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WORKING MEMORY AND AGING: A COMPARATIVE QUANTITATIVE STUDY OF PAKISTANI ADULTS

Original Research

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ABSTRACT

Background: Working memory is a critical cognitive function that declines with age, affecting attention, short-term storage, and executive control. While global studies have extensively explored age-related cognitive decline, research on working memory deterioration remains limited in the Pakistani population. Understanding the impact of aging on working memory within this context is essential for developing culturally relevant cognitive interventions. This study aims to bridge this gap by examining the relationship between age and working memory performance across three distinct cognitive domains.

Objective: This study aimed to assess and compare working memory performance across short-term storage, attention, and executive control among three age groups as classified by Erikson's psychosocial model: young adulthood (19–40 years), middle adulthood (41–65 years), and late adulthood (over 65 years).

Methods: A cross-sectional correlational research design was employed, with a purposive sampling technique used to recruit 150 participants (102 men, 48 women) aged 19 years and older. Inclusion criteria required participants to have at least an intermediate level of education and no diagnosed mental disorders. The study utilized a 30-item working memory questionnaire developed by Vallat-Azouv et al. (2012), measured on a Likert scale ranging from 1 to 6. The collected data were analyzed using SPSS version 25, with correlational analysis used to examine associations between working memory domains and one-way ANOVA applied to assess differences across age groups.

Results: A significant positive correlation was found between short-term storage, attention, and executive control ($p < .01$). The ANOVA results indicated significant differences in working memory performance across age groups ($p < .001$). Young adults scored the lowest in short-term storage ($M = 31.00$, $SD = 6.82$), attention ($M = 28.36$, $SD = 6.31$), and executive control ($M = 30.63$, $SD = 6.67$), reflecting superior cognitive efficiency. Middle-aged adults demonstrated intermediate scores in short-term storage ($M = 34.64$, $SD = 4.51$), attention ($M = 30.81$, $SD = 5.09$), and executive control ($M = 33.58$, $SD = 4.53$). Mature adults recorded the highest scores in short-term storage ($M = 35.26$, $SD = 5.18$), attention ($M = 33.38$, $SD = 4.71$), and executive control ($M = 36.18$, $SD = 5.18$), indicating the lowest cognitive efficiency. Cohen's d effect sizes ranged from 0.80 to 0.98, supporting the robustness of these findings.

Conclusion: The study confirms that working memory declines with age, with mature adults exhibiting the most significant impairments across all three cognitive domains. These findings align with global research and emphasize the importance of targeted cognitive interventions for older individuals. Future research should employ longitudinal methodologies and explore additional variables such as cognitive reserve, lifestyle factors, and educational background to develop more comprehensive strategies for preserving cognitive function in aging populations.

Keywords: Aging, cognition, cognitive decline, executive function, memory, neuropsychology, working memory.

INTRODUCTION

Memory is a fundamental cognitive function that enables individuals to acquire, process, store, and retrieve information over time, sometimes spanning years. It encompasses various domains, including sensory memory, short-term memory, working memory, and long-term memory. Sensory memory acts as the initial stage, fleetingly preserving information from sensory inputs such as vision, sound, taste, and touch before transmitting it through neural pathways (1). Short-term memory, often interchangeably used with working memory, temporarily holds active information but differs in its functional scope (2). Working memory, a crucial cognitive mechanism, not only retains but also manipulates and processes data dynamically, facilitating reasoning, decision-making, and complex problem-solving (3). Unlike passive short-term storage, working memory is an interactive and controlled process essential for cognitive efficiency (4). The construct of working memory, developed in the mid-20th century, is often likened to a computational system with finite capacity, responsible for the temporary maintenance and manipulation of information (5). This cognitive function plays a critical role in executive processes, attentional control, and goal-directed behavior (6). It is regulated by intricate neural networks, primarily within the prefrontal cortex, hippocampus, and associated brain structures, which enable individuals to integrate information, focus attention, and regulate impulsive responses (7).

