

How Successfully Can Laying Out Information in Distinct Designs Induce People to Utilize Chunking and Linking Memory?

Zier Wang

Columbus Academy, Gahanna, 43230, USA

ziziercc89@gmail.com

Abstract. This study investigates whether specific design layouts of mnemonic devices can enhance short-term memory performance by inducing the use of chunking and linking memory techniques. While prior research has demonstrated the effectiveness of mnemonic devices in improving memory outcomes, little attention has been paid to how specific visual layouts influence the application of these techniques, particularly among teenagers. Focusing on participants aged 13 to 19, this study adopts a “stealth training” approach, encouraging the development of memory strategies through design without explicit instruction. Using Psytoolkit, participants were randomly assigned to three stimulus conditions—chunking, linking memory, and random natural chunking—and asked to memorize word lists across three experimental blocks. Memory performance was assessed through response time and accuracy, analyzed using linear mixed-effects models to account for imbalanced conditions and experimental fatigue. The results indicate that chunking layouts produced the most effective short-term memory performance, while linking memory resulted in slower response times after controlling for fatigue effects, likely due to increased cognitive load. Although participants did not consistently report intentional use of the introduced techniques, the findings suggest that design layouts can influence memory outcomes independently of conscious strategy use. Overall, this study highlights the importance of layout design in mnemonic devices and suggests practical implications for educational contexts, particularly in supporting teenagers’ memory processes through implicit instructional design.

Keywords: Mnemonic devices; Chunking; Linking memory; Short-term memory; Layout design; Cognitive load; Adolescents.

1. Introduction

The exploration through mnemonic devices, techniques that assist humans in achieving better memory outcomes, has been the primary focus of cognitive science, as researchers delve into the correlation between the usage of techniques and memory outcomes. Specifically, short-term memory (STM) is an important memory that people should have, as it is considered a transformation for memory from short-term to long-term. Beyond the relative relations between techniques and memories, people haven’t known that there are specific ways for mnemonic devices in order to improve memory performance, which are not emphasized by teachers and schools. Thus, the central investigation of this study is whether special designs, particularly chunking and linking memories, in mnemonic devices can enhance memory retention in the short term by inducing people to practice these techniques.

In this study, we will also refer to “stealth training” that people will develop the processes unintentionally for memory in the design without notice, and it, in designing the layouts of the experiment, encourages participants to develop the memory skills without detection. The main target of this experiment is teenagers from 13 years old to 19 years old. The basic logic of the experiment in the study is that participants are introduced to the two concepts — linking memories and chunking. After introducing the basics, questions about whether they have used these techniques before in memorizing processes are asked. Then, the experiment is randomized by Psytoolkit, a software created explicitly for measuring response times to psychological stimuli, to assign which indicated designs participants should use, and they need to memorize 25 words in grids for three rounds within

a certain time interval. After time ends, they are required to recall the words that appear in the previous grids, where distraction words exist in between. After the testing process is done, the survey asks to indicate if people are actually using the techniques that were introduced at the beginning.

With this investigation, though we are targeting mainly teenagers who are in school, various contexts can be implemented into this study for future help. In educational conditions, teachers can insert the techniques into the teaching processes and context to better help students' academic performance. Moreover, in working fields, training modules can be updated to assist workers in the enhancement of critical information. Not only in these two fields, but the outcome can also indicate if mnemonic devices are effective in cognitive science, studying some diseases that might affect teenagers' memories.

Overall, this investigation fills the gaps of not recognizing the importance of specific layouts for mnemonic devices with the help of the experiment and the potential benefits in different fields. As the study proceeds, the main focus is on the memorizing processes with the help of specialized designs of mnemonic devices.

