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J Camosun Psyc Res. (2019). Vol. 1, pp. 37-42.
Submitted April 2019; accepted 12 July 2019.

The effect of memory encoding on neural activity.

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ABSTRACT

The present study was undertaken in order to investigate the underlying neural mechanisms of associative memory encoding. Both nonexperimental (i.e., baseline) and experimental methods were used to study variations in associative memory encoding levels, using the method of loci, on high frequency neural activity (HFA) (measured using EEG gamma activity) and low frequency neural activity (LFA) (measured using EEG theta activity). It was hypothesized that successful memory encoding would lead to a decrease in LFA and an increase in HFA. The baseline methods found a strong correlation between memory encoding and HFA, but not with LFA. Ultimately, the present experimental results did not support these hypotheses. These results are contrary to other studies, though the present study is limited in both the number of participants and number of trials. It is suggested that more research is necessary in order to determine reliability.

1. Introduction

Every day people use retrieval cues to recall previously encoded information. Retrieval cues are created by associating information with people, places, cognitive and emotional states, among others. This association enhances memory recall, because they now have something else to remind them of this new information (Greenberg et al., 2015). An example of a specific associative technique that makes memory recall easier for many people is the method of loci (MoL) (McCabe, 2015). The MoL is a mnemonic technique in which locations are used as the association with information that is to be remembered. The technique is used by imagining the new information in specific locations along a well-known route. To then retrieve this information from memory, one only has to mentally walk this path and imagine what was "placed" at each location (McCabe, 2015).

There is empirical evidence that techniques, such as the MoL, significantly improve memory recall (McCabe, 2015). In addition to this, it is fairly well understood which anatomical locations in the brain are most associated with this type of memory (including the hippocampus and peripheral cortex) (Greenberg et al., 2015, p. 257). However, the underlying neural mechanisms that account for this associative memory is less understood.

Using associative memory techniques, and measured with an electroencephalography (EEG) device, Greenberg et al. (2015) found that successful encoding of words is associated with a decrease in low frequency activity (LFA) and an increase in high frequency activity (HFA) in the brain. The present study aimed to replicate these findings.

The present study involved baseline measurements and an experimental study. During the baseline period, correlations were measured between the number of words successfully recalled using the MoL and HFA, which was measured using the average score of Muse EEG gamma activity during an encoding period. Similarly, a correlation was measured between word recall and LFA. The present experiment compared the average score of HFA, measured using gamma activity, using a procedure in which words were recalled using the MoL, as compared to words recalled when non-associative mental repetition was used. Based on previous research demonstrating changes in neural frequency, during the baseline methods, it was hypothesized that as memory increased using an associative technique, HFA would increase while LFA would decrease. In the present experiment, it was expected that successful memory encoding using the MoL would cause an increase in gamma activity.

2. Methods

2.1 Participants

A single participant was used for both the baseline methods and the experiment. This participant was a 24-year old female psychology student from Camosun College.

2.2 Materials and Apparatus

The materials used for both the baseline study and the experimental study included the “freerecall” battery from the PEBL Launcher 2.0 (Mueller and Piper, 2014) and a Muse (Muse, Interaxon Inc., Toronto, ON, Canada) EEG device.

2.3 Procedure

During the baseline study, the participant studied a list of 20 random words which were populated and presented using the PEBL Launcher 2.0 “freerecall” battery, during which time the Muse EEG device recorded neural activity. Immediately after presentation of the 20 words, an option emerged onto the screen in the PEBL software which directed the participant to type into an available space as many of the 20 words the participant could recall. For the purpose of this study, the participant tried to recall as many of the words in serial order- the order in which the words had been presented. The “freerecall” battery automatically assigns a “correct” score for a word recalled and spelled correctly regardless of order position; however, serial recall was assessed in the resulting data, which was the area of interest during the baseline and experimental measurements. The number of words recalled correctly in the correct order position was the independent variable score which the participant kept track of each day by writing in a diary.

The dependent variable was measured using the Muse EEG device; neural activity was monitored and recorded during the encoding period and a score for LFA and HFA was obtained using the Muse EEG device by using the average score for theta (4-8 Hz) and gamma (30-44 Hz) neural frequency, respectively. The scores were recorded each day in conjuction with the corresponding number of words correctly recalled in serial order.

