

## Effects of Electronic Dance Music on Word Recall and Prefrontal Eeg Oscillations During Memorisation

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**ABSTRACT:** Background: The effect of background music on cognitive performance remains debated, with conflicting evidence across music genres, task types, and individual differences. Electronic dance music (EDM), characterised by repetitive rhythmic patterns and high tempo, is widely used by students during study, yet its influence on verbal memory and associated prefrontal neural activity is poorly characterised.

Methods: Ten healthy student participants (6 female, 4 male) each completed two word memorisation sessions — one with EDM playing and one without — in a within-subjects design. During each 28-second memorisation phase, EEG was recorded using a Brain Link EEG Headband connected to the Basic Detection application, yielding relative percentage power in five frequency bands (gamma, beta, alpha, theta, delta) from prefrontal cortex sensors. Following a 15-second delay, participants had 60 seconds to recall as many words as possible from a 12-item list.

Results: Mean recall was marginally higher in the music condition ( $7.70 \pm 0.75$  vs.  $7.10 \pm 0.62$  words), although this difference was not statistically significant (paired  $t(9) = 1.15$ ,  $p = 0.28$ ). No significant differences in any EEG band were observed between conditions (all  $p > 0.30$ ). The music condition showed numerically higher delta power (44.81% vs. 40.14%) and lower beta power (13.28% vs. 16.01%), consistent with altered prefrontal processing under auditory stimulation, though individual variability was substantial.

Conclusion: EDM during memorisation did not significantly alter word recall or prefrontal brainwave patterns in this pilot sample. The directional trends — higher delta and lower beta with music — are consistent with increased cognitive load and possible disruption of working memory consolidation circuits. This study provides a methodological foundation and preliminary data for larger investigations into music, memory, and prefrontal function.

**KEYWORDS:** electronic dance music; EEG; working memory; word recall; prefrontal cortex; delta oscillations; cognitive load; memorisation; brainwave; auditory distraction

### 1. INTRODUCTION

Music is one of the most pervasive forms of auditory stimulation in everyday cognitive environments, and its effects on learning and memory have attracted sustained scientific interest. The relationship between background music and cognitive performance — sometimes framed under the 'Mozart effect' or the broader 'music and cognition' literature — is complex and context-dependent, with outcomes varying as a function of music type, tempo, familiarity, individual differences, and the cognitive task under study (1,2).

Electronic dance music (EDM) is a broad genre characterised by repetitive rhythmic structures, synthetic instrumentation, and tempos typically ranging from 120 to 160 beats per minute. Unlike classical music, which has been the focus of most experimental studies, EDM is the genre most commonly used by students during independent study sessions.(3) Despite its prevalence, the neurocognitive effects of EDM on verbal memory remain poorly characterised.

Verbal memory — specifically the ability to encode and subsequently recall a list of words — is a well-established index of episodic and working memory function.(4) The prefrontal cortex (PFC) plays a central role in encoding and retrieval processes, orchestrating attentional resources, suppressing irrelevant information, and maintaining representations in working memory (5). EEG oscillations in the prefrontal region provide a non-invasive, real-time window into these processes: beta oscillations (13–30 Hz) index active working memory maintenance and executive control (6); gamma oscillations (>30 Hz) support attentional binding and rapid information processing (7); theta oscillations (4–8 Hz) reflect hippocampal-prefrontal communication during encoding (8); alpha

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oscillations (8–13 Hz) indicate attentional gating (9); and delta oscillations (0.5–4 Hz) have been linked to motivational processing and deep inhibitory coordination under demanding cognitive conditions (10).

Background music may influence memory through several mechanisms. It may provide arousal-modulating stimulation that optimises attentional resource allocation (the Arousal and Mood Hypothesis) (2) or it may compete with verbal material for limited phonological working memory resources, thereby impairing encoding (the Irrelevant Sound Effect) (11). The direction of these effects may depend critically on the structural features of the music — notably its tempo, rhythm predictability, and presence of meaningful lyrics (12) — and on individual variability in working memory capacity (13).