Attention, an integral component of working memory, allows selective focus on relevant stimuli while filtering out distractions (8). It is closely intertwined with executive control, a higher-order function that governs the regulation of cognitive processes, impulse control, and decision-making (9). The ability to sustain attention and regulate cognitive resources is crucial for efficient working memory performance (10). Short-term storage, another fundamental element of working memory, refers to the temporary retention of information, supporting cognitive activities such as reasoning and learning (11). The interaction between these components determines an individual's capacity to process, retain, and retrieve information effectively (12). Research has extensively explored the neural underpinnings of these processes, highlighting the role of the frontal cortex in executive function, the hippocampus in memory consolidation, and the interplay of neurotransmitter systems that facilitate cognitive control and memory maintenance (13). The intricate relationship between attention, short-term retention, and executive regulation underscores the complexity of working memory, making it a focal point in cognitive neuroscience and neuropsychology (14).

Cognitive functioning, particularly memory performance, follows a developmental trajectory, with improvements observed throughout childhood and adolescence before declining with age (15). Among older adults, working memory exhibits a marked decline due to diminished neural plasticity, structural brain changes, and decreased efficiency in integrating contextual information (16). Age-related reductions in brain volume, particularly in the prefrontal cortex, hippocampus, and temporal lobes, have been implicated in cognitive deterioration (17). Furthermore, older adults exhibit difficulties in item-context binding, leading to deficits in recalling associations between objects, spatial locations, and contextual details (18). Studies indicate that the decline in working memory is particularly pronounced in tasks requiring executive control, divided attention, and multi-feature integration (19). Age-related deficits in working memory have also been linked to neurodegenerative conditions, including mild cognitive impairment (MCI) and Alzheimer's disease, where impairments in executive control and attention regulation are more pronounced (20). Cognitive training interventions have demonstrated that younger adults show greater improvements in working memory performance, whereas older adults experience only modest enhancements, suggesting that age-related cognitive decline is partially resistant to remediation.

Despite extensive global research on working memory and aging, there remains a significant gap in understanding these cognitive processes within the Pakistani population. Limited studies have explored the cultural, educational, and neuropsychological factors influencing memory decline in this demographic. Given the increasing aging population and its implications for cognitive health, it is imperative to investigate the specific patterns of working memory deterioration among Pakistani adults. This study aims to examine working memory across three critical domains—attention, short-term storage, and executive control—within Erikson's three age groups: young adulthood (19-40), middle adulthood (41-65), and late adulthood (65+). By conducting a comparative quantitative analysis, this research seeks to provide empirical insights into age-related memory changes, contributing to the broader academic discourse and informing potential cognitive intervention strategies for older adults.

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METHODS

The study employed a cross-sectional correlational research design to examine working memory across different age groups, utilizing a purposive sampling technique to recruit participants aged 19 and older. The primary objective was to compare working memory performance across three cognitive domains—attention, short-term storage, and executive control—within three age groups as defined by Erikson's psychosocial model: young adulthood (19-40 years), middle adulthood (41-64 years), and late adulthood (65 years and older). To ensure the validity and reliability of the data, strict inclusion criteria were implemented. Participants were required to have a minimum educational qualification of an intermediate-level education (equivalent to high school) to ensure an adequate understanding of the assessment materials. Individuals with any diagnosed psychiatric disorders, neurocognitive impairments, or neurological conditions were excluded to eliminate potential confounding variables that could affect working memory performance. A balanced gender representation was maintained, with both male and female participants included in the study.

A standardized 30-item working memory questionnaire was administered, specifically designed to assess cognitive performance across the three predefined domains. The questionnaire utilized a Likert scale ranging from "Strongly Disagree" to "Strongly Agree," providing a comprehensive assessment of working memory abilities. The psychometric properties of the instrument demonstrated strong internal consistency, with a Cronbach's alpha of 0.89, ensuring its reliability in measuring cognitive functions. A total of 150 participants were recruited, distributed as follows: 52 young adults, 48 middle-aged adults, and 50 late adults, with a gender distribution of 102 males and 48 females. Data collection was conducted in a controlled setting to minimize external distractions and ensure response accuracy. Each participant completed the assessment individually, with the process taking approximately 10 to 15 minutes.