2. Literature Review

2.1 Background and Motivation

Working memory (WM) is a system for storing information that can be held to execute cognitive tasks, and even transfer memories to long-term memory (LTM)[1]. The most common explanation for short-term memory (STM) is the memory that activates long-term memory; however, this explanation would underestimate STM's importance, as everything we memorize requires STM to enter LTM[2]. It could be seen that WM has a similar concept to STM, while differences remain. WM includes more theories related to cognitive tasks, retains and operates memory in STM, and uses attention to select and deploy within STM[3]. By associating information that is easier to remember, mnemonic devices help people to memorize sophisticated knowledge and material they need to understand.

Prior research has demonstrated how mnemonic devices can be used efficiently in learning, and they can often enhance the learning process; however, this knowledge has faded away over time[4]. While these techniques are known for improving memory, little research has explained how specific design elements impact the effectiveness in teenagers. Within this study, linking memory and chunking are implemented to test the short-term memory of people with a special design. Linking memory, the University of Central Florida, emphasizes an individual's ability to associate pieces of a list of examples in a sequence. Generally, by using this technique, individuals create a narrative of the pieces in order to enhance their memory of the information. As mentioned in this article, one downside of linking memories is that if one image is lost, others cannot be related. While linking memory accentuates connections between information, chunking emphasizes the generalization of information. It assists people in chunking large amounts of information into groups, so that the brain can create a compacted material about the information[5].

To address the problem of whether designed elements of mnemonic techniques, such as chunking and linking memory, can influence memory recall performance, it is essential to understand existing research on the related topic. While prior research has investigated the effectiveness of utilizing mnemonic techniques for memory outcomes, little research has been conducted about detailed layouts when people are using memory techniques, primarily focusing on teenagers who are still in the process of cognitive development. This study builds on the foundational theories that previous researchers established about STM and memory techniques, as well as evidence supporting that mnemonic techniques should be introduced in educational fields. The following part about the literature review explores the basic mechanisms of chunking and linking memory, as well as the important effects that mnemonic techniques have on adolescence, and the potential enhancement of memory performance.

2.2 Related Work

Throughout the history of researching mnemonic devices, the importance of mnemonic devices has been recognized more significantly by researchers in the field of cognitive science. In the early 1980s, one paper stated precisely what the potential issues were that caused the lack of progress in mnemonic devices, while also explaining why these devices should be studied. Essentially, the topic, mnemonic devices, was sometimes considered an outlier in memory research. Researchers debated the absence of a precise and unified definition of mnemonic devices, noting that they vary across multiple studies, and that Bellezza highlights differing viewpoints on how to classify and characterize them[6]. Moreover, certain preexisting components might be necessary to conduct research on these techniques properly, which requires a complex methodology in the process of understanding the topic. However, except for the potential issues during researching memory techniques (mnemonic devices), the paper also indicates that mnemonic devices should be studied. One of the reasons is that these techniques could have educational applications, suggesting that the rate of learning could be enhanced[6]. Likewise, this paper aims to underscore the potential of these designs for memory techniques to raise memory performance, with a specific focus on teenagers, emphasizing the need for education on memory techniques.

Adolescence is a crucial period for cognitive development. During this development, memory and cognitive learning continue to mature. By implementing mnemonic devices in the education field, schools and instructors could improve students' abilities to memorize complex information, such as historical events and psychological concepts. Not only can academic areas be underlined by memory techniques, but creativity can also be enhanced. According to a recent study in 2020, the experiment has shown that the control group, who were not using visual mnemonic devices, had only a slight increase in creativity over time, supporting the valid hypothesis that visual mnemonic devices enhance creativity in students[7]. Based on the impacts of visual mnemonic devices, the researchers also mentioned that they are incredibly suitable for educational purposes, which can promote creativity in students' courses. Moreover, research on mnemonic devices in some studies, such as a 1990 study, shows that the techniques can foster metacognitive skills, enabling teenagers to have better control over their learning processes and academic performance[8].

