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HEBB REPETITION EFFECT AND ENCODING SPECIFICITY ON MEMORY RECALL AMONG UNDERGRADUATES

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Abstract

The study tested Hebb Repetition Effect and Encoding Specificity on memory recall among undergraduates. A 3 x 3 experimental design was adopted where 24 participants were exposed to three repetition conditions (3rd, 6th trials, and control group) and three cue conditions (reinstated, extra list, and no cues) experimental conditions. Participants' memory recall performances were measured following each tested condition. The result reveals that participants exposed to repetition after the 3rd trial (Mean = 183.25) had significantly better memory recall compared to those exposed to the 6th trial (Mean = 162.38), and less with the control group (Mean = 147.00). Furthermore, the result demonstrates reinstated cues (Mean = 165.75) marginally facilitated better memory recall than extra list cues (Mean = 163.50), and less with control group (Mean = 163.38). However, there was no significant interaction effect between Hebb Repetition and Encoding Specificity. The study concludes that Hebb Repetition and Encoding Specificity independently significantly improve memory recall among study participants. The study recommends educators and policy makers to incorporate Hebb repetition and encoding specificity in the design and implementation of instructional materials to improve learners' performance.

Keywords: *Hebb Repetition Effect; Encoding Specificity; Memory Recall; Undergraduates*

INTRODUCTION

Memory is a fundamental cognitive function that enables individuals to encode, store, and retrieve information. The processes of encoding, storage, and retrieval are closely interconnected. Encoding transforms sensory input into a memory format with semantic encoding being particularly effective in promoting long-term retention (Craik & Tulving, 1975; Millidge et al., 2024). Storage ensures information remains in memory over time which is aided by repetition and meaningful connections. Retrieval is facilitated by cues that help bring stored information back into conscious awareness (Mizrak & Oberauer, 2022; Tulving & Thomson, 1973). These processes are essential for learning, decision-making, and adapting to individuals surroundings. Memory contributes to cognitive development by supporting knowledge acquisition, skill mastery, problem-solving, and decision-making(Baddeley, 2000; Eich et al., 2020).

Two factors have been identified to affect memory recall. The first one considered in this study is Hebb Repetition Effect which explains how repeated exposure to information strengthens neural connections which makes recall easier (Hebb, 1949). According to the Hebbian theory, neural connections in the brain are strengthened over time as a result of simultaneous activation. This is succinctly captured in the phrase, "cells that fire together wire together," which emphasizes that repeated and persistent co-activation of neurons leads to the enhancement of their synaptic connections (Hebb, 1949). Hebb Theory is central to understanding learning, memory, and the brain's plasticity. In a study that confirmed the Hebb

Repetition Effect, participants were tasked with recalling sequences of digits presented in a serial recall format. Most sequences were unique and appeared only once, but every 3rd trial, the same list of digits was repeated. Hebb found that recall performance improved significantly for the repeated sequences over time, demonstrating that repetition enhanced the learning and memory of the sequence.

Some studies have tested the Hebb Repetition Effect with varied results. For instance, Vachon et al. (2018) tested the susceptibility of sequence learning to auditory distraction, using a between-subjects design with 60 participants, and found that auditory distractions significantly impaired memory recall, as participants in the distraction condition performed worse than the control group. In another study, Souza and Oberauer (2022) tested the effect of Hebb Repetition Effect in visuospatial memory among college students, and found that performance on more demanding tasks (full recall) enhanced the Hebb repetition effect, while recognition tasks did not produce the same benefit. Similarly, Musfield et al. (2023) who employed a within-subjects design with 200 participants across five experiments to test Hebb repetition effect using both simple and complex span tasks found that Hebb repetition effect could transfer across tasks of varying complexity, supporting the idea that general learning mechanisms, rather than task-specific mechanisms, underlie the effect.

In addition, Henry et al. (2022) utilized a within-subjects design with 40 adolescents diagnosed with intellectual disabilities demonstrating that participants exhibited a significant Hebb repetition effect, with improved recall for repeated items. This suggests that repetition learning can enhance memory even in individuals with intellectual disabilities, supporting the universality of the Hebb repetition effect across different populations. Finally, Johnson and Miles (2019) used a within-subjects design with 60 participants who were exposed to verbal sequence learning tasks showed that verbal sequence learning was resilient, with significant improvements in recall for repeated sequences, even when variations in the timing of repetition were introduced. However, Araya et al. (2024) in a study using a within-subjects design with 240 participants, found that partial repetition, particularly in complex span tasks, did not lead to significant learning, reinforcing the importance of full exposure to sequences for optimal recall.

