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Empirical Paper

Relationship Between Scripture Memorization And Hippocampal-Amygdalae Volumes Using Magnetic Resonance Imaging

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Abstract

Purpose: This study examined the association between scripture memorization and the volumes of the hippocampus and amygdala, addressing debates around the "bigger is better" hypothesis in brain structure memory research. It specifically explored whether extensive Quran memorization is linked to variations in hippocampal and amygdala volumes among healthy adults.

Methods: Seventy-three neurologically and psychologically healthy adults aged 35–80 years participated. They were grouped into complete Quran memorizers (CMQ; n = 20), partial memorizers (PMQ; n = 35), and non-memorizers (CON; n = 18). High-resolution MRI scans were used to obtain volumetric measurements of the left and right hippocampus and amygdala. Group differences were analyzed using one-way ANOVA, followed by intracranial volume (ICV) correction to control for individual variability in brain size.

Results: Prior to ICV correction, both left and right hippocampal volumes were significantly larger in the CMQ group compared with the PMQ and CON groups ($p < 0.05$). However, these differences were no longer statistically significant after adjusting for intracranial volume. No significant differences were observed across groups for amygdala volumes.

Novelty and Contribution: As one of the few studies investigating neuroanatomical correlates of long-term scripture memorization in aging adults, this work provides new insights into how sustained cognitive practices may influence hippocampal structure.

Social and Practical Implication: Findings suggest that lifelong engagement in intensive memorization practices—such as Quran memorization may support hippocampal preservation during aging. These insights underscore the value of culturally relevant cognitive activities in promoting long-term brain health and may inform community-based cognitive wellness programs.

Keywords: MRI, Scripture memorization, Hippocampus, Amygdala, Cognitive decline, Aging

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1 Introduction

The hippocampus and amygdala are key components of the limbic system. The hippocampus is associated with the formation of new memories, learning, and the retention of old memories, while the amygdala is linked to emotional processing (Richter-Levin & Akirav, 2000). Although these two structures can function independently, they also interact in subtle and important ways, particularly in emotional situations (Phelps, 2004). Both the amygdala and the amygdalohippocampal system have been implicated in memory-related disorders, especially Alzheimer's disease (Collins & Nelson, 2008; Gosche et al., 2002; Hampel et al., 2008; Jack et al., 2000; Lehericy et al., 1994; Mortimer et al., 2004; Steffens et al., 2002). The hippocampus, an important memory structure, has extensive functional connections with other parts of the central nervous system that support various forms of memory processing (Assonov & Bozhuk, 2017). Due to the critical roles of these structures, numerous studies have sought to establish the relationship between hippocampal or amygdalae volume and memory performance. Evidence suggests that the hippocampus plays a central role in the consolidation of short-term into long-term memory (Bast, 2007; Burgess et al., 2002; Morris, 2006; Pohlack et al., 2014; Squire, 1987; Tulving & Markowitsch, 1998).

Studies examining the relationship between hippocampal volume and memory performance in healthy individuals have yielded inconsistent findings. Some have reported no significant association or even negative correlations (Chantome et al., 1999; Foster et al., 1999; MacKay et al., 1998; Sowell et al., 2001; Yurgelun-Todd et al., 2003), challenging the "bigger is better" hypothesis. In contrast, others found positive associations between hippocampal volume and memory performance (Ashtari et al., 2011; Poppenk & Moscovitch, 2011; Rajah et al., 2010). Mori et al. (1999) further established that the amygdala is involved in emotional memory, showing a positive correlation between amygdala volume and emotional memory performance. Collectively, these studies (Leuner & Gould, 2010; Lovden et al., 2013) highlight the influence of hippocampal and amygdalae changes on learning and memory enhancement. However, the novelty of the present work lies in exploring how memorization practices affect hippocampal and amygdalae plasticity, using Quran memorization as a case study.