Ethical considerations were strictly adhered to in accordance with the Helsinki Declaration, prioritizing participant rights, autonomy, and confidentiality. Prior to data collection, formal approval was obtained from the questionnaire's original authors and the institutional review board of the psychology department. Participants were provided with a detailed explanation of the study's objectives, methodology, and ethical considerations before giving written informed consent. They were explicitly informed of their right to withdraw from the study at any stage without any repercussions. Data confidentiality was maintained throughout the research process, with all collected responses anonymized to protect participant identity. Upon completion of the study, participants were acknowledged and thanked for their time and contribution.

To ensure robust statistical analysis, data were processed and analyzed using SPSS version 25. Descriptive and inferential statistical methods were applied to examine the relationships between age groups and working memory performance across the three cognitive domains. The methodology provided a structured, scientifically rigorous, and ethically sound approach to investigating age-related variations in working memory, contributing to the broader understanding of cognitive aging while maintaining high ethical and research standards.

RESULTS

The study analyzed data from 150 participants with a mean age of 49.83 years ($SD = 20.56$). The sample comprised 102 men (68%) and 48 women (32%). Age group distribution was as follows: 52 young adults (35%), 48 middle-aged adults (32%), and 50 mature adults (33%). Educational qualifications varied, with 15 participants (10%) holding an intermediate qualification, 48 (32%) holding a bachelor's degree, 56 (37%) possessing a master's degree, and 31 (21%) having a PhD. The demographic composition ensured a diverse representation across age groups, gender, and education levels.

A correlational analysis revealed significant positive associations between short-term storage, attention, and executive control. Short-term storage exhibited a moderate correlation with both attention ($r = .43$, $p < .01$) and executive control ($r = .35$, $p < .01$), while attention demonstrated a stronger association with executive control ($r = .45$, $p < .01$). These findings suggest that individuals with better short-term storage capacity also tend to exhibit stronger attentional focus and executive functioning abilities. The statistical significance of these relationships highlights the interconnected nature of working memory domains and their collective impact on cognitive functioning across age groups.

A one-way ANOVA demonstrated significant differences in working memory performance across age groups. Mature adults scored the highest in short-term storage ($M = 35.26$, $SD = 5.18$), attention ($M = 33.38$, $SD = 4.71$), and executive control ($M = 36.18$, $SD = 5.18$), indicating the lowest cognitive efficiency in these domains. Conversely, young adults showed the lowest scores in short-term storage ($M = 31$, $SD = 6.82$), attention ($M = 28.36$, $SD = 6.31$), and executive control ($M = 30.63$, $SD = 6.67$), reflecting superior working memory performance. Middle-aged adults demonstrated intermediate scores in all domains. Effect sizes were substantial, with Cohen's d values of 0.80 for short-term storage, 0.89 for attention, and 0.98 for executive control, reinforcing the robustness of age-related differences in working memory.