The second factor considered is the Encoding Specificity which explains how memory retrieval is more effective when the encoding context matches the retrieval context (Tulving & Thomson, 1973). It establishes the relationship between encoding and retrieval processes in memory. It asserts that memory retrieval would be most successful when the cues available during retrieval are congruent with those present during encoding. This means the importance of creating effective learning environments and cues for better retrieval (Godden & Baddeley, 1975). Some studies have supported the Encoding Specificity in various contexts. For instance, Yanes ett al. (2019) applied the encoding specificity paradigm to the exercise domain, demonstrating that memory recall was superior when the physical states during encoding and retrieval matched. In addition, Zeelenberg's (2005) study on encoding specificity manipulations and their effects on retrieval processes in episodic memory showed that when the encoding and retrieval contexts were congruent, memory retrieval was enhanced, which further reinforced the importance of contextual overlap in memory performance. Moreover, Leppänen et al.

(2021) explored how self-referential encoding affects memory recall and found that self-referential encoding is context-dependent, with better recall occurring when encoding and retrieval contexts align. This supports the idea that self-referential elaboration enhances memory retrieval, especially when the contexts match. Together, these studies provide strong empirical support for the encoding specificity principle, showing that matching contexts during encoding and retrieval leads to better memory performance.

Other empirical studies on encoding specificity have been reported to include that of Tamminen et al. (2019) who examined the reinstatement of odour context cues veridical memories but not false memories and found that odour cues can help reactivate memories, particularly veridical (genuine) ones, without leading to false memories. This finding aligns with that of Herz et al. (2022) and Smeets et al. (2023) who found that odours specifically trigger vivid memories without distorting them. In addition, Larsson et al. (2021) demonstrated that olfactory cues led to more detailed episodic memories than visual or auditory cues, highlighting their distinctiveness. Extending further, Laub and Frings (2020) explored the effect of encoding specificity on distractor-based retrieval and found that retrieval was more successful when the number of distractors during encoding and retrieval match. This finding aligns with the encoding specificity principle that a congruent context at both stages enhances memory retrieval. Baier and Zimmer (2019) and Nakayama and Hirai (2022) extended these ideas by showing how context congruence aids memory in different cognitive tasks.

Furthermore, Bramão et al. (2022) examined how the brain reinstates encoding contexts during competitive memory retrieval demonstrated that, even when memories compete for retrieval, the brain automatically reinstates the context associated with the correct memory. This corroborates prior research that context can resolve interference during memory retrieval, as shown in studies by (Lewis-Peacock & Norman, 2020). Finally, deBettencourt et al. (2019) used neurofeedback techniques and FMRI to explore how mental context reinstatement influences memory retrieval, and found that when participants mentally reinstated the correct context, their memory recall improved, further supporting the role of context in selective retrieval.

While there are considerable studies on Hebb Repetition and Encoding Specificity effects on memory recall among students in the developed countries, there are scarcity of studies on these two effects within the Nigerian educational contexts thus leaving a gap in knowledge to fill. Therefore, this study examines the Hebb Repetition and Encoding Specificity Effects on memory recall among undergraduates in a Nigeria university. The study sought to provide answers to the following questions: Will participants' memory recall be significantly better after repeated exposure following 3rd and 6th trial compared to none repeated exposure/control group (Hebb Repetition Effect)? Will participants' memory recall be significantly better after repeated exposure to reinstated cues, and extra-list cues compared to no cues (Encoding Specificity)? Will there be an interaction effect between Hebb Repetition Effect and Encoding Specificity on memory recall among undergraduates?

The study would provide insights on how using structured repetition and context-specific cues would improve retention and retrieval of learned materials among undergraduates. In addition, by understanding how structured repetition and context-specific cues operate, it would contribute to memory rehabilitation for patients with neurological conditions such as Alzheimer's, dementia, and PTSD to improve their daily functioning and quality of life. Finally, in organizational settings, the application of Heb Repetition Effect and Encoding Specificity would improve employee training, task performance, and decision-making as it aligns training methods with real-world conditions thereby boosting productivity.

The study tested the following hypotheses:

H1a: Participants' memory recall will be significantly better after repeated exposure following the 3rd trial compared to the 6th trial than for non- repeated exposure/control group (Hebb Repetition Effect).