Previous research on Quran memorization has shown that individuals who memorize the Quran demonstrate improved academic performance compared to non-memorizers (Nawaz & Jahangir, 2015), and generally exhibit better health outcomes. Engaging in memorization and continual mental challenge has been shown to prevent memory decline and promote brain health (Kimiaee et al., 2012; Lakzaie et al., 2019). Similarly, Quran reading and memorization have been associated with improved episodic memory and overall well-being among the elderly (Munawaroh et al., 2023). Other studies (Aslan, 2022; Hasim et al., 2023) identified additional benefits such as enhanced personal growth, general well-being, and community cohesion, while Ishak et al. (2021) reported that Quran memorizers are more likely to enjoy good physical health.

Islam encourages Quran memorization for its perceived spiritual and cognitive benefits (Nawaz & Jahangir, 2015). The Quran consists of 114 chapters (Surahs) and 6,236 verses (Ayahs), totaling 77,449 words (Quran, 2015). The largest chapter, Al-Baqarah, contains 286 verses, while Al-Kawthar has only three. Comparatively, the Jewish Torah and the Christian King James Bible contain 79,847 (Torah, 2002) and 783,137 (Bible, 2015) words, respectively. The Quran is thus remarkable not only for its structure but also because it is the only religious text that has been memorized in its entirety by millions of individuals across ages and cultures (Graham, 1993).

Magnetic Resonance Imaging (MRI) is widely used in neuroscience research for assessing brain structure and function. However, its application remains limited in many developing nations due to high costs and shortages of trained image analysts.

This study aims to investigate the association between scripture memorization and hippocampal and amygdalae volumes measured using MRI techniques. We hypothesize that scripture memorization is positively correlated with hippocampal and amygdalae volume. The Quran was chosen as the case study because of its global significance and widespread memorization. Importantly, this study focuses on the cognitive and neural implications of memorization rather than on religious practice

2 Methodology

Participants

The study employed a cross-sectional design, recruiting participants from Islamabad, Pakistan. Advertisements were posted within and outside COMSATS University Islamabad (CUI) to reach potential volunteers. A total of 125 individuals were screened using oral interviews and questionnaires. The information obtained from volunteers included demography, medical history, whether they have memorized the Quran and the extent to which they had memorized the Quran. The information provided was used for final selection and all volunteers with a history of neurological or psychological disorders were excluded from the study. Finally, 73 health adults, aged 35 to 80 years without a history of either neurological or psychological disorders were included in the study. An informed consent was obtained from all participants in writing under ethical approval from Research Ethics Committee of National University of Medical Sciences (NUMS), Islamabad, Pakistan. Participants consisted of both those who had committed the Quran to their memory and those who had not memorized any part of the scripture (control group). All participants were of almost same social-economic background. Of the 73 participants, 20 (all male) participants had completely memorized (CMQ) the Quran while 35 (25 males) had memorized part of the Quran (PMQ). The control group (CON), comprising 18 (7 males) volunteers, had not memorized any portion of the Quran. The demographics of the participants within each group are presented in Table 1.

Table 1 Demographic of the participants

	CMQ	PMQ	CON
	(n = 20)	(n = 35)	(n = 18)
Gender	20 males	25 males	7 males
Mean ± SD; range, age (y)	50.40 ± 09.27	52.48 ± 12.01	49.39 ± 07.21

Note: - CMQ, completely memorized; PMQ, partially memorized; CON, control group.

Though we did not collect information from the participants on exactly how long it took them to memorize the Quran, however, Islamic religion encourages Muslims to memorize the Quran early in life. Thus, it is common for many Muslims to have completely memorized the Quran before the age of 14 while some would complete the memorizations later in life by doing it in piecemeal. All the CMQ subjects were Imam (who led the regular daily prayers) as well as instructors of Arabic and Quran studies. Prior to inclusion in the study, participants were all subjected to a standard assessment used for assessing Quran teachers. Assessment was based on the degree of committal to memory evidenced by recitation, and correctness was with reference to the Quran. To ensure standardization, replication and unbiases, all participants were given the same assessment. In summary, memorization was assessed in three ways: (1) Ten chapters of the Quran were arbitrarily selected and each individual was asked to recite from the chapters off hand. (2) Another ten chapters or part, apart from the ones used in the previous assessment were chosen and read partly to each participant and were subsequently asked to complete the recitation. (3) Twenty words or phrases were cautiously selected from the Quran and each participant was asked to recite the complete verses containing those words or phrases. The main criteria for assessment include accuracy (pronunciation of Arabic words, correct order of verses with a chapter and following rules of recitation called Tajweed), fluency (smooth transition from verses to the chapters and completeness (recitation of the entire selected section from memory). The test results were verified by another individual (not one of the subjects) who was familiar with the Quran and met the three assessment criteria.