For the experimental study, the order of conditions alternated each day for a total of 12 days. The condition that was used during the initial trial was determined by the flip of a coin (heads= Method of Loci condition, tails= Mental Repetition condition).

During the experimental study, serial word recall was manipulated on experimental days, through the use of the MoL to encode the words while the 20 words were presented in the “freerecall” battery. Successful memory encoding was indicated by the number of words recalled, in the same order as the words were presented, immediately after the encoding period. High frequency neural activity was quantitatively measured through the measurement of the participant’s neural activity during the encoding period using the Muse device; the average the score of gamma waves was used to indicate HFA.

On control days, the participant completed the same procedure as described above, except the method of loci was not used during the encoding period. Instead, during encoding, the participant used mental repetition of the words as they appeared.

3. Results

A strong, positive, linear relationship was found between the amount of words successfully encoded and HFA, measured by gamma waves, during the baseline measurements. The correlation for this relationship, $r = 0.77$, was statistically significant, $p = 0.007$, suggesting that these two variables are strongly related (see Figure 1 and Table 1).

A weak, positive, linear relationship was found between the amount of words successfully encoded and LFA, measured by theta waves, during the baseline measurements. The correlation for this relationship, $r = 0.40$, was not statistically significant, $p = 0.265$, suggesting that these two variables are related due to chance (see Figure 2 and Table 1).

The level of significance set in this experiment was .05. The mean HFA during the Method of Loci condition was 0.8042 (*SD* = 0.26) and the mean HFA during the Mental Repetition condition was 0.8481 (*SD* = 0.24) (see Table 2). These data were analyzed using a *t*-test and the results were not statistically significant, $t = 0.3$, $p = 0.77$, suggesting that a higher number of words recalled using the method of loci does not cause higher frequency neural activity (see Figure 3).

Table 1.

Baseline correlation coefficient (r) values.

Hypothesis examined	*r*
Memory Encoding and Low Frequency Neural Activity	0.40
Memory Encoding and High Frequency Neural Activity	0.77

Table 2.

Experiment descriptive statistics.

Condition name	Statistic	Value
Method of Loci	Mean	0.8042
	S.D.	0.2600
	N.	6
Mental Repetition	Mean	0.8481
	S.D.	0.2394
	N.	6

