

Comparing Visual and Working Memory of Teenage and Elderly Populations

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ABSTRACT: Teenage participants aged 14 to 18 and elderly participants aged 65 and above completed a survey to gauge their visual and working memory abilities. Each individual's visual memory was measured through their proportion of accurately identified fragmented images, while working memory was measured through accurate recognition of a previously shown sequence of numbers. The teenage population had a significantly higher proportion of accurately identified fragmented images than the elderly population, suggesting teenagers have more efficient visual memories. While identifying fragmented images, participants were also asked to rank their confidence in recognition on a scale of 1 to 10. The difference between each population's average confidence was not statistically significant. However, the correlation between confidence and accurately identified fragmented images was significant within the teenage population, yet nonsignificant within the elderly population. The difference in the proportions of accurately identified number sequences was not statistically significant, suggesting that varying working memory efficiency between the two populations was also not statistically significant. Future research should include more questions regarding the working memory aspect to increase the validity of the results.

KEYWORDS: Behavioral and Social Sciences, Cognitive Psychology, Neuropsychology, Short-Term Memory, Cognitive Aging.

■ Introduction

The average brain of a newborn baby contains over 100 billion neurons,¹ a feat of nature that enables humans to facilitate a plethora of complex processes, including but not limited to thinking, decision-making, language interpretation and formation, sensation, perception, and memory. Throughout childhood and adulthood, the brain rapidly processes and stores unfamiliar stimuli, making way for the burgeoning formation of neural pathways while neuroplasticity is at its prime. As the brain ages, however, it diminishes in a variety of aspects, including brain volume loss, neuron cell shrinking, and demyelination.² This physical deterioration is reflected through diminished mental efficiency: as reported by the Centers for Disease Control and Prevention (CDC), approximately 1 in 10 adults ages 45 and older reports worsening memory loss or cognitive decline.³

Significantly, a common side-effect of the aging brain is its impact on short-term memory, often measured through decreased processing and executive cognitive functioning speeds.⁴ The Cleveland Clinic describes short-term memory as a “temporary storage space that holds information you learned,”⁵ albeit only a limited amount of information for a relatively short duration (seconds or minutes). Controlled by the prefrontal cortex and the hippocampus, short-term memory can be categorized into distinct types, typically depending on the type of information stored. Some examples include visual memory, which stores images; echoic memory, which stores sounds; and short-term spatial memory, which stores spatial relations between objects, with each type of memory lasting varying durations. Certain types of memory decline as the

brain ages, such as episodic memory, while others remain relatively unchanged, like procedural memory.⁶ This study focuses specifically on visual memory and a type of memory similar to short-term memory called working memory. Working memory is “the short-term maintenance and manipulation of information necessary for performing complex cognitive tasks such as learning, reasoning, and comprehension.”⁷ Through the use of short-term memory, individuals can navigate everyday activities successfully, seamlessly learning, comprehending, and solving tasks that require immediate attention.⁸

Historically, several techniques have been developed to measure short-term memory.⁹ In 1913, surgeon Howard A. Knox developed an assessment used to examine immigrants at Ellis Island called the Cube Imitation Test, where participants had to repeat a pattern tapped on four cubes by an examiner.¹⁰ The Cube Imitation Test was superseded in 1972 by Canadian psychologist Philip Michael Corsi's block-tapping test. In Corsi's block-tapping test, nine wooden blocks are quasi-randomly spaced out on a flat surface, with numbered faces only facing the examiner and not visible to the participant. The participant would then copy an arbitrary sequence tapped out by the examiner, with difficulty increased by altering the length of the sequence.¹¹ While these techniques measure a participant's visual short-term memory, assessments like the Digit Span Backward test, where an individual repeats a series of digits in reverse order, gauge working memory.¹² In recent decades, researchers have been experimenting with new metrics for short-term memory, including exploring the connection between memory efficiency and the development of disorders like Alzheimer's.

The purpose of this study is to compare teenagers' and elderly individuals' perceived accuracy and confidence in their own visual and working memories.

■ Methods

Participants:

This study focuses on two populations with distinct age ranges. The youth population consisted of 98 participants aged 14 to 18 years old, while the elderly population consisted of 50 participants aged 65 years old and above. The inclusion criteria for this study were any individual between 14 and 18 years old or 65 and above; the exclusion criteria for this study were anyone outside of these age ranges. All data were collected by the student researcher: the teenage responses were collected through a voluntary response survey distributed at a high school in Upstate South Carolina, while the elderly responses were primarily collected through a local senior center. This primary analysis study aimed to evaluate and compare the short-term visual and working memories of these populations in order to determine whether younger individuals have significantly more accurate short-term memories than elderly individuals.