Previous studies have examined the effectiveness of mnemonic devices in terms of the memory outcomes of applying them. In a study on mnemonic devices and natural memory, researchers determined the memory outcomes from using visual images of different subjects under three different conditions. The results show that subjects in the familiar cues condition have better recall performance than those in the unfamiliar cues condition. Moreover, those in the unfamiliar cue condition performed better than the no cues group. In this study, the researchers highlight the conclusion of natural learning that participants do not have to try to learn for effective learning, and they drew conclusions that corresponded to various conditions while the subjects were using different mnemonic devices[9].

With all the outcomes that previous studies had addressed, one thing that scientists had not conducted was the specified designs for mnemonic devices, and whether these designs affect the consequences of memory performance. To make this concept more forward-thinking, this paper addresses the effects on layouts of chunking and linking memory and determines whether these designs improve recall performance among teenagers.

3. Methodology

The study recruits 12 participants from local networks and social media, and the age range is 13-19 years old. There are three different results for each participant based on the sequences that they got from randomization in Psytoolkit. Moreover, based on the surveys, we know how participants feel and whether they used the concepts we introduced. Inclusion criteria are that the participants should be healthy and not have any diagnosed cognitive losses, and be fluent in English. Exclusion

criteria include that participants shouldn't have conducted similar studies or training in mnemonic devices, as belief perseverance may occur.

3.1 Materials and Measures

For this study, the whole process will be done in Psytoolkit with the experiment and the surveys. By designing the experiment, participants need to memorize three different sets of words based on random sequences, and then they will be asked about the frequency of using the techniques while providing demographic questions at last. In the experiment, there are three different layouts for each set of words, with three sets of words in total. We are trying to set up a potential picture that participants can relate to the two concepts and use them (the sequence of the words is the same): for chunking, huge gaps exist between every column with colored underlines, which the words in each column is categorized; for linking memory, colored lines are connected for words that are related, which could've induce people to create stories; for random natural chunking, it has similar layouts as chunking, but the gaps are much smaller, which people might follow natural reading from left to right (so the chunking by groups might not exist). The first survey inquires about the frequency of using the two techniques before, while the second survey is about the frequency of using them during the memorization process. Lastly, age and gender are asked at the end of the experiment.

3.2 Procedure

First, an introduction about the experiment and concepts about mnemonic devices is provided. After the basic introduction, Psytoolkit randomly assigns the sequences to be used in the experiment based on chunking, linking memory, and random natural chunking. At the beginning of the actual experiment, participants are provided with an explanation of the concepts of linking memory and chunking, so that they have a clear understanding of these. Then, participants begin the practice block before the actual blocks for memorizing, and the instructions are clarified for basic experimental steps. As mentioned above, there are three distinct blocks with corresponding conditions. For each block, they have 2 minutes to learn the words on the screen and attempt to memorize them all. After 2 minutes, the screen automatically begins to show words that either appear before or do not. If the words appear before, participants press "A"; if not, they press "L". They are required to respond within a certain time interval; otherwise, an orange hourglass is shown. After the first block, questions about whether they've used the techniques before. After completing the two blocks, a brief post-survey is conducted to assess the frequency with which they use the techniques during the experiment and their basic demographics.

3.3 Data Analysis

To examine the effects of stimulus types on memory retrieval, linear mixed-effects models are used to investigate the response time (RT) and accuracy of participants' responses, allowing for the existence of different results under imbalanced experimental conditions. Since there would be experimental fatigue across the whole experiment, comparisons between stimulus types in each block are done in order to examine the true difference across different experimental conditions. The following table (Table 1) shows the mean accuracy and response time for various blocks and stimulus types, and Figure 1 indicates the mean of RT in milliseconds (ms).