With respect to the PMQ group, 'Partial' refers to situation where the participant has not completely memorized the Quran regardless of the number of chapters or verses the individual has dedicated to memory. A questionnaire was used to elicit this information such that each subject specified the range of memorized chapters. They were also tested like those who had entirely memorized the Quran. Anyone who could not demonstrate that he/she has fully memorized the Quran was classified as partial.

MRI Acquisition

A whole body 3T Siemens MRI scanner was used to acquire Brain Structural MRI from participants at Armed Forces Institute of Radiology and Imaging (AFIRI), Islamabad, Pakistan. Imaging parameters included high resolution T1W MPRAGE with TR/RE = 2300/2.32ms; Matrix size: 256x256 with 192 contiguous slices 0.90mm thickness, in-plane resolution 0.93mm. The default orientation which is sagittal was used for the image acquisition.

Brain Tissue Volume Measurements

Images were pre-processed by converting to Analyze 7.5 (Clinic, 2007) from the DICOM file format. Subsequently, the images were re-oriented to AC-PC positions and resliced to a resolution of 1mm thickness isotropic. Prior to image segmentation, the T1W images were brain extracted using Optimized Brain Extraction for Pathological Brains (optiBET) (Luktkenhoff et al., 2014) optiBET makes use of the freely available algorithms including FMRIB's Software Library (Smith et al., 2004) and has an increased accuracy of brain extraction as compared to some other popular, publicly available brain extraction methods(Luktkenhoff et al., 2014). Each subject's anatomical scan was then segmented into grey matter (GM), white matter (WM) and cerebrospinal fluid (CSF) using Gaussian mixture model implemented in Statistical Parametric Mapping (SPM, www.fil.ucl.ac.uk/spm, version 12). This was followed by the estimation of WM, GM and CSF volumes as described previously (Rahman et al., 2020). The intracranial volume (ICV) was calculated by summing the volumes of GM, WM and CSF. The hippocampi and amygdalae (of both hemispheres) of each subject's anatomical scan were segmented using FSL (Smith et al., 2004) followed by the calculation of the respective volumes (See Figures 1 and 2). To correct for head size and atrophy, each of the volumetric measurements was divided by ICV.

