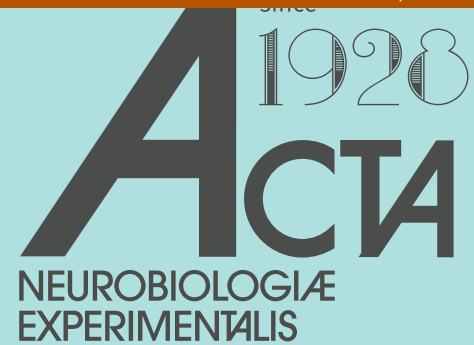


RESEARCH PAPER

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Association between scripture memorization and brain atrophy using magnetic resonance imaging

Mukaila Alade Rahman^{1*}, Benjamin Segun Aribisala^{1,2}, Irfan Ullah³ and Hammad Omer³

¹ Department of Computer Science, Lagos State University (LASU), Nigeria,

² Brain Research Imaging Centre, Division of Neuroimaging Sciences, University of Edinburgh, Edinburgh, UK,

³ Department of Electrical and Computer Engineering, COMSATS University Islamabad (CUI), Pakistan,

* Email: rahmalade@yahoo.com

We investigated the association between scripture memorization and brain tissue using magnetic resonance imaging techniques. Participants comprised 63 healthy adults between the ages of 35 and 80 years old with no neurological or psychological disorders. Of these, 19 had completely memorized the Quran, 28 had partially memorized parts of Quran while 16, the control group, had not committed the Quran into their memory. White matter, grey matter and cerebrospinal fluid volumes were calculated. The brain tissue volumes of those who memorized the entire Quran and those who memorized only a small portion were compared with the control group using one-way ANOVA implemented in SPSS. There was no significant effect of age between the three groups ($p > 0.50$). The group who completely memorized the Quran had larger grey matter and white matter volumes than the control group. Our results showed that those who memorized scripture had more brain tissues preserved compared with those who had not memorized scripture. These findings suggest that engaging our brains by memorizing scripture may increase brain health.

Key words: brain atrophy, magnetic resonance image, memorization, human mental decline, scripture

INTRODUCTION

The brain, without a doubt, is one of the largest and most complicated organs in the human body (Mohsen et al., 2018), especially in terms of its composition and structure. This complex structure experiences apparent alterations in its size, vascular system and cognition at various stages in the human lifespan (Peters, 2006). For instance, decline in human cognitive ability is reportedly more pronounced in the aged (Hamiz et al., 2014; Nichols 2017) than the younger population. It was also shown that in the early stages of brain cell development, ineffective cells are pruned off unless efforts are made to engage them in one activity or the other (Shors et al., 2012). Brain atrophy manifests as a reduction in total brain tissue volume, a decrease in the volume of other specific tissue classes like white or grey matter volumes, increased ventricular volumes

and/or enlargement of the superficial sulci (Resnick et al., 2003; Muller et al., 2011). Age related atrophy can be seen in human brains as early as age 35 but is more pronounced above 60 (Hedman et al., 2012). This may be normal aging in individuals or may be associated with specific neurological diseases such as degenerative disorders and dementias (den Heijer et al., 2006; Appelman et al., 2009).

The need to continuously engage the brain in various tasks in order to keep it active cannot be over-emphasized. Using the brain's neurons tends to make them become stronger and assist in delaying age-related decline in cognitive function (Park and Bischof, 2013). Likewise, as one ages, the effective neural connections that are being utilized get retained while ineffective connections or weak circuitry are pruned away (Payne, 2010). Thus, many spirited and active efforts are required to protect the aging brain from cognitive

decline. These could include regular activities as well as increased cognitive efforts in the form of education or occupational attainment (Peters, 2006). Self-protective factors also include healthy eating (Kurlak and Stephenson 1999; Kalmijn et al., 2004; Rampersaud et al., 2005; Tucker and Fishbein 2008), physical exercises (Wu et al., 2007; Andel et al., 2008; Aribisala et al., 2013; Yuan et al., 2015; Godman 2016), brain stimulation (Sobel 2001; Verghese et al., 2003; Mechelli et al., 2004) and abstinence from alcohol and cigarettes (Bruce and Pihl 1997; Bastianetto et al., 2000; Sobel 2001; Assunção et al., 2007; McNeely and Blanchard, 2009). The brain can also be sheltered from declination through social interaction (Bassuk et al., 1999; Ybarra et al., 2008), learning new things (Hatch et al., 2007; Sisti et al., 2007) and acquiring new languages (Craik et al., 2010). Sometimes, a combination of these activities makes the brain healthier (Bamidis et al., 2014; Philips 2017). Other methods for keeping the brain healthy include sleeping and short naps (Aribisala et al., 2020; Gais and Born, 2004; Guzman-Marin et al., 2008; Tucker and Fishbein, 2008; Wagner and Born, 2008), stress management (Lupien et al., 2005; Madrigal et al., 2006; Chen et al., 2008), musical training (Parbery-Clark et al., 2011; Tierney and Kraus 2013; Banai and Ahissar, 2013; Miendlarzewska and Trost, 2014) as well as brain teasing and practicing memorization (Hirabayashi and Ogawa 1999; Olichney et al., 2000; Dutch, 2000; Bialystok et al., 2012).