Study Design:

Visual memory. The survey was adapted from Anne Cleary *et al.*'s 2004 study, "Recognition without picture identification: Geons as components of the pictorial memory trace", in which participants were asked to: identify the item depicted by a set of fragmented lines (see Figure 1); identify whether the picture fragment belonged to an image they were previously shown; and rate on a scale of 0 to 10 the likeliness that the picture fragments originated from an image at study.¹³

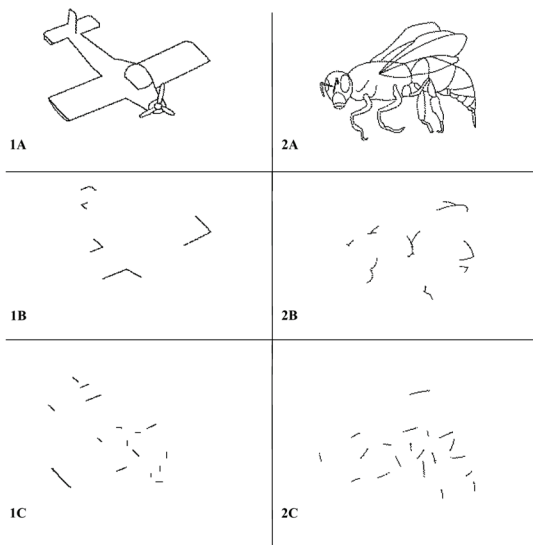


Figure 1: Sample stimuli. Sample stimuli from the original study. 1A and 2A depict the original images, with 1B and 2B depicting the geon fragments, and 1C and 2C depicting the non-geon fragments (Cleary *et al.*, 2004).

This observational study utilized voluntary responses submitted through a Google Form. This study adapted the 2004 study by incorporating "filler" elements, which were used to gauge the participants' natural recollection ability when not

initially prompted to remember a stimulus. The theory was that, when these seemingly unrelated questions were interspersed throughout the survey, the participant would be less likely to dedicate energy specifically to remembering any one. These filler elements were presented as general knowledge questions, such as "Who was the first president of the United States of America?" and "What is 3×7 ?"

Among the filler elements included were questions asking the participant to identify an unfragmented image from a drop-down of nine answer choices ('Horse,' 'Car,' 'Turkey,' 'Airplane,' 'Octopus,' 'Parrot,' 'Helicopter,' 'Seahorse,' & 'Hummingbird'). There were a total of five unfragmented images, shown in the following order: Airplane, Turkey, Parrot, Seahorse, Helicopter.

Following the initial survey sections containing filler questions, the participant was then directed to the Fragmented Image section (see Figure 2). In this section, each prompt depicted a set of lines and asked the participant to rate on a scale of 1 to 10 the familiarity of the fragmented image. Four out of six of the fragmented images provided were derived from images shown to the participant earlier in the survey, but the remaining stimuli (serving as red herrings) were derived from unfragmented images not previously shown to the participant. The fragmented images were shown in the following order: red herring, Seahorse, red herring, Turkey, Airplane, Parrot.



Figure 2: Unfragmented and fragmented image comparison. On the left is the unfragmented Parrot; on the right is the fragmented Parrot. Below the fragmented image, the 1-10 scale was provided for participants, which was used to indicate the participants' confidence in recognizing the image.

The participant was then asked to identify each fragmented image to the best of their ability without returning to a previous section. The provided drop-downs were identical to the ones provided earlier in the survey, with an additional tenth choice stating, "I have not seen this image," ideally to be used for the red herrings.

Working memory. Among the unfragmented images and filler questions, there were two questions regarding a series of numbers used to evaluate the short-term working memory of the participants, the secondary purpose of this study. The first question asked the participant to identify an item in a sequence of numbers, in order to subtly introduce the numbers to the participants: "In the given sequence {2, 3, 9, 5, 7, 1}, what is the *second* number?" Later in the form, the participant was asked to recall the sequence they saw earlier, including the correct order of the numbers.

