Do medical students who are multilingual have higher spatial and verbal intelligence and do they perform better in anatomy examinations?

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Short title: Multilingualism and spatial and verbal intelligence

Abstract

We have already reported that medical students who have prior knowledge of classical Greek and Latin perform better in anatomy examinations. It has also been shown that fluency in more than one language can influence spatial and verbal intelligence and here we hypothesise that medical students who have linguistic skills develop higher spatial and verbal intelligence compared with monolingual students, that there are gender differences, and that there are positive effects on performance in anatomy examinations.

One hundred and seventy-three Second Year medical students at Cardiff University responded to spatial and verbal intelligence questions that were adapted from the British MENSA website. This is a 63% response rate for the student cohort. The students were then categorised into different groups depending upon their linguistic knowledge and skills. Across all groups, no gender differences were discerned for either spatial or verbal intelligence. Students who were categorised as monolingual (with only skills in English) had lower spatial and verbal intelligence than those who were multilingual. Medical students who had fluency in English and non-European languages showed greater spatial and verbal intelligence than other groups. However, there was no significant improvement in their examination marks for anatomy, although the examination performance might be complicated by cultural considerations.

A further finding from our study was that, where an anatomy test required spatial recognition using cadaveric specimens, students with low spatial intelligence had

significantly poorer performances. Furthermore, where tests used multiple choice questions, the level of spatial and verbal intelligences had no influence.

We would advocate that, when all newly-recruited medical students are tutored in medical terminologies to help them develop the extensive vocabulary required for their professional careers, they should also be made aware of any deficiencies in spatial and verbal skills that could affect their learning abilities. Given that we would expect students to benefit in their careers from developing spatial and verbal skills, we also recommend that examination tests in anatomy should avoid the exclusive use of multiple choice questions.

Introduction

According to a European Commission report published in 2006, multilingualism relates both to a situation where several languages are spoken within a specific geographical area and to the ability of a person to master several languages. Marian and Shook (2012) reported that most of the world's population is bilingual or multilingual and they claimed that the 'bilingual brain' is better adapted for switching between tasks (i.e., multi-tasking) because of the ability to inhibit one language in order to imply the another.

The rewards of being multilingual are not restricted just to linguistic knowledge. Benefits also appear to extend into cognitive, social, personal, academic, and professional attributes (Thomas and Collier, 1998; Cook and Vivian, 1999). It has been established that much of language functioning is processed in two areas in the cerebral cortex, Wernicke's area (the posterior superior temporal gyrus) and Broca's area of the frontal lobe (Price *et al*., 1996; Binder *et al*., 2011; Ge *et al*., 2015; Gębska-Kośla *et al*., 2017; Stefańczyk and Majos; 2017). These areas are usually located in the dominant hemisphere (i.e., the left hemisphere in 97% of people) and are considered the most important areas for language processing (e.g., Fitzpatrick *et al*., 2004; Beharelle *et al*., 2010). It has been suggested that monolingual persons use specific, and restricted, regions of the brain to process language in comparison to multilingual persons who employ a greater neural profile (frontal and bilateral cortex recruitment) (e.g., Kim *et al*., 1997; Dehaene *et al*., 1997; Hernandez *et al*., 2000; Hahne and Friederici, 2001; Marian *et al*., 2003). A structural imaging study of grey matter within multilinguals revealed that their volume of grey matter was increased in the left inferior parietal lobe (Miller *et al*., 1980; Mechelli *et al.*, 2004), this area being concerned with language processing and with balancing knowledge between multiple languages, mathematical operations, and sensory information (Fabbro et al., 2000). Owing to the larger neural profile and overlap of the control centres in the brain, it is thought that multilinguistic persons are better at both spatial and verbal intelligence (Bialystok *et al*., 2012).

We have already reported that medical students in the early stages of their course strongly believe that it is important to have some understanding of classical Greek and Latin since these languages form the basis of anatomical and medical terminologies (Stephens and Moxham, 2016). We have also shown that medical students who have had some tuition in classical Greek and Latin prior to entering medical school perform better at examinations in anatomy (Stephens and Moxham, 2018). Medical students provide a useful group of university students to assess the importance of multilingualism in developing spatial and verbal intelligence. They are often regarded as being academically talented and they have a demanding curriculum and educational training regime (there being a considerable body of knowledge to acquire and many precise skills to attain). Furthermore, excepting for those who enter medical school as graduates, their medical/university education is generally unlike anything they have experienced in school prior to entering university. Indeed, because of the new and extensive medical terminology they must acquire, it is as if they have to learn a new language. Although we would advocate that an appreciation of a newly-recruited medical student's linguistic skills is required, it is noteworthy that, in a study to ascertain anatomists requirements of the skills and attributes of newly-recruited medical students, linguistic skills were only regarded as being 'desirable' and not as being 'required' (Moxham *et al*., 2018). Notwithstanding this finding, in the present study, we test the following hypotheses:

- that medical students who are multilinguistic have higher spatial and verbal intelligence;
- that there are gender differences in spatial and verbal intelligence, female medical students performing better verbally but not spatially (this hypothesis is in line with the findings of Downing *et al*. (2008) and Zaidi (2010));
- that, if medical students who are multilingual have higher spatial and verbal intelligence, they perform better at anatomy examinations.