The present study addresses the specific question: does EDM played during word memorisation affect the number of words recalled and the prefrontal EEG oscillatory profile recorded during memorisation? We employed a within-subjects counterbalanced design in ten student participants, using a commercially available EEG headband (Brain Link; Basic Detection application) to record prefrontal brainwave activity during a modified CERAD-inspired word list memorisation task.

## 2. MATERIALS AND METHODS

### 2.1. Ethical Statement

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Written informed consent was obtained from all participants prior to any data collection. Participation was entirely voluntary; participants were informed of their right to withdraw at any time without consequence. No financial rewards, academic credit, or material incentives of any kind were offered. The study procedures were entirely non-invasive, and no physical or psychological harm was inflicted on any participant. All data were collected and stored in anonymised form. Participant names have been replaced with neutral identifiers (Participant 1–10) throughout.

### 2.2. Participants

Ten healthy student participants (6 female, 4 male) were recruited for this study. All participants were native or near-native speakers of English and reported normal or corrected-to-normal vision and normal hearing. Participants were naive to the specific hypotheses of the study and had no self-reported history of neurological or psychiatric disorder.

### 2.3. Stimuli: Word Lists

Three 12-word lists were prepared for use across participants (Table 1). Each list contained common, visually concrete nouns of similar difficulty and familiarity. Words were printed in large, clear font on A4 paper, with three words per page. The three lists were designated Set 1, Set 2, and Set 3.

**Table 1. Three 12-Word Lists Used in the Memorisation Task**

| Set 1   | Set 2     | Set 3     |
|---------|-----------|-----------|
| Chair   | Fork      | Parachute |
| Road    | Jar       | Stairs    |
| Racket  | Tuna      | Circle    |
| Lamp    | Hoop      | Trout     |
| Eraser  | Ladder    | Flask     |
| Wall    | Drone     | Knife     |
| Balloon | Partition | Bench     |
| Steps   | Wiper     | Lane      |
| Ring    | Bulb      | Bat       |
| Fish    | Club      | Light     |
| Bottle  | Street    | Rubber    |
| Spoon   | Sofa      | Fence     |

Words were matched across sets for concreteness and familiarity. Each participant received two of the three sets, randomly assigned to music and no-music conditions.

For each participant, two word lists were randomly selected from the three available and randomly assigned to the music and no-music conditions. The remaining list was held in reserve. This ensured that the same list was not used for both conditions by any single participant, controlling for list-specific familiarity effects.

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## 2.4. EEG Recording Equipment

Prefrontal EEG was recorded using the Brain Link EEG Headband (MacroTelect, China), a dry-electrode device positioned on the forehead. The device was connected via Bluetooth to the Basic Detection application, which provided real-time recording and readout of relative percentage power in five frequency bands: delta (0.5–4 Hz), theta (4–8 Hz), alpha (8–13 Hz), beta (13–30 Hz), and gamma (30–50 Hz), using a proprietary algorithm based on the eSense protocol.(14) EEG devices have been used in prior cognitive research and can yield useful exploratory band-power indices (15).

## 2.5. Procedure

The full experimental procedure was explained to each participant before commencement. Participants confirmed understanding of each step before proceeding. The Brain Link EEG headband was attached to the forehead, adjusted to ensure sensor contact, and connected to the Basic Detection application. Participants were instructed to sit upright, look straight ahead, and remain still throughout the memorisation phase.

Each memorisation session proceeded as follows. When the examiner initiated EEG recording, sets of three words printed on A4 paper were presented sequentially: each sheet was displayed for 7 seconds before being replaced by the next, yielding a total memorisation duration of approximately 28 seconds (4 sheets × 7 s/sheet). In the music condition, EDM was played continuously throughout the memorisation phase; in the no-music condition, the room was silent. EEG recording was stopped immediately after the final word sheet was removed.

After a mandatory 15-second rest interval, participants were given 60 seconds to verbally recall as many words as possible in any order. One point was awarded for each correctly recalled word (maximum score: 12).