H1b: There will be an interaction effect between Hebb Repetition Effect and Encoding Specificity on Memory Recall among undergraduates.

H2: Participants' memory recall will be significantly better after repeated exposure to reinstated cues, and extra-list cues compared to no cues (Encoding Specificity). The hypothesis was tested using Bonferroni multiple comparison test and the results are presented in Table 2.

METHOD

The study utilized a 3×3 within subject factorial design. It comprised two independent variables, each at three levels. The independent variable was at 3-level of Hebb Repetition Effect at repeated exposure after 3rd and 6th trials with the control group. The dependent was memory recall measured at 3-level of encoding specificity at reinstated cue, extra list cue and the control group. The 3×3 factorial design allows for the determination of the independent effects of each independent variable and their potential interaction effects on the dependent variable. The study was conducted at the BNI building, located opposite Idia Hall, at the University of Ibadan, Nigeria. The location was chosen due to its conducive environment for academic research. The experiment took place in a quiet, controlled room within the building to minimize external distractions and ensure that participants focused solely on the task at hand. The room was well-lit and furnished to provide a comfortable setting for the participants and experiment. Silence was maintained throughout the study to enhance concentration and reduce the likelihood of interference that could affect memory recall. This controlled setting was essential to provide a reliable environment for observing the effects of the Hebb Repetition Effect and Encoding Specificity on memory recall.

The participants in this study were undergraduates from the Faculty of Technology, Education, of the Social Sciences, Sciences, and Arts at the University of Ibadan. Descriptive statistics revealed that 15 (62%) of the participants were females while 9 (38%) were males. In terms of the distribution of the participants, 13% of the participants were from the Faculty of Technology, 25% from Education, 29% from the Social Sciences, 17% from the Sciences, and 16.7% were from the Faculty of Arts.

The instruments and materials used in this experiment include cardboard with word lists, whiteboard marker, timer, notebook, and pens.

Procedures

The study adapted Zeelenberg (2005) and Donald Hebb (1961) experiment and their procedures for the study while modifying the exact list of words. The experiment was conducted for three consecutive days and utilized a 3×3 within-subject experimental design to investigate the effects of Hebb Repetition Effect and Encoding Specificity on memory recall.

Each condition of Hebb Repetition Effect involved 24 trials, during which participants studied a list of words for 40 seconds and then attempted to recall the words for 20 seconds. In the first condition (repeated exposure after the third trial), the same list of words was reintroduced after every 3rd trial, resulting in a total of eight exposures before the 24th trial. In the second condition (repeated exposure after the 6th trial), the same list of words was presented after every 6th trial, totaling four exposures. In the third condition (no repeated exposure), participants were exposed to a randomly sequenced list of words across all 24 trials, with no repeated exposure to the same list.

For Encoding Specificity, the first condition (reinstated cues) provided participants with the same cue words during recall that were paired with target words during encoding. The cue words were presented in lowercase letters, while target words were in uppercase (e.g., clean LOITTER), and participants were instructed to study the pairs together. In the second condition (extra list cues), participants were provided with strongly associated but unstudied cues during the recall phase (e.g., "railway" to recall "train"). In the third condition (no cues), no cue words were provided during either the encoding or recall phase, serving as the control condition. After each experimental session, participants' recall data were collected, scored, and recorded. For Hebb Repetition Effect, the maximum possible score was 192, while for Encoding Specificity, the maximum score was 8. The scores were systematically organized into a score sheet for easy analysis.

IBM^{R} SPSS version 23 was used for data analysis. Both descriptive and inferential statistics were computed. The data were analyzed using the Statistical Package for Social Sciences (SPSS) 23. All the hypotheses were tested using 2-way within-subject Analysis of Variance and accepted at $p <.001$. The study was conducted with strict careful adherence to ethical guidelines to ensure the participants' rights and well-being were respected throughout the research process:

Anonymity: To protect participants' identities, each individual was assigned a unique identifier (e.g., Participant 1, Participant 2, etc.). No personally identifiable information was collected or linked to the data obtained during the study. Voluntary Participation**:** Participation in the study was entirely voluntary. Participants were provided with clear information about the study's objectives and were free to withdraw at any point without any consequences or penalties. Informed Consent: Participants were informed about the nature of the experiment, the procedures involved, and the potential benefits of their participation. They consented to partake in the study under these conditions.

RESULTS

Hypotheses testing

H1a: Participants' memory recall will be significantly better after repeated exposure following the 3rd trial compared to the 6th trial than for non- repeated exposure/control group (Hebb Repetition Effect).