We tested these hypotheses by means of questionnaires distributed to medical students at Cardiff University whose examination performances were available anonymously and in line with agreed directives from the ethical committee of Cardiff University.

Methods

Following ethical approval from the Research Ethics Committee at the Cardiff School of Biosciences (Stephens 0115-2), questionnaires were distributed to all Second Year medical students at Cardiff University. Second Year students were chosen as we already have data for this group with respect to their knowledge of, and attitudes towards, classical languages and also have detailed information concerning their performances in anatomy examinations.

In order to assess the reliability and validity of the questionnaire by means of Cronbach's alpha tests, a group of 20 students who were not involved in the present study completed the questionnaire twice, the second time three weeks after initially completing the questionnaire.

The medical students in the cohort being investigated were given an information sheet and a consent form that emphasised that their participation in the study was voluntary. The students had time to ask questions to the principal investigator before responding to the questionnaire.

The questionnaire consisted of two sections that tested verbal intelligence and spatial intelligence, each section comprising ten questions. These questions were adapted from the British MENSA website (www.mensa.org.uk). Figure 1 provides examples of the questions employed to assess spatial intelligence. From the responses to the questions, each student could be assigned scores between 0-10 for both spatial and verbal intelligence.

Two sets of data relating to the surveyed students' examination performances were available for analyses. Firstly, the students undertook formative tests in anatomy that were comprised mainly of questions requiring identification of anatomical structures from human cadaveric specimens. These questions therefore required spatial intelligence abilities. Secondly, the students sat summative examinations that consisted of multiple choice questions more suited to requiring verbal intelligence abilities.

Data were placed into Excel spreadsheets and analysed using Anderson-Darling normality tests, Mann-Whitney U tests, Cronbach's alpha tests, and Kruskal-Wallis tests.

Results

One hundred and seventy-three students responded to the questionnaire. The student cohort comprised two hundred and seventy-five students and therefore the response rate was 63%. As mentioned in the Methods section, Cronbach's alpha tests were used to assess the reliability of the questionnaire. The alpha coefficient calculated was 0.79 (a coefficient between 0.65 and 0.8 showing that a questionnaire is reliable and valid). Figures 2 and 3 show the results of conducting Darlington-Anderson normality tests. For both verbal and spatial intelligence data, since a p value <0.0005 was calculated for these tests, the data were not normally distributed.

From the questionnaire, a maximum score for both verbal and spatial intelligence was ten. Our findings showed that 59% of the students scored between 7 and 10 for spatial intelligence and 60% between 7 and 10 for verbal intelligence. Figure 4 provides a histogram comparing the average performance between male and female students in spatial and verbal intelligence**.** Kruskal-Wallis tests were conducted to establish the significance between the performances of male and female students. H values (critical values) of -570.4 and -572.7 were derived for female verbal and spatial intelligence respectively. H values (critical values) of -637.9 and -638.2 were calculated for male spatial and verbal intelligence respectively. As all the values were less that the X^2 value of 7.81, it was concluded that there were no significant differences between the performances of male and female students.

Whitney-Mann U tests were then conducted to compare students who were monolingual (English language only) with those who were multilingual and/or had knowledge of classical and modern languages. For the monolingual group, the mean spatial score was 7.7 ± 1.49 SD and the mean verbal score was 8.1 ± 1.66 SD. For the students who were not monolingual, the mean spatial score was 8.28 ± 1.19 SD and the mean verbal score was 8.78 ± 1.08 SD. As the Z score for the Whitney-Mann U tests was 1.86 for verbal intelligence and 0.97 for spatial intelligence (p<

0.05), the difference in the means between monolingual and multilingual students is statistically significant and the probability of the difference being due to chance is less than 0.05%. Thus, students who are monolingual (fluent in English only) show less verbal and spatial intelligence compared to the multilingual groups.

From the responses to the questionnaire, the respondents could be categorised into eight groups (Table 1).

Table 1: The categories of medical students with different linguistic skills.

	Categories	**Number of students**
Group A	Students who had prior knowledge of Greek and/or Latin from school (Pre GCSE) (age less than 14 years)	10 5 males, 5 females
Group B	Students who have studied Greek and/or Latin in GCSE (aged 14-16 years)	18 7 males, 11 females
Group C	Students who are fluent in English and other European language	21 8 males, 13 females
Group D	Students who are fluent in English and also other non-European languages	14 7 males, 7 females

Group E	Students who are fluent in English only	25
		15 males, 10 females
Group F	Students who are moderately fluent in English with high fluency in other non-European languages	11
		5 males, 6 females
Group G	Students who are fluent in English with moderate fluency in other European and non-European languages	74
		43 males, 31 females
Group H	Students who have studied Greek and/or Latin from school and have fluency in English and another modern language	24
		10 males, 14 females

Figure 5 provides a histogram comparing the average scores attained by the various categories of Second Year medical students for spatial and verbal intelligence. This suggests that students who are fluent in English and other non-European languages (Group D) perform better in both verbal and spatial intelligence tests. The histogram also suggests that students from all the categories performed better in verbal intelligence than in spatial intelligence tests. In order to ascertain whether there are statistical significant differences between different groups of students, Kruskal-Wallis tests were employed. It was found that Group D students who are fluent in English and in other non-European languages were statistically significantly different from other groups (H value (critical value) 15.49 is greater than X^2 value of 14.06 for verbal intelligence, while H value (critical value) of 56.11 is greater X^2 value of 14.06 for spatial intelligence).

