

ARTICLE INFO

Received: 25-03-2023

Accepted: 31-10-2023

Online: 29-03-2024

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

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To cite this article: Ilyas MF, Wiyono N, Ghozali DA, Hastami Y, Handayani S, Munawaroh S, et al. Visual-spatial intelligence and learning modality preference for neuroanatomy comprehension among medical students. *Education in Medicine Journal*. 2024;16(1):149–164. <https://doi.org/10.21315/eimj2024.16.1.10>

To link to this article: <https://doi.org/10.21315/eimj2024.16.1.10>

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. This cross-sectional observational analytic study 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 (UNS), Indonesia. VSI level was measured using the Revised Purdue Spatial Visualization Test: Visualization of Rotations (PSVT:R); learning modality preference using the VAK or visual (V), auditory (A), and kinaesthetic (K) 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*

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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 maximising 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. 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 old; (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 or visual (V), auditory (A), and kinaesthetic (K) learning style (17) and the VAK learning style inventory by Victoria Chislett and Alan Chapman (18) were used to determine the participants' learning modality preferences. The VAK questionnaire consists of three preferences (visual, auditory, and kinaesthetic) and 30 multiple-choice questions (MCQs) with three 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 ($\alpha = 0.700$ – 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 visualisation 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. (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.

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.

Table 1: Item description of the neuroanatomy final examination

Item number	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

(Continued on next page)

Table 1: (Continued)

Item number	Description	VSI-required
21	Structure naming	Yes
22	Clinical comprehension	No
23	Structure identification, function comprehension	Yes
24	Structure identification, function comprehension	Yes
25	Structure naming	No

Data were analysed using SPSS (ver. 27, IBM, Armonk, New York, US). 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.

**NUMBER 5**

The indicated part is a structure anterior to the sulcus centralis in the left hemisphere. What are the clinical manifestations due to the lesion of the designated part?

- Left-sided hemiparesis
- Right-sided hemiparesis
- Motor aphasia
- Sensory aphasia
- Ataxia

Figure 1: VSI-required solving questions in Item 5.

Source: Department of Anatomy, Faculty of Medicine, UNS.

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 $59.9/100 \pm 17.627$ and 69.87 ± 18.057 , respectively. Table 2 shows the entire sample characteristics.

Based on the number of learning modality preference approaches, no significant difference in age, sex, VSI and neuroanatomy comprehension between the uni-modal, bi-modal and tri-modal groups was found. 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, significant differences

were found in neuroanatomy comprehension between bi-modal learning modality preferences—visual-auditory (VA), visual-kinaesthetic (VK), and auditory-kinaesthetic (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 (year)	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	
VA	14 (6.1%)
VK	9 (3.9%)
AK	16 (7.0%)
Tri-modal	
VAK	16 (7.0%)
VSI level	59.90 ± 17.627
Neuroanatomy comprehension level	69.87 ± 18.057

Notes: Nominal data are presented as frequencies and percentages. Numerical data are presented as mean ± standard deviation.

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

Characteristic	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

Notes: Nominal data are presented as frequencies and percentages. Numerical data are presented as mean ± standard deviation. ^aChi-square test and ^bKruskal-Wallis test were utilised.

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

Characteristic	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*}

Notes: Nominal data are presented as frequencies and percentages. Numerical data are presented as mean ± standard deviation. ^aChi-square test and ^bKruskal-Wallis test were utilised. * $p \leq 0.05$ (statistically significant).

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.