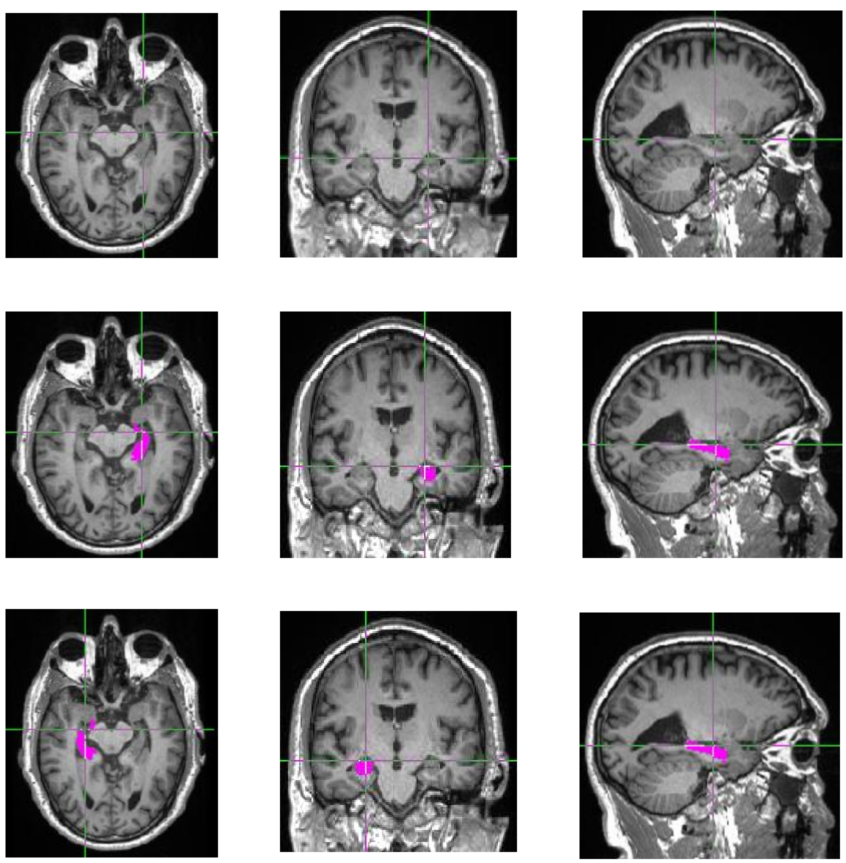

Figure 1 Axial, coronal and sagittal slices of a representative images showing the hippocampus image overlays on the CMQ T1W image. Top – T1W images; middle – overlays of left hippocampus; bottom – overlays of right hippocampus.

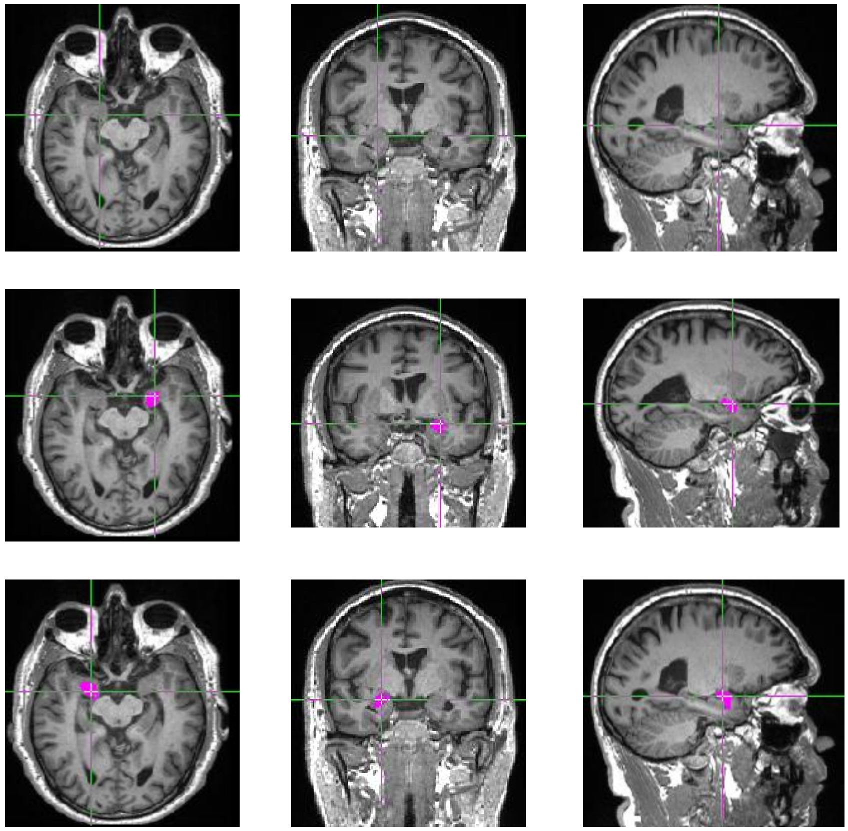

Figure 2 Axial, coronal and sagittal slices of a representative image showing the amygdala image overlays on the CMQ T1W image. Top – T1W images; middle – overlays of left amygdala; bottom – overlays of right amygdala.

