Education in Medicine Journal

ORIGINAL ARTICLE

Title: Visual-Spatial Intelligence and Learning Modality Preference for Neuroanatomy Comprehension Among Medical Students

Authors: Muhana Fawwazy Ilyas, Nanang Wiyono, Dhoni Akbar Ghozali, Yunia Hastami, Selfi Handayani, Siti Munawaroh, Muthmainah Muthmainah, Winastari Yarhanim Triniputri, Dhito Putranto Dwi Widodo, Khonsa Khoirumuna

Submitted Date: 25-03-2023

Accepted Date: 31-10-2023

To cite this article: Ilyas MF, Wiyono N, Ghozali DA, Hastami Y, Handayani S, Munawaroh S, Muthmainah M, Triniputri WY, Widodo DPD, Khoirumuna K. Visual-spatial intelligence and learning modality preference for neuroanatomy comprehension among medical students. Education in Medicine Journal. (early view).

ORIGINAL ARTICLE

ARTICLE INFO

Submitted: 25-03-2023
Accepted: 31-10-2023

Visual-Spatial Intelligence and Learning Modality Preference for Neuroanatomy Comprehension Among Medical Students

Muhana Fawwazy Ilyas[1,2], Nanang Wiyono[1], Dhoni Akbar Ghozali[1], Yunia Hastami[1,3], Selfi Handayani[1], Siti Munawaroh[1,3], Muthmainah Muthmainah[1,4,5], Winastari Yarhanim Triniputri[6], Dhito Putranto Dwi Widodo[7], Khonsa Khoirumuna[8]

[1]Department of Anatomy, Faculty of Medicine, Universitas Sebelas Maret, Surakarta, INDONESIA
[2]Department of Neurology, Faculty of Medicine, Universitas Sebelas Maret, Surakarta, INDONESIA
[3]Department of Medical Education, Faculty of Medicine, Universitas Sebelas Maret, Surakarta, INDONESIA
[4]The Florey Institute of Neuroscience and Mental Health, Mental Health Research Theme, Parkville, Melbourne, Victoria, AUSTRALIA
[5]The Florey Department of Neuroscience and Mental Health, University of Melbourne, Parkville, Melbourne, Victoria, AUSTRALIA
[6]Department of Anatomical Pathology, Faculty of Medicine, Universitas Sebelas Maret, Surakarta, INDONESIA
[7]Faculty of Medicine, Universitas Sebelas Maret, INDONESIA
[8]Department of Psychology, Faculty of Psychology, Universitas Sebelas Maret, Surakarta, INDONESIA

To cite this article: Ilyas MF, Wiyono N, Ghozali DA, Hastami Y, Handayani S, Munawaroh S, Muthmainah M, Triniputri WY, Widodo DPD, Khoirumuna K. Visual-spatial intelligence and learning modality preference for neuroanatomy comprehension among medical students. Education in Medicine Journal. (early view)

ABSTRACT

Neuroanatomy comprehension, an essential aspect of medical education, is important for understanding and diagnosing neurological cases. However, neuroanatomy is perceived as one of the most difficult subjects, thus contributing to the prevalence of neurophobia among medical students worldwide. In this cross-sectional observational analytic study, we aimed to investigate the association of visual-spatial intelligence (VSI) levels and learning modality preferences with neuroanatomical comprehension levels among 229 freshman medical students of Universitas Sebelas Maret, Indonesia. VSI level was measured using the Revised Purdue Spatial Visualization Test: Visualization of Rotations; learning modality preference using Visual, Auditory and Kinaesthetic (VAK) Learning Styles Survey; and neuroanatomical comprehension level using neuroanatomy final examination. The results show a significant correlation between VSI and comprehension of neuroanatomy ($r = 0.229$; $p < 0.0001$), with notable differences in learning modality preferences. Students with visual preferences (V, VA, VK, and VAK) exhibited higher neuroanatomical comprehension compared to those without visual preferences (A, K, and AK). Visual learning modality preference was a significant predictor of VSI ($\beta = 0.206$; $p = 0.006$) and neuroanatomy comprehension ($\beta = 0.161$; $p = 0.033$), and VSI was a significant predictor of neuroanatomy comprehension ($\beta = 0.305$; $p < 0.0001$). This study highlights the importance of considering VSI and learning modality preference in the context of neuroanatomy comprehension among medical students.

Keywords: *Anatomy, Learning Modality, Medical Education, Neuroanatomy, Visual-Spatial Intelligence*

CORRESPONDING Nanang Wiyono, Department of Anatomy, Faculty of Medicine, Universitas Sebelas Maret, Indonesia

Email: nanang.wiyono@staff.uns.ac.id

INTRODUCTION

Neuroanatomy comprehension, an essential aspect of medical education, plays a significant role in understanding and diagnosing neurological cases. However, neuroanatomy is perceived to be challenging, leading to the development of neurophobia among medical students worldwide. Neurophobia is a fear/phobia of neuroscience/clinical neurology that is experienced by medical students and doctors (1). This perception may be attributed to the lack of understanding of basic sciences, especially neuroanatomy (2–5). Studies conducted worldwide, including in Sri Lanka (2), Saudi Arabia (3) and Northern Ireland (4), suggest that neurophobia is a global issue. Recent studies found that medical students have lower knowledge and confidence in neuroanatomy material compared to other subjects due to various reasons, such as low-quality teaching (2,4). With the increasing prevalence of neurophobia, the implementation of effective learning systems and methods is needed to increase medical students' interest and better comprehension of neuroanatomy. Early interventions such as improved curriculum design, enhanced teaching methodologies and supportive learning environments can be incorporated to improve learning and retention of neuroanatomy in medical students.

Neurological cases are the leading cause of disability and death worldwide. In 2015, neurological cases were the largest contributors to disability-adjusted life-years (DALYs) and the second largest to global mortality. Between 1990 and 2015, there was an increase in the number of deaths by 36.7% and DALYs by 7.4% due to neurological causes. Among neurological cases, stroke (67.3%) was the leading cause of death (6). Because most neurological cases are emergent in nature, a thorough comprehension of neurology—basic science (especially neuroanatomy) and clinical neurology—is critical to avoid diagnostic and management errors.