Table 1. Mean accuracy and response time (RT) by block and stimulus type

Block	Type	n	Mean Accuracy	SD Accuracy	Mean RT(ms)	SD RT(ms)
1	chunk	3	0.9	0.06	904.2	182.7
1	link	1	0.94		863	
1	random	8	0.91	0.05	856.5	126.4
2	chunk	6	0.5	0.05	792.3	186
2	link	4	0.43	0.08	971.5	242
2	random	2	0.52	0.08	831.2	107.5
3	chunk	6	0.51	0.07	676.7	101.1
3	link	4	0.47	0.04	996	159.5
3	random	2	0.47	0.04	533.9	200.3

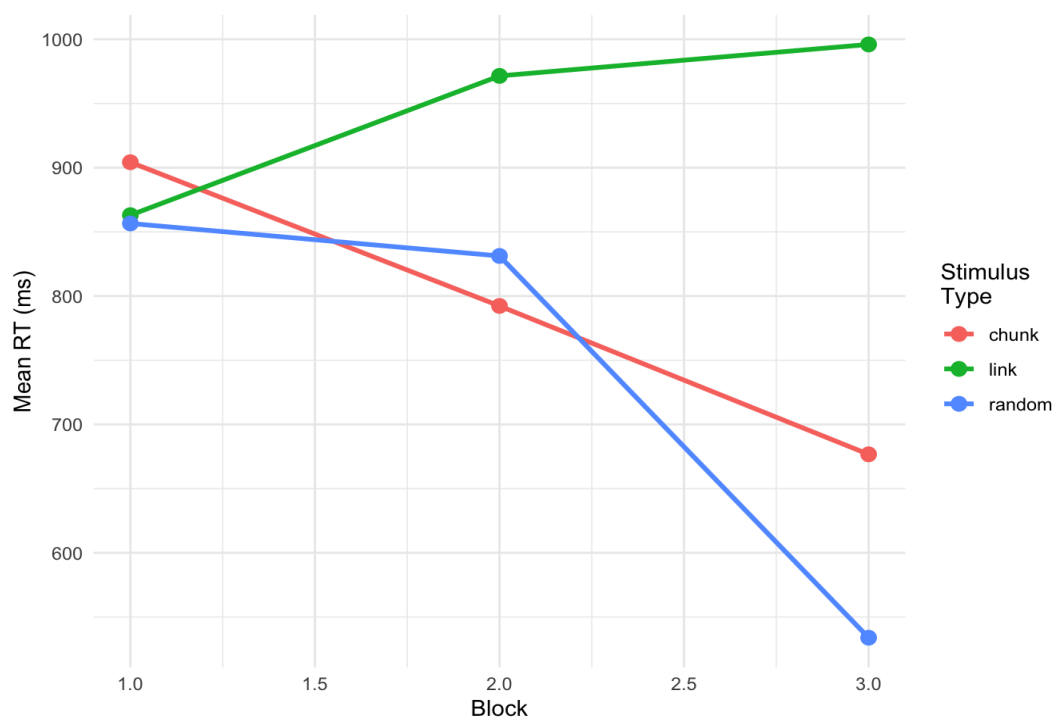


Figure 1. Mean Response Time (RT) by Block and Stimulus Types

The model included the following fixed effects of stimulus types and block number. The intercept, which is the baseline condition and represents the mean RT of chunking in the above figure and table (Figure 1 and Table 1), was 949.73 ms (SE = 75.10, $t(34.30) = 12.647$, $p < 0.001$). Linking memory, represented by the green line, was significantly slower than chunking, $b = 196.37$, SE = 62.94, $t(35.59) = 3.12$, $p < 0.004$, indicating the difference is statistically significant. The estimated RTs of random natural chunking compared to chunking are not statistically significant, as $b = -13.35$, $p = 0.807$. Moreover, each block later in the experiment was associated with an average RT decrease of 82.7 ms – likely due to practice effect – and this was statistically significant. Besides the RTs of different stimulus types, the accuracy contributed to the overall conclusion of the study about whether designs are effective in response to memory retrieval.

