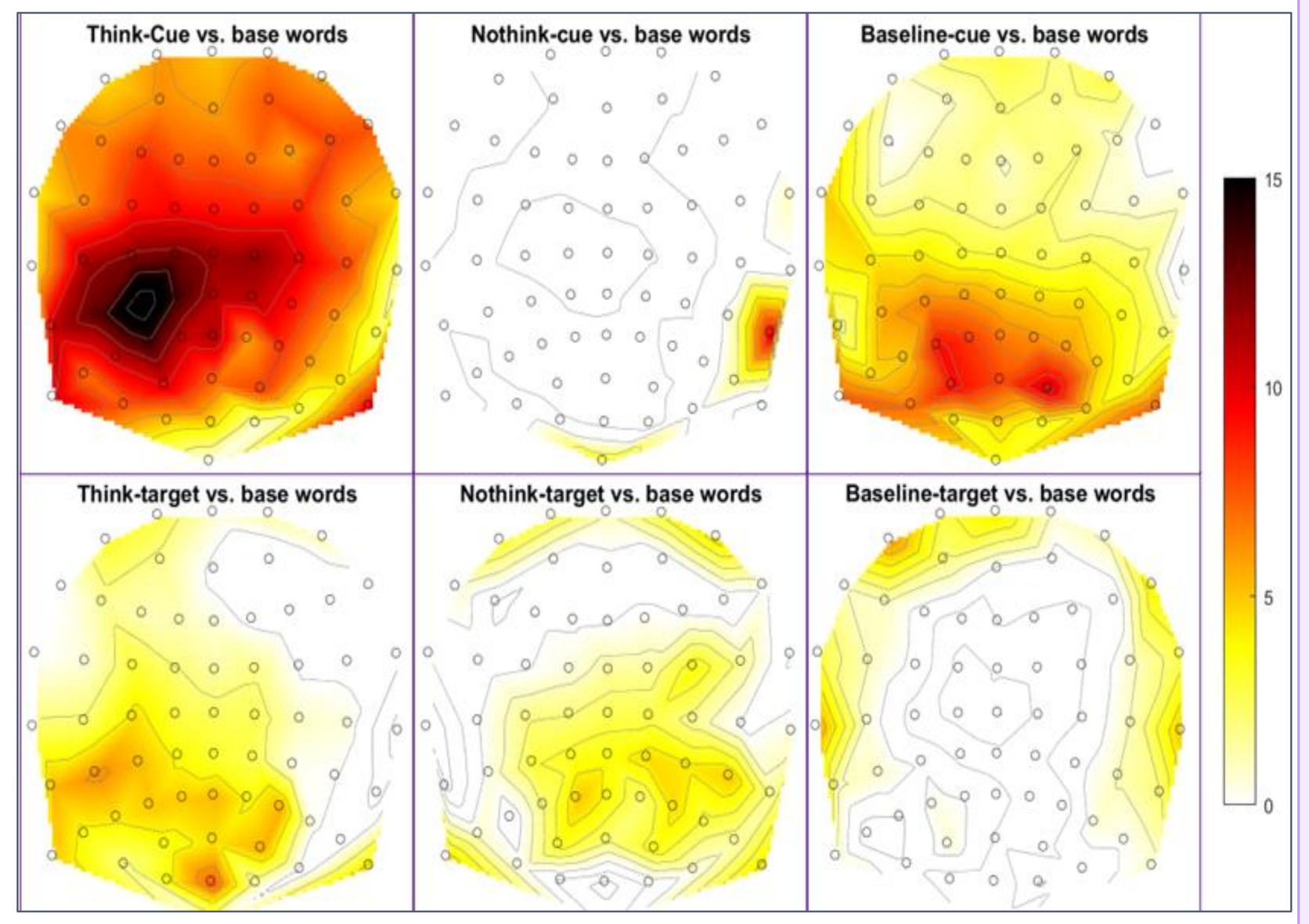


Fig. 4.. The topographic plots of the electrophysiological response to TNT-word-stimuli frequencies of six different contrast (grand-averaged data, n = 18 participants).

- Based on above results, the SNR and corrected amplitude in left occipitoparietal electrodes were calculated with harmonics of 3/5/6/7 Hz, and both them represented automatic memory-involved attention bias. We observed a significant peak in think-cue conditions and think-target conditions (fig. 5)..