Visual-spatial intelligence (VSI) is the ability to manipulate objects in the mind in three-dimensional (3D) form (7). This suggests a possible association between VSI level and neuroanatomical understanding. A study found that 3D learning techniques can be an effective tool to improve neuroanatomical knowledge (8). Similarly, another study showed that visual-spatial ability has a positive effect on gross anatomy learning performance in medical students (9). However, while some studies have investigated the association between VSI and anatomy (9–12), none were neuroanatomy-specific.

Learning modalities are sensory pathways through which individuals give, receive and store information. A lecturer's knowledge of student learning modality preferences can be beneficial in facilitating better learning. Moreover, students' own knowledge of their learning modality preferences can help change their study habits/preferences, thereby maximizing the understanding process of a subject (13). Studies worldwide have yielded contradicting results; for instance, some medical students in Colombia demonstrated no strong correlation between learning styles and summative anatomy exam performance (14). Similarly, another study including medical students in India showed no correlation between students' academic performance and their Visual, Aural, Read/Write and Kinaesthetic (VARK) learning modality preferences (13). However, contrary to these findings, some studies found that students with multimodal learning preferences showed improved academic performance (15,16).

Nevertheless, findings regarding the association between learning modalities, VSI and academic performance remain inconclusive (13–16), and to our knowledge, studies regarding this topic are lacking, including in Indonesia. Therefore, this study aimed to determine the association of VSI levels and learning modality preferences with neuroanatomical comprehension levels.

METHODS

This cross-sectional observational analytic study was conducted at the Faculty of Medicine, Universitas Sebelas Maret (UNS), Surakarta, Indonesia, between May and June 2021. The study was approved by the Health Research Ethical Committee of Dr. Moewardi General Hospital (approval number: 404/IV/HREC/2021). Freshman medical students of UNS who met the inclusion criteria were included. The inclusion criteria were as follows: (1) male and female students aged 17–21 years, (2) currently in the second semester of pre-clinical medical study and (3) voluntarily consented to participation. Participants with incomplete data and who stopped or did not fully participate in the entire study process were excluded. Data were obtained from 229 samples using a total sampling technique.

Howard Gardner's VAK learning style (17) and the VAK Learning Style Inventory by Victoria Chislett and Alan Chapman were used to determine the participants' learning modality preferences. The VAK questionnaire consists of 3 preferences (Visual, Auditory and Kinaesthetic) and 30 multiple-choice questions (MCQs) with 3 options. Each option aims to categorise the respondents' preferences. The preferred learning modality was concluded based on the highest frequency of options for each category. The validity of the instrument was assessed by peers, psychologists (18) and a panel of experts in the field, who reviewed it for clarity, relevance and adequacy in achieving its goals (19). In addition, the validity test using Karl Pearson's product-moment correlation showed that all items were valid (correlation coefficient >0.30) for the statement of each visual, auditory and kinaesthetic learning modality preference (20). Meanwhile, the reliability of the questionnaire was also determined using the retest-retest approach, which showed that each category (visual, auditory and kinaesthetic) had a high reliability score (α = 0.700–0.900) (21).

VSI level was measured using the Revised Purdue Spatial Visualization Test: Visualization of Rotations (PSVT:R). The Revised PSVT:R, developed by Yoon (22), is a newer version of the PSVT:R, which was originally developed by Guay (23). The uniqueness of this test is that it includes a variety of 3D objects (including objects with inclined, oblique and/or curved surfaces), and it requires a high level of spatial visualization ability (24). The test has been primarily used in research on educational settings in science, technology, engineering and mathematics (STEM) disciplines for more than three decades. The Cronbach's alpha coefficient was >0.800 (23,25–27), which was considered valid and reliable. While the Revised PSVT:R has been primarily used in STEM disciplines, VSI is a cognitive ability that extends beyond specific disciplinary boundaries. Given that neuroanatomy involves comprehending intricate spatial relationships and structures, which relies heavily on visual-spatial skills, it was justifiable to extend the application of the Revised PSVT:R to assessing VSI in the context of neuroanatomical understanding. In this study, the Revised PSVT:R was administered online, and the respondents were given a maximum of 25 minutes to answer the 30 MCQs, in accordance with the procedure used in Maeda et al.'s study (25). The individual participant's raw response on each of the 30 items was recorded as a dichotomous variable (correct=1, incorrect=0) for the proceeding analysis. A raw total score was computed by counting the number of correct responses among the 30 items and then converted to VSI level on a scale of 0–100.

Table 1: Item description of the neuroanatomy final examination

Item	Description	VSI-required
1	Embryology, structure naming	No
2	Structure identification, embryology	Yes
3	Embryology	No
4	Structure identification	Yes
5	Structure identification, clinical comprehension	Yes
6	Structure identification, structure connection	Yes
7	Structure identification, structure connection	Yes
8	Structure identification, structure connection	Yes
9	Structure identification	Yes
10	Function comprehension	No
11	Structure identification, function comprehension	Yes
12	Structure identification, function comprehension	Yes
13	Structure identification, structure naming	Yes
14	Structure identification, structure connection	Yes
15	Structure identification	Yes
16	Structure identification	Yes
17	Structure identification, structure connection	Yes
18	Structure naming	Yes
19	Structure naming	Yes
20	Structure identification	Yes
21	Structure naming	Yes
22	Clinical comprehension	No
23	Structure identification, function comprehension	Yes
24	Structure identification, function comprehension	Yes
25	Structure naming	No

Abbreviation: VSI, visual-spatial intelligence.

Neuroanatomy comprehension level was measured in relation to the scores obtained during the neuroanatomy final examination, which was prepared by anatomy and neuroanatomy experts from the Department of Anatomy, Faculty of Medicine, UNS. The final examination was tested for validity and reliability by 10 anatomy laboratory assistants, who found it valid and reliable ($\alpha = 0.891$). Of the 25 questions in the neuroanatomy final examination, only 20 VSI-required questions were used. Table 1 details the description of each item. The neuroanatomy comprehension level was obtained based on the number of correct VSI-required questions, which was then converted to a score of 0–100. Figure 1 shows an example of VSI-required solving questions.

