Investigating the Effect of Information Intake Modality on Memory Retention in Adolescent Students: A Neuroscience Experiment

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Abstract

This neuroscience experiment aimed to investigate the most efficient method of information intake and storage for memory retention in adolescent learners. The study involved three categories of 9th and 10th-grade students who were tested on their memory retention through reading, writing, and listening. The participants were asked to engage in writing/copying, reading, or listening to a four sentence paragraph and then answer questions related to the content. The hypothesis predicted that writing would be the most effective technique for memorizing in adolescents. The result revealed that the group that participated in writing demonstrated the highest memory retention levels and answered the questions more accurately. This supports the notion that writing is the most efficient modality for memory retention in adolescent students compared to reading and listening. The experiment also explored the underlying processes involved in memory and highlighted the role of motor and kinematic memories in writing. The findings have significant implications for teaching strategies and technology design and interventions for individuals with memory difficulties. Overall this experiment contributes to our understanding of memory retention modalities in adolescents and their societal importance in education or technology, health and communication; etc.

Introduction

Memory is a sophisticated process that entails various brain regions and functions, like encoding, consolidation, retrieval, and forgetting information (Roüast and Schönauer). These mechanisms work together to enable organisms to retain and recall information over time. Learning through reading, writing, and listening have different impacts on memory. Understanding neuroscience aspects of memory is important because effective learning is essential for adolescent students to perform academically. Investigating which information intake and storage method is most efficient for adolescent learning and memory retention is essential. This information can inform teaching strategies, technology design, and interventions for individuals with memory difficulties.

Memory can be grouped into several categories, like short-term, sensory, and long-term memory, based on the time, nature, and quantity of the retained information. In this neuroscience lab experiment, the subjects that participated were three categories of 9th and 11th-grade learners tested for memory retention through reading, writing, and listening. The test was a four-sentence paragraph issued by 1) writing/copying, 2) reading, 3) listening, and then answering the questions given for each category. From the three groups that participated in the neuroscience experiment, it was predicted that Group 1, which participated in writing only, best

memorized the four-sentence paragraph and answered the questions about the copied paragraph more correctly. Based on the results examined during this experimental investigation, it was discovered that writing is the most effective technique for memorizing in adolescents. Thus, the most efficient modality for adolescent students is to retain and memorize information in writing rather than reading and listening techniques (Korte).

Memory influences behavior. However, it is not a behavior itself. During this neuroscience experiment, it was discovered that physical activities such as writing stimulate kinematic and motor memories, which aid in the retention of information in the brain (Zimmer and Engelkamp 81). First, motor memory is encompassed in the physical processes of writing, such include fine motor control needed to grasp a pen or pencil to form letters on paper(Korte). Writing involves coordinating hand movements and muscle control, which necessitates motor memory. Secondly, kinematic memory is also involved in writing concerning the spatial and temporal aspects of the movement of the pen or pencil across the surface (Zimmer and Engelkamp 82). Kinematic memory is concerned with memorizing the details of the movement of the pen, like the direction and speed of the lines being drawn and the pressure being applied to the page.

Studying the differences in memory retention through modalities such as reading, writing, and listening in adolescents has societal significance for the following reasons. First, understanding the efficiency of memory techniques assists in identifying the suitable method of education (Cowan et al. 5). Comprehension of how adolescents learn and remember knowledge through different modalities can guide the pedagogical practice of and policymaking concerning the best teaching strategies (Korte). Secondly, as they develop, adolescents can identify the most effective means of communication by understanding their most efficient memory encoding and recall modalities (Zhang). Third, the application of technology in pedagogy, work, health, and personal life, is influenced by the modalities of memory and modes of input, such as reading, typing/writing, and listening. This study can guide the design of digital learning platforms and tools to optimize lesson outcomes.

It was vital to choose this research topic because there are cases where students are reprimanded by teachers for their poor memory retention. For instance, a teacher in an Asian classroom or in a school in India and other countries may induce corporal punishment for students who do not recall the lessons learnt previously or short term notes taken in class or if students are unable to recall particular mathematical equations during a lesson. Based on my personal experience of visiting such environments, I observed firsthand the evidence supporting this claim. One day, I witnessed a teacher physically striking a student for their inability to comprehend an equation, emphasizing the connection between the two incidents. Furthermore, students who fail to remember are subjected to violent physical punishments (UNICEF). Education plays a critical role in molding individuals and societies, thus it should ideally foster an environment that enhances personalized learning, critical thinking, and creativity. When punitive

action, especially violent remarks or physical abuse, are applied to discipline students for academic shortcomings, they have adverse impacts on the learners' self-esteem, motivation, and mental well-being. Additionally, it creates an atmosphere of fear, inhibiting students' ability to express their views and take part in meaningful learning experiences. Hence, studying the suitable memory modes via reading, writing, and listening in adolescents has societal importance for education, technology, health, and communication.

The Neuroscience

The discipline of neuroscience investigates the underlying processes of memory at the cellular, molecular, and systems levels. Memory is a complex mechanism involving most of the brain regions working together. The three major processes of memory include encoding, storage, and retrieval. The encoding process involves the triggers and information from the external environment being transformed into neural representations that can be kept in the brain. The storage of these signals is due to the formation of new neural connections called synapses, which strengthen with time through the long-term potentiation (LTP) process (Moore and Loprinzi 6961). The retrieval stage entails the reactivation of the neural networks in response to external cues or internal stimuli. Several brain regions, neurotransmitters, and nervous system pathways are engaged in different aspects of memory (Díaz, Caffino, and Fumagalli 953). The hippocampus, situated in the medial temporal lobe, is a vital structure for forming new memories. It encodes and retrieves, and consolidates memories from short-term to long-term storage (Cowan et al. 1). The prefrontal cortex is situated in the frontal lobes and executes working memory and executive functions like attention and decision-making. The amygdala is located in the temporal lobes and is crucial for the emotional control of memory, especially fear conditioning.

Neurotransmitters like acetylcholine, glutamate, and dopamine are also involved in memory processes (Díaz, Caffino, and Fumagalli 955). Dopamine is essential for consolidating long-term memories; and motivation and reward-based learning processes. Acetylcholine is utilized in learning, attention, and memory consolidation (Cowan et al. 2). While glutamate is the primary excitatory neurotransmitter in the brain and is applied in synaptic plasticity and LTP (Moore and Loprinzi 6960). The autonomic nervous system (ANS) of nervous system innervation regulates emotional arousal, which influences the memory processes (Battaglia and Thayer). The sympathetic system of the ANS is linked to the "fight or flight" decision and enhances memory consolidation for emotionally arousing occurrences, whereas the parasympathetic system controls the "rest and digest" response and facilitates memory retrieval (Quadt, Critchley, and Nagai 102948). Thus, the ability to input and remember information engages numerous brain regions and mechanisms, such as the prefrontal cortex, hippocampus, amygdala, and neurotransmitters like acetylcholine and dopamine. These brain regions and neurotransmitters are functional in encoding, consolidating, and retrieving information (Cowan et al. 2). Writing

modality involves several brain region responses and is believed to enhance memory consolidation more than reading or listening alone.

Scientific Studies

In Study 1 conducted by Mueller and Oppenheimer (1159-1168), the researchers explored the impact of note-taking methods on memory retention. The study compared the effects of taking notes by hand versus typing on a keyboard. The subjects watched a lecture and wrote handwritten notes or typed on a computer. The major finding was that participants who wrote notes by hand better-understood lectures and remembered more data than those who typed (Mueller and Oppenheimer 1165). The results were measured by their ability to answer conceptual quizzes about the content. The subjects who typed notes on computers did not perform well on the contextual quizzes, whereas the ones who wrote “notes longhand” performed better (Mueller and Oppenheimer 1160). Transcription of lecturer’s verbatim on laptops instead of “processing information” and rephrasing it slowed down memorizing (Mueller and Oppenheimer 1162). The significance of the results lies in the findings that suggest writing by hand may be more benevolent to memory retention than typing because writing by hand involves several areas of the brain than keyboard typing. Hence, the best method of information intake is writing for better memory retention. This study has explored the significance of engaging with the material for memory retention and retrieval. The next study will investigate the depth of processing theory in more detail.

In Study 2, a context of Craik and Tulving (268) investigating the depth of processing theory predicts that deeper levels of processing result in higher memory retention. Subjects were requested to respond yes/no to questions concerning a word (shallow processing) or imagining the meaning of the word (deep processing. The major finding was that subjects who participated in deep processing retained more information than those who participated in shallow processing (Craik and Tulving 268). The results showed that knowledge processing at a deep level is “superior to retaining " information processed at a shallow level (Craik and Tulving 268). The significance can be found in that the depth of engagement with the material is an essential factor in memory retention. Especially processing information at a deeper level. Writing triggers thinking about the meaning of the information and hence can result in better memory retention. The next study will investigate the effect of writing on long-term memory.