Outcome Measures:

Demographic information was collected, including participants' highest level of education, preferred gender orientation, race, and whether they have been diagnosed with any memory-affecting conditions, such as concussions, traumatic brain injuries, or Alzheimer's disease. Certain demographics, such as education and memory-affecting conditions, were collected due to potential associations they may have with recognition and recall ability. For instance, those who have taken higher levels of education may exhibit better visual and working memory compared to those who have not. Furthermore, memory-affecting conditions are likely to have an impact on a participant's ability to recall and recognize visual and numeric components of the survey.

Visual memory was used in this study as "the capacity to remember what has previously been seen in the form of visual images".¹⁴ Visual memory was captured through the usage of the unfragmented and fragmented images. For the unfragmented images, participants selected the answer choice they felt best identified the image from a drop-down menu. During the fragmented image section, participants first indicated on a scale from 1 to 10 how familiar the fragmented image was, which suggested their confidence in recognizing the image. After that, they identified the image to the best of their abilities by selecting an answer choice from a similar drop-down menu, only with an additional option stating, "I have not seen this image."

Working memory was used in this study as "the short-term maintenance and manipulation of information necessary for performing complex cognitive tasks such as learning, reasoning, and comprehension."¹⁷ Working memory was captured by the participants' retention of a given sequence of numbers. The participants were initially introduced to the sequence by identifying the second item, and were later asked to identify which sequence from five answer choices was the same as the one they were shown earlier.

Data Analysis:

Descriptive statistics, such as mean, median, and mode, were collected for the following demographics: participants' highest level of education, preferred gender orientation, race, and whether they have been diagnosed with any memory-affecting conditions, such as concussions, traumatic brain injuries, or Alzheimer's.

Visual Memory. For this study's primary purpose of comparing visual memories of the two populations, Levene's Test for Equality of Variances was utilized to determine the skewness of the results. Then, a two-sample t-test was performed in order to determine whether the difference in accuracy rates of the two populations was statistically significant.

Working Memory. For this study's secondary purpose of comparing working memories of the two populations, a two-proportion z-test was used to determine the statistical significance of the differing population proportions of those who correctly identified the sequence of numbers.

Correlation between average confidence and accuracy. Additionally, Levene's Test and a two-sample t-test were performed

again to determine whether each population's average confidence indicated by the recognition scale for each fragmented image was significantly different. Correlation plots were also created to visualize the association between average confidence rates and average accuracy rates of each population.

Results and Discussion

Demographics:

98 responses were collected from the 14-18-year-old teenage population, with an average age of 15.71 ± 1.06 years. 50 responses were collected from the 65- 93-year-old elderly population, with an average age of 72.92 ± 6.02 years. Notably, over 80% of both populations reported having been diagnosed with no memory-affecting conditions, while 11.22% of teens reported having been diagnosed with a concussion at some point, and only 6% of elderly individuals reported having been diagnosed with stroke, dementia, or multiple sclerosis. Additional demographics, including preferred gender orientation and race, were collected, as seen in Table 1.

Table 1: Demographics table. Demographics collected included age, preferred gender orientation, race, and memory-affecting conditions. Most notably, more than 80% of both populations reported having been diagnosed with no memory-affecting conditions.

Demographic Category	Sub-categories	Percentage (Count)	
		14-18 years	65+ years
Age	Avg. Years $\pm$ Std. Dev. (Range)	15.71 $\pm$ 1.06 (14-18)	72.92 $\pm$ 6.02 (65-93)
Preferred Gender Orientation	Male	39.80 (39)	48.00 (24)
	Female	53.06 (52)	46.00 (23)
	Nonbinary	2.04 (2)	0
	Other (i.e., genderqueer, transgender)	3.06 (3)	0
	Missing data	2.04 (2)	6.00 (3)
Race	White	57.14 (56)	46.00 (23)
	Black or African American	22.45 (22)	8.00 (4)
	Asian	10.20 (10)	46.00 (23)
	Hispanic	7.14 (7)	0
	Other (i.e., Brazilian, MENA, Mixed Race)	3.06 (3)	0
Memory-Affecting Conditions	None	83.67 (82)	88.00 (44)
	Concussion	11.22 (11)	0
	Multiple Sclerosis	0	2.00 (1)
	Stroke / Dementia	0	2.00 (1) - Stroke & Dementia 2.00 (1) - Dementia only
	ADHD / ADD	2.04 (2)	2.00 (1)
	Other (i.e., Major Depressive Disorder, lack of sleep)	2.04 (2)	0
	Missing Data	1.02 (1)	4.00 (2)
	TOTAL	98	50

Comparison of Accurately Identified Fragmented Images

To evaluate the differences between the visual memories of teenagers ages 14-18 and elderly individuals ages 65 and older, equality of variances was first tested using Levene's Test for homogeneity. The F-test indicated no significant difference in variance between the two groups, $F(1, 146) = 1.42$, $p = 0.18$, suggesting that the assumption of equal variances was met.