All participants completed both conditions (within-subjects design). The no-music condition was always administered first, followed by the music condition, to avoid carryover effects from music-induced arousal to the no-music condition. Different word lists were used for each condition.

This procedure was inspired by the CERAD Word List Memory Task(16) but was modified to examine the effect of auditory stimulation during memorisation rather than assessing recall ability per se. Unlike the original CERAD protocol, this study does not include delayed recall, intrusion monitoring, or recognition components.

## 2.6. Outcome Measures

The primary outcome measures were: (1) word recall score (0–12) per condition; and (2) relative EEG band power (%) in each of five frequency bands during the memorisation phase. EEG data represent one log file per participant per condition, recorded only during the 28-second memorisation phase.

## 2.7. Statistical Analysis

Descriptive statistics (mean, standard deviation [SD], and standard error of the mean [SEM]) were computed for all outcome measures by condition. Within-subject differences between music and no-music conditions were tested using paired-samples t-tests. All statistical tests were two-tailed with  $\alpha = 0.05$ .

## 3. RESULTS

### 3.1. Word Recall Scores

Table 2 presents individual recall scores and EEG band power data for the music condition; Table 3 presents the corresponding data for the no-music condition. Figure 1 illustrates individual scores and paired changes between conditions.

**Table 2. Word Recall Scores and EEG Band Power (%) — Music Condition (N = 10)**

| Participant | Gender | Score /12 | Gamma (%) | Beta (%) | Alpha (%) | Theta (%) | Delta (%) |
|-------------|--------|-----------|-----------|----------|-----------|-----------|-----------|
| 1           | Female | 8         | 9.8       | 20.3     | 20.4      | 22.2      | 27.3      |
| 2           | Female | 5         | 7.4       | 11.0     | 5.2       | 13.9      | 62.6      |
| 3           | Female | 5         | 3.8       | 7.6      | 9.9       | 15.3      | 63.4      |
| 4           | Male   | 5         | 9.2       | 16.0     | 14.9      | 22.6      | 37.2      |
| 5           | Male   | 8         | 11.0      | 16.2     | 16.7      | 21.1      | 35.0      |
| 6           | Male   | 9         | 5.4       | 13.1     | 16.5      | 26.8      | 38.2      |
| 7           | Female | 11        | 9.8       | 13.9     | 7.1       | 17.0      | 52.3      |
| 8           | Female | 11        | 4.7       | 8.8      | 16.5      | 29.2      | 40.7      |
| 9           | Male   | 6         | 4.2       | 14.5     | 18.5      | 25.8      | 37.1      |

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| Participant | Gender | Score /12 | Gamma (%) | Beta (%) | Alpha (%) | Theta (%) | Delta (%) |
|-------------|--------|-----------|-----------|----------|-----------|-----------|-----------|
| 10          | Female | 9         | 8.5       | 11.4     | 9.7       | 16.1      | 54.3      |
| Mean        | —      | 7.7       | 7.4       | 13.3     | 13.5      | 21.0      | 44.8      |
| SD          | —      | 2.36      | 2.65      | 3.76     | 5.17      | 5.27      | 12.43     |

Band power values represent relative percentage of total spectral power during the 28-second memorisation phase. Score = words correctly recalled out of 12.