To determine the link between the anatomy examination performance and spatial and verbal intelligence, the students were categorised into three different groups based on their test scores for spatial and verbal intelligence: scores between 8 and 10, 5 and 7 and less than 4. According to the histogram shown in Figure 6, there appears to be a relationship between the verbal-spatial scores and anatomy examination performance. Using a Kruskall-Wallis test, a H (critical value) of 5.56 and $p=0.018$ was calculated for the formative examination results of students with spatial intelligence less than 4. Thus, there was statistical significance for the above group but there were no significant differences between any other categories of students for either summative or formative examinations.

In order to ascertain whether there are statistically significant differences for examination performances of groups of students with different linguistic skills, Whitney-Mann U tests were undertaken. In particular, we wished to establish whether the multilingual students with the highest spatial and verbal intelligence (i.e., Group D students with English and non-European languages) performed better in their anatomy examinations (Figure 7). It was found that there were no statistically significant difference from other groups, either for their formative or their summative anatomy examinations.

Discussion

That many medical students were assigned scores between 7 and 10 in our tests (59% of students with high spatial intelligence; 60% of students with high verbal intelligence) accords with reports that students with relatively high spatial abilities tend to gravitate towards, and excel in, scientific and technical fields such as the physical sciences, engineering, mathematics, and computer science (Wai *et al*., 2009). According to Trickett and Trafton (2007), a student who has high visual-spatial ability is able to generate mental representations of intricate ideas and then mentally manipulate those representations, which is a skill that is needed for creative productivity and theory development in STEM subjects.

Although, there were students in the surveyed cohort who had low spatial and verbal intelligence scores (i.e., <4), across the class, and regardless of the spatial and verbal intelligence scores, little difference in examination performances were recorded. However, the students with spatial intelligence scores less than 4 performed poorer in the formative examinations that required spatial abilities. Regrettably, the use of multiple choice questions in the summative examinations do not require visual-spatial abilities and indeed no differences in examination performances could be discerned for students with different spatial intelligence scores. Furthermore, no differences could also be discerned for multiple choice examination performance between students with different verbal intelligent scores. Whatever the multiple choice questions are testing (primarily factual recognition), we conclude that these types of question do not differentiate between students with different spatial and verbal intelligence.

Despite there being some conflict in the literature, evidence regarding gender differences for spatial and verbal intelligences generally suggests that males perform better at spatial tasks while females perform better at verbal and memory tasks (e.g., Downing et al*.,* 2008; Zaidi, 2010). We found however that there were no significant gender differences in our data. This accords with the findings of Aluja-Fabregat et al. (2000) and Colom et al. *(*2006) who reported that, while males have a larger brain size, females have greater brain density. Thus, the sexual dimorphism allows the same number of neurons in male and female brains, despite the difference in size. According to Allen et al. (2002), in males and females the proportional size of regions relative to total volume of the hemisphere are similar. Thus, the representation of different centres in both the sexes are similar. This could explain why there are no gender difference in spatial and verbal intelligence. Alternatively, admission procedures and criteria for recruiting medical students could 'wash out' gender differences. It is been suggested that environmental factors, educational policies, learning styles, geographical distribution and socio-economic factors play more important rôles than gender in the development of intelligence (e.g., Miller and Halpern, 2014). These factors have yet to be assessed for medical students.

Concerning personality traits, we previously reported that medical students who are multilingual classified themselves as being curious, organised, outgoing and friendly (Stephens and Moxham, 2018). This contrasted with monolingual students who considered themselves as being cautious, easy going, reserved and detached. Several reports have linked the 'Openness' personality trait to multilingualism (Dewaele and Van Oudenhoven, 2009; Dewaele, 2010 a and b; Korzilius et al., 2011; Dewaele and Stavans, 2012). 'Openness' is related to an ability to appreciate new ideas and to adapt to new cultures and societies (John and Srivastava, 1999). Thus, multilingual persons with 'Openness' are thought to be more skilful in conversation because they see the world from an interlocutor's point of view. They consequently would be expected to have higher verbal intelligence because of a strong understanding of vocabulary and language (Cook, 2002; Dewaele, 2007; Dewaele and Wei, 2012). Marchman et al., (2010) reported that monolinguals perform better at verbal skills tests as they do not have to switch between languages and because their vocabulary in one language tends to be larger than their multilingual peers. However, our results do not support this view, the multilinguals performing better at both the verbal and spatial intelligence tests.

Our questionnaire was written in Basic English with easy to understand statements and the spatial intelligence section of the questionnaire consisted of a series of images that analysed problem solving and spatial reasoning without relying upon, or being limited by, language skills. Assuming that all the participants had a sound understanding of the English language (a reasonable assumption given that all were Second Year medical students), interpreting the questionnaire should not have posed a challenge. Our data also suggest that, regardless of their linguistic skills, all groups of students perform better at verbal compared to spatial intelligence questions. This finding might related to the fact that, being the first part of the questionnaire with questions that were straightforward to comprehend, the verbal intelligence questions could be more easily interpreted.