The structure and function of the brain can be modified depending on “experience and behaviour, including any kind of sensory and motor activity, environmental exposure, or stimulus deprivation” (Rogenmoser et al., 2018). Professional musicians are an excellent example, representing a well-known and ideal model for studying brain plasticity (Schlaug, 2015). Many previous studies have reported that musicians exhibit better cognitive performance (working memory) than non-musicians. D’Souza et al. (2018) assessed whether cognitive benefits from training existed and how unique they were to each training domain, using music proficiencies and bilingualism. Participants were carefully selected based on inclusion criteria (such as age, music lesson duration and demographic background among other things) and later grouped before assessment of the vocabulary and non-verbal intelligence between these groups. It was evident from the work that a strong association between musical training and working memory existed. In terms of structure changes, larger grey matter volume in the areas that are important for playing an instrument were found in musicians compared with non-musicians (Schneider et al., 2002; Gaser and Schlaug 2003). In these studies, all subjects and controls were matched with regard to age, handedness as well as verbal skills. The observed

structural differences were a result of long-term skill learning and repetitive rehearsal of the musical skills. Various skills and rehearsal strategies including fragmentation, whole-part-whole, self-assessment and overlearning through repetition are often employed when memorizing music (Hallam, 1997). Scriptural memorization combines many of these skills.

While a healthy brain will be good at memorization, it is not clear whether or not memorization could improve brain health. Previous studies regarding the effect of memorization of the Quran showed that those who memorized the Quran had better academic achievements than those who did not (Nawaz and Jahangir, 2015). The work focused on the academic achievement of Huffaz (memorizers) after the complete memorization compared to before they embarked on the memorization. There was a significant difference between the pre and post academic achievement of Huffaz using a purposive research instrument. These results suggest that there was a significant improvement in the academic performance of Huffaz after Hifz (memorization) though other factors, including educational and social, could also be responsible for this observation. It has also been suggested that memorizing and continuous challenging of the brain prevents memory loss and keeps the brain healthy (Kimiaee et al., 2012; Trinova and Wati 2016). In the second study, students of Islamic studies education and teacher training (with the same age bracket and similar social activities) were observed and asked to complete questionnaires on the contribution of Quranic Tahfidz (memorization) to mental health. The results indicated that those with a greater number of chapters memorized were thought to have a tendency to perform better compared to others. A study had previously reported that Quran memorization protects from Alzheimer’s disease (Al-Attas, 2011). This was based on the result of a Chi-squared test carried out on two groups of religious individuals, one half who memorized the Quran and the other half who had not memorized the Quran. It was determined that memorization of the Quran had an effect on their mental stimulation. However, it might be possible that their educational qualification and the demographic data of participants, which were not explicitly stated, could have been responsible for these results. The limitation of these studies is that they were based on administration of questionnaires and qualitative analysis of the data collected. Additionally, the data collected were very subjective. In this work, we aimed to investigate if there are any associations between scripture memorization and brain tissue, using magnetic resonance imaging (MRI) measurements. We hypothesized that those who memorized the scriptures have more brain tissue preserved compared to those who have not. Scriptures were chosen as a case study because they are

some of the most read books in the world. Specifically, the Quran was chosen because it is the only book, religious or secular, that has been memorized completely by millions of people (Graham, 1993) of all ages and intellectual abilities, including non-Arabic speakers. Generally speaking, Islamic religion encourages people to memorize the Quran because of the belief that this offers spiritual benefits (Nawaz and Jahangir, 2015). The Quran is arranged in chapters (Surahs) and verses (Ayahs). It has 114 chapters and 6,236 verses. The total number of words in Quran is 77,449. The largest chapter, called Al Baqarah, has 286 verses while the smallest chapter is Al Kawthar and it contains only 3 verses. The holy Quran has a fewer number of total words when compared with several other holy books, such as the Christian King James bible and the Jewish Torah, which have approximately 783,000 and 80,000 words, respectively.

