# Electroencephalography correlates of retrieval in episodic memory: Auditory sentence recognition

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**ABSTRACT:** This study used electroencephalography (EEG) to investigate the correlates of remembering previously experienced events. Three young healthy adults listened to "old" meaningful sentences which they had studied 24 hr previously. As a control task the subjects listened to comparable "new" sentences that they had never heard before. During the process of encoding as well as recollection of the sentences, the participants' brain activity was monitored. The main hypothesis of this experiment is to check whether correct encoding in memory leads to correct retrieval in certain events, which in this case is an auditory stimuli in the form of 'sentences'. Conversely, it also checks whether incorrect encoding leads to wrong retrieval of certain incidents or events.

***Keywords*:** memory, encoding, familiarity, retrieval, EEG, auditory sentence recognition, cognition

## 1. Introduction

*1.1. Intro:*

The present speculation of human memory takes the stand that there are five critical structures or systems of human memory. Out of these five, one is episodic memory, which enables people to remember effectively experienced events i.e. it makes it practical for a man to know about what is going on and later survey that event. Episodic memory is immovably related to semantic memory, which registers, stores and makes open for recuperation individual shared learning of the world in the broadest sense. (Tulving, 1995) Past electroencephalography- based weariness related research principally centered around the relationship between simultaneous intellectual execution and time-bolted physiology. The objective of this study was to research the capacity of EEG to evaluate the effect of weakness on both present and future intellectual execution amid a 20-min supported consideration undertaking, the 3-decision dynamic cautiousness assignment, that obliges subjects to separate one essential focus from two auxiliary non-target geometric shapes. The ebb and flow study exhibited the capacity of EEG to gauge present, as well as future psychological execution, using a solitary, joined response time (RT), and precision execution metric. The relationships in the middle of's watched and evaluated execution, for both present and future execution, were solid. The models could reliably evaluate "unsuitable" execution all through the whole 3CVT, i.e., exorbitantly missed reactions and/or moderate response times, while satisfactory execution was perceived less precisely later in the task.The created models were prepared on a generally extensive dataset (n = 50 subjects) to expand solidness. This study demonstrates that EEG can be utilised to foresee gross-execution corruptions 5–15 min ahead of time. (Stikic, 2011)

*1.2. Description:*

The point of human computer interaction is to

enhance the cooperations in the middle of human and PCs. Since most computers absence of comprehension of client's feelings, infrequently they can't react to the client's requirements naturally and accurately. A standout amongst the most fascinating feelings is joy. world bliss report mirrors another overall interest for more consideration regarding joy and nonattendance of wretchedness as criteria for government strategy. Being cheerful is identified with numerous constructive outcomes including certainty, positive thinking, self-viability, amiability, movement, vitality, physical prosperity, adaptability, inventiveness, and the capacity to adapt to push. These advantages are the reasons why we ought to be glad. In the previous decades, a large portion of feeling acknowledgment explores have just centered around utilizing outward appearances and discourse. In any case, it is anything but difficult to fake outward appearances or change tone of discourse and these signs are not ceaselessly accessible, and they vary from utilizing physiological signs, which happen constantly and are difficult to cover, for example, Galvanic Skin Response (GSR), Electrocardiogram (ECG), Skin Temperature (ST), and, particularly, Electroencephalogram (EEG). EEG is the sign from voltage vacillations in the cerebrum, that is, the focal point of feelings. Feelings are thought to be connected with action in cerebrum zones that direct our consideration, inspire our conduct, and decide the hugeness of what is happening around us. Feeling is connected with a gathering of structures in the focal point of the cerebrum called limbic framework, which incorporates amygdala, thalamus, hypothalamus, and hippocampus. Electroencephalogram (EEG) is the recording of electrical action on the scalp. EEG measures voltage changes coming about because of ionic current streams inside of the neurons of the mind. There are five noteworthy mind waves recognized by their diverse recurrence groups (number of waves every second). These recurrence groups from low to high frequencies, separately, are called Delta (1–3 Hz), Theta (4–7 Hz), Alpha (8–13 Hz), Beta (14– 30 Hz), and Gamma (31-50 Hz). (Jatupaiboon, 2013)

*1.3. Definition:*

What this experiment plans to do it somewhat similar to an experiment already done before. The title of the paper is “ERP old/new effects at different retention intervals in recency discrimination tasks” (Curran, 2014). It is also quite similar in procedure to a paper named, “Neuroanatomical correlates of retrieval in episodic memory: Auditory sentence recognition.” (Tulving, 1995). The brain activity of the participants will be monitored when they are memorising sentences. 24 hours later, they’ll be given double the number of sentences and they will have to mentally classify them as old or new. the EEG signals of their brains will be recorded at the time of them recalling/ recognising/ identifying the sentences as old and new and will be followed by a performance review where they’ll be given all sentences for classification as old and new. The recorded data may then be used to compare with the base level of memorising vs recall of certain things. This can be used to check the consistency of a patient suffering from amnesia and similar disorders. The brain activity of a person faking amnesia will definitely be different from a person who genuinely has amnesia and this test can clarify that.