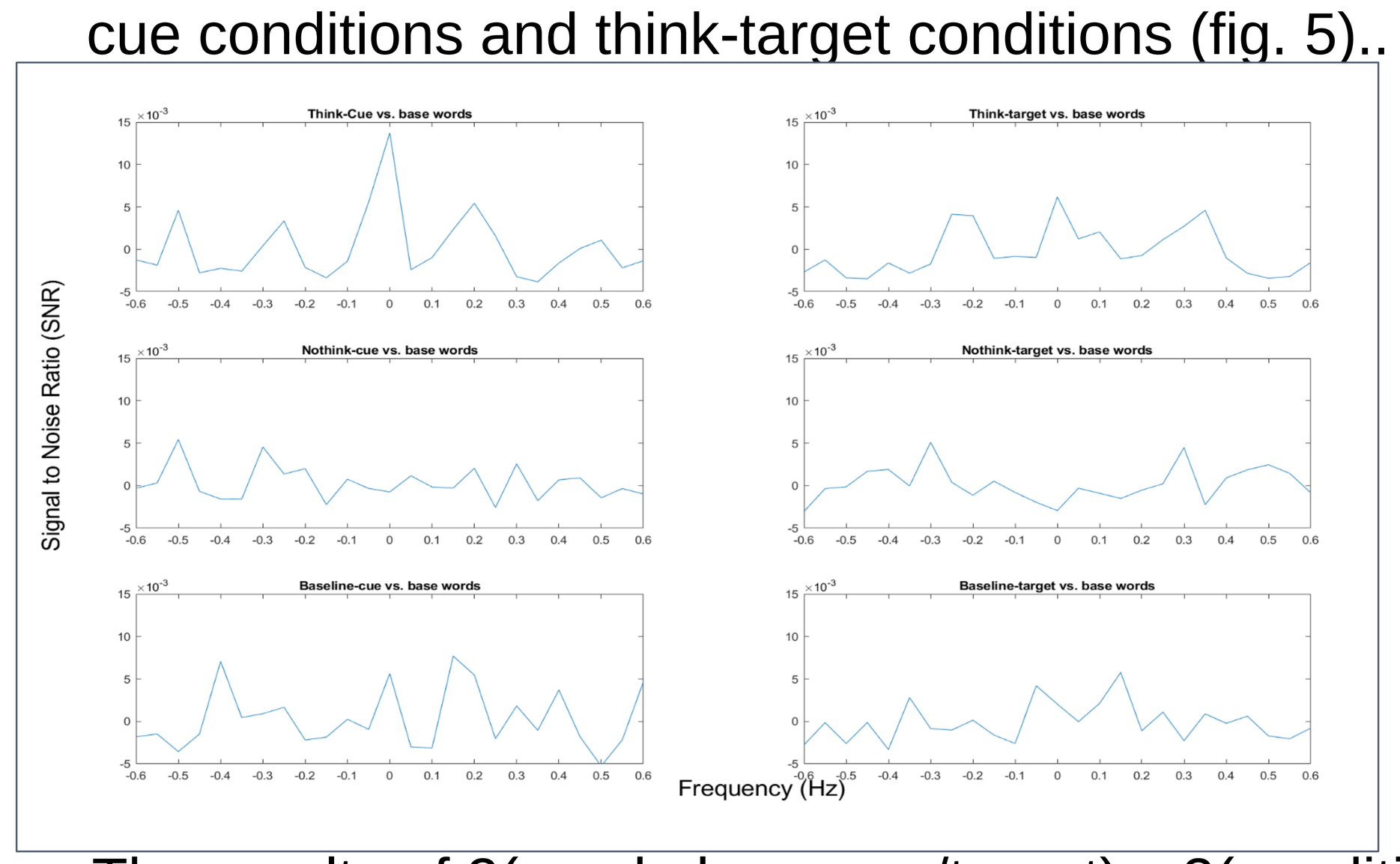


Fig . 5. The central peak represented the summarise SNR of 4 harmonics.

- The results of 2(word place: cue/target) x 3(conditions: think/no-think/baseline) RM-ANOVA showed a significant main effect of ($F(2,32) = 4.467$, $p = .019$) condition and an approached significance for interactive effect ($F(2,1) = 2.96$, $p = .66$). Post-hoc analysis revealed decreased SNR of no-think words when both as cue or target compared to think and baseline condition, which were (borderline) significant (fig. 5).
- The summarised SNR of no-think target word was also positively correlated with the accuracy of initial learning memory test for no-think word pairs ($r_{spearman} = 0.870$, $p < .001$).

DISCUSSION

Explained Results

- There were no significant differences among the three TNT conditions for behavioral data and classic ERP data. Our adaptive TNT paradigm with newly self-made stimulation failed to replicate reliable results. This variance among studies was reported much and remained debatable.
- For the FPVS results, the frequency spectrum of response and the z-score distribution of topography in the think condition suggested the sensibilizations of attention to wanted clues (cue and target words). The same response was not found in the no-think condition, which suggested that the attention to unwanted memory has been automatically inhibited.
- The same results were proved by subsequent RM-ANOVA and correlational relationship. The decreased response to no-think targets relative to baseline targets demonstrated that the target words were also affected by this memory-suppressing process This was hardly reported in previous research, which might support the theory that the target words were also inhibited (at least shown in the brain automatic pattern), complementing the current memory suppression model.

Implications and Limitations

- Using FPVS, the automatic pattern of the brain toward suppressed memory was detected. This supported the suppression hypothesis in memory suppression.
- Due to the limitation of the sample (small number and largely university students from UoM), the effect of the FPVS to conveniently measure suppressed memory was hard to generalize to other populations. While these results could largely inspire future research both in laboratory and clinical situations.

CONCLUSION

- Using a high sensitivity and time-saving FPVS paradigm, we provided evidence of the brain's automatic pattern to the current model of memory suppression, revealing a translation from voluntary control to automatic control of memory.
- It suggested the sensitivity of FPVS for studies in high-level executive functions.

REFERENCE

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All code used is accessible at https://github.com/bingo1218/University_of_Manchester/tree/main/project