Data were analysed using IBM SPSS Statistical version 27.00 software. The Kolmogorov–Smirnov test was used for normality. The Chi-square, Mann–Whitney, Kruskal–Wallis and Pearson's correlation tests were used for statistical analysis. Furthermore, path analysis with multiple linear regression was also conducted (28). $P \leq 0.05$ was considered statistically significant.

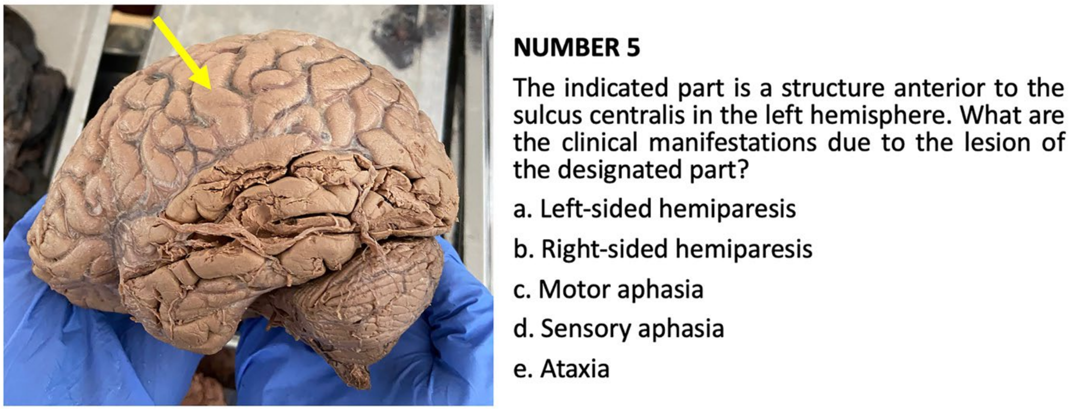


Figure 1: Visual-spatial intelligence-required solving questions in Item 5

RESULTS

A total of 229 freshman medical students were recruited to investigate the relationship between neuroanatomy comprehension level and age, sex, learning modality preference and VSI. Of these, 69.4% were females, 40.2% were 18 years old and 76.0% (174 respondents) had a uni-modal learning modality preference, with the majority being visual (34.9%). The average VSI and neuroanatomy comprehension levels were 59.9/100 ± 17.627 and 69.87 ± 18.057, respectively. Table 2 shows the entire sample characteristics.

Based on the number of learning modality preference approaches, we found no significant difference in age, sex, VSI and neuroanatomy comprehension between the uni-modal, bi-modal and tri-modal groups. The detailed data differences are shown in Table 3.

The analysis of each group demonstrated a significant difference in the proportion of sex ($p = 0.008$) between uni-modal learning modality preferences—V, A and K, wherein males have a preference distribution of 41.2% V, 29.4% A and 29.4% K, and females have 48.0% V, 41.5% A and 10.6% K. In addition, there was a significant difference in VSI levels between uni-modal learning modality preferences ($p = 0.019$). Furthermore, we found significant differences in neuroanatomy comprehension between bi-modal learning modality preferences—VA, VK and AK. Students who exhibited a visual component of learning modality preference, encompassing V, VA, VK and VAK modalities, tend to demonstrate a higher neuroanatomy comprehension level. Differences between each uni-modal and bi-modal learning modality preferences are presented in Table 4.

Table 2: Sample characteristics (n = 229)

Characteristic	n (%)
Sex	
Male	70 (30.6%)
Female	159 (69.4%)
Age (years)	18.71 ± 0.836
17	9 (3.9%)
18	92 (40.2%)
19	89 (38.9%)
20	35 (15.3%)
21	4(1.7%)
Learning modality preference	

Uni-modal	
Visual	80 (34.9%)
Auditory	66 (28.8%)
Kinaesthetic	28 (12.2%)
Bi-modal	
Visual-Auditory	14 (6.1%)
Visual-Kinaesthetic	9 (3.9%)
Auditory-Kinaesthetic	16 (7.0%)
Tri-modal	
Visual-Auditory-Kinaesthetic	16 (7.0%)
VSI level	59.90 ± 17.627
Neuroanatomy comprehension level	69.87 ± 18.057

Note: Nominal data are presented as frequencies and percentages. Numerical data are presented as means ± standard deviations. Abbreviation: visual-spatial intelligence.

Table 3: Differences based on the number of learning modality preferences

	Learning modality preference			**p-value**
	Uni-modal (n = 174)	**Bi-modal (n = 39)**	**Tri-modal (n = 16)**	
Sex				0.721[a]
Male	51 (72.9%)	14 (20.0%)	5 (7.1%)	
Female	123 (77.4%)	25 (15.7%)	11 (6.9%)	
Age	18.73 ± 0.806	18.62 ± 0.815	18.69 ± 1.195	0.712[b]
VSI	59.10 ± 18.335	61.31 ± 16.232	65.19 ± 11.635	0.378[b]
Neuroanatomy comprehension	69.19 ± 18.654	69.95 ± 16.472	77.06 ± 13.955	0.253[b]