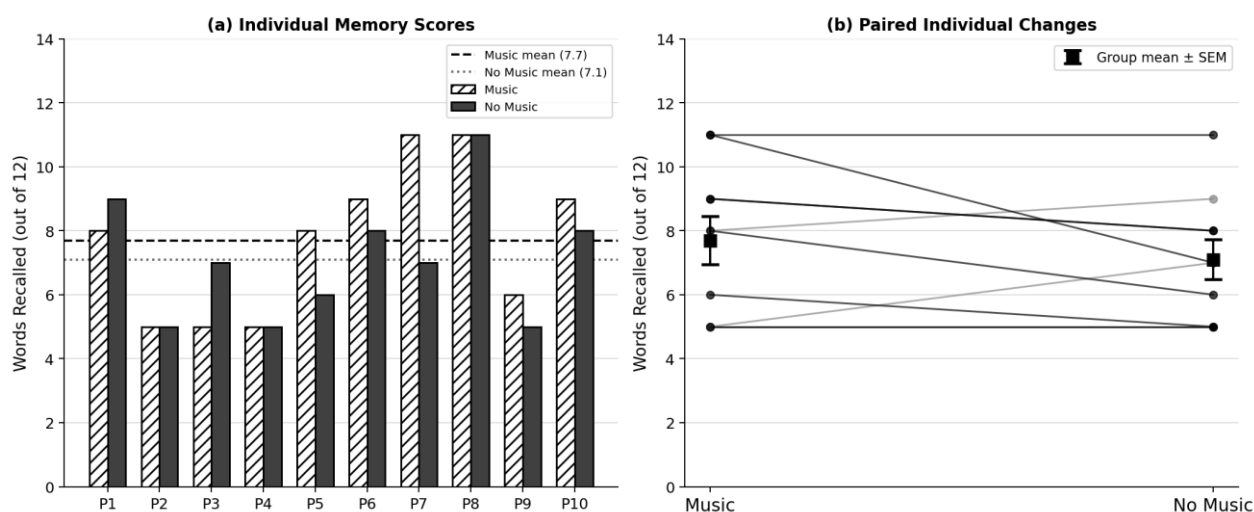
**Table 3. Word Recall Scores and EEG Band Power (%) — No Music Condition (N = 10)**

| Participant | Gender | Score /12 | Gamma (%) | Beta (%) | Alpha (%) | Theta (%) | Delta (%) |
|-------------|--------|-----------|-----------|----------|-----------|-----------|-----------|
| 1           | Female | 9         | 10.1      | 17.7     | 15.8      | 18.8      | 37.7      |
| 2           | Female | 5         | 8.2       | 11.2     | 5.1       | 13.0      | 62.5      |
| 3           | Female | 7         | 14.8      | 27.6     | 13.8      | 19.0      | 24.8      |
| 4           | Male   | 5         | 8.0       | 19.3     | 21.6      | 26.1      | 25.0      |
| 5           | Male   | 6         | 12.2      | 19.0     | 18.8      | 23.3      | 26.6      |
| 6           | Male   | 8         | 4.8       | 11.7     | 16.7      | 30.1      | 36.7      |
| 7           | Female | 7         | 3.7       | 4.4      | 4.4       | 13.8      | 73.7      |
| 8           | Female | 11        | 5.6       | 11.0     | 15.5      | 25.3      | 42.6      |
| 9           | Male   | 5         | 14.1      | 25.8     | 18.5      | 19.5      | 22.1      |
| 10          | Female | 8         | 8.1       | 12.4     | 11.9      | 17.9      | 49.7      |
| Mean        | —      | 7.1       | 9.0       | 16.0     | 14.2      | 20.7      | 40.1      |
| SD          | —      | 1.97      | 3.83      | 7.22     | 5.65      | 5.47      | 17.35     |

Band power values represent relative percentage of total spectral power during the 28-second memorisation phase. Score = words correctly recalled out of 12.

Mean recall was  $7.70 \pm 0.75$  words in the music condition and  $7.10 \pm 0.62$  words in the no-music condition. A paired-samples t-test indicated no statistically significant difference between conditions ( $t(9) = 1.152$ ,  $p = 0.279$ ). At the individual level, five participants recalled more words with music, three recalled fewer, and two scored identically across conditions (Figure 1b).

**Figure 1. Word Recall Scores: Music vs. No Music Condition (N = 10)**



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Figure 1. Word recall scores by condition. (a) Individual scores for each participant in Music (white hatched) and No Music (dark) conditions. Dashed and dotted lines indicate group means. (b) Paired individual changes between conditions; filled squares show group mean  $\pm$  SEM. Format optimised for black-and-white reproduction.

### 3.2. EEG Band Power: Condition Comparison

Table 4 summarises group mean band power and recall scores for both conditions, together with paired t-test results. Figure 2 presents grouped bar charts of mean band power by condition with  $\pm 1$  SEM error bars.