METHODS

Participants

Participants comprised 63 volunteers (healthy adults) between the ages of 35 and 80 years old with no neurological or psychological disorders. They were recruited from Islamabad, Pakistan. Written informed consent was obtained from all the participants under a protocol approved by local health research and ethics committees for the study (Research Ethics Committee of National University of Medical Sciences, Islamabad). Participants consisted of both the scripture memorizers and those who had not committed any part of the scripture to memory (control group). All volunteers were of a similar social-economic background. Apart from oral interview, questionnaires were administered on potential volunteers to elicit information including medical history, as well as the extent of the memorization, which were also used for final selection of the participants. 19 (all male) participants had completely memorized (CMQ) the Quran while 28 (20 males) had partially memorized (PMQ) the Quran. 16 (7 males) volunteers, comprising the control group (CON), had not committed any portion of the Quran into their memory.

Although we did not explicitly collect information from the participants regarding exactly how long it took them to memorize the Quran, the period for the CMQ subjects to fully memorize the Quran differed between individuals; some memorized it before age 14, while some completed it in their early 20s. All of these subjects were imam (they lead the regular daily prayers) as well as teachers of Arabic and Quran studies. Sometimes they constantly sought audience with someone holding the print copy and read off-hand. This continu-

al practice assisted them in maintaining what they had memorized. Verification on the level of memorization was done in three ways: ten chapters of the Quran were randomly selected and each participant was asked to recite the chapters off-hand, another ten chapters, different from the ones used in the first assessment, were chosen and read partially to each participant, then the participant was asked to complete the recitation, and twenty words or phrases were carefully selected from the Quran and each participant was asked to recite the complete verses containing those words or phrases.

'Partial' as used for the PMQ group refers to the inability to have completely memorized the Quran irrespective of the number of chapters or verses the person has committed to memory. A questionnaire was used to elicit this information where each subject indicated the range of memorized chapters. They were also tested like those who had completely memorized the Quran. Anyone who did not demonstrate that he/she has completely memorized the Quran was classified as partial.

MRI Acquisition

A structural MRI of the brain was acquired from the participants using a whole body 3T Siemens MR imaging scanner available at Armed Forces Institute of Radiology and Imaging (AFIRI), Islamabad, Pakistan. Imaging parameters included high resolution T1W MPRAGE with TR/RE=2300/2.32 ms; Matrix size: 256x256 with 192 contiguous slices 0.90 mm thickness and in-plane resolution 0.93 mm. The images were acquired in sagittal orientation by default.

Brain Tissue Volume Measurements

Images were pre-processed by converting from DICOM to Analyze 7.5 format (Mayo 2008) before image processing. Thereafter, the images were re-oriented to AC-PC positions and resliced to a resolution of 1 mm thickness. Prior to image segmentation, the T1W images were successfully brain extracted using Robust Brain Extraction (ROBEX) (Iglesias et al., 2011). One major strength of ROBEX is that it offers improved accuracy over several other popular, publicly available brain extraction methods. 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). The volumes of WM, GM and CSF were then calculated. Total brain volume (TBV) was calculated by adding the volumes of GM and WM. Likewise, intracranial volume (ICV) was calcu-

lated by adding the volumes of GM, WM and CSF. Then the percentage of each tissue in ICV was calculated.

Statistical analysis

All statistical analyses were performed using IBM SPSS version 22 (IBM Corporation, New York, USA), with all the statistical tests being two-tailed, and p values <0.05 were considered to be statistically significant. Brain volumetric measurements were normally distributed and the brain tissue volumes of those who memorized the entire Quran and those who memorized only a small portion were compared with the control group using one-way ANOVA with Tukey *post hoc* tests. We also performed the statistical analysis for the comparison using a t -test while correcting for multiple comparisons using Bonferroni. The result of the t -test analysis after Bonferroni multiple correction was similar to that of one-way ANOVA, so we reported only the result of the one-way ANOVA for brevity.