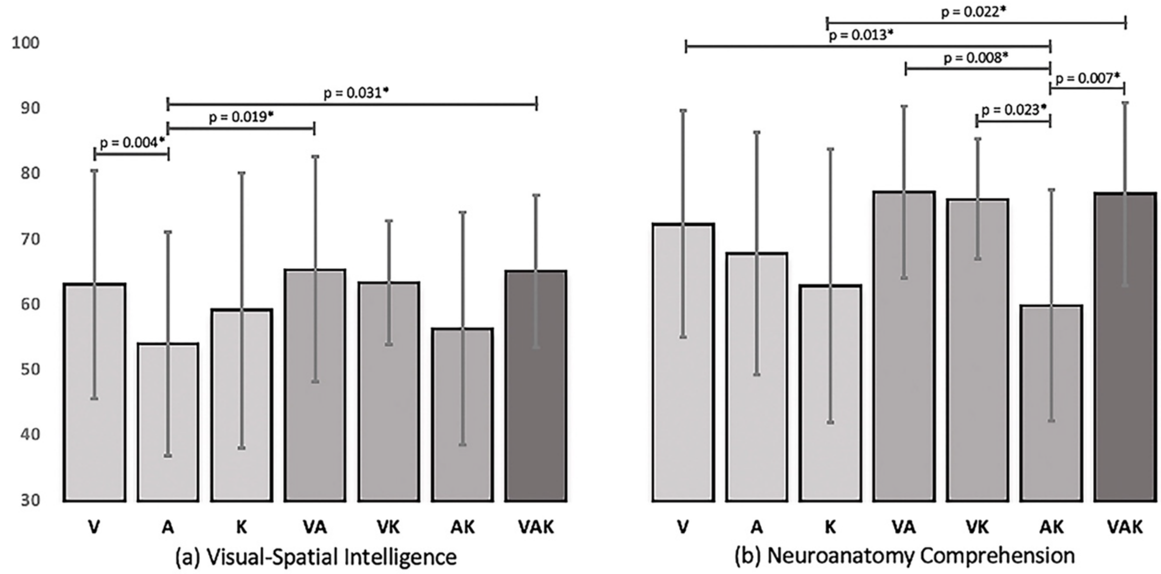
Note: Nominal data are presented as frequencies and percentages. Numerical data are presented as means ± standard deviations. [a]Chi-square test and [b]Kruskal-Wallis test were utilised. Abbreviation: visual-spatial intelligence.

Table 4: Differences between each uni-modal (V, A and K) and bi-modal (VA, VK and AK) learning modality preferences

	Learning modality preference							
	Uni-modal (n = 174)				**Bi-modal (n = 39)**			
	V	**A**	**K**	***p***	**VA**	**VK**	**AK**	***p***
Sex				**0.008[a]***				0.061[a]
Male	21 (41.2%)	15 (29.4%)	15 (29.4%)		4 (28.6%)	1 (7.1%)	9 (64.3%)	
Female	59 (48.0%)	51 (41.5%)	13 (10.6%)		10 (40.0%)	8 (32.0%)	7 (28.0%)	
Age	18.68 ± 0.808	18.85 ± 0.827	18.61 ± 0.737	0.375[b]	18.57 ± 0.852	18.67 ± 0.866	18.63 ± 0.806	0.974[b]
VSI	63.18 ± 17.468	54.09 ± 17.126	63.01 ± 20.875	**0.019[b]***	65.50 ± 17.279	63.44 ± 9.449	56.44 ± 17.795	0.178[b]
Neuroanatomy comprehension	72.46 ± 17.359	67.91 ± 18.505	63.01 ± 20.875	0.091[b]	77.29 ± 13.158	76.22 ± 9.189	60.00 ± 17.686	**0.013[b]***

Note: Nominal data are presented as frequencies and percentages. Numerical data are presented as means ± standard deviations. [a]Chi-square test and [b]Kruskal-Walis test were utilised. *$p \leq 0.05$ (statistically significant). Abbreviations: V, visual; A, auditory; K, kinaesthetic; VA, visual-auditory; VK, visual-kinaesthetic; AK, auditory-kinaesthetic; VSI, visual-spatial intelligence.

A cross-analysis was performed on the entire learning modality preferences (V, A, K, VA, VK, AK and VAK), which showed significant differences in VSI between V and A (p = 0.004), VAK and A (p = 0.031) and VA and A (p = 0.019). Significant differences in neuroanatomy comprehension were also observed between VA and AK (p = 0.008), VK and AK (p = 0.023), VAK and K (p = 0.022), VAK and AK (p = 0.007) and V and AK (p = 0.013). While students with visual preferences (V, VA, VK and VAK) showed no significant difference in VSI, they demonstrated a higher trend of VSI and neuroanatomy comprehension than the group without visual preferences (A, K and AK). The differences across learning modality preferences (V, A, K, VA, VK, AK and VAK) are presented in Figure 2.



Note: Data are presented as mean ± standard deviation; Mann–Whitney test was utilised. *p ≤ 0.05 (statistically significant). Abbreviation: V, visual; A, auditory; K, kinaesthetic; VA, visual-auditory; VK, visual-kinaesthetic; AK, auditory-kinaesthetic; VAK, visual-auditory-kinaesthetic.

Figure 2: Differences across learning modality preferences (V, A, K, VA, VK, AK and VAK)

Furthermore, this study showed a significant correlation between VSI and neuroanatomy comprehension level (r = 0.229; p < 0.0001). Meanwhile, there was no significant correlation between age and VSI or neuroanatomy comprehension. The detailed results are presented in Table 5. In addition, the gender-based analysis showed no significant difference between males and females in age, VSI and neuroanatomy comprehension (Table 6).

Variables including age, sex, learning modality preference and VSI level were examined using a path analysis with multiple linear regression for predicting neuroanatomy comprehension (only the uni-modal learning modality preference group was included in the analysis to determine which modality was a significant predictor). The results showed that visual learning modality preference was a significant predictor of VSI (β = 0.206, p = 0.006) and neuroanatomy comprehension (β = 0.161, p = 0.033). Furthermore, VSI was also a significant predictor of neuroanatomy comprehension (β = 0.305, p < 0.0001), as shown in Figure 3 (only significant predictors are visualised).

Table 5: Correlation among age, VSI and neuroanatomy comprehension

		Correlation coeff.	*p*
Age	**VSI**	-0.123	0.062
Age	**Neuroanatomy comprehension**	0.062	0.726
VSI	**Neuroanatomy comprehension**	0.229	**<0.0001***

Note: Pearson correlation test was utilised. **p* ≤ 0.05 (statistically significant). Abbreviation: VSI, visual-spatial intelligence.