The question should be posed: do students come to university with an education that has allowed them to develop properly their spatial and verbal intelligence? According to Machin and Vignoles (2006), U.K. educational policy in the 1950s was such that most schools had specific core academic, vocational and business courses that were available to pupils. They stated that in 1990s:

"literacy and numeracy hours were introduced in the U.K. through a national standardised curriculum. This meant that the students had specific periods of time to spend developing reading, writing and maths abilities. This had greatly compromised the free selection of vocational courses that the student could choose from. With the change in curriculum, in order to stand out in the saturated job market, a student is expected to get involved in sports, volunteering and a host of extra-curricular activities".

These changes greatly undermined the amount of practical hours a student could choose, thus possibly affecting their spatial orientation skills and intelligence. Cognitive abilities, such as spatial intelligence and spatial visualization, are not recognised currently at schools through traditional methods of assessment. This could have serious implications as students with relatively strong spatial abilities tended to gravitate towards, and excel in, science, technology, engineering and mathematics (STEM) disciplines (Wai et al., 2009; Kell and Lubinski, 2013; Kell et al., 2013).

Several studies have demonstrated a clear link between spatial ability with career progress and with performance of complex, discipline-related tasks, even when taking into account other forms of intelligence (Benbow and Stanley, 1982; Hambrick et al., 2012). According to Al-Rukban et al. (2010), Tektas et al. (2013), Husbands et al. (2014), and Petterson et al. (2016), the current selection methods in medical schools (such as academic records and interviews) are not robust and reliable enough to judge whether candidates are likely to be successful in medical training and as clinicians. Elam et al. (2002) reported that, where aptitude test scores are employed for medical admissions, they are one of the most influential factors determining decisions. Aptitude tests often include assessment of spatial and verbal intelligence. Eyal et al. (2001) and

Wanzel et al. (2002) claim that admitting students with poor spatial intelligence into medicine might affect their training, visuo-spatial ability being thought of as fundamental to the cognitive understanding of the three-dimensional environment that medical students face in their clinical careers. Furthermore, the ability to mentally visualize anatomical structures and relationships in three-dimensions plays an important part in the understanding of anatomy, in the development of surgical competencies and in the interpretations of medical imagery.

In our pervious study (Stephens and Moxham, 2018), we reported that students with prior knowledge of Greek and Latin perform better in their anatomical examinations. This might be related to the fact that anatomical terminologies are derived from classical languages such as Greek and Latin and a sound understanding of these languages would help with knowledge recall and thus examination performance. That advantage seems to have faded when it comes to interpreting spatial and verbal intelligence questions. Understanding of these languages may not have influenced the brain in the same way as language acquisition. Hence, the advantages were not evident while solving spatial and verbal intelligence problems in the questionnaire.

Our findings indicate that the students who are fluent in English and other non-European languages perform better in both spatial and verbal intelligence. According to Sakamoto and Spiers (2014) and Rodic et al. (2015 a and b), children from Asian countries perform better at spatial intelligence tests as they have an increased spatial ability to interpret complex, visuo-spatially arranged, character-based, reading and writing systems. English language is based on letter-based scripts, where complexity is linear. For many Oriental languages, the complexity of the characters increases with the number of elements (such as strokes and sub-character components all set out into the same square configuration) (Tang et al., 2006). Thus, when reading or writing Oriental languages, visuo-spatial processing and analysis are necessary. It is possible that continuous engagement in such processing leads to superior development of relevant brain networks, which in turn may lead to advantage in spatial intelligence (Tang et al., 2006). Another reason the students at Western universities that originate from Asian regions perform well might relate to their parents' stable socio-economic status, parental expectations, and access to educational resources at home and in communities (Goyette and Xie, 1999).

Limitations of the study: While our analysis suggests that multilingual medical students performed better at spatial and verbal intelligence tasks, our data was limited by the fact that there was no information on how these languages were acquired nor on the culture and history of the region in which those languages were acquired. We also do not have information relating to the socio-economic backgrounds of the students. Future studies could establish the psycholinguistic aspect of multilingualism by investigating the functional anatomy of the brain, perhaps by means of functional MRI. The medical student cohort at Cardiff University is essentially U.K. based, although multi-ethnic. It is hoped that studies similar to our own will be conducted at medical schools outside Europe and Western cultures.

Recommendations: It could be beneficial to introduce aptitude tests that assess spatial and verbal intelligence during medical interviews. That we recorded a difference in examination performance dependent upon spatial intelligence argues for this recommendation. Given that we believe that the medical students would also benefit from tutorials/lectures that help them understand Latin and Greek medical terminologies, we further recommend that such tutorials/lectures could coincide with the assessments of spatial and verbal intelligences and appreciation of the student's linguistic skills.