In Study 3 conducted by Conway and Gathercole (513-527), the researchers investigated the relationship between writing and long-term memory. The researchers proposed that writing helps to transform knowledge into a more memorable form than just listening or reading it. The study's major findings showed that participants who wrote about a subject remembered more details than those who only read it silently or listened to the story (Conway and Gathercole 513). Thus “writing enhances long-term memory” by transforming information from a perceptual to an

abstract form (Conway and Gathercole 526). The results of this article are significant since they predict that writing can help learners retain knowledge in long-term memory more effectively than other modalities like listening or reading. The next section briefly discusses the comparison of Study 1 and Study 2.

Study 1 by Mueller and Oppenheimer (1159-1168) and Study 2 by Craik and Tulving (268) elucidate the essence of the technique of information intake and the level of engagement with the material for memory retention. In comparison, study 3 by Conway and Gathercole (513-527) expounds on the relationship between writing and long-term memory. On the one hand, Mueller and Oppenheimer (1159-1168) compared the impacts of taking notes by hand versus typing on a laptop on memory retention and suggested that writing enhances memory retention more than typing or reading alone. On the other hand, Craik and Tulving (268) studied the depth of processing theory and suggested that deeper levels of processing result in more efficient memory retention. The study predicted that deeper engagement with the material enhances memory retention. While Conway and Gathercole (526) that writing enables higher retention of memory than reading. The next section will investigate the relationship between memory retention and the modality of information intake (reading, writing, or listening) in adolescents.

Aim and Hypothesis

This investigation aims to determine the most effective method of information intake for memory retention in adolescent students. The mode of grouping is Group 1: Writing only, Group 2: Reading only, Group 3: Listening only. The method of information intake is the independent variable (Reading, writing, listening), while the variable entity is the result (memory retention level). Based on previous research, it is hypothesized that writing will result in higher memory retention than reading or listening. The null hypothesis is that there will be no significant difference in memory retention among writing, reading, and listening. The control group will be Group 2 and Group 3, and the experimental group will be Group 1. The results predicted are such that the writing group will retain higher memory than the reading and listening groups.

Participants

The neuroscience laboratory experiment's main purpose was to determine the most effective method of reading, writing, and listening for remembering or recalling information in short-term memory. Identifying individuals who encounter such tasks in their daily lives is important. Therefore, conducting this experiment with middle and high school students was deemed ideal. Middle and high school students must remember various types of information throughout their school life. For example, they may need to recall math formulas for their math problems, grammar rules for their English class, or historical facts for their social studies class. These

students frequently encounter situations where effective information retention is crucial. Hence, middle and high school students are the ideal participants for this neuroscience study.

The participants' selection was from a High School and Middle School in NYC. These students were randomly chosen to take part in the study. All test subjects were in grades 7 to 11, making them adolescents between 14 and 17 years old. Seventy-two participants participated in this study, with 35 identifying as male, 35 as female, and two as "other." This distribution resulted in approximately 48.6 per cent male, 48.6 per cent female and 2.8 per cent non-binary participants. The study did not consider race as a factor in memory tests. Out of the 72 participants, three were from the 7th-grade class, while the majority, 55 students, were from the 9th-grade class. There were also 12 students from the 10th-grade class and only two from the 11th-grade class. This combination indicates that there were a total of 3 students from middle school and 69 students from high school participating in this study.

The GPA of the middle and high school students was also included under the academic details during data collection (see APPENDIX B). Furthermore, this study's exclusion criterion included factors such as grade level (middle school to high school), physical disability, health status, medication use, and history of neurological or psychological conditions that could affect memory function. The participants with visual, auditory and physical disabilities that would affect their participation in the experiment were excluded.

Materials

All 72 participants were required to complete a consent form (see APPENDIX A) containing information about the experiment, including the purpose of the study, procedures, confidentiality, risks and benefits, voluntary participation agreement, the contact information of the principal investigator, and a statement of consent. Additionally, participants were asked to provide demographic information through the Personal Background Questionnaire survey (see APPENDIX B). This survey included questions about their academic GPA, participant name, gender, grade class, and two additional questions. The first question asked participants which of the three methods (reading, writing, or listening) they believed was most effective for memory retention or recalling information based on their personal experience. The second question asked participants to select an option that best described their learning style (e.g., visual learner, auditory learner, and kinesthetic learner). Collecting this information allowed the investigators to understand the participants' motivation and anticipated results, which could contribute to the data analysis.

Each participant was provided a fully charged Acer Chromebook (MODEL NO. N20Q10 and C724 series Laptop) to complete the experiment and survey (see APPENDIX C). They were also given instructions on a PowerPoint presentation slide (see APPENDIX D) which guided

them on completing the test and interacting with their classmates on the classroom teacher board. It was essential for participants to complete the test as a class rather than individually. Ensuring that no one was left behind. Participants were instructed not to move ahead until instructed to do so and were asked to wait for their peers to finish each section before proceeding to the next. This order was a critical aspect of the study as completing the test as a class allowed all students to have the same amount of time for reading and writing and listening sections to ensuring consistency among the participants.

APPENDIX E contained Part 1: Reading Test, including a reading passage and questions. All participants received the same passage and answered the questions based on it. Similarly, APPENDIX F contained Part 2: Listening Passage and Questions. The listening passage was played on a loudspeaker, ensuring all participants heard the information. Lastly, APPENDIX G (Part 3: writing test and passage) was similar to APPENDIX E and F, featuring a 4-sentence passage that participants copied and wrote by hand. A pen and a foolscap were provided for the writing test. Participants answered questions based on the copied information to assess their short-term memorization skills. Under each test, the “Answer Key” was given to guide the investigators in analyzing the students’ performances.

Procedure

The first step was to identify the 72 participants. All the participants entered the core subject class, and all students sat quietly. Next, all the participants who participated in the study were required to complete the neuroscience consent form. Participants who did not consent to the terms and conditions had their data deleted, and they were excluded from the study as required by the Administration of the Department of Science at the institution. The experiment began with brainstorming the idea and outlining the process. Instructions were presented to the participants to avoid any bias in the experiment. The entire experiment took place in a quiet classroom, and information was presented to the participants through a slideshow. The slideshow instructed the participants on when to move on to each section, emphasizing the importance of completing the test in one sitting to avoid time management bias.

Moreover, all participants were supervised by the principal investigator. As stated in the consent agreement, distractive participants had their data excluded from the experiment without their knowledge. This exclusion was necessary to minimize potential biases associated with those specific participants. The test was administered in six different classrooms under the supervision of teachers and the principal investigator. A quiet environment was provided, with 10-15 students per classroom. A PowerPoint presentation was displayed on the teacher board to guide the participants through each section and facilitate a smooth test completion process.

First, all participants were instructed to grab a laptop and log in using their school credentials. They were then asked to open their school provided google mail accounts to access the Google Form links provided for the test (including Appendices A, B, D, E, F, and G). Once the participants received the Google Form link they were instructed to work on the Neuroscience test without sharing any information with others. The goal was to ensure that nobody was left behind and that everyone completed the task along with their classmates. Participants were also instructed not to move ahead until specifically instructed to do so and to wait for their peers to finish each section before proceeding to the next. After successfully receiving these instructions and accessing the Google Form test the participants were asked to complete the first section "Section 1: About You," which required them to provide their personal information, such as name, gender and grade. After opening the test form via the provided link and they were given approximately 40 seconds to complete this section. Once the 40 seconds had elapsed; all students were expected to have finished the form. The investigators of this experiment then checked the progress and confirmed if all students had completed section 1. In Section 2 the participants were given 40 seconds to complete a survey question regarding their high school GPA grades. The options provided were: A for Honor, B for Exceeds, and C for Meets. They were then asked another question on the test form: "Based on your personal experience, which of the three methods - reading, writing, or listening - is most effective for memory retention (recalling information/memorizing)?" Additionally, participants were asked to select the option that best described their learning method: visual learning, auditory learning, or kinesthetic learning.

Once the 40 seconds elapsed, all participants were instructed to move on to the next part of the test. The first test in this section was Part 1: Reading Test. A 5-sentence passage was presented on the board, and participants were asked to read it once. They were given only 3 minutes to complete this reading. After the 3 minutes, participants were asked to answer seven questions based on the reading within 4 minutes. The test then proceeded to Part 2: Listening section. A 1-minute and 23 seconds long passage was played through a speaker, generated by a voice generator. Participants were allowed to listen to the passage only once. After listening to the passage, they had 4 minutes to answer seven questions based on the content they heard.

Lastly, for the final part of this study all participants were instructed to move on to Part 3: Writing. Each participant received a blank piece of loose-leaf paper and a 5-sentence passage was displayed on the classroom board. They were instructed to copy the entire passage to the best of their ability within a 4-minute time frame. Participants were allowed to take notes while avoiding reading the passage directly; which could introduce potential bias. They were free to use their note-taking or copying methods in the classroom. After completing all three parts of the experiment within the given time frame participants were asked to complete a survey question to identify which method, reading, writing, or listening, they believed to be the most effective after completing the test.