Statistical Analysis

All statistical analyses were performed using IBM SPSS version 22 (IBM Corporation, New York, USA), with all statistical tests being two-tailed, and p values<0.05 were considered to be statistically significant. The volumes of hippocampus and amygdala were normally distributed, test was done using Shapiro-Wilk tests of normality. All volumetric measurements of those who memorized the entire Quran and those who memorized only a small portion were compared with the control group using Tukey post hoc tests of the ANOVA statistics. We did a multiple regression analysis to assess the effect of gender on hippocampus volume. This is very important because our study had more male than female.

3 Results

It was observed that the volumes of the left and right hippocampal tissue were statistically significantly larger for the CMQ subjects compared to the PMQ subjects (p = 0.013 and p = 0.033 respectively) and the CON subjects (p = 0.031 p = 0.013 respectively). The ICV and hippocampal and amygdalae volumes obtained for the three groups are shown in Table 2. Among the groups, there were significant differences between the volumes of both the left and right hippocampal (p = 0.010) while no difference existed between the left and right amygdalae volumes (p = 0.175 and p = 0.566 respectively). The ICV did differ significantly among the three groups (p <0.001). Except for the right hippocampus volumes obtained after ICV correction which was significantly different (p = 0.044), all other volumes for the left hippocampus, and the two amygdalae are not significantly different. The Tukey post hoc was applied to the one-way ANOVA and the results are depicted in Table 3.

Table 2 F, test statistic from the ANOVA models for the left and right volumes, as well as the percentage of left and right volumes of the ICV for hippocampal and amygdalae structures.

	***F*(2,70)**	***p-value***
Age, years	0.60	0.552
L_Hipp matter volume, mm^3	4.961	**0.010**
R_Hipp matter volume, mm^3	4.934	**0.010**
L_Amgy matter volume, mm^3	1.786	0.175
R_Amgy matter volume, mm^3	0.573	0.566
ICV, mm^3	14.428	**0.000**
% of L_Hipp matter in ICV	2.805	0.067
% of R_Hipp matter in ICV	3.280	**0.044**
% of L_Amgy matter in ICV	1.341	0.268
% of R_Amgy matter in ICV	0.046	0.632

P<0.05 are in bold

Table 3 The Turkey post-hoc test for the means (pairwise) comparison of the three groups

	CMQ	**PMQ**	***P***
Age, years	50.40 ± 09.27	52.48 ± 12.01	0.753
L_Hipp volume, mm^3	3810.60 ± 441.07	3341.40 ± 658.55	**0.013**
R_Hipp volume, mm^3	3792.40 ± 367.50	3497.91 ± 415.29	**0.033**
L_Amgy volume, mm^3	1070.40 ± 206.94	1139.83 ± 411.02	0.732
R_Amgy volume, mm^3	1165.80 ± 259.96	1152.17 ± 363.59	0.988
ICV, mm^3	1132107.55 ± 107971.01	1045680.31 ± 105505.34	**0.013**
% of L_Hipp in ICV	0.3370 ± 0.0289	0.3194 ± 0.0576	0.378
% of R_Hipp in ICV	0.3360 ± 0.0279	0.3357 ± 0.0353	1.000
% of L_Amgy in ICV	0.0945 ± 0.0165	0.1093 ± 0.0436	0.255
% of R_Amgy in ICV	0.1030 ± 0.0200	0.1093 ± 0.0302	0.689
	PMQ	**CON**	
Age, years	52.48 ± 12.01	49.39 ± 07.21	0.560
L_Hipp volume, mm^3	3341.40 ± 658.55	3329.22 ± 515.69	0.997
R_Hipp volume, mm^3	3497.91 ± 415.29	3403.39 ± 441.26	0.707
L_Amgy volume, mm^3	1139.83 ± 411.02	960.22 ± 239.91	0.150
R_Amgy volume, mm^3	1152.17 ± 363.59	1061.67 ± 335.86	0.616
ICV, mm^3	1045680.31 ± 105505.34	948280.11 ± 101940.93	**0.006**
% of L_Hipp in ICV	0.3194 ± 0.0576	0.3505 ± 0.0371	0.062
% of R_Hipp in ICV	0.3357 ± 0.0353	0.3595 ± 0.0378	**0.048**
% of L_Amgy in ICV	0.1093 ± 0.0436	0.1006 ± 0.0201	0.635
% of R_Amgy in ICV	0.1093 ± 0.0302	0.1106 ± 0.0278	0.984
	CMQ	**CON**	
Age, years	50.40 ± 09.27	49.39 ± 07.21	0.950