**Table 4. Summary: Group Mean  $\pm$  SEM, Paired t-Test Results — Music vs. No Music Condition**

| Band/Measure | Music Mean $\pm$ SEM | No Music Mean $\pm$ SEM | Difference | t      | p     |
|--------------|----------------------|-------------------------|------------|--------|-------|
| Recall Score | 7.70 $\pm$ 0.75      | 7.10 $\pm$ 0.62         | +0.60      | 1.152  | 0.279 |
| Gamma (%)    | 7.38 $\pm$ 0.84      | 8.96 $\pm$ 1.21         | -1.58      | -0.975 | 0.355 |
| Beta (%)     | 13.28 $\pm$ 1.19     | 16.01 $\pm$ 2.28        | -2.73      | -1.078 | 0.309 |
| Alpha (%)    | 13.54 $\pm$ 1.63     | 14.21 $\pm$ 1.79        | -0.67      | -0.654 | 0.529 |
| Theta (%)    | 21.00 $\pm$ 1.67     | 20.68 $\pm$ 1.73        | +0.32      | 0.276  | 0.789 |
| Delta (%)    | 44.81 $\pm$ 3.93     | 40.14 $\pm$ 5.49        | +4.67      | 0.922  | 0.381 |

SEM = standard error of the mean. t = paired t-test statistic. p = two-tailed p-value. N = 10. No comparison reached statistical significance (all p > 0.05).

No statistically significant differences were observed for any EEG frequency band between conditions (all p > 0.30; Table 4). Descriptively, the music condition showed numerically lower beta power (13.28% vs. 16.01%), lower gamma power (7.38% vs. 8.96%), marginally lower alpha (13.54% vs. 14.21%), marginally higher theta (21.00% vs. 20.68%), and notably higher delta power (44.81% vs. 40.14%) compared to the no-music condition.