Table 6: Gender-based analysis in age, VSI and neuroanatomy comprehension

	Sex		*p*
	Male	**Female**	
Age	18.79 ± 0.849	18.67 ± 0.831	0.361
VSI	60.30 ± 18.435	59.72 ± 17.315	0.797
Neuroanatomy comprehension	69.14 ± 17.893	70.19 ± 18.176	0.495

Note: Data were presented as means ± standard deviations. Mann–Whitney test was utilised. Abbreviation: visual-spatial intelligence.

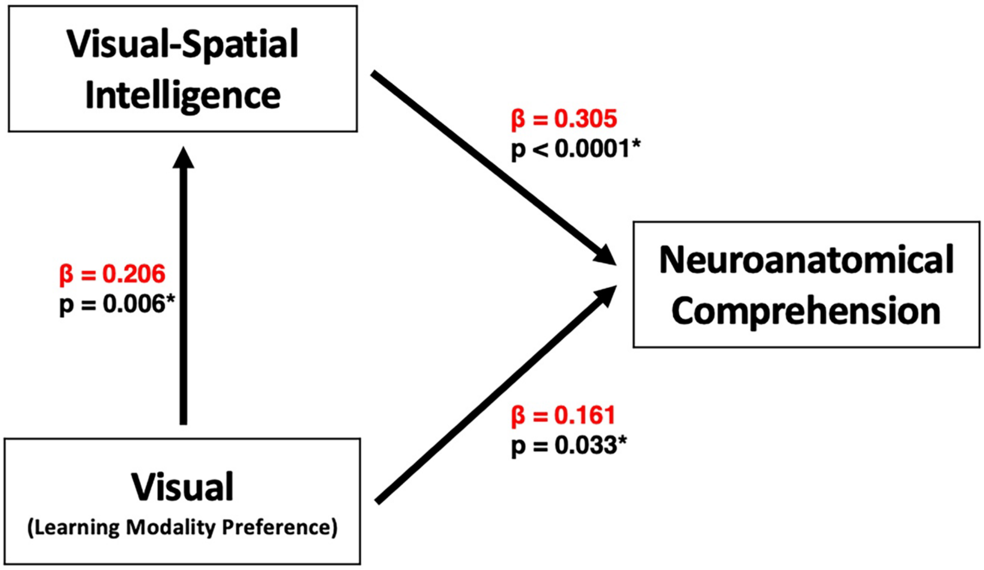


Figure 3: Path analysis with linear regression for neuroanatomical comprehension

DISCUSSION

This study aimed to determine the association of VSI levels and learning modality preferences with neuroanatomical comprehension levels. Our findings indicated a correlation between VSI and neuroanatomy comprehension, and the differences between each learning modality preference were significant. The group with visual preferences (V, VA, VK and VAK) showed a higher comprehension of neuroanatomical knowledge than the group without visual preferences (A, K and AK). Visual learning modality preference was a significant predictor of VSI and neuroanatomy comprehension, and VSI itself was a significant predictor of neuroanatomy comprehension.

Learning Modality Preference and Visual-Spatial Intelligence

As indicated previously, there were significant differences in VSI levels between groups with and without visual preferences. Visual learning modality preference was a significant predictor of VSI, and this may be attributed to several hypotheses. First, learners with a preference for visual learning modalities use visual modalities and visual thinking in their learning process to increase their VSI. Cakmak (2009) and Eisenberg (1999) showed that visual instruction develops spatial abilities. Second, learners with a high VSI level find it easier to understand materials with visual modalities, making them their dominant learning modality preference (29,30). A study found that there was a higher correlation between scores for visual learning and spatial ability compared to scores for learning using other modalities, with visual, kinaesthetic, multimodal, reading and auditory learning learners ranking at the top (31). On the contrary, Nordin et al. (2013) found no correlation between visualization skills and learning styles (32). According to Gardner's theory of multiple intelligence, a person has eight types of intelligence, one of which is VSI with different levels. One can maintain and strengthen these types of multiple intelligences, and no intelligence works independently (7).

Learning Modality Preference and Neuroanatomy Comprehension Level

Visual learning modality preference was a significant predictor of neuroanatomy comprehension, and this finding was different from those reported in previous studies. For instance, a study conducted in Colombia showed no statistically significant association between students' VARK learning model and their mid-term test results (14). While this could be attributed to several factors, the most likely explanation is in accordance with a study that found that academic achievement was significantly better in students whose learning modality preferences matched the dominant learning media component (33). Another possible explanation is that there is a difference in the effectiveness of learning and the suitability of learning methods with preferences for learning modalities.

As a preferred visual learning modality for anatomy, students have traditionally been using anatomy textbooks, which usually contain a large number of drawings, photographs and radiographs, including surgical atlases and manuals (34). Similarly, the dominant learning media in UNS is visual learning modalities, such as videos and pictures. On the other hand, other learning modality preferences showed a lower comprehension of neuroanatomical knowledge. First, this may be because the available learning media in UNS that support a preference for auditory learning modalities were limited to only lecture recordings and discussions. Second, owing to the coronavirus disease 2019 pandemic, the students had to enroll in an online learning system, leaving them with no opportunity to learn using real human bodies in the anatomy laboratory. This affected students with a preference for kinaesthetic learning modalities.

Visual-Spatial Intelligence and Neuroanatomy Comprehension Level

VSI not only significantly correlated with neuroanatomy comprehension level but is also a significant predictor. Lufler (2011) showed that students who scored in the highest quartile on the spatial intelligence Mental Rotations Test (MRT) had a much higher average score on the anatomy practicum test than those who scored in the lowest quartile on the MRT (9). This finding was in line with the research by Vorstenbosch (2013), which showed that students with high scores on the MRT systematically scored higher on tests of understanding anatomy material (33). In addition, the study found that medical students studying anatomy demonstrated greater improvement between two consecutive MRT tests than educational sciences students. The study also highlighted VSI's dual effect on learning, i.e., it can improve comprehension of neuroanatomy material, and learning anatomy can improve spatial intelligence (33). Other studies also supported the results of this study by showing a significant positive correlation between MRT scores and spatial anatomy task (SAT) scores, a significant negative correlation between MRT scores and time spent on the SAT, and a significant positive correlation between MRT scores and accuracy of SAT answers (35).