In this neuroscience laboratory experiment the subjects that participated were three categories of 9th and 11th-grade learners tested for memory retention through reading, writing, and listening. The test was a four-sentence paragraph issued by 1) writing/copying, 2) reading, 3) listening and then answering the questions given for each category. From the three groups that participated in the neuroscience experiment each students scores on the test were measured and the data were recorded in a Microsoft Excel sheet on the computer. The statistical analysis used in the experiment was finding the means of the scores of each test category (writing, listening, and reading). Following this the test was concluded and all participants were congratulated for taking 20 minutes of their class time to complete the test. The participants were then wished good luck on their upcoming Neuroscience experiment and dismissed.

Primary Analysis

This primary analysis entails the original analysis conducted by researchers to answer the research questions and objectives of the experiment. It directly examined the collected data through Microsoft Excel plots to address the goals of the neuroscience lab experiment. The data for this analysis was collected through various methods like surveys, questionnaires, interviews, and observations. After the data collection the statistical analyses were performed empirically to aid conclusions. This section of primary analysis is the initial and direct investigation and testing of the positive and null hypotheses, and it encompasses a detailed examination of the data collected to elucidate their significance. The plots are guided by the prompts and questions raised during the neuroscience experiment for the entire process. From data collection to analysis and interpretation of results. In this primary statistical data analysis section, the main data analysis tool used was Microsoft Excel.

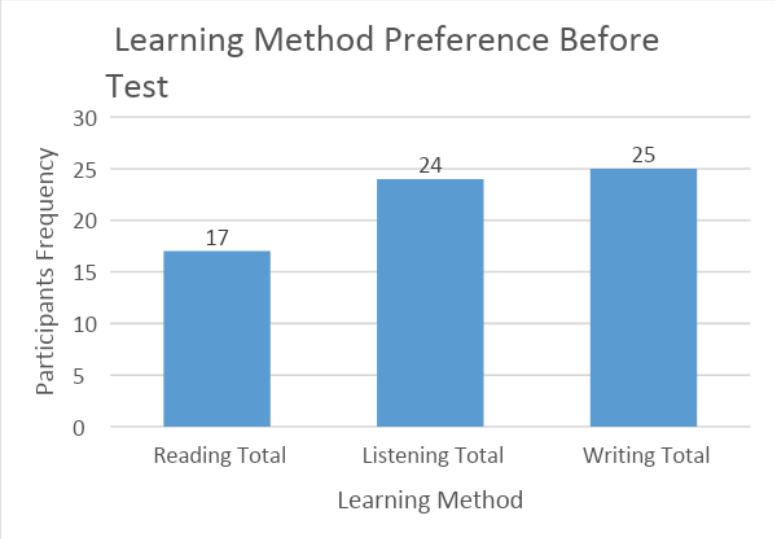
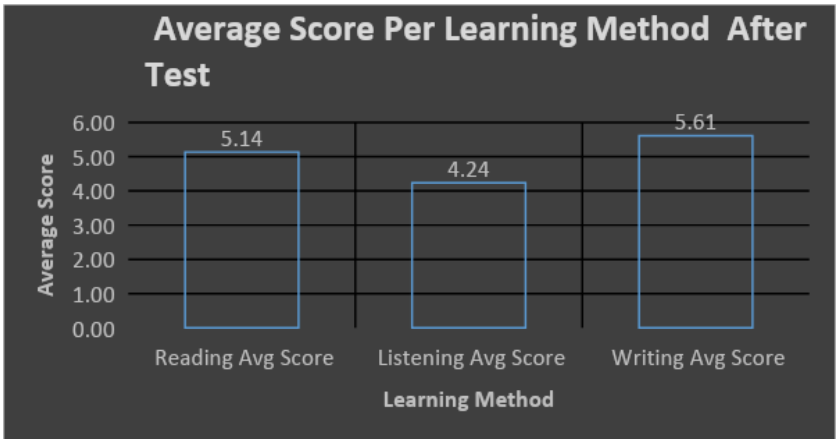


Figure 1. Frequency bar graph comparing learning modalities by participants' beginning learning method preference

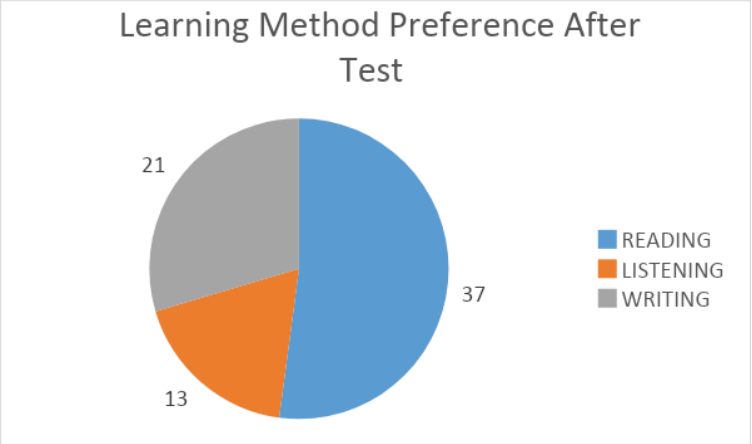
This bar graph represents the participant's preferred learning method before the test. The rectangular bars show the lengths proportional to the values they represent. From Figure 1, the study demonstrated that most participants preferred writing as a modality for memory retention even before they took the test. These findings strengthened the positive hypothesis. This empirical data required no statistical test to prove its statistical significance as the empirical data were collected through direct participant records. However, they provided the foundation for conducting statistical tests to determine the significance of observed patterns or relationships.

Figure 2. A frequency histogram comparing the average scores (out of 7 marks) of each learning modality after the test



From the histogram data plot, the writing Group had the highest average score of 5.61 out of 7 marks, followed by the reading group at 5.14, and lastly, the listening test scored the least in terms of results (4.24), which reflected memory retention. These findings demonstrate that the writing modality is the most efficient learning method for maximum memory retention in adolescents, as illustrated in Figure 2. The mean scores indicated the central tendency of each learning modality which supported the recorded preferred methods, with writing being the most preferred mode of learning and the most efficient memory retention technique, as proven by high test scores.

Figure 3. Pie chart showing the proportions of participants' preferred learning method after the test



From the pie chart in Figure 3, the proportion of participants who preferred the reading modality increased to 37, surpassing the writing modality preference (21) and Listening method (13), as illustrated by the pies representing each category and its proportion. This deviation from the initial graphs was crucial to this study as it refuted the alternative hypothesis. The result will be proven to be statistically significant in the next section.

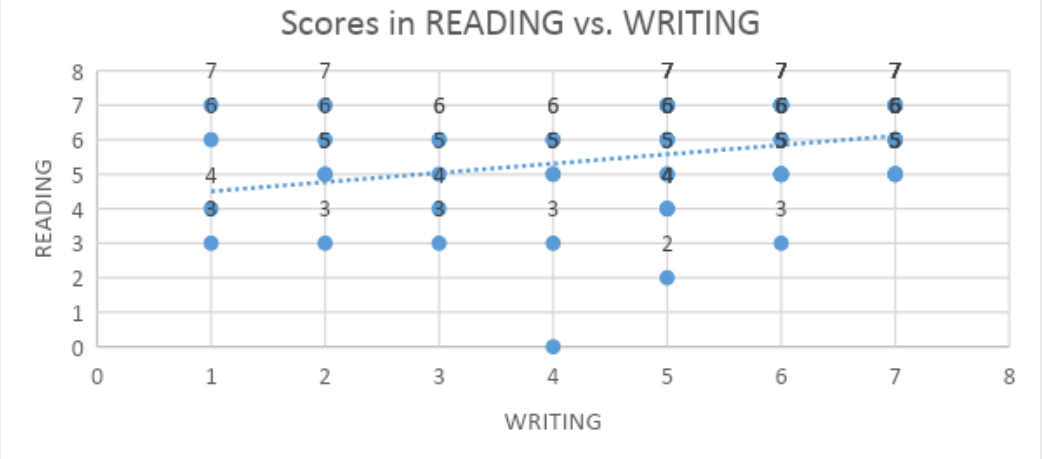


Figure 4. Scatter plot for reading against writing modality scores

From Figure 4, the scatter plot shows a null relationship between writing and reading learning methods scores. The data provided a comprehensive description of the score plots depicted in Figure 4, which shows a scatter plot representing the relationship between reading and writing learning method scores.