**Figure 2. Mean Relative EEG Band Power: Music vs. No Music Condition (Error bars =  $\pm 1$  SEM, N = 10)**

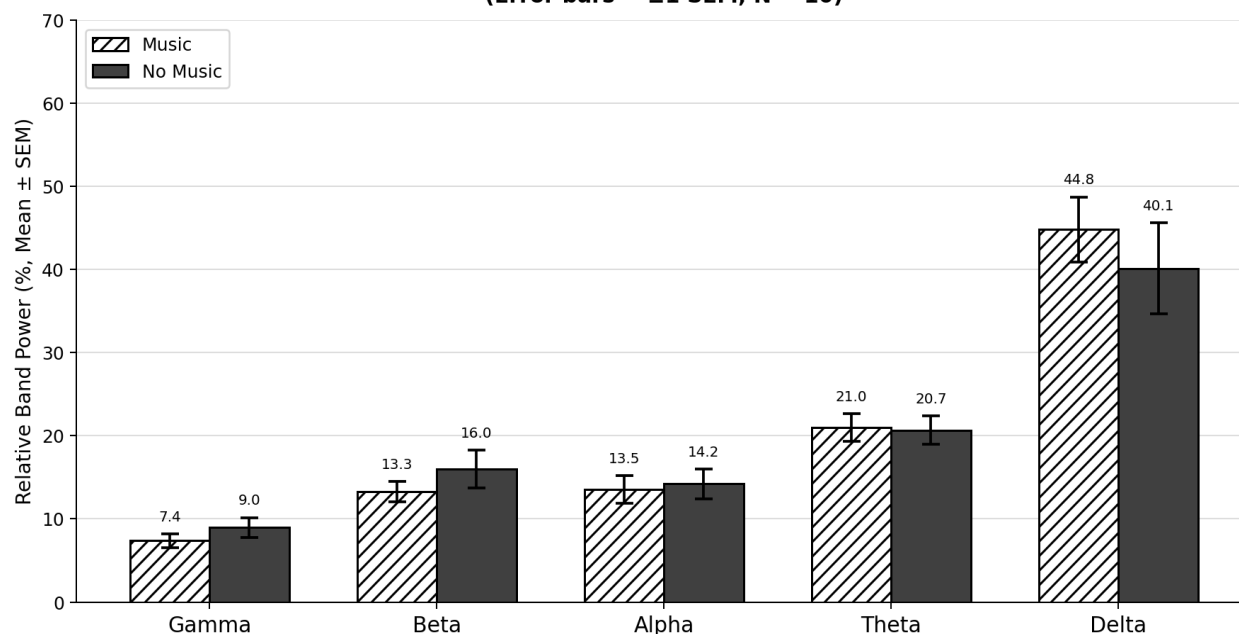


Figure 2. Mean relative EEG band power (%) in Music (white hatched) and No Music (dark) conditions. Error bars =  $\pm 1$  SEM, N = 10. Value labels indicate group means. Format optimised for black-and-white print reproduction.

### 3.3. Individual EEG Profiles

Figure 3 shows individual EEG band power profiles for all 10 participants in both conditions. Substantial inter-individual variability was evident in both conditions, particularly in delta power (range: 27.3% – 63.4% with music; 22.1% – 73.7% without music). Despite this variability, the overall pattern of delta dominance was consistent across participants in both conditions.

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**Figure 3. Individual EEG Band Power Profiles: Music vs. No Music (N = 10)**  
Inset: Recall score Music (M) / No Music (NM)

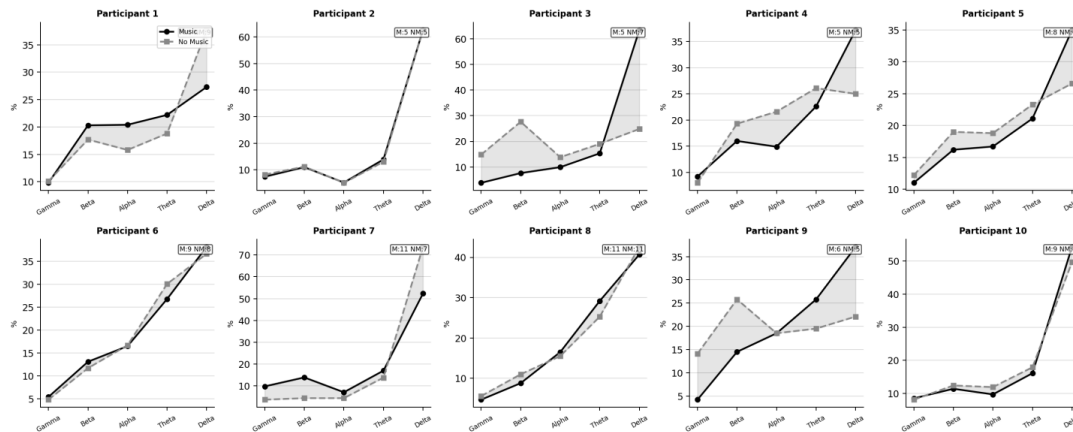


Figure 3. Individual EEG band power profiles (%) for each participant. Solid black lines = Music; dashed grey lines = No Music. Shaded regions indicate the area of change between conditions. Recall scores are shown as insets (M = Music, NM = No Music).

## 3.4. Delta and Beta Power Changes

Figure 4 shows the individual change in delta and beta power (music minus no-music) per participant. Delta power increased in the music condition for 5 participants and decreased for 5, yielding a mean change of +4.67 percentage points. Beta power decreased in the music condition for 7 of 10 participants, with a mean change of -2.73 percentage points.