## 2. Method

*2.1. Subjects:*

Three male right-handed university students

aged 19-20 years participated in this study at Ashoka University. Participants were chosen in such a way that they had no previous record of mental illness.There were no exclusions. All data is presented here.

*2.2. Task Design:*

A unit of cognitive material consisted of a sentence frame and a semantically related word; the total constituting of the meaning of the word (e.g., definition of something: meaning, the celestial heaven: sky etc.). These units of cognitive material will henceforth be called 'sentences'. They require deep semantic processing and are meaningfulA total of sixty sentences were used. Half were presented to the participants in an initial study session and all 60 were presented in a recognition test 24 hours later. During both sessions, the participants' EEG data (i.e., brain activity) was recorded.

In the initial session, while the participants sat on a chair, they heard 30 sentences on a PC using EarPods at the rate 3-4 seconds per sentence. The sentences were presented in a random order with an interval of two seconds between two successive sentences. The sentences were repeated twice successively. The participants' EEG data (i.e., brain activity) was recorded during the time they heard the sentences.

In the second session, 24 hours later, each subject was made to hear 60 sentences. Amongst those 60 sentences, the first 20 were all old in a random order, the second set of 20 were a mix of 10 old and 10 new sentences, while the last set of 20 sentences were all new sentences i.e., sentences they had never encountered before. The sentences in each set of 20 was randomised among themselves. Their data was recorded at all times during the final scan and they were told to take a mental note of which sentences are 'old' and which sentences are 'new'. Additionally, after the final session was over, the participants had to fill up a 'performance verification.' This involved a sheet of paper containing the list of 60 words. Participants had to answer whether the sentences in the list were old or new.

*2.3. EEG recording:*

The participants' EEG data was recorded using an Emotive EPOC+ consisting of 14 channels and the sampling rate being 128 Hz. The data was recorded if and only if at least 11 of the 14 channels picked up a fair signal. The only thing about the EPOC+ was the difficulty in setting it up as it was a tedious job to get it working and record data. Emotiv Xavier Test Bench was used to record the data during the initial and the final session.

## 3. Results

*3.1. Methodology*

The basic method used in this study was to do a linear regression on an arbitrary column chosen arbitrarily from any of the EEG channels. This was done thrice for the three participants and the data found was as follows:

The regression test was done to find out whether correct/ incorrect retrieval of episodic memory was dependent on correct/ incorrect encoding of memory.This study looks into a multiple linear regression tests, where the extent of retrieval is predicted by encoding of an episodic memory.. An average variance ($R^2$ = 0.0003) means that there is almost no effect of encoding on retrieval of memory in EEG correlates. (Appendix A, B and C) Despite the low $R^2$ value, there is one instance where the p-value is less

than 0.001 and this can be seen as statistically significant. The F-value (with df 1, 38782) in each case was very low (in the power of 2 x $10^{-1}$), except for the first participant, wherein the F value with similar degrees of freedom was 26.21, Incase of the first participant, the p-value showed significance with $p < 0.001$, whereas the others showed that the statistical data was insignificant. (Appendix A) To look further into the study, the standardised coefficients were looked at. Both health and happiness affected the amount of self-satisfaction. The t-value was quite significant in one of the cases, whereas in the others, despite being in the positive direction, they were more or less negligible. The Standardised values i.e., b was 0.026 incase of the first test; while the others showed almost negligible results (2 x $10^{-2}$) (Appendix A, B and C) with the t-value showing the same results i.e., 5.12 incase of the first participant and 4 x $10^{-1}$ incase of the others, with degree of freedom (df) = 38783.

*3.2. Other tests:*

Another test was run on the variables to find out whether there exists any correlation between each ordered set of data. The test was a correlation matrix test and the results are attached in Appendix D.

The correlation matrix shows us that in most cases of ordered pair variable correlation, the correlation is negligible. Incase of Initial vs Final ordered pair, the Pearson's R value, as well as the p-value point towards statistical insignificance. The only instance where the data is statistically significant is Initial 1 vs Final 1, wherein there exists a positive correlation and a p value less than 0.001. (Appendix D)

The analysis of the data was done using JASP (Just Another Statistical Program).