RESULTS

There was no significant difference in age between the three groups as determined by one-way ANOVA ($F_{(2,60)}=0.0680$, $p=0.934$, Table I). Among the groups, there were significant differences between the volumes of GM ($F_{(2,60)}=15.599$, $p=0.001$), WM ($F_{(2,60)}=6.3130$, $p=0.003$), CSF ($F_{(2,60)}=5.1520$, $p=0.009$), ICV ($F_{(2,60)}=15.461$, $p=0.001$), TBV ($F_{(2,60)}=13.468$, $p=0.001$) and % of WM in ICV ($F_{(2,60)}=6.1710$, $p=0.004$). The box plots showing the comparison of GM (left), WM (middle) and CSF (right) tissue volumes are illustrated in Fig. 1.

Table I. The result of group comparison using one-way ANOVA.

	$F_{(2,60)}$	p -value
Age, years	0.0680	0.934
Grey matter volume, mm ³	15.599	0.001
White matter volume, mm ³	6.3130	0.003
CSF volume, mm ³	5.1520	0.009
ICV, mm ³	15.461	0.001
TBV, mm ³	13.468	0.001
% of Grey matter in ICV	4.4670	0.663
% of White in ICV	6.1710	0.004
% of CSF in ICV	1.3860	0.258

$p < 0.05$ are in boldface

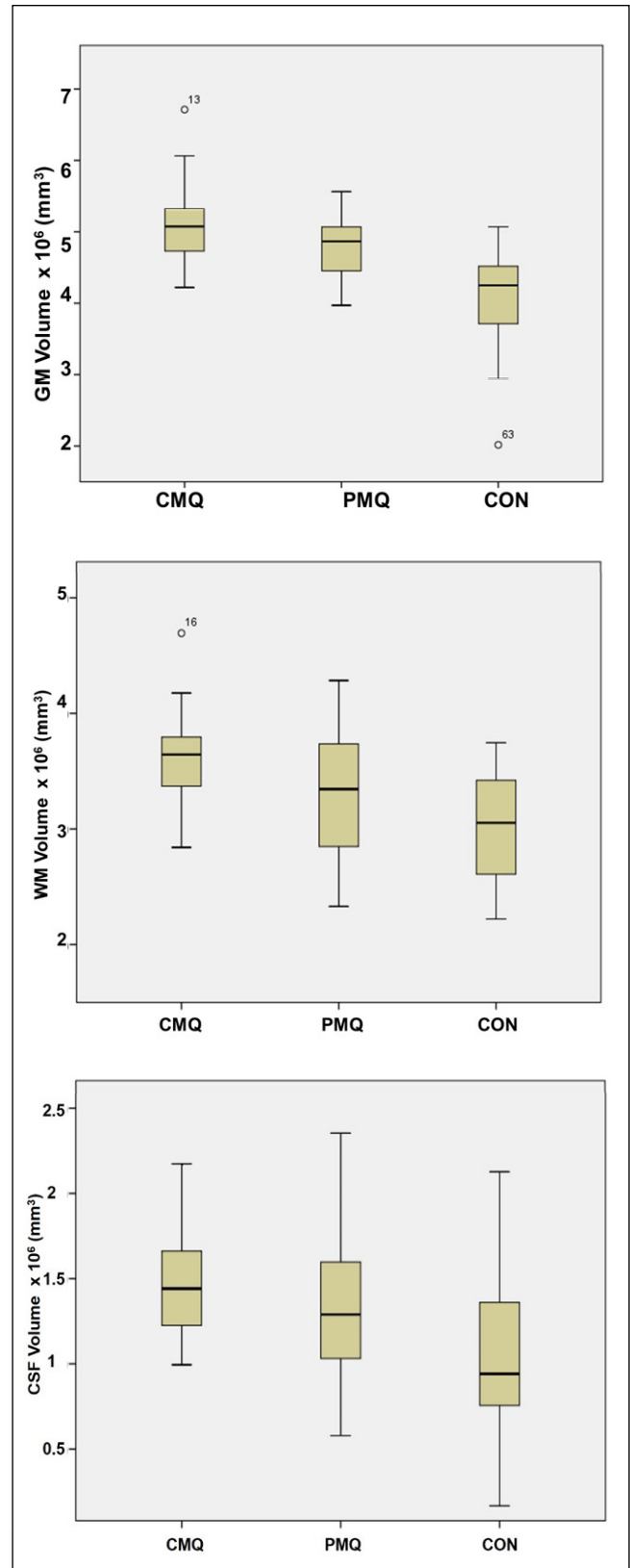


Fig. 1. Box plots showing the comparison of GM (top), WM (middle) and CSF (bottom) tissues. CMQ=Completely Memorized Quran, PMQ=Partially Memorized Quran, CON=Control.