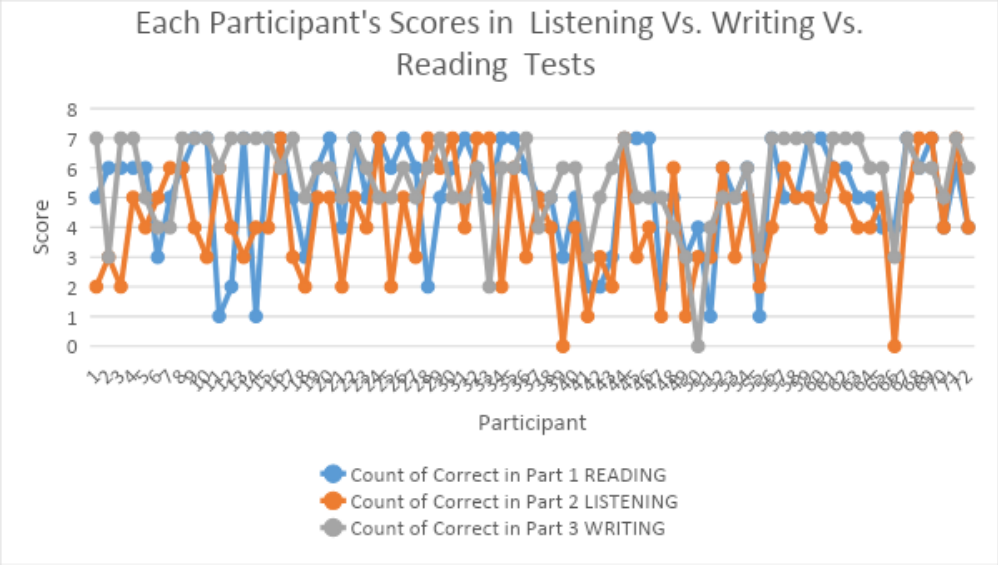


Figure 5. A marked line graph showing the score of the three tests for every participant

The marked graph shows that most participants scored the highest grades in the writing test, followed by the reading and listening tests. The comparison of individual participant's score per test was significant because it showed the mean and mode of the scores which favored writing modality.

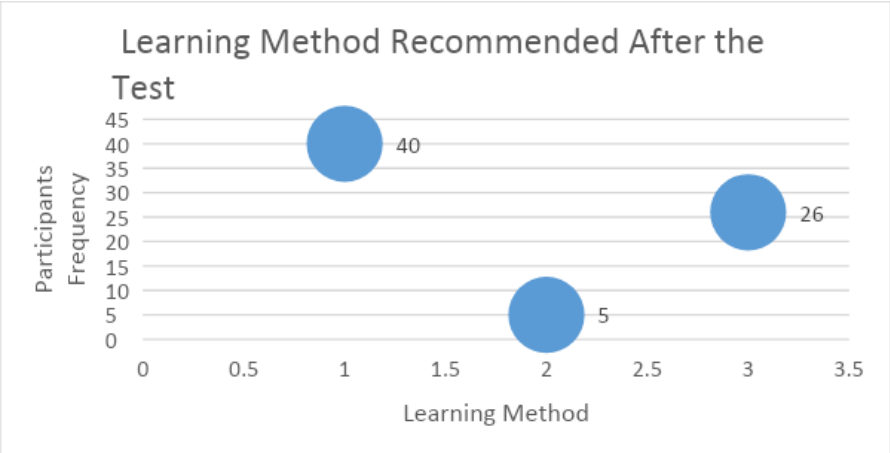
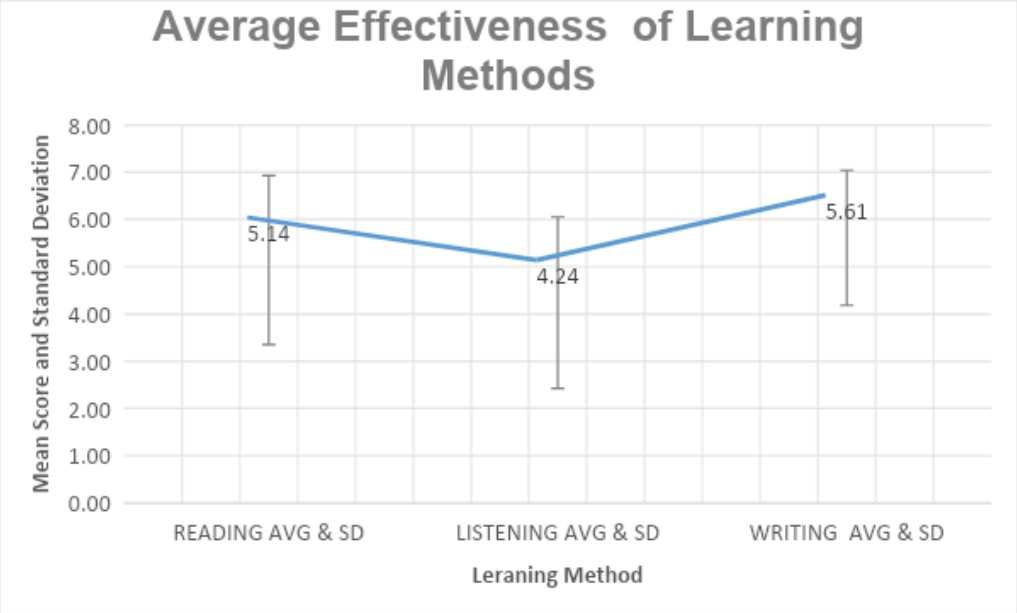


Figure 6. A bubble chart illustrating the recommended learning method based on the test results

From the bubble chart in Figure 6, the recommended learning methods were as follows: 1. Reading (Visual Learner) at a frequency of 40 participants, 2. Listening (Auditory Learner) at a frequency of 5 participants and 3. Writing (Kinesthetic Learner) at a frequency of 26 participants.

The results again confirmed the positive hypothesis by placing reading before writing as the –



most effective learning and memory retention modality.

Figure 7. A line graph illustrating the means and standard deviations of writing vs. listening vs. reading effectiveness

The results in Figure 7 highlight the central tendencies and variability within each modality. Suggesting that the writing modality was the most effective method for enhancing learning outcomes like short-term memory and memory preservation. Determining a variable statistical significance depends on comparing the test statistic (i.e., the t-value) to a critical value or by examining the p-value. Statistical significance (α) is normally defined using a predetermined significance level such as α = 0.05.

T-test:

T-test is the statistical test applied in determining whether there exists a significant variation between the means of two groups of data. T-test is typically applied when comparing the averages of a variable between two independent categories. When comparing the averages of variables under the same group under different conditions. This report calculated the t-value and representing the difference between the average relative to the variability within the learning groups. The t-value was then compared to the significant value; evaluated using the p-value to determine if the observed difference was statistically significant. The formula for the t-test was applied to the two contradictive independent learning methods and writing and reading. The independent samples t-test was applied to compare the means of reading and writing scores independent learning and memory retention modalities.

The formula for independent samples t-test is: t = (M1 - M2) / √ ((SD1^2 / n 1) + (SD2^2 / n 2)), whereby M1 and M2 represent the averages of the reading (5.14) and writing (5.61); SD1 (1.79) reading, and SD2 (1.43) writing represent the standard deviations of the two groups; and n1 and n2 are the sample sizes of reading and writing modalities. After calculations using the Microsoft

Excel tool, the t-value obtained from the display was compared to critical values from the t-distribution to determine the statistical significance of the difference between the reading and writing methods.

t-Test: Paired Two Sample for Means		
	Variable 1:READING	*Variable 2: WRITING*
Mean	5.138888889	5.611111111
Variance	3.248043818	2.07198748
Observations	72	72
Pearson Correlation	0.336008167	
Hypothesized Mean Di	0	
df	71	
t Stat	-2.118714726	
P(T<=t) one-tail	0.018807259	
t Critical one-tail	1.666599658	
P(T<=t) two-tail	0.037614517	
t Critical two-tail	1.993943368	

Figure 8. T-test plots comparing the significance of the difference between mean scores of reading and writing modalities

From Figure 8, the two-tailed p-value (0.038) is lower than the significance level α =0.05. Thus, the difference between means of writing and reading was discovered to be statistically significant. As a result, the null hypothesis became void. This statistical test supports the observed differences between the reading and writing modalities, proving that the writing (X2= 5.61) modality was the most effective for enhancing learning outcomes against reading (X1=5.14). Overall, this t-test helped solve the earlier contradiction by assessing whether the difference between reading and writing groups was likely due to chance or if it is statistically significant, providing evidence for a genuine difference.

ANOVA:

ANOVA refers to the Analysis of Variance. It is a statistical test used to compare the averages of three or more data groups to examine if there are significant differences among them. This neuroscience laboratory experiment compared the mean scores of listening, reading, and writing methods. The single factor ANOVA was used to test the null hypothesis by examining whether there were significant differences in the average scores between the test results of the three learning modalities: writing, listening, and reading.

Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Score in READING	72	370	5.138888889	3.248043818		
Score in LISTENING	72	305	4.236111111	3.337832551		
Score in WRITING	72	404	5.611111111	2.07198748		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	70.28703704	2	35.14351852	12.17743284	9.82938E-06	3.038264
Within Groups	614.7083333	213	2.885954617			
Total	684.9953704	215				

Figure 9. Single-factor ANOVA analysis comparing listening vs. writing vs. reading test result scores from Microsoft Excel data analysis

The ANOVA table summarized the variation between and within the three groups, giving information about the statistical significance of the discrepancies. Concerning the difference between the groups, the sum of squares (SS) for the between-groups variation was 70.29, with 2 degrees of freedom (df). The mean sum of squares (MS) was determined to be 35.14. Next, the within-groups variation had the sum of squares of 614.71, with 213 df. The approximate MS was 2.89 and the total sum of squares was generated as 684.99, totaling 215 df. The test statistic had an F-value, calculated as the ratio of the summation of mean squares among the groups to the mean squares inside each group, which was 12.18. The p-value associated with this F-value was generated as 9.83E-06, affirming statistical significance.

The interpretation of the ANOVA data is as follows. The ANOVA analysis showed a statistically significant discrepancy in the average test results between the listening, writing, and reading methods ($p= 9.82938E-06 < 0.05$). Consequently, this study rejected the null hypothesis. Furthermore, the critical F-value of 3.04 indicates that the variation between the three groups was significantly larger than within each group. Thus, the ANOVA analysis in Microsoft Excel demonstrated the significant differences in the test result scores among the listening, writing, and reading methods, with the writing group having the highest mean (M=5.61), proving it was the most efficient method of memory retention. Since ANOVA does not determine the averages that are different, multiple comparisons via Post Hoc Tests with ANOVA are recommended.

Reading vs Writing Methods SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.336008167							
R Square	0.112901488							
Adjusted R Square	0.100228653							
Standard Error	1.709531153							
Observations	72							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	26.03634	26.03634	8.908936368	0.003906311			
Residual	70	204.5748	2.922497					
Total	71	230.6111						
	Coefficients	*tandard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2.778323263	0.816125	3.404287	0.001101459	1.150613333	4.406033	1.150613333	4.406033193
Count of Correct in	0.420694864	0.140946	2.984784	0.003906311	0.139585943	0.701804	0.139585943	0.701803785

Figure 10. Regression analysis comparing writing and reading test result scores from Microsoft Excel data analysis

Regression in Figure 10 shows the p-value at intercept = 0.0011 (less than α =0.05), implying that the variation in reading and writing modalities is statistically significant. Single-factor ANOVA test showed more consistency, in writing memorization modality, affirmed by less variance in the writing method, 2.07.

Based on the ANOVA plot shown in Figure 9 and using a significance threshold of α = 0.05, a single-factor ANOVA analysis was conducted in Microsoft Excel to compare test scores among the listening, writing, and reading methods. The results were determined to be significant as they showed the variation within the groups with writing method being more consistent.

Secondary Analysis

This secondary analysis section encompasses further analysis of the primary data collected to find more relationships between the variables and the conditions. By comparing the neuroscience experiment results with other subtle aspects, this report utilized the datasets to gain further insights from the secondary data.

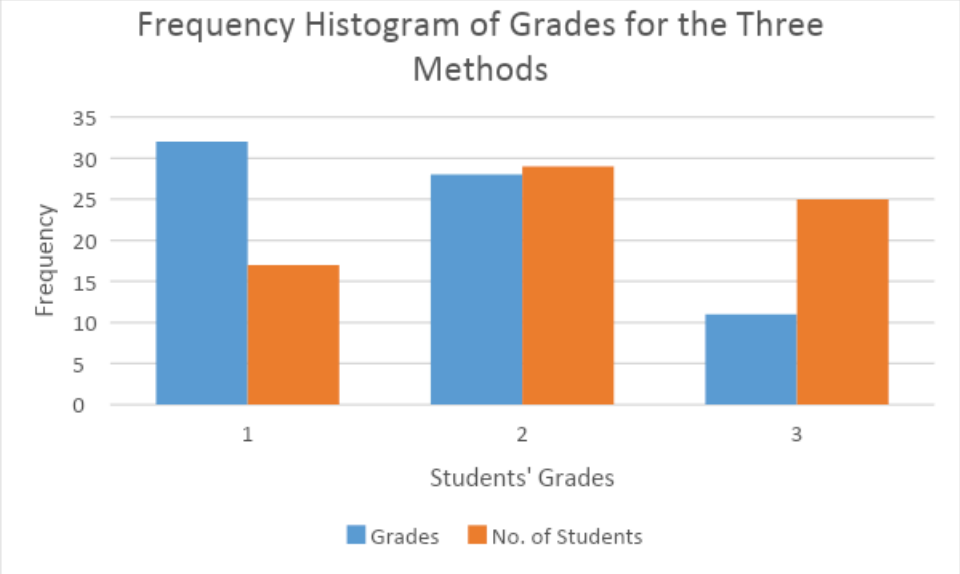
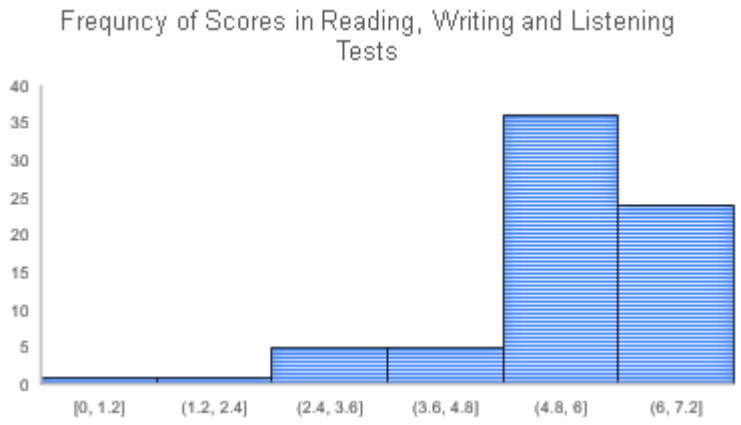


Figure 11. A grading frequency histogram showing the proportion for listening, reading, and writing methods of memorization

The key for the memorization methods: 1 = Reading, 2 = Listening, 3 = Writing. From the histogram shown in Figure 11, writing had more students than reading. However, the listening method had the highest number of students' preferences as a method of study. This plot is dissimilar to the mean scores in Figure 2 in the primary analysis. This finding proves that preference is subjective and cannot be used to establish a suitable learning modality for memory retention in adolescents.

Figure 12. A frequency line graph showing the proportion of proportions of scores in writing, listening, and reading tests



From Figure 12, the reading category, most of the scores were above average for every learning modality, writing, listening, and reading. The similarity in scores showed that the learners' preferred method of the study did not affect the memory retention result of the other tests. The p-value associated with this F-value was generated as 9.83E-06, affirming statistical significance. The interpretation of the ANOVA data is as follows. The ANOVA analysis showed a statistically significant discrepancy in the average test results between the listening, writing, and reading methods ($p = 9.82938E-06 < 0.05$).

ANOVA test showed statistical significance, consequently, this study rejected the null hypothesis. Furthermore, the critical F-value of 3.04 indicates that the variation between the three groups was significantly larger than within each group.

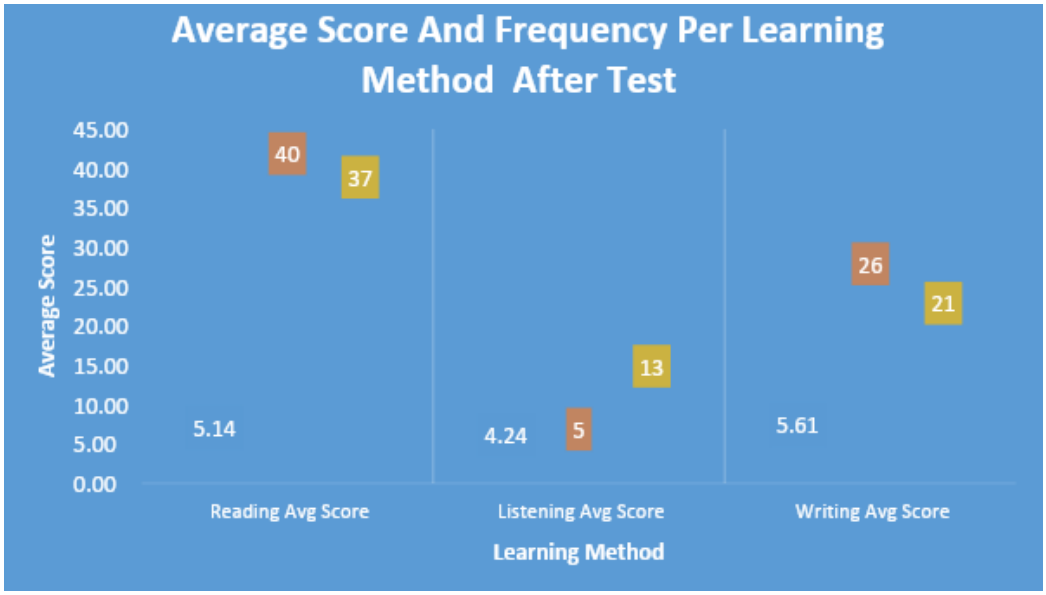


Figure 13. A histogram showing the preference frequency before and after the tests and means of each method of memorization

Figure 13 shows that the preferences increased after the tests for both readings from (37 to 40) and writing (from 21 to 26), but the preference for listening modality decreased from 13 to 5.