L_Hipp matter volume, mm^3	3810.60 ± 441.07	3329.22 ± 515.69	**0.031**
R_Hipp matter volume, mm^3	3792.40 ± 367.50	3403.39 ± 441.26	**0.013**
L_Amgy matter volume, mm^3	1070.40 ± 206.94	960.22 ± 239.91	0.558
R_Amgy matter volume, mm^3	1165.80 ± 259.96	1061.67 ± 335.86	0.600
ICV, mm^3	1132107.55 ± 107971.01	948280.11 ± 101940.93	**0.000**
% of L_Hipp matter in ICV	0.3370 ± 0.0289	0.3505 ± 0.0371	0.645
% of R_Hipp matter in ICV	0.3360 ± 0.0279	0.3595 ± 0.0378	0.092
% of L_Amgy matter in ICV	0.0945 ± 0.0165	0.1006 ± 0.0201	0.841
% of L_Amgy matter in ICV	0.1030 ± 0.0200	0.1106 ± 0.0278	0.665

P<0.05 are in bold

However, between the groups, the left and right hippocampal volumes obtained after ICV correction were not significantly different (p > 0.05). subjects. The only exception was the case where the mean right hippocampus volumes of the CON were larger than that of the PMQ subjects and the difference was significant (p = 0.048). The volumes of both the left and right amygdalae between any the two respective groups showed no significant difference even though the volumes of the control group are larger in most cases compared with the CMQ and PMQ subjects. The multiple regression analysis also showed that CMQ has higher total hippocampus volume and higher left hippocampus volume than the CON group (Appendix 1) Also, the multiple regression analysis showed that gender is not a predictor of hippocampus volume in this study.

4 Discussion

We investigated the association between memorizing the scripture and hippocampus-amygdala volumes in older adults of three groups, those who memorized the scriptures completely, those who memorized the scripture partially and those who did not commit any part of it to their memory. It was discovered that there is no significant difference in the ages of the study groups compared with the control group. This suggests that age has no effect on the results obtained in this study. We also found that gender had no effect on our results.

Our results show that those who memorized the Quran completely had bigger hippocampi tissue volumes than the control group. Also, those who memorized completely have bigger hippocampi tissue volume than those who partially memorized. Unfortunately, the significance disappeared when hippocampus volumes were corrected for by ICV. However, the case of both the left and right amygdalae is quite different as we did not find any significance difference in the volumes of hippocampus across the 3 groups studied.

For instance, acute video gaming is beneficial for brain function and structure among which is the hippocampus (Denilson et al., 2019; West et al., 2018). Likewise, it was earlier reported that hippocampal volume shrinked yearly in nondementia adults which results in the risk of cognitive impairment development later in life (Jack et al., 2010; Raz et al., 2005). However, it was discovered that aerobic exercise is neuroprotective and engaging in this even later in life has tendencies to enhance cognition or augmenting brain volume including the hippocampus structure (Kandola et al., 2016; ten Brinke et al., 2015).

Our result on lack of significance difference in amygdala between the 3 groups is not a surprise because the specific role of the amygdala in memory formation has been subjected to various arguments (Goodman et al., 2017; Richter-Levin, 2004). Notwithstanding, there are previous results that concluded that amygdala is also involved in the formation of emotion-related memories (Bradley & Sambuco, 2022; Brosch et al., 2013; Roozendaal et al., 2009). From the literature, many factors are often responsible for physical changes in neural structures including the subcortical tissues (Maldonado & Alsayouri, 2023; Yang & Chang, 2019; Yang et al., 2024).