After applying the Tukey *post hoc* on the one-way ANOVA, the volume of GM was statistically significantly larger for the CMQ subjects ($513263.32 \pm 58547.93 \text{ mm}^3$, $p=0.001$, Table II) and PMQ subjects ($476540.96 \pm 46822.35 \text{ mm}^3$, $p=0.001$) compared to the CON subjects ($401025.19 \pm 79961.73 \text{ mm}^3$). There was no significant difference between the CMQ and PMQ groups ($p=0.108$). The WM volume was significantly larger for the CMQ subjects ($361848.84 \pm 43545.38 \text{ mm}^3$, $p=0.002$) compared to the

CON subjects ($303218.75 \pm 48160.43 \text{ mm}^3$). There was no significant difference between the PMQ and CON groups ($p=0.176$). Similarly, the volume of CSF was significantly larger for the CMQ subjects ($151283.32 \pm 34795.87 \text{ mm}^3$, $p=0.007$) compared to the CON subjects ($103742.13 \pm 48259.89 \text{ mm}^3$). There was no significant difference between the PMQ and CON groups ($p=0.059$). The ICV was significantly larger for the CMQ subjects ($1026395.47 \pm 105771.73 \text{ mm}^3$, $p=0.001$) and PMQ subjects ($943602.11 \pm$

Table II. The result of group comparison using one-way ANOVA after Tukey *post hoc* test.

	CMQ	PMQ	P
Age, years	51.47 \pm 8.91	51.04 \pm 13.74	0.990
Grey matter volume, mm ³	513263.32 \pm 58547.93	476540.96 \pm 46822.35	0.108
White matter volume, mm ³	361848.84 \pm 43545.38	330892.68 \pm 52436.14	0.092
CSF volume, mm ³	151283.32 \pm 34795.87	136168.46 \pm 47748.21	0.490
ICV, mm ³	1026395.47 \pm 105771.73	943602.11 \pm 102884.11	0.051
TBV, mm ³	875112.16 \pm 89615.77	807433.64 \pm 87694.82	0.058
% of Grey matter in ICV	50.08 \pm 3.36	50.72 \pm 4.2	0.859
% of White in ICV	35.23 \pm 1.77	34.94 \pm 2.89	0.933
% of CSF in ICV	14.69 \pm 2.74	14.33 \pm 4.42	0.952
	PMQ	CON	
Age, years	51.04 \pm 13.74	50.13 \pm 6.52	0.962
Grey matter volume, mm ³	476540.96 \pm 46822.35	401025.19 \pm 79961.73	0.001
White matter volume, mm ³	330892.68 \pm 52436.14	303218.75 \pm 48160.43	0.176
CSF volume, mm ³	136168.46 \pm 47748.21	103742.13 \pm 48259.89	0.059
ICV, mm ³	943602.11 \pm 102884.11	807986.06 \pm 147315.58	0.001
TBV, mm ³	807433.64 \pm 87694.82	704243.94 \pm 120127.54	0.004
% of Grey matter in ICV	50.72 \pm 4.2	49.57 \pm 4.85	0.651
% of White in ICV	34.94 \pm 2.89	37.87 \pm 3.46	0.004
% of CSF in ICV	14.33 \pm 4.42	12.56 \pm 4.59	0.348
	CMQ	CON	
Age, years	51.47 \pm 8.91	50.13 \pm 6.52	0.930
Grey matter volume, mm ³	513263.32 \pm 58547.93	401025.19 \pm 79961.73	0.001
White matter volume, mm ³	361848.84 \pm 43545.38	303218.75 \pm 48160.43	0.002
CSF volume, mm ³	151283.32 \pm 34795.87	103742.13 \pm 48259.89	0.007
ICV, mm ³	1026395.47 \pm 105771.73	807986.06 \pm 147315.58	0.001
TBV, mm ³	875112.16 \pm 89615.77	704243.94 \pm 120127.54	0.001
% of Grey matter in ICV	50.08 \pm 3.36	49.57 \pm 4.85	0.932
% of White in ICV	35.23 \pm 1.77	37.87 \pm 3.46	0.019
% of CSF in ICV	14.69 \pm 2.74	12.56 \pm 4.59	0.274

102884.11 mm³, $p=0.001$) compared to the CON subjects (807986.06 ± 147315.58 mm³). There was no significant difference between the CMQ and PMQ groups ($p=0.051$).