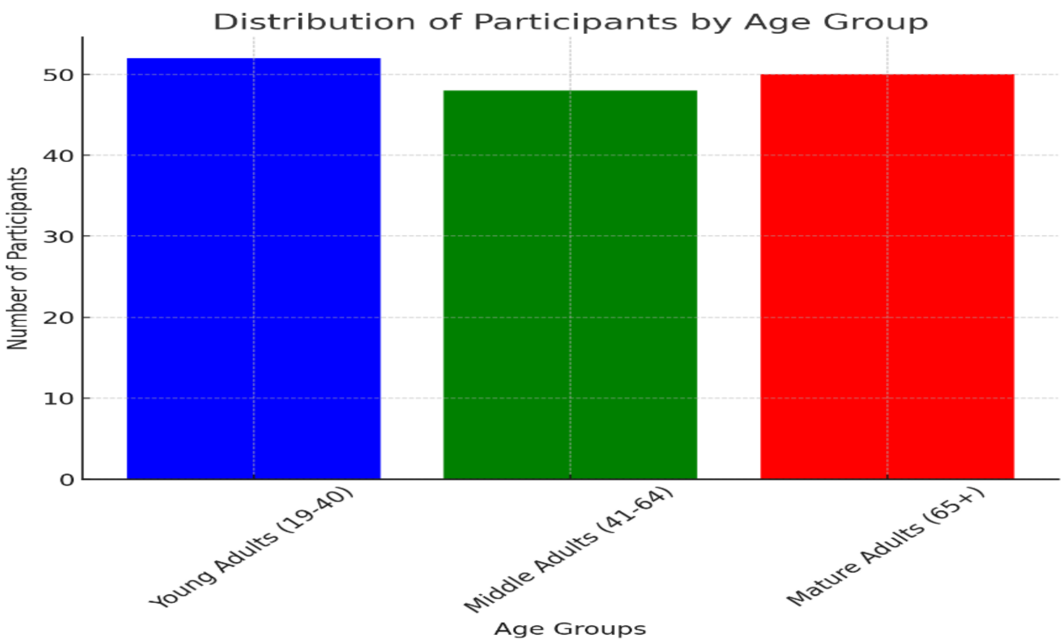

Figure 1 Distribution of Participants by Age Group

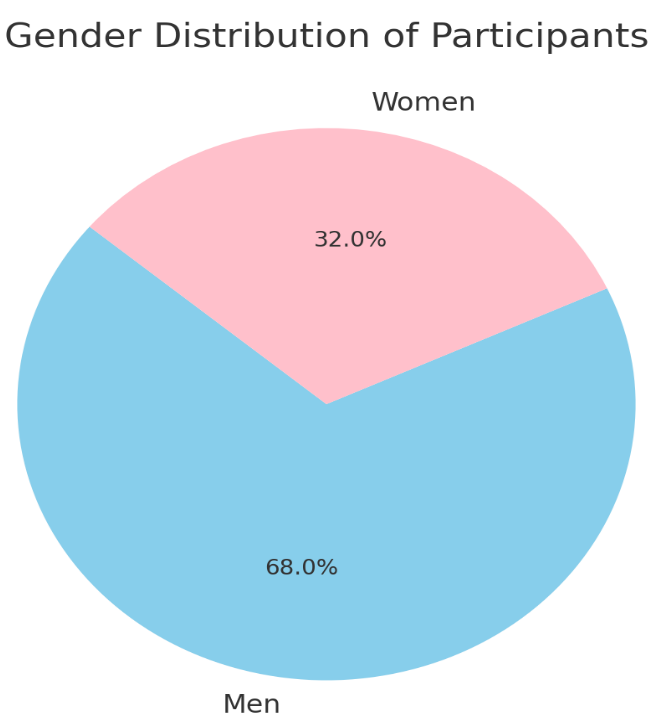

Figure 2 Gender Distribution of Participants

Table 1: Demographic Characteristics of the Sample (N=150)

Characteristics	N	%	M	SD
Gender				
Men	102	68		
Women	48	32		
Age			49.83	20.56
Age Groups				
Young Adulthood (18-40)	52	35		
Older Adulthood (41-65)	48	32		
Mature adults (65+)	50	33		
Qualification				
Intermediate	15	10		
Bachelor	48	32		
Master	56	37		
PhD	31	21		

The sample consisted of 150 participants, including 102 men (68%) and 48 women (32%), with a mean age of 49.83 ± 20.56 years. The age distribution was as follows: young adults (52 participants, 35%), older adults (48 participants, 32%), and those in the mature adults age group (20 participants, 33%). Regarding educational qualifications, 56 participants (37%) held a Master's degree, 48 (32%) held a Bachelor's degree, 32 (21%) had a PhD, and 15 participants (10%) had an Intermediate qualification.