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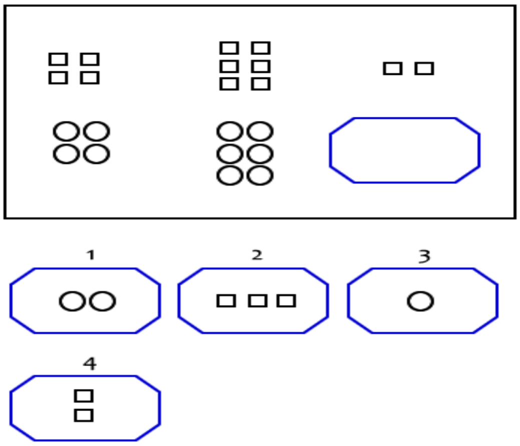
Figure

Spatial intelligence questionnaire:

1 For each of the following diagrams, select the item below it which would complete the pattern: (Please circle the appropriate answer.)



2 For each of the following diagrams, select the item below it which would complete the pattern: (Please circle the appropriate answer.)

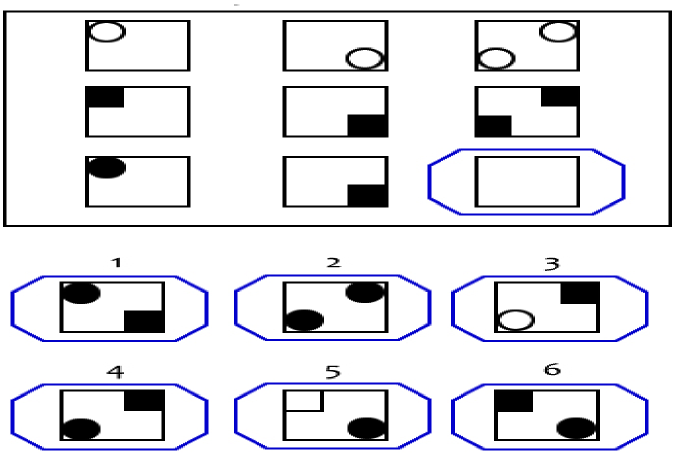


Figure 1: Sample questions to assess spatial intelligence.