H1b: There will be an interaction effect between Hebb Repetition Effect and Encoding Specificity on Memory Recall among undergraduates.

Table 1: A 2-way ANOVA of the main and interaction effects of Hebb Repetition Effect and Encoding Specificity on memory recall

Source	**Sum of Squares**	**df**	**Mean Square**	**F**	**p**
1. Hebb Repetition Effect	47669.25	2	23834.63	34.85	<.001
2. Encoding Specificity	257.25	2	128.63	23.41	<.001
3. Hebb*Encoding	.00	4	.00	.00	>.05

Table 1 presents the results of a 2-way ANOVA of the main and interaction effects of Hebb Repetition Effect and Encoding Specificity on memory recall among study participants. The result revealed a significant effect of the Hebb Repetition Effect on memory recall among study participants, $F_{(2,46)} = 34.85$, $p < .001$. Furthermore, the result indicated a significant effect of Encoding Specificity on memory recall among study participants, $F_{(2,46)} = 23.41$, $p < .001$. However, there was no main interaction between Hebb Repetition Effect and Encoding Specificity, $F_{(2,46)} = .00$, $p > .05$.

H2: Participants' memory recall will be significantly better after repeated exposure to reinstated cues, and extra-list cues compared to no cues (Encoding Specificity). The hypothesis was tested using Bonferroni multiple comparison test and the results are presented in Table 2.

Table 2. Bonferroni Pairwise Comparisons Test Of The Mean Differences In Memory Recall Across Conditions Of Encoding Specificity

Encoding Specificity Condition	**Mean Differences (I- J)**				
	Reinstated Cues (J1)	**Extra-list Cues (J2)**	**No Cues (J3)**	**Mean**	**SD**
1. Reinstated Cues (I1)	0.00	2.25***	2.38**	165.75	2.05
2. Extra-list Cues (I2)		0.00	.13	163.50	2.12
3. No cues (I3)			0.00	163.38	2.06

** *Mean difference is significant at the .001 level*

Table 2 represents the mean differences in memory recall across conditions of Encoding Specificity. The result indicated a significant difference in memory recall (Mean Difference = 2.25, $p < .001$) between participants exposed to the reinstated cues condition (Mean =165.75, SD = 2.05) and those exposed to the extra-list cues condition (Mean=163.50, SD =2.12) compared to the no cues (control group). This shows that participants' memory recall was significantly better after exposure to reinstated cues compared to those exposed to extra-list cues. Further, the result revealed a significant difference in memory recall (Mean Difference=2.38, $p < .001$) between participants exposed to the reinstated cues condition (Mean =165.75, SD =2.05) and those exposed to the no cues condition (Mean=163.38, SD =2.06). This shows that participants' memory recall was significantly better after exposure to reinstated cues compared to those exposed to no cues. Therefore, the hypothesis was confirmed.

DISCUSSION

The hypothesis that participants' memory recall will be significantly better after repeated exposure following the 3^{rd} trials compared to the control group was confirmed. Participants who were exposed after the 3rd trial yielded significantly higher mean memory recall compared to the control group. This finding aligns with the concept of Hebb Repetition Effect which states that repeated exposure to a stimulus enhances memory recall by strengthening neural connection (Hebb, 1949). Moreover, the result corroborates that of Souza and Obeurer (2022) who found that repeated exposure to visuospatial stimuli after every 3rd trial, particularly under more demanding conditions, led to significantly improved memory recall performance. Finally, the result corroborates that of Araya etal. (2024) who found that repetition of the verbal items had a stronger effect on memory after the 3^{rd} trial.

Similarly, the repeated exposure of participants after the 6th trial yielded a significantly higher mean recall than those in the control group which confirmed the hypothesis. Exposure of participants to more immediate repetitions (repetitions after 3rd trial) yielded more favorable results in memory recall than the delayed repetitions. This finding aligns with that of Inoue et al. (2021) that participants who received repeated auditory stimuli after the 6th trial showed enhanced recall accuracy, confirming that delayed repetition after several trials significantly improves recall over non repetitions.