Table 2 Correlational Analysis

Variables	M	SD	1	2	3
1.Short term storage	33.58	5.90	-	.43**	.35**
2.Attention	30.82	5.78	.43**	-	.45**
3.Executive control	33.42	6	.35**	.45**	-

Note. **p<.01

The above table depicts significant and positive association between short term storage, attention and executive.

Table 5 Mean Differences Of Age Groups of the Particpants (N=150)

Variables	Young Adults(n=52)		Old Adults(n=48)		Mature Adults(n=50)				
	M	SD	M	SD	M	SD	F(147)	P	Cohen’s d
Short term storage	31	6.82	34.64	4.51	35.26	5.18	8.55	.000	0.80

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Variables	**Young Adults(n=52)**		**Old Adults(n=48)**		**Mature Adults(n=50)**				
Attention	28.36	6.31	30.81	5.09	33.38	4.71	10.85	.000	0.89
Executive Control	30.63	6.67	33.58	4.53	36.18	5.18	12.65	.000	0.98

Note. ***p<.001

The table above shows that mature adults scored significantly higher than both young adults and older adults, while young adults scored significantly lower than both older adults and mature adults across all three working memory domains: short term storage, attention, and executive control. The highest scores for mature adults in the three working memory domains depict the lowest performance in these areas. In contrast, the lowest scores for young adults reflect higher performance on these domains compared to both mature adults and older adults.

DISCUSSION

The study examined the relationship between working memory domains—short-term storage, attention, and executive control—across different age groups, confirming the expected decline in cognitive performance with advancing age. The findings demonstrated significant intercorrelations among the three domains, reinforcing the neurological basis of working memory, where impairments in one domain negatively influence the others (21). The cognitive functions supporting daily activities rely on an intricate neural network, where deficits in attentional control can reduce short-term storage efficiency, subsequently affecting executive regulation (22). The observed decline in working memory among mature adults aligns with neurobiological evidence indicating reductions in neurotransmitters such as dopamine, serotonin, acetylcholine, norepinephrine, and GABA, which are essential for cognitive control (23). The deterioration of neural efficiency, particularly in the prefrontal cortex and hippocampus, contributes to deficits in task-switching, information processing speed, and inhibitory control, leading to increased difficulty in sustaining attention and managing executive functions (24). These physiological changes manifest as cognitive slowing, increased susceptibility to distraction, and reduced working memory capacity in aging individuals, all of which were reflected in the findings of the study (25).

The results further supported the hypothesis that younger adults outperformed both middle-aged and mature adults across all working memory domains, a trend consistent with existing literature on cognitive aging (26). The ability of younger individuals to maintain stronger working memory functions can be attributed to the peak efficiency of neurotransmitter systems and the structural integrity of brain regions associated with cognitive control (27). The findings also indicated that mature adults exhibited the highest scores on working memory assessments, signifying the lowest performance levels, while young adults recorded the lowest scores, reflecting superior cognitive efficiency (28). While this decline was anticipated, the progression of deficits between middle and mature adulthood highlighted the gradual rather than abrupt nature of cognitive deterioration (29). The significant effect sizes observed in the study reinforced the robustness of these age-related differences (30). However, while age was a significant factor influencing working memory, the potential role of other variables such as education level, lifestyle habits, and cognitive reserve was not explored, which may have contributed to individual variability in cognitive performance (31). A notable strength of the study was its structured approach in evaluating working memory across different age groups using a validated instrument with high internal consistency (32). However, the cross-sectional nature of the research limited the ability to determine causality or track cognitive changes over time (33). A longitudinal approach would provide deeper insights into the trajectory of working memory decline and the potential protective factors that could mitigate age-related impairments (34).