The TBV was significantly larger for the CMQ subjects (875112.16 ± 89615.77 mm³, $p=0.001$) and PMQ subjects (807433.64 ± 87694.82 mm³, $p=0.004$) compared to the CON subjects (807986.06 ± 147315.58 mm³). There was no statistically significant difference between the CMQ and PMQ groups ($p=0.058$). Likewise, the % of WM in ICV was significantly smaller for the CMQ subjects (35.23 ± 1.77 mm³, $p=0.019$) and PMQ subjects (34.94 ± 2.89 mm³, $p=0.004$) compared to the CON subjects (37.87 ± 3.46 mm³). There was no statistically significant difference between the CMQ and PMQ groups ($p=0.933$).

DISCUSSION

We investigated differences between the brain tissues of three groups; those who memorized the scriptures completely, partially and those who did not. We found no significant difference in the ages of the study groups' participants compared with the control group. Our results showed that those who memorized the Quran had larger volumes of GM and WM than the control group. To the best of our knowledge, this is the first MRI-based study that has investigated the association between scripture memorization and brain atrophy.

There were no significant differences in the ages of the three groups. This suggests that age had no effect on the results obtained in this study. We found that those who memorized the Quran completely had more brain tissue than those who partially memorized, and that those who memorized partially had more brain tissues than those who did not memorize any portion of the Quran. This was true for GM, WM and TBV. However, there were no significant differences between those who had completely memorized the Quran and those that had partially memorized the Quran. This may suggest that the usage of their brains for the memorization resulted in this observed difference when compared with the control group.

With the exception of WM, the significant difference between most of the brain tissue classes (GM and TBV) of the control group and those who memorized the Quran (partially and completely) was attenuated when the tissue classes were corrected for head size using ICV. The ICV of those who had completely memorized the scripture was greater than those who had partially memorized it as well as those who had never memorized the scripture. As discovered, those who did not memorize the scripture had a greater percentage of WM in ICV than those who had memorized it. This appears in the opposite direction of the expected re-

sults. Thus, a higher sample size is required to further investigate this observation.

It was not surprising that the volumes of grey, white and total brain in those who memorized the Quran were greater than those who memorized only part or those who did not memorize the Quran because the more the brain is used, the higher the chance of preserving brain tissue. Our result also supports the work of Hartzell et al. (2016), in which it was discovered that the GM volume in some parts of the brain of Sanskrit verbal memory specialists was significantly greater than that of the control subjects. In a similar vein, while assessing the GM volume differences of textual memorizers and the control subjects using voxel-based morphometric, it was revealed that the GM of the memorizers was significantly increased compared to the control group (Sapuan et al., 2016).

Our results, that engaging the brain improves brain health, corroborate a study involving musicians that showed GM volume was highest in professional musicians, intermediate in amateur musicians and lowest among non-musicians (Hutchinson et al., 2003; Gaser and Schlaug, 2003; Sapuan et al., 2016;). Using diffusion tensor imaging, similar results were obtained where musicians were compared with non-musicians (Schmithorst and Wilke, 2002). In a related study on bilingualism, the tendency for greater proficiency in a second language, and likewise earlier acquisition of that language, correlated with greater GM and WM brain volumes (Mechelli et al., 2004; Luk et al., 2011).

These findings suggest that memorizing the scripture may increase the health of our brains through the maintenance of cognitive reserve, often by fending off a natural decline of cognitive function (Craik et al., 2010; Bialystok et al., 2012). Cognitive reserve refers to the resourceful utilization of brain networks to enhance brain usage during aging (Marian and Shook, 2012).

One major strength of this work is its uniqueness in the use of MRI techniques to study the effect of memorization in a developing nation. MRI is very useful and it is well suited for clinical studies in the developed world but rarely used in developing nations because of many cost-related reasons. In this study, all of the participants underwent MRI scanning and they were from a developing nation. Another strength of the study is the use of standard image analysis techniques. SPM, developed by the Wellcome Trust Centre for Neuroimaging group at University College London (UCL), is a standard image analysis toolbox that has been well validated and widely used all over the world. Using SPM implies that we adhered to the best practices in image processing. 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 type of study, a larger sample size is needed.

However, we do not anticipate that findings will be different significantly from those reported in this work.

CONCLUSION

In summary, our results indicated that those who memorized the scripture have more brain tissue preserved compared to those who have not memorized the scripture. This suggests that those who memorize the Quran may have lower cognitive impairment that could lead to neurological conditions. The implication is that people should be encouraged to memorize the scriptures so that their brains can maintain health in old age.

Future work should explore subcortical structures associated with memory and brain connectivity. It is anticipated that this approach could provide information and explanation on the association between the memorization and brain imaging biomarkers.

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