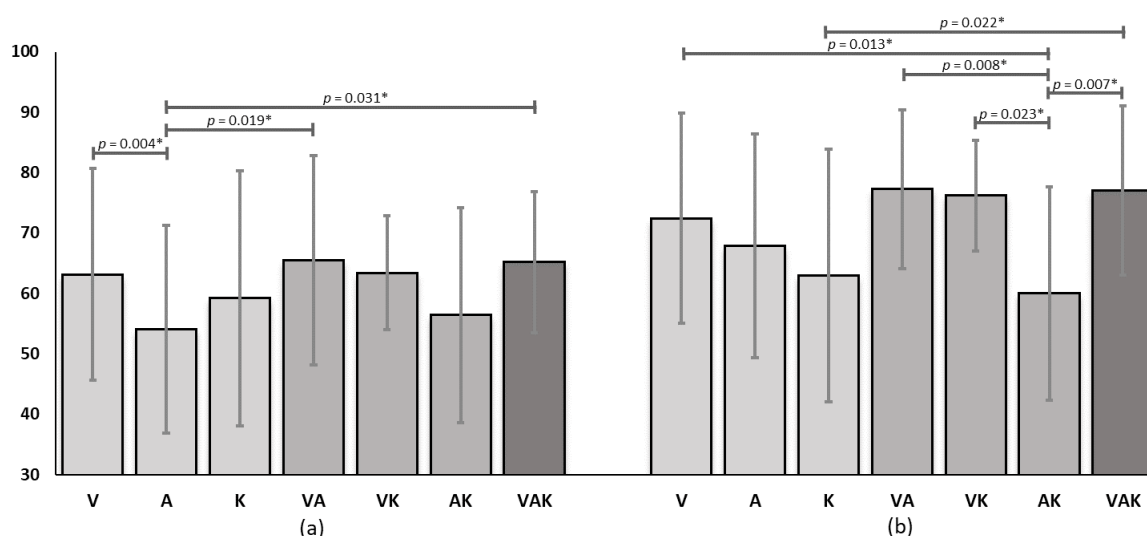


Figure 2: Differences across learning modality preferences (V, A, K, VA, VK, AK, and VAK) for (a) visual-spatial intelligence and (b) neuroanatomy comprehension.

Notes: Data are presented as mean ± standard deviation; Mann–Whitney test was utilised. * $p \leq 0.05$ (statistically significant).

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 ($\beta = 0.206, p = 0.006$) and neuroanatomy comprehension ($\beta = 0.161, p = 0.033$). Furthermore, VSI was also a significant predictor of neuroanatomy comprehension ($\beta = 0.305, p < 0.0001$), as shown in Figure 3 (only significant predictors are visualised).

Table 5: Correlation among age, VSI and neuroanatomy comprehension

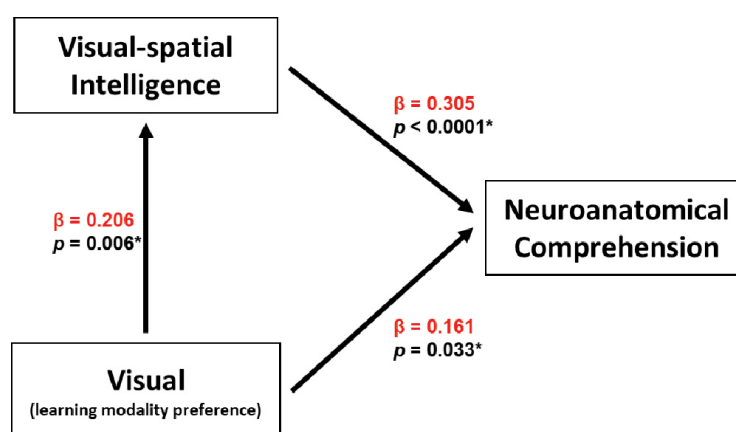
Variable	Correlation coefficient	p
Age VSI	-0.123	0.062
Age Neuroanatomy comprehension	0.062	0.726
VSI Neuroanatomy comprehension	0.229	<0.0001*

Notes: Pearson correlation test was utilised. * $p \leq 0.05$ (statistically significant).

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

Variable	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

Notes: Data were presented as mean ± standard deviation. Mann–Whitney test was utilised.

**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. The 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 VSI

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. Çakmak (29) and Eisenberg et al. (30) 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. (32) found no correlation between visualisation skills and learning styles. According to Gardner's (7) 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 COVID-19 pandemic, the students had to enrol 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.

VSI and Neuroanatomy Comprehension Level

VSI not only significantly correlated with neuroanatomy comprehension level but is also a significant predictor. Lufler et al. (9) 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. This finding was in line with the research by Vorstenbosch et al. (33), which showed that students with high scores on the MRT systematically scored higher on tests of understanding anatomy material. 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 VSI

A significant gender-based difference in the uni-modal learning modality preferences was observed in this study, consistent with the findings of Martinez and Tuesca (14) and Sarabi-Asiabar et al. (37). While kinaesthetic was the preferred learning modality among both sexes in Martinez and Tuesca's study (14), it was visual in this 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 VAK learning styles (39).

Regarding bi-modal learning modality preferences, no significant differences between both sexes was found in this study. 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, this study concludes that no generalisations 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 visualisation 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. 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

This study 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 this 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, recognising 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.

ACKNOWLEDGEMENTS

Authors sincerely thank the Medical Study Programme and the Anatomy and Embryology Laboratory of the Faculty of Medicine, UNS, Indonesia and the respondents who have been willing to be research subjects, as well as other parties who participated in this research.

ETHICAL APPROVAL

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

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