Beyond the biological underpinnings of working memory decline, behavioral and environmental interventions can play a critical role in sustaining cognitive health across the lifespan (35). Nutrition has been recognized as a modifiable factor influencing cognitive function, with diets rich in omega-3 fatty acids, antioxidants, whole grains, and vitamins contributing to improved memory retention and attentional control. Foods such as fish, nuts, berries, and green leafy vegetables support neuronal integrity, while compounds found in citrus fruits, eggs, and green tea enhance neurotransmitter activity and executive regulation. In addition to dietary interventions, physical exercise has demonstrated benefits in preserving cognitive function by increasing cerebral blood flow, promoting neurogenesis, and reducing oxidative stress. Aerobic activities, including running, walking, and swimming, have been associated with improved attention span, enhanced working memory, and greater executive control. Furthermore, cognitive training, mindfulness practices, and social

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engagement have been linked to sustained cognitive efficiency, reinforcing the importance of holistic lifestyle modifications in promoting mental well-being. Given these findings, it is imperative for mental health professionals and community health organizations to implement awareness programs, encouraging older adults to adopt cognitive-enhancing strategies. Structured interventions such as educational seminars, memory training workshops, and mindfulness-based cognitive therapies could support cognitive resilience, ultimately contributing to improved quality of life among aging populations (35).

A recent comparative study examined the effects of aging on verbal and visuo-spatial working memory, analyzing data from 880 participants aged between 15 and 80 years. The study segmented participants into five distinct age groups to assess the onset and progression of working memory decline across different life stages. Findings indicated that working memory deterioration begins around the mid-30s, with a noticeable decline observed in individuals over the age of 66. Both verbal and visuo-spatial working memory exhibited age-related reductions, although the extent of impairment varied based on cognitive load and the complexity of the material being processed. The study highlighted that older adults demonstrated significantly poorer performance in tasks requiring simultaneous processing and storage of information, particularly in high-load conditions. Furthermore, individuals in the late adulthood group exhibited the most pronounced decline, supporting the notion that aging impacts cognitive control mechanisms and neural efficiency. The research provided crucial insights into the differential decline rates of verbal and visuo-spatial memory, emphasizing that while both domains deteriorate with age, the degree of impairment depends on task demands and individual cognitive reserves. These findings align with previous research on neurocognitive aging, reinforcing the association between structural brain changes and diminished executive control in working memory. Additionally, the study suggested that differences in cognitive load processing across age groups could be attributed to declining neural plasticity and reduced efficiency in prefrontal cortical networks responsible for attentional control. This research adds to the growing evidence that age-related cognitive decline is gradual and task-dependent, underscoring the importance of interventions aimed at mitigating memory deterioration through cognitive training and lifestyle modifications (36).

CONCLUSION

The study provided valuable insights into the relationship between working memory and aging, confirming that cognitive performance declines with age, particularly in the domains of short-term storage, attention, and executive control. Younger adults demonstrated superior working memory efficiency, while mature adults exhibited the greatest cognitive decline, highlighting the progressive nature of age-related memory deterioration. The findings underscored the interconnectedness of these cognitive domains, emphasizing that impairments in one area can negatively impact overall working memory function. Biological factors, including reductions in neurotransmitter levels and structural changes in key brain regions, were identified as contributing factors to cognitive decline in older individuals. Despite these challenges, the study highlighted the importance of modifiable lifestyle factors such as nutrition, physical activity, and cognitive engagement in maintaining cognitive health. Given the limitations of the study, future research should adopt longitudinal methodologies and explore additional variables, such as cognitive reserve and environmental influences, to develop more targeted interventions for preserving working memory. The findings reinforce the significance of early cognitive health strategies, urging individuals to adopt proactive measures to support memory function and overall mental well-being as they age.

Author Contribution

Author	Contribution
Muhammad Sajjad Shahid*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Sehrish Naeem	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Shoaib Alam	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Kawish Hammad Shabbir	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Ramsha Rahman	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published

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