The mean scores demonstrated statistical significance by showing the method of memorizing that resulted in the most successful and efficient memorizing method. These findings refute the hypothesis from a neuroscience experiment that posited improved memory retention in adolescents through the reading method. However, the report emphasizes that mean scores are more statistically significant than subjective preferences indicating that the writing method remains the most effective for memorization as demonstrated by the higher mean score.

	Count of Correct in Part 1 READING	*Count of Correct in Part 2 LISTENING*	*Count of Correct in Part 3 WRITING*
Count of Correct in Part 1 READING	1		
Count of Correct in Part 2 LISTENING	0.353494701	1	
Count of Correct in Part 3 WRITING	0.336008167	0.249634882	1

Figure 14. Higher-level statistical analysis table of correlation between reading, writing, and listening methods of learning

The correlation coefficient indicates the direction and strength of the association between variables. From Figure 14, the experiment results show that neither reading nor writing strongly correlates in terms of memory retention.

Analysis/Result

The data indicated that writing and reading modalities of learning are the most effective methods of memory retention in adolescents (Figure 1-7). From the histogram data plot, the writing Group had the highest average score of 5.61 out of 7 marks, followed by the reading group at 5.14, and lastly, the listening test scored the least in terms of results (4.24), which reflected memory retention. The line graph illustrates the mean scores and standard deviations of the writing, listening, and reading modalities recorded after the test. From the line graph with error bars as depicted in Figure 7, the modality results showed central tendencies of the Reading method Average Score of 5.14 while the Reading Standard Deviation was1.79; the Listening Average Score of 4.24, whereas the listening had an SD of 1.81; the Writing Average Score of 5.61 while writing had an SD of1.43. These empirical results showed that the writing method achieved the highest average score of 5.61 (SD = 1.43). These results highlight the central tendencies and variability within each modality, suggesting that the writing modality was the most effective method for enhancing learning outcomes like short-term memory and memory preservation.

The effectiveness scores were then tested to determine the statistical significance of the data (Figure 8-10). The statistical significance of the results was further affirmed by secondary analysis (Figure 11-14). From the ANOVA plot shown in Figure 9, the significance threshold was $\alpha = 0.05$. The Microsoft Excel single-factor ANOVA analysis compared the test scores between the listening, writing, and reading methods and yielded the following results. First, the reading method group had a mean score of about 5.14 and a variance of 3.25. Secondly, the listening

method group had an average score approximated to 4.24 and a variance of 3.34. Thirdly, the writing group had a mean test score of about 5.61, with a variance of 2.07.

From the display in Figure 10, the p-value at intercept = 0.0011 (less than α =0.05), implying that the variation in reading and writing modalities are statistically significant, thus supporting the alternative hypothesis that writing is more efficient in memory retention than reading or listening methods. From the graph in Figure 13, writing had the highest mean score after the test (M= 5.61), but it was the second recommended method of memorizing (F = 37). Reading was the most frequently preferred method of studying (F = 40) but had the second average score (M= 5.14). This study refuted the neuroscience experiment hypothesis that the complex task of writing results in improved memory retention in adolescents. However, this report considers the mean more statistical than the subjective "preferences." Thus, the writing method still is the most effective method of memorization, as proven by the higher mean score.

The correlation coefficient between writing and reading test scores was 0.34, showing a positive association between the variables. The correlation coefficient between writing and listening memorization test scores was 0.25, indicating a weak positive relationship. Similarly, the correlation coefficient between listening and reading memorization test scores was 0.35, indicating a positive association. The correlation coefficients were below 0.5 for all three variables and indicated weak associations (Figure 14). Thus, memory retention by one method of learning is considered independent of the modality. Although the results obtained for the preferred and recommended learning methods supported that reading was the most efficient studying technique, the statistical scores (arithmetic means) proved that writing is the most efficient modality for memory retention among adolescents. Both primary and secondary analyses supported the hypothesis that the writing modality of learning was the most efficient method to instill memory retention in adolescents. This study supported the alternative hypothesis because the arithmetic mean was more objective than the participants' subjective preferences and the researchers' subjective recommendations. Thus, from the statistical analysis of the data collected from the 72 voluntary participants, during this neuroscience laboratory experiment, it was deduced that the writing modality is more efficient in helping adolescent students retain information than reading or listening.

Discussion: Relate Results to the Hypothesis

The results of the neuroscience experiment supported the alternative hypothesis that writing is the most effective method of information intake for memory retention in adolescent students compared to reading or listening. The investigation discovered that learners who engaged in writing exhibited higher memory retention levels and better understanding than reading or listening. This aligned with secondary research findings that participants who wrote about a test remembered more details and comprehended lectures better than subjects who read silently or listened. Moreover, the ANOVA analysis confirmed the findings by illustrating a statistically significant discrepancy in the average test results among the three memorizing modalities. The rejection of the null hypothesis suggested a significant difference in memory retention among writing, reading, and listening. The discrepancy among the three groups was significantly larger than within each group, indicating that the writing modality had the greatest influence on memory retention. The results emerged due to the active brain engagement and cognitive processing involved in the motor-kinaesthetic writing process that aids in encoding information more effectively. Furthermore, writing enhances attention, focus, and organization, thus

enhancing memory retention and comprehension of the material. Consequently, this experiment provided strong evidence supporting the effectiveness of writing as the most efficient learning modality for maximizing memory retention in adolescents.

Relate it to Background Research

The results of this neuroscience experiment were oriented to the findings of background research discussed in the introduction, which supported the hypothesis that writing is the most effective method of information intake for memory retention in adolescents in contrast to reading or listening. Numerous secondary sources highlighted in the introduction prove that participants who engage in the writing process retained the highest memory and better-understood concepts than participants who only read or listened. For example, Conway and Gathercole (513) asserted that subjects who wrote about a topic recalled more details than the ones who only read or listened to the subject. These results supported the claim that writing enhances long-term memory by reshaping the data from a perceptual to an abstract form (Conway and Gathercole 526). Additionally, the material by Mueller and Oppenheimer (1165) proved that subjects who wrote notes by hand retained more lecture memories and understood better than the ones who typed. The findings affirm that writing triggers deeper thinking and engagement with the material, resulting in better memory retention. In addition, the secondary resources indicated that deep information processing, which involves engaging with the material at a meaningful level, leads to better memory retention than shallow processing (Craik and Tulving 268). This research focused on the significance of cognitive engagement, which can be enhanced through writing.

Research from Moore and Loprinzi showed that memory storage is facilitated by forming synapses and strengthening neural connections (6961). Furthermore, Zhang suggested that the comprehension of one's efficiency in memory encoding and recall modalities aids in determining the suitable method of communication. Díaz, Caffino, and Fumagalli explained that several brain regions, neurotransmitters, and nervous system pathways facilitate memory (953), such include glutamate, acetylcholine, and dopamine (955). The autonomic nervous system (ANS) impacts memory processes by controlling emotional arousal (Battaglia and Thayer), the sympathetic system facilitates memory consolidation for arousing events, and the parasympathetic system enhances retrieval (Quadt, Critchley and Nagai 102948). Investigations by Mueller and Oppenheimer (1159-1168), Craik and Tulving (268), and Conway and Gathercole (513-527) delved into the connection between writing, reading, listening, and long-term memory retention. Mueller and Oppenheimer compared note-taking methods with writing and discovered that writing enhanced memory retention more than typing or reading, whereas Craik and Tulving highlighted deeper interaction with the material resulting in better memory. Finally, Conway and Gathercole emphasized the increased memory retention through writing modality compared to reading (526).

The statistical data analysis presented in the analysis section also supported the findings from the background research. The preferences for reading and writing methods increased after the tests, while the preference for listening decreased. This finding agrees that participants preferred writing as a modality for memory retention before they even took the tests, as mentioned in the introduction. Moreover, the correlation coefficients between the different methods (writing, reading, and listening) and memory retention test scores were generally weak, indicating that memory retention by one learning modality is considerably independent of others.

This finding was consistent with the notion that the effectiveness of writing as a memory retention method was not solely dependent on its relation to the rest of the methods but rather on the cognitive processes encompassed in the writing process. Generally, the outcomes of the investigation were in alignment with the background research mentioned in the introduction. The sources proved that writing is the most efficient learning modality for maximum memory retention in adolescents, as supported by previous studies. The writing process promotes deeper engagement with the material, triggers critical thinking concerning the meaning of the data, and enhances the transformation of information into long-term memory. The findings had important implications for education and pedagogical practices, as comprehending the efficiency of memory techniques guides the development of effective learning and teaching strategies. By recognizing the benefits of writing for memory retention, educators can incorporate writing activities into instructional methods to optimize learning outcomes for adolescent students.