**Figure 4. Individual Changes in Delta and Beta Band Power (Music – No Music)**  
Positive = higher power during music condition

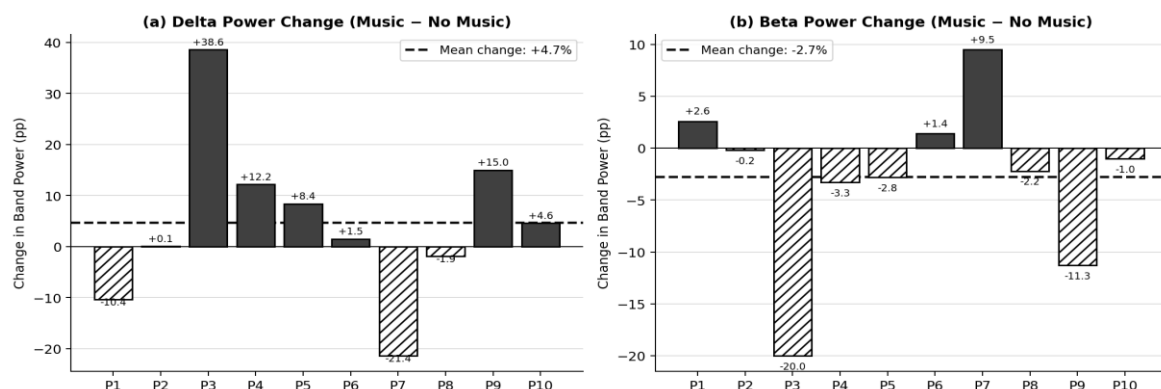
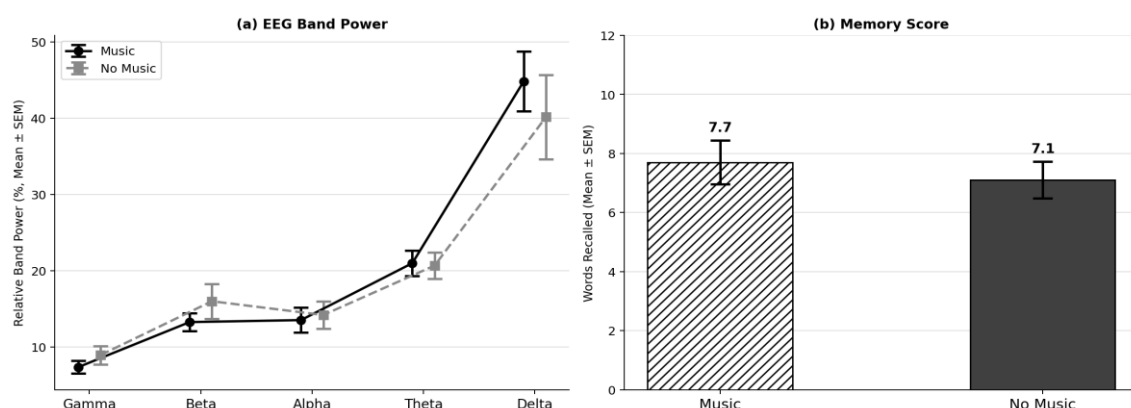


Figure 4. Individual changes in (a) delta and (b) beta band power (Music – No Music, %). Dashed lines indicate group mean changes (+4.67 pp and -2.73 pp, respectively). Dark solid bars = positive change; white hatched bars = negative change.

## 3.5. Summary

Figure 5 presents a consolidated group summary (mean  $\pm$  SEM) for both EEG band power and recall score across conditions.

**Figure 5. Group Summary: Mean  $\pm$  SEM for EEG Band Power and Memory Score**  
Music vs. No Music Condition (N = 10)



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Figure 5. Group summary (N = 10). (a) Mean  $\pm$  SEM relative EEG band power (%) for all five frequency bands: Music (filled circles, solid line) and No Music (open squares, dashed line). (b) Mean  $\pm$  SEM word recall score. Error bars =  $\pm 1$  SEM.

### 4. DISCUSSION

#### 4.1. Word Recall: No Significant Effect of EDM

The primary finding is that EDM played during memorisation did not significantly alter the number of words recalled compared to a silent control condition ( $t(9) = 1.152$ ,  $p = 0.279$ ). The direction of the effect — marginally higher scores with music — is consistent with some proposals that moderate arousal-inducing music could facilitate attentional engagement during encoding.(2) However, the effect is small (Cohen's  $d \approx 0.28$ ), statistically non-significant, and reversed in three of ten participants, indicating substantial individual heterogeneity.