## 4. Discussion

The main aim of this study was to predict whether correct/ incorrect encoding of episodic memory, through auditory stimuli leads to correct/ incorrect retrieval of the aforesaid memory. The experiment was quite similar to one conducted by Tulving in 1995 and to that conducted by Bransford and Franks in 1972 (Bransford, 1972). Only in this case, the analysis, method of presentation of stimuli, time and other factors were aired to a certain extent. This paper gave me valuable insight on how to work with EEG data, how to work with an Emotiv EPOC+ headset, as well as creating a design to conduct a standalone experiment. The experiment in itself was quite challenging and it was quite fun to do it.

## 5. Conclusion

The conclusion of this study is that encoding and retrieval of memory varies from person to person and under different circumstances can vary within a person as well. The analysed data shows us that there is almost no correlation between encoding of episodic memory and retrieval of the same. This tells us about how cognition works, and how the human mind is different from that of a computer's processor which runs on pre-built processes.

Since the analysed data does not show any significant results, it can be concluded that correct/ incorrect encoding of memory is independent of correct/ incorrect retrieval of episodic memory. Encoding and retrieval of data varies from person to person and depends on various other factors, which are beyond the scope of this paper and hence cannot be discussed further.

## 6. Acknowledgment

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## APPENDIX A

### Linear Regression

Model Summary

| Model | R | $R^2$ | Adjusted $R^2$ | RMSE |
|---|---|---|---|---|
| 1 | 0.026 | 0.001 | 0.001 | 45.300 |

ANOVA

| Model | | Sum of Squares | df | Mean Square | F | p |
|---|---|---|---|---|---|---|
| 1 | Regression | 53784 | 1 | 53784 | 26.21 | < .001 |
| | Residual | 7.958e +7 | 38782 | 2052 | | |
| | Total | 7.964e +7 | 38783 | | | |

Coefficients

| Model | | Unstandardized | Standard Error | Standardized | t-value | p |
|---|---|---|---|---|---|---|
| 1 | intercept | 4129.424 | 10.272 | | 402.005 | < .001 |
| | Final 1 | 0.013 | 0.002 | 0.026 | 5.120 | < .001 |

APPENDIX B

## Linear Regression

Model Summary

| Model | R | $R^2$ | Adjusted $R^2$ | RMSE |
|---|---|---|---|---|
| 1 | 0.002 | 0.000 | −0.000 | 31.827 |

ANOVA

| Model | | Sum of Squares | df | Mean Square | F | p |
|---|---|---|---|---|---|---|
| 1 | Regression | 245.5 | 1 | 245.5 | 0.242 | 0.622 |
| | Residual | 3.928e +7 | 38782 | 1012.9 | | |
| | Total | 3.928e +7 | 38783 | | | |

Coefficients

| Model | | Unstandardized | Standard Error | Standardized | t-value | p |
|---|---|---|---|---|---|---|
| 1 | intercept | 4158.194 | 60.351 | | 68.900 | < .001 |
| | Final 2 | 0.007 | 0.014 | 0.002 | 0.492 | 0.622 |

APPENDIX C

## Linear Regression

Model Summary

| Model | R | $R^2$ | Adjusted $R^2$ | RMSE |
|---|---|---|---|---|
| 1 | 0.002 | 0.000 | −0.000 | 47.810 |

ANOVA

| Model | | Sum of Squares | df | Mean Square | F | p |
|---|---|---|---|---|---|---|
| 1 | Regression | 472.6 | 1 | 472.6 | 0.207 | 0.649 |
| | Residual | 8.865e +7 | 38782 | 2285.8 | | |
| | Total | 8.865e +7 | 38783 | | | |

Coefficients

| Model | | Unstandardized | Standard Error | Standardized | t-value | p |
|---|---|---|---|---|---|---|
| 1 | intercept | 4143.647 | 90.659 | | 45.706 | < .001 |
| | Final 3 | 0.010 | 0.022 | 0.002 | 0.455 | 0.649 |

APPENDIX D

## Correlation Matrix

Pearson Correlations

| | | Initial 1 | Final 1 | Initial 2 | Final 2 | Initial 3 | Final 3 |
|---|---|---|---|---|---|---|---|
| Initial 1 | Pearson's R | — | 0.026 | −0.043 | −0.000 | −0.012 | −0.000 |
| | p-value | | < .001 | < .001 | 0.923 | 0.015 | 0.923 |
| Final 1 | Pearson's R | | — | −0.026 | 0.006 | −0.044 | 0.006 |
| | p-value | | | < .001 | 0.215 | < .001 | 0.215 |
| Initial 2 | Pearson's R | | | — | 0.002 | 0.005 | 0.002 |
| | p-value | | | | 0.622 | 0.315 | 0.622 |
| Final 2 | Pearson's R | | | | — | 0.002 | 1.000 |
| | p-value | | | | | 0.649 | < .001 |
| Initial 3 | Pearson's R | | | | | — | 0.002 |
| | p-value | | | | | | 0.649 |
| Final 3 | Pearson's R | | | | | | — |
| | p-value | | | | | | |