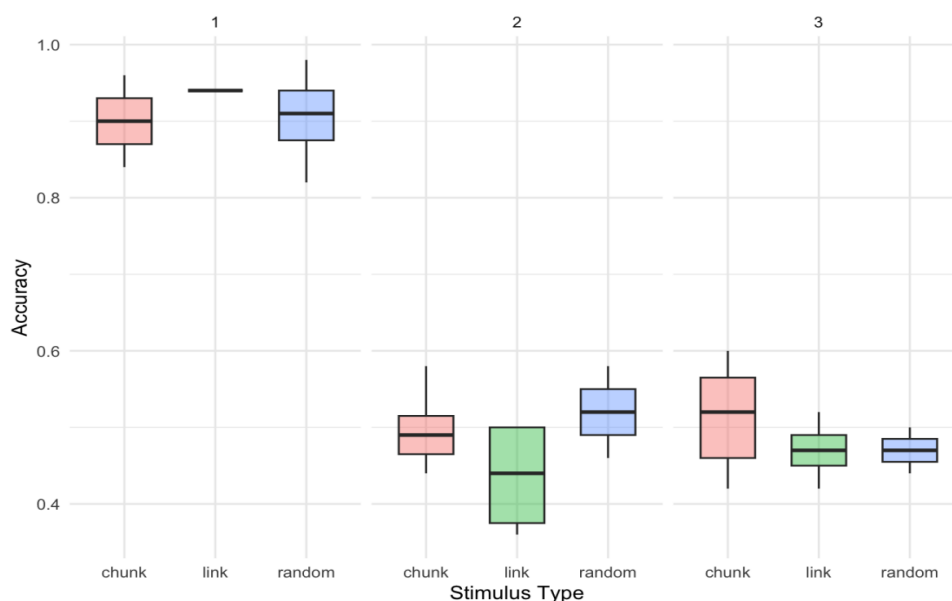


Figure 2. Accuracy of Blocks by Stimulus Types

The above figure (Figure 2) indicates the accuracy of the three stimulus types under each block. The rightmost bars, implying the accuracy of the first block, show a drastically higher result than the other two blocks. The intercept, showing the accuracy of chunking in block one, was 0.997 (99.7%, SE = 0.063, $t(36) = 15.839$, $p < 0.001$). Neither linking memory ($b = -0.052$, SE = 0.047, $t(36) = -1.105$, $p = 0.276$) nor random natural chunking ($b = 0.053$, SE = 0.047, $t(36) = 1.129$, $p < 0.266$) differed significantly from chunking. Similar to the results of RTs, the accuracy decreased by 18.77% per block, primarily due to experimental fatigue or reduced attention as participants began to respond faster, while accuracy was lower.

In summary, Table 1 and Figures 1 & 2 show that the chunking method has the most significant effect on people's short-term memory, according to the results of RTs and accuracy. Furthermore, due to experiment fatigue and learning processes, participants' RTs dropped as the sessions went on, while their accuracy also decreased significantly, suggesting a trade-off between response time and accuracy. The imbalanced design (e.g., $n = 1$ for link (linking memory) in Block 1) was addressed by the mixed-effect model, which measured block effects to eliminate the stimulus type differences.