VSI includes spatial attention, spatial working memory, long-term spatial memory, spatial navigation and spatial imagery (36). According to this, there are several hypotheses that state that neuroanatomy comprehension levels can be influenced by VSI. First, increased spatial working memory is believed to increase the ease of processing, defending and manipulating neuroanatomical material. Second, increased long-term spatial memory is believed to increase the ability to store neuroanatomical material. Third, increased spatial navigation is believed to increase the ease of mastery of neuroanatomical pathway material. Lastly, increased spatial imagery is believed to increase the ability to create imaginary images of neuroanatomical material in the brain.

Sex with Learning Modality Preference and Visual-Spatial Intelligence

In this study, we observed a significant gender-based difference in the uni-modal learning modality preferences, consistent with the findings of Tuesca and Sarabi-Asibar (14,37). While kinaesthetic was the preferred learning modality among both sexes in Tuesca's study (14), it was visual in our study. On the contrary, a study found no significant gender differences in terms of preferences for different learning modalities (38). In another study, auditory was the most common learning modality preference for females and auditory and kinaesthetic for males (13). One study showed that while male subjects preferred auditory learning styles, females preferred visual, auditory and kinaesthetic learning styles (39).

Regarding bi-modal learning modality preferences, we found no significant differences between both sexes. However, gender-based differences in the proportion of learning modality preferences vary in several studies, and this may be attributed to the following reasons. First is the diversity and variability of individual preferences within each sex group. While some studies suggested that certain learning modalities are more prevalent among one sex, the range of preferences within each group may be substantial, making it difficult to establish a clear overall association. Second, learning modality preferences are influenced by individual factors such as sex, age, personality, heritage, race and environmental influences that can change over time (quality of education, parents' education level and culture) (40), leading to variations in the results across different studies. Furthermore, the specific educational practices and pedagogical approaches employed within each institution may play a role. The institution's learning environment, teaching methods and curriculum design may create an inclusive educational setting that minimises the influence of sex on learning modality preferences. Given the inconsistent results of various studies, we conclude that no generalizations can be made regarding the effect of sex on the preferences for learning modalities.

In general, there are two kinds of factors that influence intelligence: innate factors (genetically determined) and environmental factors (process-related learning) (41). A study suggested that both males and females experienced significant visual-spatial benefits during participation in a gross medical anatomy course (9). The finding, which is different from that previously reported, indicated that the VSI level in male respondents was not significantly different from females. Other studies showed a tendency for higher scores on the spatial intelligence MRT for males, although this difference did not reach statistical significance (42,43). Another study including teachers also showed that male teachers had higher spatial visualization abilities than their female counterparts. A study on the effectiveness of computer-based and traditional learning in anatomy learning showed that the VR learning group demonstrated no additional increase in their spatial abilities (43). This may be related to anatomical mastery because there were more female subjects in the group, and females reportedly have poorer spatial abilities (44,45). In addition, other studies also revealed that males scored significantly higher MRT than females (9,33,35).

Furthermore, many studies have shown that males outperform females in the area of spatial ability, especially in mental rotation (46). Sex differences in spatial ability appear as early as around 3–5 months of age (47) and are more evident by 95 years of age (48). Moreover, based on data obtained from more than 200,000 subjects from 53 countries, Lippa et al. (2010) showed that males performed better than females on visuospatial tasks (49). Neuroimaging studies have shown that males have larger parietal lobules (50), which may explain males' superiority in spatial ability (51). The right parietal cortex is involved in visuospatial processing (52). For instance, when the right parietal cortex was suppressed, participants were unable to perform spatial tasks (53). Interestingly, when males perform spatial tasks, their bilateral hemispheres are involved, whereas females tend to rely on their right hemispheres (54). It is also possible that the larger parietal cortices in males, especially in the right hemisphere (55), account for better performance on spatial tasks (47).

Limitations

We did not explore previous academic performances, learning environment roles and learning motivation. Future larger sample studies including participants from different populations and geographical locations are warranted. In addition, studies using other measurement tools such as VARK questionnaire, MRT and online 3D ability test, including other intelligence variables (logical-mathematical, linguistic and bodily-kinaesthetic intelligence) should be conducted. Finally, research with a longitudinal study approach can also be conducted to observe changes in learning modality preferences that are not fixed and tend to change with maturity and progress through a career.

CONCLUSION

The prevalence of neurophobia among medical students underscores the need for targeted educational strategies that cater to individual learning preferences and cognitive abilities. This study highlights the importance of considering VSI and learning modality preference in the context of neuroanatomy comprehension among medical students. The findings of our study suggest that students with higher VSI and a preference for visual learning modalities have an advantage in understanding complex neuroanatomical concepts. By incorporating visual-spatial learning techniques and providing resources that accommodate diverse learning modalities, educators or lecturers can enhance students' comprehension of neuroanatomy. Moreover, the results of this study emphasise the importance of personalised approaches to medical education, recognizing that different individuals have unique strengths and preferences when it comes to learning complex subjects. By addressing these individual differences, educators can foster a more inclusive and effective learning environment, promoting greater confidence and competence in neuroanatomy among medical students.

ETHICAL APPROVAL

This research was approved by the Health Research Ethical Committee of Dr. Moewardi Hospital (approval number: 404/IV/HREC/2021).

REFERENCES

1. Jozefowicz RF. Neurophobia: The Fear of Neurology Among Medical Students. Arch Neurol 1994;51:328–9. https://doi.org/10.1001/archneur.1994.00540160018003.

2. Matthias AT, Nagasingha P, Ranasinghe P, Gunatilake SB. Neurophobia among medical students and non-specialist doctors in Sri Lanka. BMC Med Educ 2013;13. https://doi.org/10.1186/1472-6920-13-164.