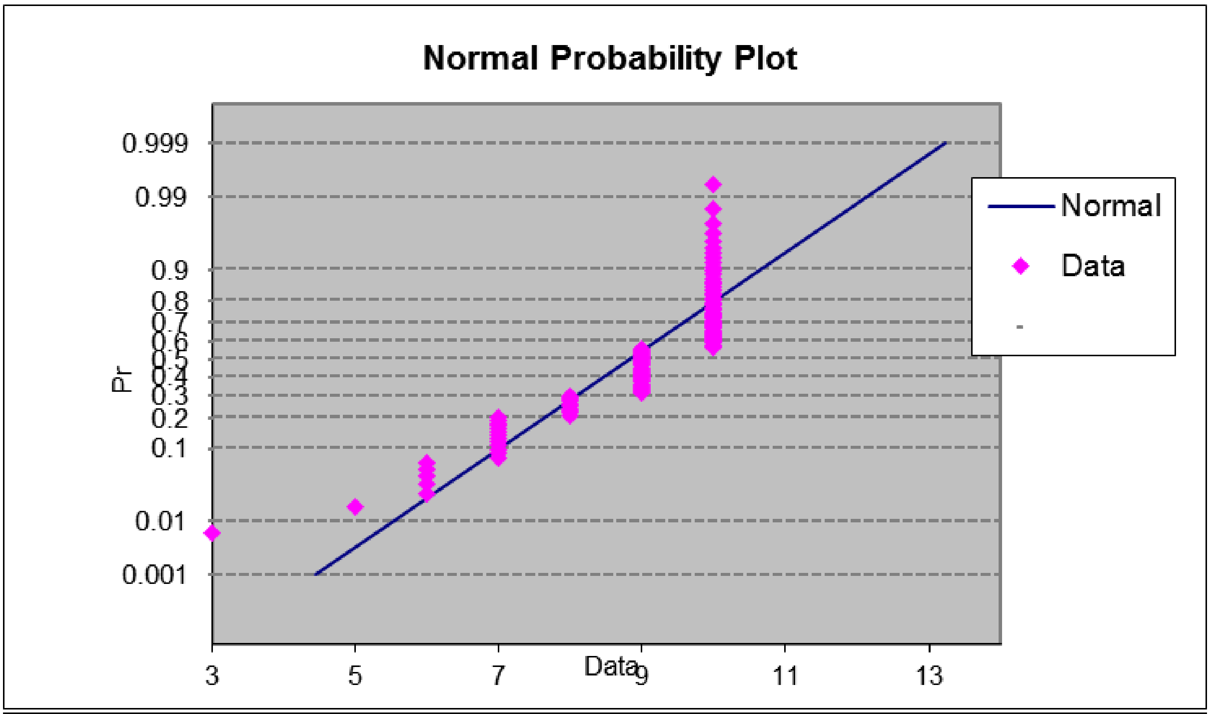


Figure 2: Darlington-Anderson normality test for verbal intelligence

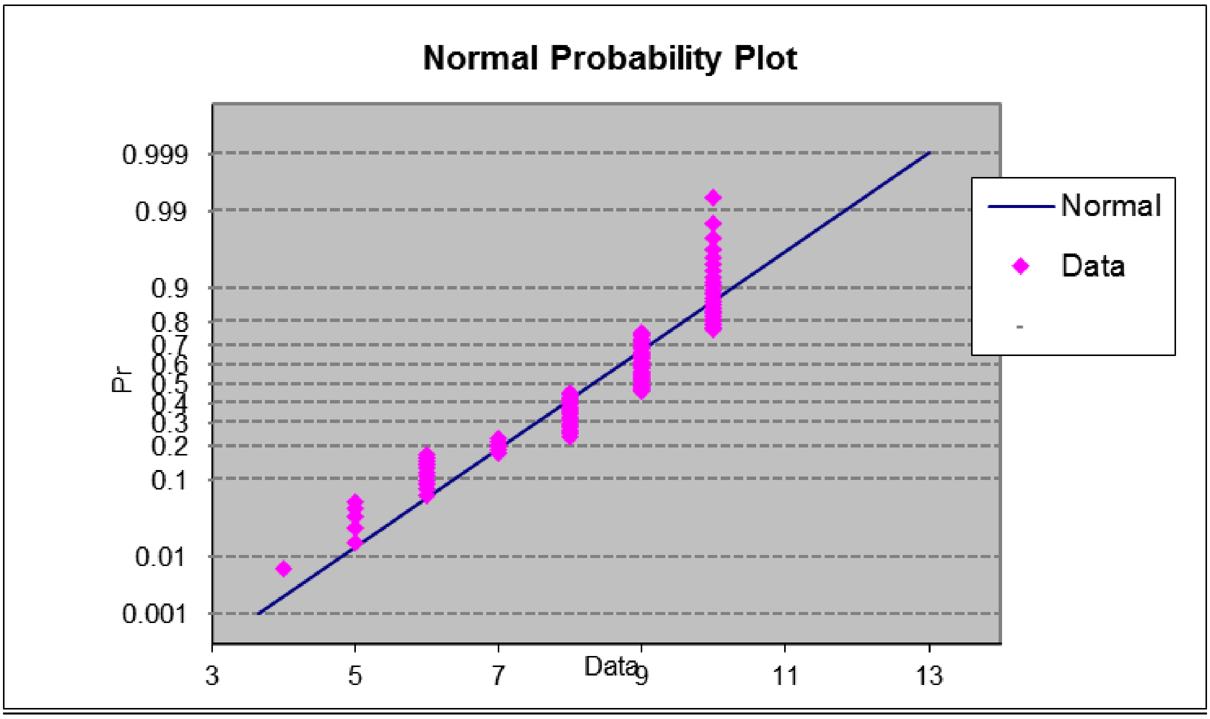


Figure 3: Darlington-Anderson normality test for spatial intelligence

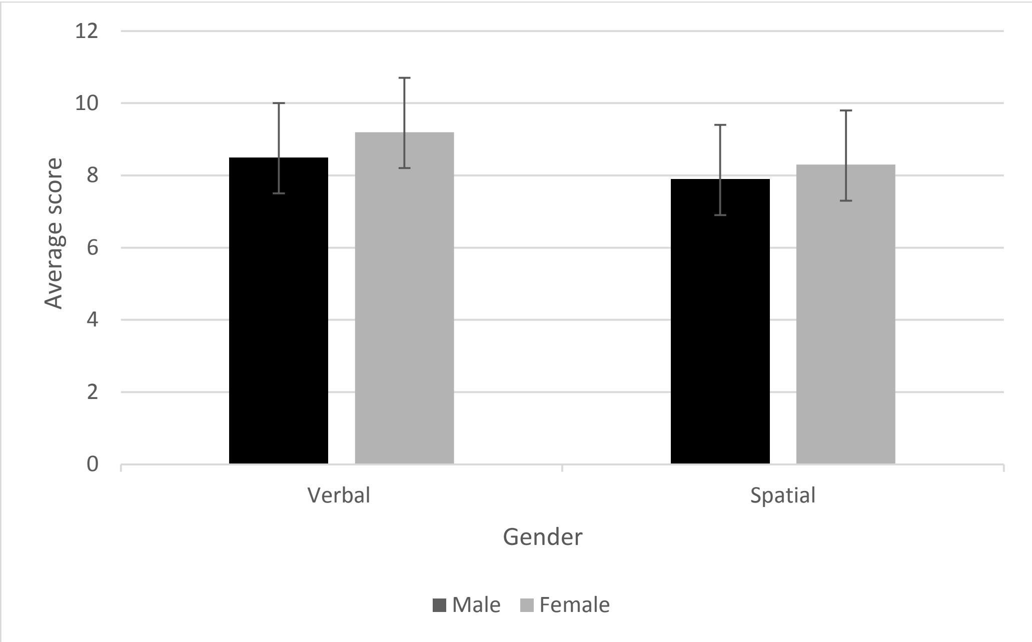


Figure 4: Comparison between the average performance of male (in black) and female (in grey) students for spatial and verbal intelligence. The graph shows the error bars as standard deviations.