Limitations and Bias

The neuroscience laboratory experimental design of this study conducted in a school environment introduced several limitations that could have impacted the results and introduced potential sources of bias. First, the study relied on voluntary participation, which may have introduced a self-selection bias since some subjects who chose to participate may have had a pre-existing preference for writing as a memorization method. Self-selection bias could result in the overrepresentation of participants who already advocated for writing modality, potentially escalating the effectiveness of writing compared to reading or listening. Furthermore, the experimental population was limited to 9th and 11th-grade students, which restricted the generalizability of the findings to other age groups and levels of education. In addition, the nature of the experimental conditions may have influenced the results. The participants in the control groups (reading and listening) did not actively engage in encoding the information like the experimental group (writing). The lack of active engagement may have curtailed the control groups' memory retention scores. The study also relied on a single test paragraph that may not have entirely captured the most appropriate contexts for each modality of memorization. This limited combination of aspects may have introduced limitations in the ecological validity of the neuroscience experiment.

Next, some forms of bias that influenced the experimental outcomes include confirmation bias, as the researchers had a prior expectation that writing would be the most effective modality. Confirmation bias affected the interpretation of the results and the emphasis on the effectiveness of the writing modality. Moreover, the Hawthorne effect or observation bias could have influenced the outcomes, as subjects might have modified their behaviour or responses due to the awareness of being part of an experiment (MRC/CSO Social and Public Health Sciences Unit). Hawthorne effect could have artificially increased the performance in the writing condition, for instance, due to the test's perceived significance. The neuroscience experiment design could have had limitations that influenced the outcomes and instituted sources of bias. The main limitations were the dependence on voluntary participation, limited sample size, inadequate engagement in the control groups, and the application of one test paragraph. The bias entailed confirmation bias, self-selection bias, and observation bias. The limitations and biases discussed should be considered when interpreting the outcomes and their repercussions for the effectiveness of writing memory retention modality among adolescents.

Conclusion

This neuroscience experiment studied the influence of different memory retention methods (reading, writing, and listening) among adolescents. The outcome aligned with the hypothesis that writing is the most effective modality for memory retention compared to reading and listening. Our findings demonstrated that the writing process involves active encoding and the stimulating kinematic. Motor memories and enhancing retention. The results are significant in educational practice and strategies. Teachers and educators can incorporate more writing-based activities into their teaching practice to promote memory retention in adolescent students.

Moreover these experimental results should inform the design of online learning platforms and tools to optimize learning outcomes and promote memory retention. Additionally in the future two fields of investigation can be explored. First future research should study the long term effect of writing on memory. Developing the current experiment focuses on short term memory retention and a longitudinal examination could analyze how writing as a learning method affects long-term memory consolidation and retrieval. Second, examining the relationship between writing and cognitive processes like attention and executive functions aslo can provide an understanding of the pertinent mechanisms that enhance the effectiveness of writing memory retention modality and performance.

Finally this neuroscience experiment affirmed that writing is adolescents' most efficient memory retention method. The outcomes are important for guiding educational practices and designing learning interventions. Further research could expound on the long-term impacts of writing on memory retention thus promoting deeper understanding and optimizing the memorizing mechanisms.

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APPENDIX

APPENDIX A | *Consent Form*

Consent Form for Memory Retention Experiment

Investigating the Impact of Reading, Writing, and Listening on Memory Retention

Purpose of the Study
The purpose of this study is to investigate which of the three methods - reading, writing, or listening - is the most effective in memory retention among students in grades 6-11.

Procedures
By participating in this study, you will be asked to complete a series of learning tasks using one of the three methods (reading, writing, or listening). Following the learning tasks, you will be tested on the information you have learned to assess your memory retention. The entire process will take approximately 15-20 min to complete. and "you" AGREE to COMPLETE this full procedure.

Confidentiality
Your participation in this study is confidential, and your identity will not be disclosed in any reports, publications, or presentations. The research team will use a unique identifier to track your data, and the study results will be reported in aggregate form only.

Risks and Benefits
There are no significant risks associated with participating in this study. The information gained from this study will contribute to the understanding of the most effective methods for memory retention in learning and education, which may help improve teaching practices and learning outcomes in the future.

Voluntary Participation
Your participation in this study is voluntary, and you may withdraw at any time without penalty. If you choose not to participate or decide to withdraw, it will not affect your relationship with the researchers or the educational institution.

Contact Information
If you have any questions or concerns about the study, please contact the principal investigator
Dep. of Neuro
Mohammad Ibrahim at – mibrah04@g.syr.edu only when school hours and when in session.

Statement of Consent
I have read and understood the information provided in this consent form. I have had the opportunity to ask any questions I may have, and I voluntarily agree to participate in this study.

APPENDIX B | *Personal Information And Academic, Beginning Survey*

Your Name: _____ _____
Student: (First and Last Name)

Gender: Male, Female, Other

What grade are you in at ICE: ____

What is your current overall High School (if you are in High School) OR Middle School (if you are in Middle School) GPA in Letter Grade?

Letter Grade	Ranges %	GPA
A	93 - 100	4
A-	90 - <93	3.7
B+	87 - <90	3.3
B	83 - <87	3
B-	80 - <83	2.7
C+	77 - <80	2.3
C	73 - <77	2

(SEE TEST GOOGLE FORMS for options)

Beginning Survey Question 1:

(pick one option)

Based on your personal experience, which of the three methods - reading, writing, or listening - is most effective for memory retention (recalling information/memorizing)?

- ➔ For me, reading is the most effective method, as I can better remember a concept when I read it.
- ➔ For me, Writing is the most effective method, as I can better remember a concept when I write it.
- ➔ For me, listening is the most effective method, as I can better remember a concept when I listen/hear it.

Beginning Survey Question 2:

(pick one option)

What option best describes you?

- ➔ I am a visual learner: who prefers to see information in writing, diagrams, or images.
- ➔ I am an auditory learner: who learns best through listening.
- ➔ I am a kinesthetic learner: who prefers learns best through hands-on experiences and physical activities.

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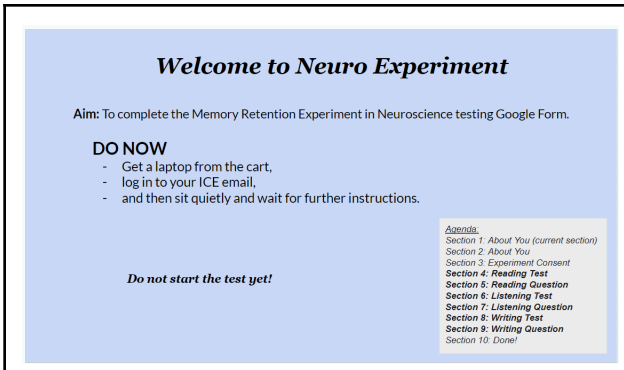
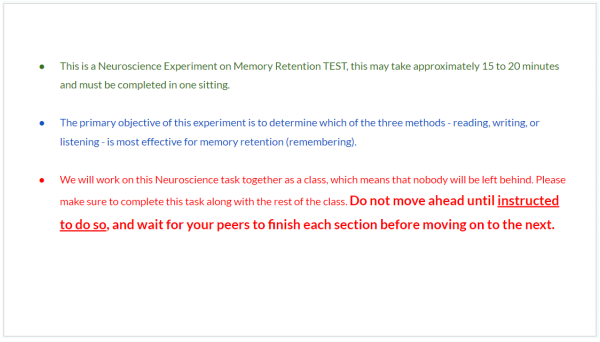
APPENDIX C | *Laptop*

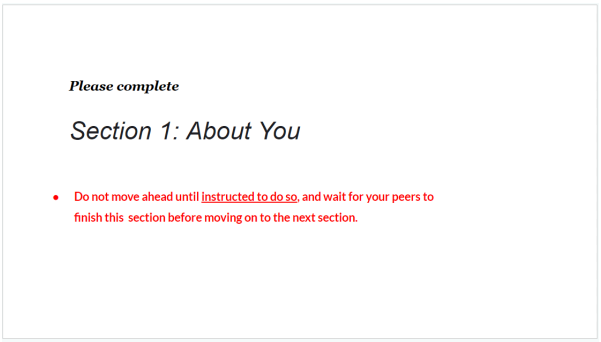
Acer Chromebook

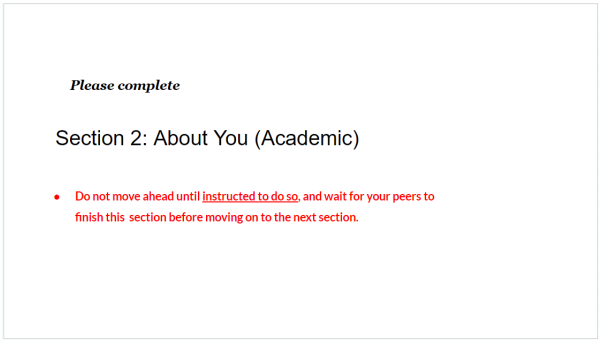
**MODEL NO. N20Q10 and
C724 series Laptop
Series 2023**