This approach was emphasized to greatly increase the quantity of new neurons that are produced in the hippocampal development. However, for the survival of these newly formed neurons, mental training via skill learning is highly required especially when the training goals are quite challenging (Shors, 2014). Scripture memorization is one of such challenging tasks. We suspect that the duration of training for the memorization, coupled with the amount of text from the scripture memorized could have been responsible for the positive hippocampal development observed from this study. However, these seeming reasons that caused the change are difficult to establish from this work.

(Black et al., 2020) discovered that there were no differences between Quran memorisers (either fully or partially) and those who have not committed any portion of it to memory in their capacity to memorise verbal or visuospatial material. Thus, it was concluded that there was no evidence of generalization of learning capacity among those that had committed the whole Quran to their memories.

To the best of our knowledge, this is the first study that investigated the association between scripture memorization, hippocampal and amygdalae volumes in adults using MRI. A foremost strength of this work is its distinctiveness in the use of MRI techniques in studying the association between memorization and brain atrophy in a developing country. MRI is very useful and it is well used for clinical studies in the developed nations but seldom used in developing countries because of many costs related reasons. In this work, all the participants were from a developing nation and all successfully underwent MRI scanning. Another strength of the work is the use of standard image analysis practices. We used both FMRIB Software Library and Statistical Parametric Mapping (SPM) for image processing. FSL and SPM are very good image processing tools commonly used in neuroimaging community. The study has limitations, nonetheless. The sample size is relatively modest because of limited availability and high cost of MRI. For better inference in this kind of study, a larger sample size is needed.

5 Conclusions

In this paper, we explored the association between memorization and brain imaging biomarkers as it affects the brain subcortical structures most especially in the limbic system. Specifically, we focused on the hippocampus and amygdala structures because of their important roles in the consolidation and manipulation of memory.

Limitations and Future Research Direction

This study demonstrated greater hippocampal tissue preservation among individuals who memorized scripture, though no significant association was found with the amygdala or other subcortical structures. The relatively modest sample size, constrained by limited participant availability and the high cost of MRI, represents a key limitation. Future studies should employ larger and more gender-balanced cohorts to enhance statistical power and generalizability.

In this work, participants who memorized a single chapter were grouped with those who memorized nearly all chapters, potentially obscuring differences within the partial memorization group. Defining the range and extent of memorization more precisely could improve classification and strengthen the interpretation of intermediate groups such as the Partial Memorization Quotient (PMQ). Interestingly, the control group exhibited a larger relative right hippocampal volume than partial memorizers, a finding warranting further investigation to elucidate its neurobiological significance.

Another major limitation is the absence of participants' clinical and health data, which may have influenced observed outcomes. Future studies should incorporate such variables and statistically control for confounding factors—including age, sex, and educational status—since brain volume naturally declines with age. Investigating these relationships in children could provide insights into how memorization influences cognitive development and brain plasticity at early stages. Furthermore, examining the effects of memorization practices in dementia or Alzheimer's populations may clarify whether such activities confer neuroprotective benefits.

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Data Availability

The datasets used and/or analysed during the current study are available from the corresponding author on request.

Conflict of Interest

The authors declare no conflicts of interest" should be included if there is no conflict of interest.

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Appendix

Appendix 1 Multiple Regression for the Prediction of Hippocampus Volume using ANCOVA

Model	Total Hippocampal volume		Left Hippocampus volume		Prediction of Right Hippocampus volume	
	Standardized Coefficients (β)	Pval.	Standardized Coefficients (β)	Pval.	Standardized Coefficients (β)	Pval.
Gender	.001	.991	-.078	.551	.138	.273
Age	-.217	.059	-.168	.146	-.244	.028
CMQ	.464	.008	.507	.004	.265	.111
PMQ	.161	.273	.165	.264	.111	.432
ICV	-.135	.313	-.303	.027	.190	.143

Notes: - Each column gives the standardized coefficients and Pvalue of predicting the indicated volume based on gender, age, group membership, and ICV. The predictor variables were gender, age, group membership, and ICV while the outcome variables are the hippocampus volumes. The reference group is the Control Group (CON).