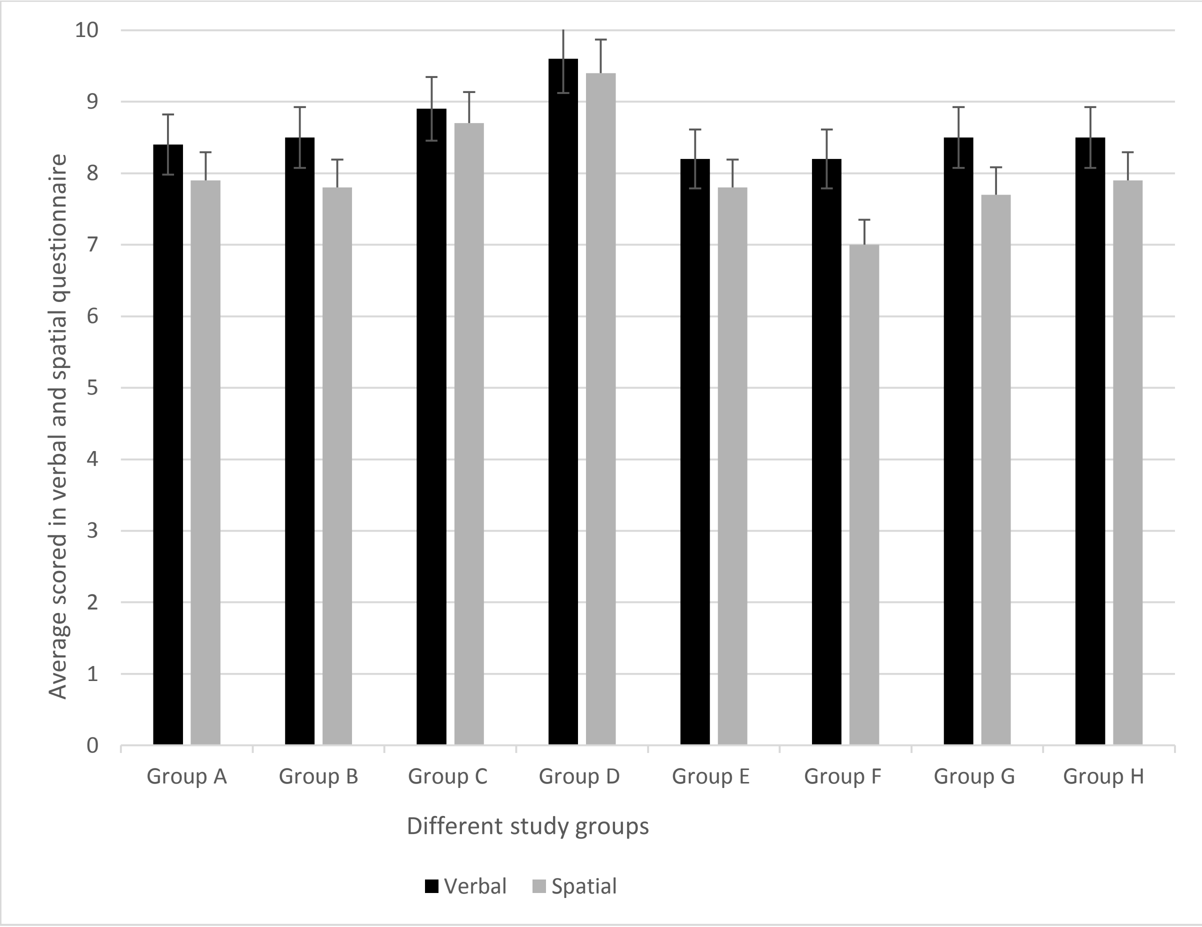


Figure 5: Provides a histogram comparing the average scores attained by the various categories of Second Year medical students for verbal (in black) and spatial (in grey) intelligence questionnaire. Standard deviation is shown in in above histogram. Group A: Students who had prior knowledge of Greek and/or Latin from school, Group B: Students who have studied Greek and/or Latin in GCSE, Group C: Students who are very fluent in English and other European language, Group D: Students who are very fluent in English and also other non-European languages, Group E: Students who are fluent in English only, Group F: Students who are moderately fluent in English with high fluency in other non-European languages, Group G: Students who are very fluent in English with moderate fluency in other European and non-European languages, Group H: Students who have studied Greek and/or Latin from school and fluency in English and another modern language