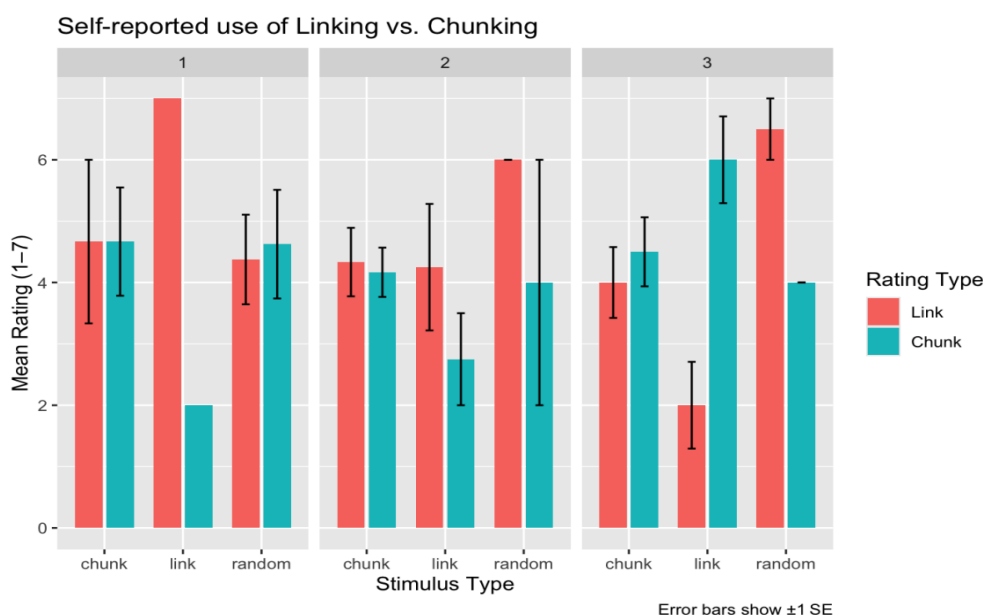


Figure 3. Mean Ratings of Memory Techniques by Block and Alignment

The linear mixed-effects model was used to examine whether participants reported the use of chunking or linking memory when the designated layouts are aligned with intended stimulus types. The model contains various alignments and block numbers as fixed effects; however, the model did not reveal a significant effect of alignment. None of the conditions significantly differed from the reference level (*chunk_aligned*), as all p-values are greater than 0.279. These results indicate that participants did not consistently report using more chunking or linking memory when the specific block was designed to encourage the usage of the two techniques.

4. Expected Results

The expected results for the study are that the design layouts of the words should help the memory outcomes. Differences should appear in natural chunking vs chunking and natural chunking vs linking memory, where the two mnemonic devices should have high accuracy in the recalling processes. According to one previous study stated above, the experimental groups that used visual imaging, regardless of the conditions, had better creativity than the control group, which did not have hints during memorization[7]. As previous research has shown, the use of visual imaging and non-use of it reveal specific potentials that people using chunking and linking memory would be more successful in recalling those words than the words that are aligned by natural chunking. Though there are different randomized sequences in the experiment, the overall results should not be affected by the special sequences. While sequences trigger no distinct results, the study could emphasize the impact of specific designated layouts on memory usage.

5. Significance and Broader Impact

The study examines a factor that hasn't been tested before: the design process of using mnemonic devices; yet, certain limitations in the study should be recognized. First, the study is largely limited in sample size and group balancing, resulting in only one datapoint under certain experimental conditions, which restricts the valid reference for drawing conclusions. Moreover, the study fatigue, essentially the concept that participants might lose attention and increase tiredness during the experiment, was also one of the limitations that were discussed above in data analysis. Lastly, humans exhibit variations in memorization and short-term memory. One study about the impact of age on cognition shows that as humans become older, their cognitive abilities, including processing working memory, making decisions, and executing cognitive functions, decline the most compared to cumulative knowledge and experimental skills[10]. Thus, the study does not provide an absolute answer applicable to all populations across different age groups. In future studies, there should be more experimental studies to test out the alignment and design before the full experiment, ensuring the outcomes of the designs align with the design intention.

Despite the limitations, we still revealed that design has an influence on memory outcomes; notably, people performed worse in linking memory after controlling for fatigue issues, likely due to increasing cognitive load in the specific stimulus. According to this conclusion, future work should focus more on memory designs that are more beneficial to memory, rather than hindering it. Practically, studies in mnemonic devices should enhance the education of memory techniques in several different fields, underscoring the significance of mnemonic devices for teenagers as well, due to the expected results that layouts are an important factor in memory performance. Instructors in secondary schools could impact students' methods of learning to influence their performances in memory and academics. Moreover, future research can focus on testing the different effects of these devices on various age groups, from children to seniors. By exploring the field of cognitive-related memory deeply, more approaches to memory for curing cognitive impairments can be accentuated.

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