A standard independent two-sample t-test was then conducted to compare the percentages of accurately identified fragmented images between participants in the teenage popu-

lation ($n = 98, 0.39 \pm 0.20$) and those in the elderly population ($n = 50, 0.29 \pm 0.17$), as seen in Figure 3. Results revealed a **statistically significant** difference in the proportion of accurately identified fragmented images between the two groups, $p = 0.00$, Cohen's $d = 0.54$, indicating a moderate effect size in favor of the teenage population. These results suggest that teenage participants aged 14-18 have significantly more accurate visual memories compared to those of elderly individuals aged 65 and older.

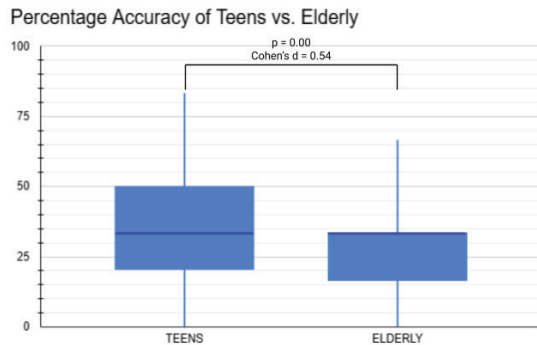


Figure 3: Percentage Fragmented Image Accuracy of Teens vs. Elderly. This boxplot compares the percentage of accurately identified fragmented images between the teenage population and the elderly population. This difference is statistically significant, with $p = 0.00$. Notably, the medians of both populations are equivalent, at 33.33%.

Comparison of Working Memories:

A two-proportion z-test was conducted to compare the working memories of the teen population and the elderly population. In the teenage group, 33 out of 98 participants (34%) accurately recognized the sequence of numbers, compared to 18 out of 50 participants (36%) in the elderly group. The difference in proportions was **not statistically significant**, $z = -0.28$, $p = 0.60$, indicating that varying working memory efficiency between these two populations is also not statistically significant.

Confidence in Fragmented Image Recognition:

To compare the average confidence of the two populations, equality of variances was first tested using Levene's Test for homogeneity. The F-test indicated unequal variance between the two groups, $F(1, 146) = 2.43$, $p = 0.00$.

Due to the unequal variance, an unequal-variance Welch's two-sample t-test was conducted to compare the average confidence on a scale of 1 to 10 of the teenage group ($n = 98, 4.74 \pm 1.92$) and of the elderly group ($n = 50, 5.01 \pm 2.98$). Results revealed a difference that was **not statistically significant** between the average confidence of the two groups, $p = 0.57$, Cohen's $d = -0.12$, indicating a small effect size.

Correlation of Confidence and Accurately Identified Fragmented Images:

A Pearson correlation was conducted to examine the relationship between confidence, indicated on a scale of 1 to 10, and the accuracy of identifying fragmented images in the teenage population. Results showed a **significant** moderate, positive correlation between the two variables, $r(97) = 0.42$, $p = 0.00$. This suggests that participants who indicated greater

confidence in recognizing the fragmented image are associated with greater accuracy. See Figure 4.

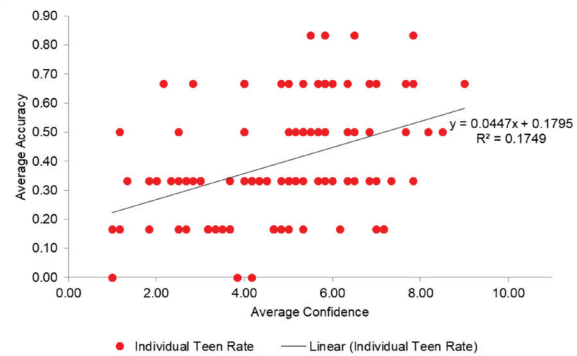


Figure 4: Correlation of confidence and average accuracy rate in the teenage population. This correlation is statistically significant. Results showed a moderate, positive correlation between the two variables.