These results align with studies showing that background music has minimal net effects on recall of verbal material when the music lacks meaningful lyrics and when participants are accustomed to music-accompanied study.(1,12) The lack of a significant decrement is notable in the context of the Irrelevant Sound Effect literature, which predicts that irrelevant auditory material interferes with serial verbal recall via competition for phonological working memory resources.(11) EDM's lack of meaningful lyrical content and its rhythmic regularity may reduce its disruptive impact on phonological encoding relative to speech or music with lyrics.(12)

#### 4.2. EEG Band Power: Direction of Changes with EDM

Although no EEG comparison reached statistical significance, the directional patterns are interpretively coherent and merit discussion as hypothesis-generating observations.

The numerically lower beta power during the music condition (13.28% vs. 16.01%) is consistent with reduced top-down executive maintenance activity, as beta oscillations in the prefrontal-parietal network index the active, effortful maintenance of task-relevant representations in working memory.(6) If EDM provides a low-level rhythmic scaffold that partially structures the temporal encoding of word sequences — a form of 'auditory scaffolding'(17) — less effortful top-down maintenance may be required, reducing beta power. Alternatively, beta suppression under the music condition could reflect attentional resource competition: the need to simultaneously process auditory rhythmic input and verbal material may partially destabilise the executive working memory network.(13)

The higher delta power during music (44.81% vs. 40.14%) is consistent with greater cognitive load or inhibitory processing demands.(10) The concurrent presence of EDM rhythms likely required the prefrontal cortex to actively filter and suppress task-irrelevant auditory processing — a form of proactive inhibitory effort reflected in delta oscillations.(10) This interpretation is supported by the fact that beta and delta moved in opposite directions, a pattern previously observed during high-demand inhibitory override tasks.(5)

Gamma and alpha power were modestly lower in the music condition, consistent with a slight reduction in attentional binding efficiency and a minor increase in processing of irrelevant input. Theta power was nearly identical across conditions (21.00% vs. 20.68%), suggesting that hippocampal-prefrontal communication during encoding was not substantially disrupted by EDM at the group level.(8)

#### 4.3. Individual Differences

Individual variability was substantial throughout this dataset, particularly in delta power. This is consistent with the broader music-cognition literature, in which individual differences in working memory capacity,(13) music experience, and arousal sensitivity(2) are known moderators of music's effects on cognitive performance. Some participants showed markedly higher delta power in the music condition (e.g., Participant 3:  $\Delta +38.6$  pp), suggesting strong inhibitory demands, while others showed minimal changes. Similarly, the score benefit of music was restricted to specific participants, raising the possibility of a subgroup of learners who benefit from rhythmic auditory scaffolding during encoding.

#### 4.4. Gender Differences

Exploratory analysis revealed that female participants showed numerically higher mean recall in both conditions (Music: 8.17 vs. 7.00; No Music: 7.83 vs. 6.00 for male participants), though formal gender comparisons were underpowered in this pilot ( $n = 6$  female, 4 male). This directional observation warrants follow-up in larger, sex-balanced samples.

### 5. CONCLUSION

This pilot study found no statistically significant effect of EDM on word recall or prefrontal EEG oscillations during memorisation in ten student participants. Directional trends — marginally higher recall, higher delta power, and lower beta power with music — are consistent with mild increases in cognitive load and possible inhibitory processing demands imposed by background auditory stimulation, but require replication in adequately powered studies to establish reliability. The absence of a significant decrement in recall suggests that EDM does not constitute a strongly disruptive auditory irrelevant sound for this type of verbal memory task.

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These findings provide a methodological foundation and pilot data to guide future investigations into the neural and cognitive effects of EDM on learning and memory.

## Author Contributions

N.S.: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Writing – Original Draft Preparation, Writing – Review and Editing, Visualization, Supervision, Project Administration. The author has read and agreed to the published version of the manuscript.

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## Data Availability Statement

The raw data supporting the conclusions of this article are available from the corresponding author upon reasonable request.

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## Conflict of Interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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