3. Abulaban AA, Obeid TH, Algahtani HA, Kojan SM, Al-Khathaami AM, Abulaban AA, et al. Neurophobia among medical students. Neurosciences 2015;20:37–40.

4. McCarron MO, Stevenson M, Loftus AM, McKeown P. Neurophobia among general practice trainees: The evidence, perceived causes and solutions. Clin Neurol Neurosurg 2014;122:124–8. https://doi.org/10.1016/j.clineuro.2014.03.021.

5. Abushouk AI, Duc NM. Curing neurophobia in medical schools: Evidence-based strategies. Med Educ Online 2016;21. https://doi.org/10.3402/meo.v21.32476.

6. Feigin VL, Krishnamurthi R V., Theadom AM, Abajobir AA, Mishra SR, Ahmed MB, et al. Global, regional, and national burden of neurological disorders during 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. Lancet Neurol 2017;16:877–97. https://doi.org/10.1016/S1474-4422(17)30299-5

7. Gardner H. Frames of mind: The theory of multiple intelligences. 20th ed. New York: Basic Books; 2004.

8. Ekstrand C, Jamal A, Nguyen R, Kudryk A, Mann J, Mendez I. Immersive and interactive virtual reality to improve learning and retention of neuroanatomy in medical students: a randomized controlled study. CMAJ Open 2018;6:E103–9. https://doi.org/10.9778/cmajo.20170110.

9. Lufler RS, Zumwalt AC, Romney CA, Hoagland TM. Effect of visual-spatial ability on medical students' performance in a gross anatomy course. Anat Sci Educ 2012;5:3–9. https://doi.org/10.1002/ase.264.

10. Rochford K. Spatial learning disabilities and underachievement among university anatomy students. Med Educ 1985;19:13–26. https://doi.org/10.1111/j.1365-2923.1985.tb01134.x.

11. Guillot A, Champely S, Batier C, Thiriet P, Collet C. Relationship Between Spatial Abilities, Mental Rotation and Functional Anatomy Learning. Advances in Health Sciences Education 2007;12:491–507. https://doi.org/10.1007/s10459-006-9021-7.

12. Hegarty M. Ability and sex differences in spatial thinking: What does the mental rotation test really measure? Psychon Bull Rev 2018;25:1212–9. https://doi.org/10.3758/s13423-017-1347-z.

13. Urval RP, Kamath A, Ullal S, Shenoy AK, Shenoy N, Udupa LA. Assessment of learning styles of undergraduate medical students using the VARK questionnaire and the influence of sex and academic performance. Adv Physiol Educ 2014;38:216–20. https://doi.org/10.1152/advan.00024.2014.

14. Martinez EG, Tuesca R. EducaciónMédica outcomes at a Colombian School of Medicine. Educación Médica 2019;20:79–83.

15. Nuzhat A, Salem RO, Quadri MSA, Al-Hamdan N. Learning style preferences of medical students: a single-institute experience from Saudi Arabia. Int J Med Educ 2011;2:70–3. https://doi.org/10.5116/ijme.4e36.d31c.

16. Peyman H, Sadeghifar J, Khajavikhan J, Yasemi M, Rasool M, Yaghoubi MY, et al. Using VARK approach for assessing preferred learning styles of first year medical sciences students: A survey from Iran. Journal of Clinical and Diagnostic Research 2014;8:1–4. https://doi.org/10.7860/JCDR/2014/8089.4667.

17. Gardner HE. The unschooled mind: How children think and how schools should teach. Basic books; 2011.

18. Anu S, Meena T. Assessment of learning style preference among undergraduate medical students-Using VAK assessment tool. International Journal of Medical and Clinical Research 2012;3:229.

19. Ramayah M, Sivanandan P, Nasrijal NH, Letchumanan T, Leong LC, Ramayah M. Preferred learning style: Gender influence on preferred learning style among business students. Journal of US-China Public Administration 2009;6:65–78.

20. Nizaruddin N, Rochmad R, Isnarto I. Validitas dan reliabilitas angket gaya belajar VAK. InProsiding Seminar Nasional Matematika dan Pendidikan Matematika 2020;5:435-441.

21. Hussein Ibrahim R, Hussein DA. Assessment of visual, auditory, and kinesthetic learning style among undergraduate nursing students. International Journal of Advanced Nursing Studies 2015;5:1. https://doi.org/10.14419/ijans.v5i1.5124.

22. Yoon SY. Psychometric properties of the revised purdue spatial visualization tests: visualization of rotations (The Revised PSVT: R). Indiana: Purdue University; 2011.

23. Guay R. Purdue spatial vizualization test. Indiana: Purdue University; 1976.

24. Yue J. Spatial Visualization By Orthogonal Rotations. Annual Conference Proceedings, ASEE Conferences 2004; 9.1114.1-9.1114.10. https://doi.org/10.18260/1-2--14032.

25. Maeda Y, Yoon SY, Kim-Kang G, Imbrie PK. Psychometric Properties of the Revised PSVT:R for Measuring First Year Engineering Students' Spatial Ability. International Journal of Engineering Education 2013;29:763-776.

26. Sorby SA, Baartmans BJ. The Development and Assessment of a Course for Enhancing the 3-D Spatial Visualization Skills of First Year Engineering Students. Journal of Engineering Education 2000;89:301–7. https://doi.org/10.1002/j.2168-9830.2000.tb00529.x.

27. Alkhateeb HM. Spatial Visualization of Undergraduate Education Majors Classified by Thinking Styles. Percept Mot Skills 2004;98:865–8. https://doi.org/10.2466/pms.98.3.865-868.

28. Azwar S. Metode Penelitian. Yogyakarta: Pustaka Pelajar; 2010.

29. Sedanur Çakmak. An investigation of the effect of origami-based instruction on elementary students' spatial ability in mathematics. Middle East Technical University, 2009.

30. Eisenberg N, Fabes RA, Shepard SA, Guthrie IK, Murphy BC, Reiser M. Parental Reactions to Children's Negative Emotions: Longitudinal Relations to Quality of Children's Social Functioning. Child Dev 1999;70:513–34. https://doi.org/10.1111/1467-8624.00037.