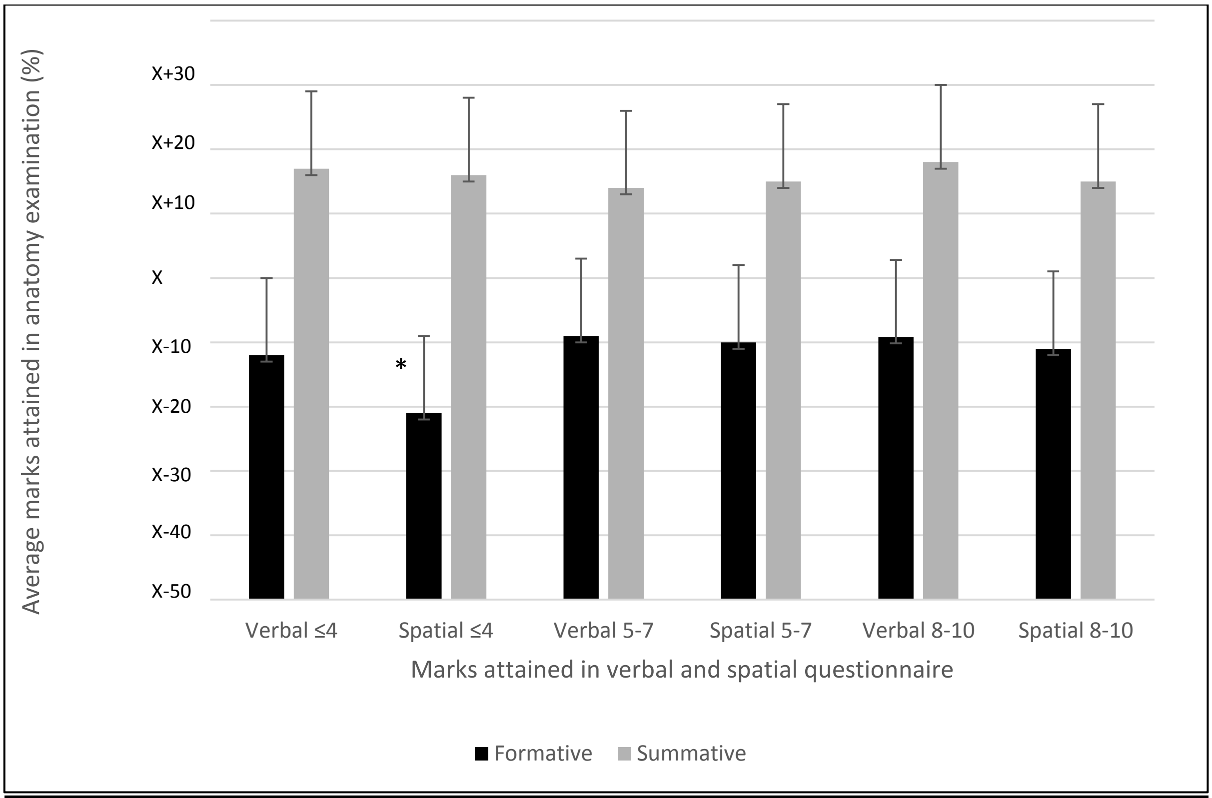


Figure 6: Provides a histogram comparing the performance of verbal and spatial intelligence distinct categories and their anatomy examination scores (Black - formative marks, Grey – summative marks. The graph shows the error bars as standard deviations). Note that, in order to maintain confidentiality, the percentage marks are shown as a concealed value (i.e., x) plus or minus 10 to 50%.

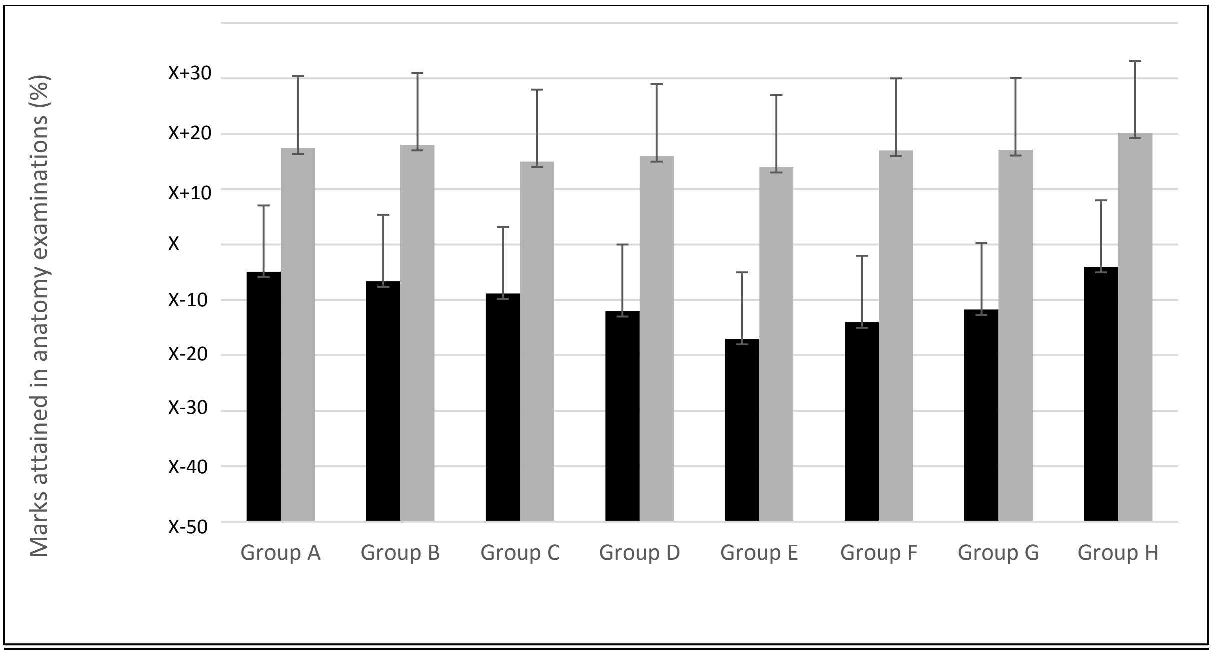


Figure 7: Provides a histogram comparing the performance of various groups in their anatomy examinations (Black - formative marks, Grey – summative marks. The graph shows the error bars as standard deviations). Note that, in order to maintain confidentiality, the percentage marks are shown as a concealed value (i.e., x) plus or minus 10 to 50%.