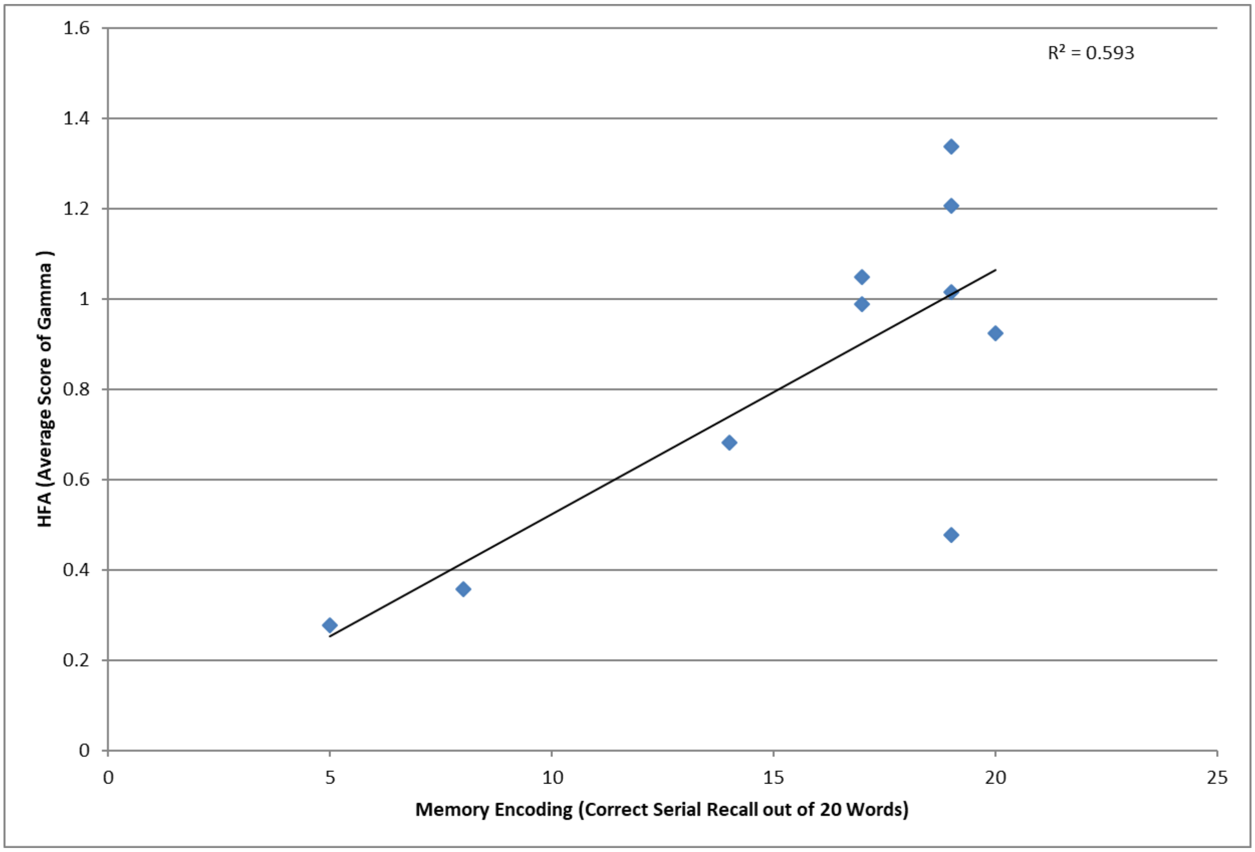

Figure 1. Correlation for HFA and Memory Encoding

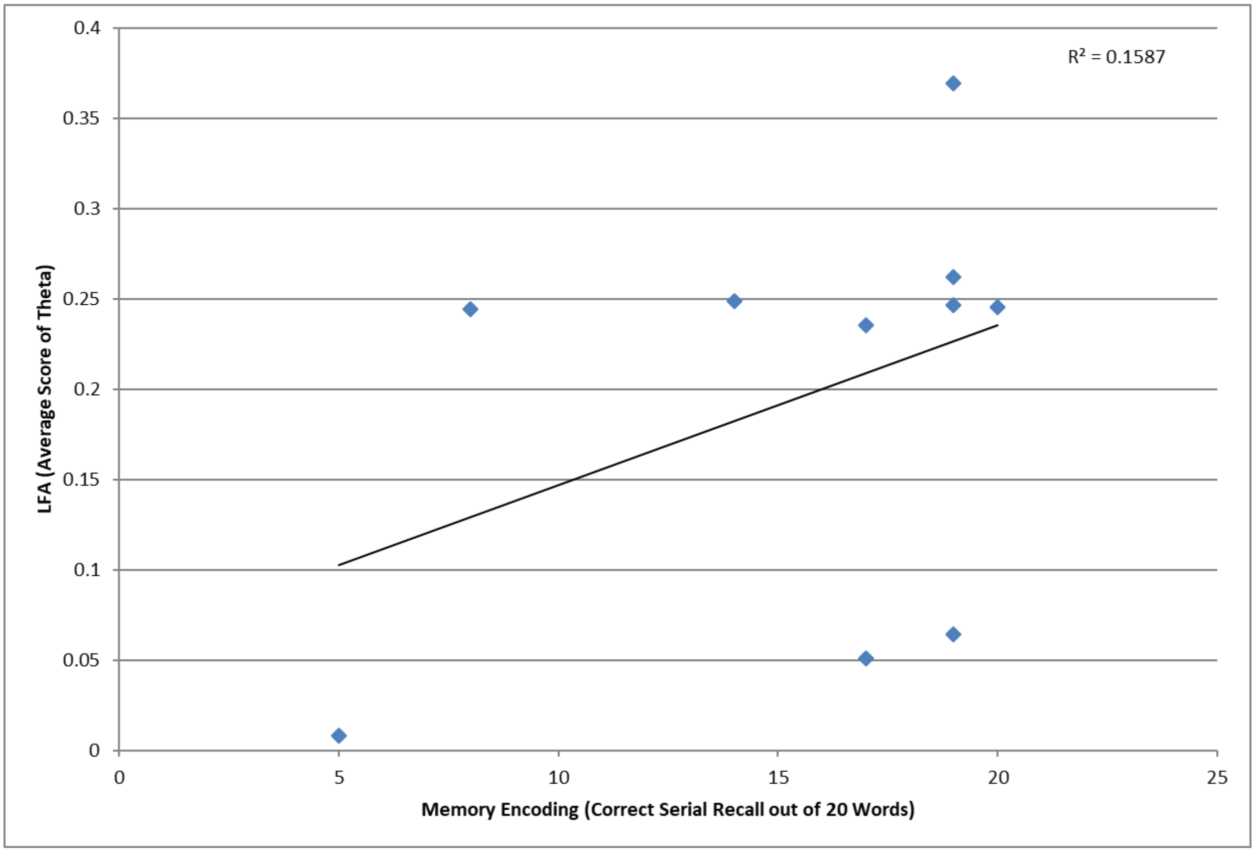

Figure 2. Correlation for LFA and Memory Encoding

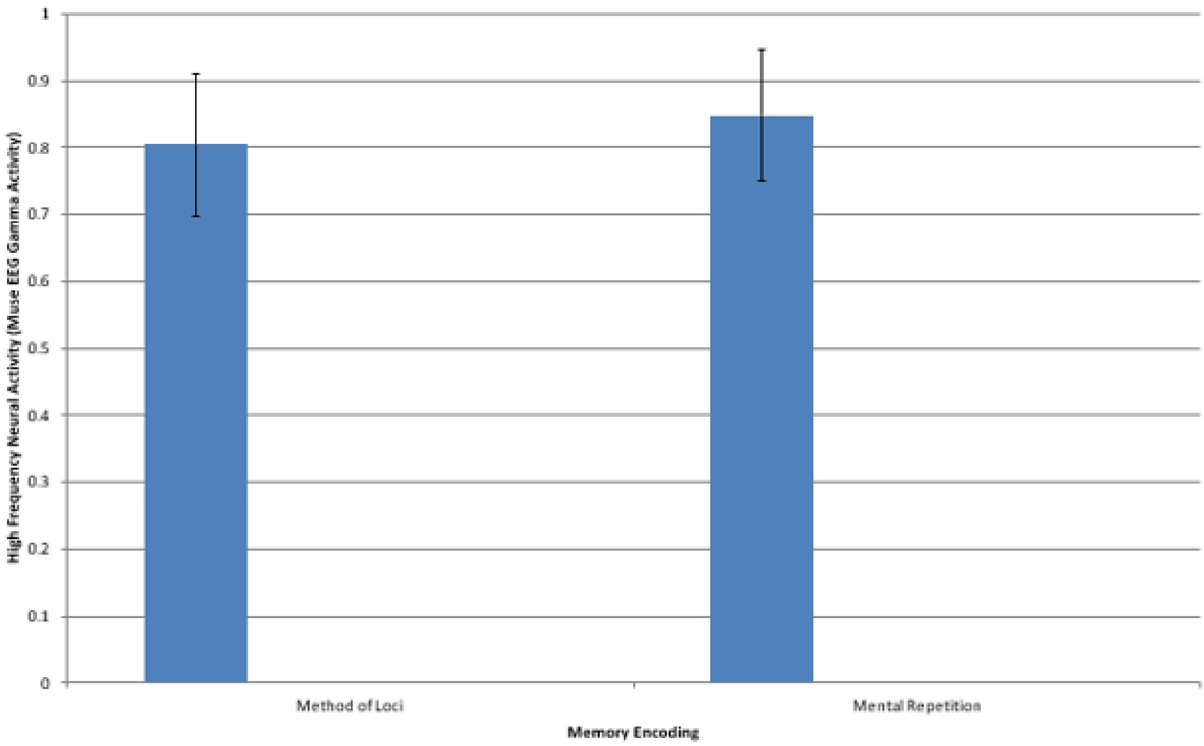

Figure 3. The mean HFA in the Method of Loci and Mental Repetition conditions.

4. Discussion

The hypothesis under investigation in the current study, that as memory encoding increases, HFA would increase was supported in a correlational analysis, but did not hold up in an experimental design. The hypothesis, that as memory encoding increases, LFA would decrease was not supported in a correlational analysis and so was not tested experimentally.

The current results are inconsistent with other studies that have demonstrated an increase in HFA and decrease in LFA that occurs with successful associative memory encoding (Greenberg et al., 2015). Limitations of the current study that should be considered include the limited number of participants and limited number of trials. Further research should consider such limitations. However, it is important to consider the inconsistency with previous studies and for further research to be undertaken in order to understand the reliability of these findings.

References

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