31. Danişman Ş, Erginer E. The predictive power of fifth graders' learning styles on their mathematical reasoning and spatial ability. Cogent Education 2017;4:1266830. https://doi.org/10.1080/2331186X.2016.1266830.

32. Nordin MS bin, Amin N binti M, Subari K bin, Hamid MZ bin A. Visualization Skills and Learning Style Patterns among Engineering Students at Universiti Teknologi Malaysia. Procedia Soc Behav Sci 2013;93:1769–75. https://doi.org/10.1016/j.sbspro.2013.10.114.

33. Vorstenbosch MATM, Klaassen TPFM, Donders ARTR, Kooloos JGM, Bolhuis SM, Laan RFJM. Learning anatomy enhances spatial ability. Anat Sci Educ 2013;6:257–62. https://doi.org/10.1002/ase.1346.

34. Koch J, Salamonson Y, Rolley JX, Davidson PM. Learning preference as a predictor of academic performance in first year accelerated graduate entry nursing students: A prospective follow-up study. Nurse Educ Today 2011;31:611–6. https://doi.org/10.1016/j.nedt.2010.10.019.

35. Nguyen N, Mulla A, Nelson AJ, Wilson TD. Visuospatial anatomy comprehension: The role of spatial visualization ability and problem-solving strategies. Anat Sci Educ 2014;7:280–8. https://doi.org/10.1002/ase.1415.

36. Cona G, Scarpazza C. Where is the "where" in the brain? A meta-analysis of neuroimaging studies on spatial cognition. Hum Brain Mapp 2019;40:1867–86. https://doi.org/10.1002/hbm.24496.

37. Sarabi-Asiabar A, Jafari M, Sadeghifar J, Tofighi S, Zaboli R, Peyman H, et al. The Relationship Between Learning Style Preferences and Gender, Educational Major and Status in First Year Medical Students: A Survey Study From Iran. Iran Red Crescent Med J 2014;17. https://doi.org/10.5812/ircmj.18250.

38. Pour MS, Ghoreishinia G, Zare S, Arbabisarjou A. Identification of Medical Students' Learning Styles in Terms of Gender. Glob J Health Sci 2016;9:76. https://doi.org/10.5539/gjhs.v9n4p76.

39. Sulaiman T. Intelligence and Learning Style : Gender-Based Preferences. International Review of Social Sciences and Humanities 2013;5:28–35.

40. O'Mahony SM, Sbayeh A, Horgan M, O'Flynn S, O'Tuathaigh CMP. Association between learning style preferences and anatomy assessment outcomes in graduate-entry and undergraduate medical students. Anat Sci Educ 2016;9:391–9. https://doi.org/10.1002/ase.1600.

41. Halpern D. Sex Diffenrences in Cognitive Abilities. New York: Psychology Press; 2013.

42. Keedy AW, Durack JC, Sandhu P, Chen EM, O'Sullivan PS, Breiman RS. Comparison of traditional methods with 3D computer models in the instruction of hepatobiliary anatomy. Anat Sci Educ 2011;4:84–91. https://doi.org/10.1002/ase.212.

43. Khot Z, Quinlan K, Norman GR, Wainman B. The relative effectiveness of computer-based and traditional resources for education in anatomy. Anat Sci Educ 2013;6:211–5. https://doi.org/10.1002/ase.1355.

44. Vandenberg SG, Kuse AR. Mental Rotations, a Group Test of Three-Dimensional Spatial Visualization. Percept Mot Skills 1978;47:599–604. https://doi.org/10.2466/pms.1978.47.2.599.

45. Masters MS, Sanders B. Is the gender difference in mental rotation disappearing? Behav Genet 1993;23:337–41. https://doi.org/10.1007/BF01067434.

46. Voyer D, Voyer SD, Saint-Aubin J. Sex differences in visual-spatial working memory: A meta-analysis. Psychon Bull Rev 2017;24:307–34. https://doi.org/10.3758/s13423-016-1085-7.

47. Quinn PC, Liben LS. A Sex Difference in Mental Rotation in Young Infants. Psychol Sci 2008;19:1067–70. https://doi.org/10.1111/j.1467-9280.2008.02201.x.

48. Tran US, Formann AK. Piaget's water-level tasks: Performance across the lifespan with emphasis on the elderly. Pers Individ Dif 2008;45:232–7. https://doi.org/10.1016/j.paid.2008.04.004.

49. Lippa RA. Gender Differences in Personality and Interests: When, Where, and Why? Soc Personal Psychol Compass 2010;4:1098–110. https://doi.org/10.1111/j.1751-9004.2010.00320.x.

50. Frederikse ME. Sex Differences in the Inferior Parietal Lobule. Cerebral Cortex 1999;9:896–901. https://doi.org/10.1093/cercor/9.8.896.

51. Koscik T, O'Leary D, Moser DJ, Andreasen NC, Nopoulos P. Sex differences in parietal lobe morphology: Relationship to mental rotation performance. Brain Cogn 2009;69:451–9. https://doi.org/10.1016/j.bandc.2008.09.004.

52. Arsalidou M, Taylor MJ. Is 2+2=4? Meta-analyses of brain areas needed for numbers and calculations. Neuroimage 2011;54:2382–93. https://doi.org/10.1016/j.neuroimage.2010.10.009.

53. Rosenthal, R., & Rosnow RL. rtifacts in behavioral research: Robert Rosenthal and Ralph L. Rosnow's classic books. Oxford University Press.; 2009.

54. Clements DH, Sarama J. Engaging young children in mathematics: Standards for early childhood mathematics education. 2003. https://doi.org/10.4324/9781410609236.

55. Baibakov SE, Fedorov VP. Morphometric Characteristics of the Brain in Children Aged One Year (magnetic resonance tomography data). Neurosci Behav Physiol 2010;40:69–72. https://doi.org/10.1007/s11055-009-9224-5.