Moreover, the hypothesis that there would be an interaction effect between Hebb Repetition and Encoding Specificity on memory recall was not confirmed. This means that Hebb Repetition Effect and Encoding Specificity independently contribute to memory recall, their combined effect did not provide additional benefits beyond their individual contributions. The absence of an interaction effect would be explained by the nature of memory retrieval itself. Retrieval is a complex process that involves accessing and reconstructing information from memory traces. If repetition strengthens these traces enough, the retrieval process would not require additional contextual cues to be successful. The lack of a significant interaction between the Hebb Repetition Effect and Encoding Specificity in this study highlights the possibility that repetition alone could be sufficient to activate and retrieve memory traces(Cooke et al., 2020; Greenberg, 2023; Schlegelmilch et al., 2023). The more a memory trace is strengthened through repetition, the easier it becomes accessible during retrieval. When the memory trace is solid enough, the brain may not need external cues to aid in recall. In this sense, repetition alone might activate the memory trace fully (Chen & Zhao, 2021; Eich et al., 2020).

Furthermore, the hypothesis that participants exposed to reinstated cues would significantly perform better than those exposed to extra-list cues and the no cues (control group) was supported. This means that reinstated cues enhance recall performance more effectively than extra-list or no cues (control group). These findings are consistent with the encoding specificity principle which posits that memory retrieval is more efficient when the cues available during recall match those present at the time of encoding (Zeelenberg, 2005). Moreover, the present finding corroborates Kumar et al. 's (2022) results that participants who were exposed to reinstated cues performed better than those exposed to extra-list cues or no cues, particularly when the recall task involved verbal or word association tasks. However, the result contradicts that of Xu et al. (2021) who compared the effectiveness of reinstated and extra-list cues in a visual memory recall task and found that while reinstated cues improved recall for some participants, others performed equally well with extra-list cues especially when these cues were meaningfully related to the task.

Similarly, participants exposed to extra-list cues performed better in memory recall tasks compared to those exposed to no cues. This means that there was significant difference in recall performance between the extra-list cue condition and the no cue condition. This means that extra-list cues provide a measurable advantage over the absence of cues in facilitating memory recall. The result in this study is consistent with the finding of Huang and Lee (2020) who found that while extra-list cues would trigger new associations and promote flexible thinking, it significantly improved recall performance compared to no cues in tasks requiring the exact recall of previously learned material. Furthermore, the results support the finding of Sydner and Johnson (2023) who found that extra-list cues to be useful in some contexts for generating alternative retrieval strategies, and led to significantly better memory recall performance than no cues in tasks requiring the recall of specific, learned words.

CONCLUSION

This study provides valuable insights into the mechanisms of memory recall particularly focusing on the Hebb Repetition Effect and Encoding Specificity. The findings underscore the importance of repeated exposure to enhance memory recalls with evidence supporting that repeated exposure, especially after the 3rd trial, significantly strengthens memory performance. The role of context-specific cues, particularly reinstated cues, was significant, reinforcing the theory that memory retrieval is most effective when the cues during recall align with those present during encoding.

RECOMMENDATION

The study makes the following recommendations. To begin with, the importance of repetition in improving memory recall is evidenced from the findings of the Hebb Repetition Effect. Therefore, educators should consider incorporating more spaced repetition techniques in their teaching practices. Moreover, the study found the role of context-specific cues, particularly reinstated cues, in enhancing recall. This supports the idea of encoding specificity, which suggests that memory retrieval is more accurate when the cues provided during recall match those encountered during encoding. Hence, educators should integrate reinstated cues in both learning and testing environments.

However, the study found that extra-list cues did not significantly improve memory recall compared to no cues at all. This implies that while extra-list cues would encourage creativity or alternative thinking, they are not particularly effective for tasks requiring precise recall. Therefore, educators should be cautious about relying heavily on extra-list cues in tasks where exact memory retrieval is required.

The study also found that there was no significant interaction between the Hebb Repetition Effect and Encoding Specificity, meaning that while both repetition and context-specific cues independently contributed to improved recall, their combined effect was not necessarily greater than the sum of their individual contributions. This points to the possibility that repetition alone can sufficiently activate and retrieve memory traces, making external cues less crucial when repetition is effectively applied.

LIMITATIONS

The study has some limitations that need to be addressed in further study. For instance, the difficulty to separate the effect of memory recall from how quickly participants wrote their answers would have affected the accuracy of their recall. Therefore, further study should address the issue of speed and recall by controlling for or accounting for speed by ensuring that participants have enough time to recall information accurately without focusing solely on completing the task quickly. In addition, the study took a long time to complete which would have increased the level of fatigue by the participants thus affecting their performance, therefore, further study should adopt a between-subjects design to reduce the level of fatigue by the participants.

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