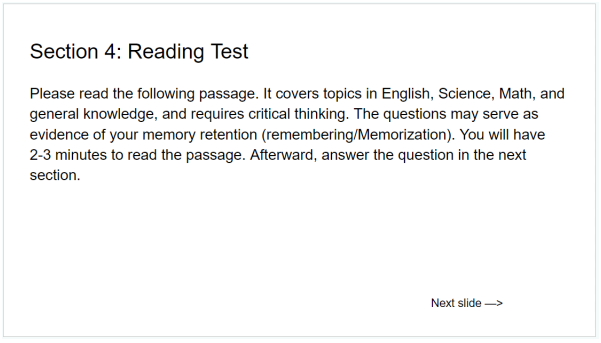
APPENDIX D | *Instruction Google Slide*

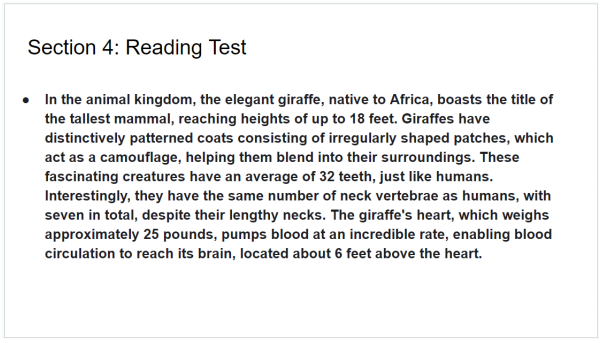












Please complete

Section 5: Reading Question

- Do not move ahead until instructed to do so, and wait for your peers to finish this section before moving on to the next section.

Section 6: Listening Test

Now, you will listen to a one-minute-long passage. Based on this passage, you will answer a few multiple-choice questions. Please listen to the passage carefully, as the audio will only be played once.

Please complete

Section 7: Listening Question

- Do not move ahead until instructed to do so, and wait for your peers to finish this section before moving on to the next section.

Section 8: Writing Test

This is the final segment of this experimental test. Please write down the following three-sentence passage about "The Great Barrier Reef." You will have 3-4 minutes to copy the entire passage. Write each sentence carefully. Once you finish copying the passage, I will collect the piece of paper from you, and then you can move to the next section to answer a few questions based on this passage.

Next slide —>

Section 8: Writing Test

- The Great Barrier Reef, located off the coast of Australia, is the world's largest coral reef system. It spans over 1,400 miles and is composed of roughly 2,900 individual reefs, providing a home to more than 1,500 species of fish. This underwater ecosystem also hosts about 600 types of coral, which are actually living organisms. Coral polyps, the tiny creatures that create coral, extract calcium carbonate from seawater to build their external skeletons. Unfortunately, rising ocean temperatures and pollution have contributed to coral bleaching, a process where corals expel the algae that give them their vibrant colors, leaving them more susceptible to disease.

Please complete

Final section
Section 9: Writing Question

- Do not move ahead until instructed to do so, and wait for your peers to finish this section before moving on to the next section.

Please complete

Final section
Section 10: Finishing Survey

Thank you for completing this neuroscience experiment. Good luck with your future neuroscience experiments.

Notice: This Google Slide Can be accessible here: Welcome to Neuro Experiment

APPENDIX E | *Reading Test passage and Questions*

In the animal kingdom, the elegant giraffe, native to Africa, boasts the title of the tallest mammal, reaching heights of up to 18 feet. Giraffes have distinctively patterned coats consisting of irregularly shaped patches, which act as a camouflage, helping them blend into their surroundings. These fascinating creatures have an average of 32 teeth, just like humans. Interestingly, they have the same number of neck vertebrae as humans, with seven in total, despite their lengthy necks. The giraffe's heart, which weighs approximately 25 pounds, pumps blood at an incredible rate, enabling blood circulation to reach its brain, located about 6 feet above the heart.

Reading Part 1: Questions

Which continent are giraffes native to?
a. Asia
b. Africa
c. Australia
d. South America

What is the primary purpose of a giraffe's patterned coat?
a. Attracting mates
b. Camouflage
c. Regulating body temperature
d. Intimidation

How many teeth do giraffes have on average?
a. 20
b. 24
c. 28
d. 32

How many neck vertebrae do giraffes have?
a. 5
b. 7
c. 9
d. 11

Approximately how much does a giraffe's heart weigh?
a. 10 pounds
b. 15 pounds
c. 20 pounds
d. 25 pounds

How does a giraffe's heart help blood circulation reach its brain?
a. By pumping blood at a slow rate
b. By pumping blood at a moderate rate
c. By pumping blood at a rapid rate
d. By pumping blood at an irregular rate

Which of the following is NOT a similarity between humans and giraffes?
a. Number of teeth
b. Number of neck vertebrae
c. Patterned skin
d. Native continent

Answer Key: **b. Africa, b. Camouflage, d. 32, b. 7, d. 25 pounds, c. By pumping blood at a rapid rate, c. Patterned skin**

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APPENDIX F | *Listening Test passage and Questions*

The Amazon Rainforest, often called the "lungs of the Earth," covers an area of about 2.7 million square miles, roughly equivalent to the size of the contiguous United States. This dense, diverse ecosystem houses approximately 400 billion individual trees, representing over 16,000 species. Remarkably, the Amazon is also home to one in ten known species on Earth, including the famous poison dart frog, which gets its name from indigenous peoples using its toxic secretions on their blowdarts. The Amazon River, which flows through the heart of the rainforest, stretches approximately 4,000 miles in length, making it the second-longest river in the world. Calculating the river's width can yield varying results, as it ranges from 1 to 6.2 miles wide, depending on the season and location.

Listening Test Questions

How large is the Amazon Rainforest?
a. 1.5 million square miles
b. 2.7 million square miles
c. 3.9 million square miles
d. 5.1 million square miles

How many individual trees are there in the Amazon Rainforest?
a. 100 billion
b. 200 billion
c. 300 billion
d. 400 billion

How many tree species are found in the Amazon Rainforest?
a. 4,000
b. 8,000
c. 12,000
d. 16,000

What proportion of known species on Earth are found in the Amazon Rainforest?
a. One in five

What is the source of poison for indigenous peoples' blowdarts in the Amazon Rainforest?
a. Poison ivy
b. Venomous snakes
c. Poison dart frog
d. Toxic plants

How long is the Amazon River?
a. 2,000 miles
b. 3,000 miles
c. 4,000 miles
d. 5,000 miles

What is the Amazon River's ranking in terms of length among the world's rivers?
a. First
b. Second
c. Third
d. Fourth

b. One in ten c. One in twenty d. One in thirty	

Answer Key: b. 2.7 million square miles, d. 400 billion, d. 16,000, b. One in ten, c. Poison dart frog, c. 4,000 miles, b. Second

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APPENDIX G | *Writing Test passage and Questions*

The Great Barrier Reef, located off the coast of Australia, is the world's largest coral reef system. It spans over 1,400 miles and is composed of roughly 2,900 individual reefs, providing a home to more than 1,500 species of fish. This underwater ecosystem also hosts about 600 types of coral, which are actually living organisms. Coral polyps, the tiny creatures that create coral, extract calcium carbonate from seawater to build their external skeletons. Unfortunately, rising ocean temperatures and pollution have contributed to coral bleaching, a process where corals expel the algae that give them their vibrant colors, leaving them more susceptible to disease.

Writing Test passage Questions

Where is the Great Barrier Reef located? a. Off the coast of Florida b. Off the coast of Mexico c. Off the coast of Australia d. Off the coast of Japan What is the approximate length of the Great Barrier Reef? a. 700 miles b. 1,000 miles c. 1,400 miles d. 1,800 miles How many species of fish call the Great Barrier Reef home? a. 500 b. 1,000	What do coral polyps extract from seawater to build their skeletons? a. Calcium carbonate b. Magnesium sulfate c. Sodium chloride d. Potassium iodide What is the primary cause of coral bleaching? a. Rising ocean temperatures and pollution b. Overfishing c. Natural disasters d. Predators What do corals expel during coral bleaching? a. Algae b. Calcium carbonate c. Seawater

c. 1,500 d. 2,000 How many types of coral are found in the Great Barrier Reef? a. 300 b. 450 c. 600 d. 750	d. Other coral polyps

Answer Key: **c. Off the coast of Australia, c. 1,400 miles, d. 2,900, c. 1,500, c. 600, a. Calcium carbonate, a. Algae**

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