A Pearson correlation was conducted to examine the relationship between confidence indicated on a scale of 1 to 10 and the accuracy of identifying fragmented images in the elderly population. Results showed a **nonsignificant**, weak, negative correlation between the two variables, $r(49) = -0.09$, $p = 0.55$. This suggests that participants who indicated greater confidence in recognizing the fragmented image are associated with lower accuracy rates. See Figure 5.

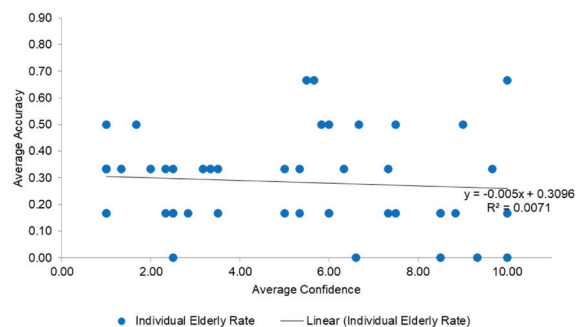


Figure 5: Correlation of confidence and average accuracy rate in the elderly population. This correlation is not statistically significant. Results showed a weak, negative correlation between the two variables.

Limitations:

This study is limited by its sampling technique, utilization of a voluntary response survey, inclusion of participants with memory-affecting conditions, and the testing method of working memory. Participants were primarily based in local senior centers and a local high school, possibly affecting the generalizability of the results. Due to the use of a Google Form survey, it is possible that participants may have returned to previous sections of the Form. Self-reported information could potentially lead to skewed results. Additionally, the inclusion of participants with memory-affecting conditions, such as concussions, ADHD, or stroke, may have skewed the findings. Finally, this study's objective to compare the working memories of two populations may be limited by the fact that there was only one pair of questions pertaining to this objective.

Overall, these limitations may affect the generalizability and validity of the findings. As a result, further research and exploration are recommended to develop more definitive con-

clusions. Even so, this research remains significant despite the limitations because it provides valuable insight regarding changes in visual and working memory throughout the aging process, inviting new understandings of how short-term memory is affected by age.

■ Conclusion

In summary, this study compared the visual and working memories of teenagers and elderly individuals. The findings demonstrate that there was a **statistically significant** difference in the proportion of accurately identified fragmented images between the two populations, suggesting that teenagers may have better visual memories than elderly individuals. This finding is supported by Ebaid & Crewther's 2019 study: "A decline in cognitive functions, including ... speed of visual information processing [and] working memory ... associated with the normal aging process is commonly reported in the scientific literature."¹⁵ It is reasonable to infer that the typical cognitive decline associated with aging is responsible for this difference in short-term visual memories.

The difference in proportions of accurately identified number sequences was not statistically significant, suggesting that differences in working memory efficiency of these populations may not be significant either. Interestingly, Freitas *et al.*'s 2007 study states, "Numerous studies have suggested that performance in [complex cognitive] tasks [in context of working memory] is related to age, where older adults have a lesser performance than the young."¹⁶ When considering this, a possible explanation for the nonsignificant finding could be the limitation that working memory is only tested using one pair of questions in the survey.

When comparing the average confidence of the two populations, the results revealed that the differences were **not statistically significant**. Curiously, however, a moderately strong positive correlation between the variables of confidence and accurately identified fragmented images was found specifically within the teenage population, while the elderly population indicated a **nonsignificant** weak negative correlation between the two variables. This could indicate that teenagers exhibit better recall when they have more confidence in their memory abilities, possibly due in part to the fact that younger people typically do not experience memory issues.

In future research comparing the working memories of these two populations, the researchers should incorporate several test questions to increase the validity of their results. Additionally, future studies should more closely examine the relationship between confidence and recall ability, particularly in populations that have been diagnosed with memory-affecting conditions like Alzheimer's or strokes.

New findings regarding how different types of short-term memory change throughout the aging process could offer crucial insight into the development of serious memory-affecting conditions like dementia and Alzheimer's. Additionally, they could enhance current understanding of how the role of memory in disorders such as ADHD, where the brain's chemistry is regulated in a different way than typical, or Major Depressive Disorder, where there is oftentimes a chemical imbalance in

the brain, deviates from expectation. These insights could shed light on various aspects of society, from reforming standardized testing accommodations so that they more efficiently aid students to informing current treatments of memory conditions.

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