Gender Stereotypes and Spatial Ability: Do Males Really Perform Better?

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ABSTRACT

Numerous studies have shown that gender differences in spatial ability can be influenced by biological, social, and environmental factors. Information processing theory suggests that males tend to rely more on visuospatial working memory, whereas females are more likely to use strategies based on verbal working memory, which may impact their performance in spatial tasks. This study aims to analyze the differences in spatial ability between male and female students. A quantitative approach was employed, involving 78 students aged 15 to 17 from three schools in Bandung, Indonesia. The t-test results indicated a significant difference in spatial ability between males and females (p = 0.008), with males demonstrating superior spatial skills. However, the overlapping distribution of scores suggests that some females possess spatial abilities equivalent to or even higher than some males. Therefore, although males tend to excel in certain aspects of spatial ability, these differences are not absolute and may be influenced by external factors, environmental conditions, and varying learning opportunities among individuals.

Keywords: Spatial ability, Gender differences, Working memory, Adolescents, Quantitative study.

INTRODUCTION

Spatial ability is a crucial aspect of human cognition, encompassing the capacity to represent, transform, generate, and recall information in three-dimensional space (Govier & Salisbury, 2000). Numerous studies have identified gender differences in spatial ability, with males generally outperforming females in tasks such as mental rotation and spatial visualization (Aguilar et al., 2024; Reilly et al., 2016; Wang & Carr, 2014). However, these differences are not absolute and may be influenced by various biological, social, and environmental factors.

One theory that explains gender differences in spatial ability is information processing theory, which posits that the relative strength of visuospatial working memory compared to verbal working memory can influence the strategies used to complete spatial tasks (Wang & Carr, 2014). Experience and environmental factors also play a role, as males tend to engage more frequently in activities that develop spatial skills, such as playing video games or using spatial toys from an early age (Kotsopoulos et al., 2017; Matthews, 1987).

Additionally, several studies highlight the relationship between spatial ability and achievement in STEM (Science, Technology, Engineering, and Mathematics) fields. Mental rotation skills, for instance, are strong predictors of success in mathematics and engineering (Bokhove & Redhead, 2025; Lombardi et al., 2019). However, gender stereotypes regarding spatial ability have influenced women's participation in these fields, reinforcing a deficit model that undermines their confidence in spatial and STEM-related skills (Bartlett & D. Camba, 2023).

Nevertheless, recent research suggests that spatial ability is not a fixed skill and can be improved through practice and educational interventions (Chan, 2007; Reilly et al., 2016). Therefore, understanding the factors influencing gender differences in spatial ability is crucial for designing more inclusive learning strategies and reducing gender disparities in fields that require these skills.

LITERATURE REVIEW

Spatial ability is a cognitive skill that involves the representation, manipulation, and understanding of spatial relationships in a three-dimensional environment (Govier & Salisbury, 2000). This ability comprises several key components, including mental rotation, spatial orientation, and spatial visualization (Telaumbanua et al., 2024). Mental rotation refers to an individual's ability to mentally rotate objects, while spatial orientation relates to the ability to determine the relative position of an object in space. Spatial visualization, on the other hand, involves the skill of imagining object transformations from various perspectives (Huang & Voyer, 2017).

Gender differences in spatial ability have been extensively studied across various research fields. Meta-analytic studies indicate that men tend to score higher than women on mental rotation tests (Bartlett & D. Camba, 2023). The Mental Rotation Test (MRT) often reveals the most pronounced gender differences, with men demonstrating a significant advantage over women (Aguilar et al., 2024). Additionally, studies suggest that men are more likely to rely on cardinal directions and metric information for spatial navigation, whereas women tend to use landmarks as reference points (Kessler & Wang, 2012).

However, not all spatial tasks favor men. Some studies have found that women outperform men in spatial location memory, which involves the ability to remember the locations of objects within an environment (Gilmartin & Pattont, 1984). Social and cultural factors also contribute to these differences. For example, men are more likely to engage in activities that develop spatial skills from an early age, such as playing video games and using spatial-based toys (Kotsopoulos et al., 2017; Ogunkola & Knight, 2019).

Several studies suggest that gender differences in spatial ability have a biological basis. The sexual dimorphism model posits that differences in visuospatial skills can be partially explained by sex hormones and structural variations in the brain between men and women (Aguilar et al., 2024). Research on hormones indicates that higher testosterone levels may be associated with superior performance in mental rotation tasks (Barel & Tzischinsky, 2017).

In addition to biological factors, information processing theory suggests that gender differences in working memory also influence spatial ability. The relative strength of visuospatial and verbal working memory can determine the strategies used to solve spatial tasks (Wang & Carr, 2014). Studies indicate that women tend to rely more on verbal working memory, whereas men are more dependent on visuospatial working memory (Reilly et al., 2016).

The environment and learning experiences play a crucial role in the development of spatial skills. Studies have found that children who receive early training in spatial tasks tend to develop stronger spatial abilities later in life (Joh, 2016). Gender differences in engagement with spatial activities also emerge at an early age, with boys more frequently provided with spatial-based toys compared to girls (Kotsopoulos et al., 2017).

Research on gender differences in spatial ability suggests that social factors and experiences play a crucial role in the development of these skills. Self & Golledge 1994) argues that differences in spatial ability may be more attributable to social stereotypes and educational biases rather than inherent biological differences. These stereotypes can limit women's access to activities that foster spatial skills, such as construction-based play or navigation-based environmental exploration. Additionally, Ogunkola & Knight (2019) highlights that males and females tend to employ different spatial problem-solving strategies, shaped by their early experiences and upbringing.

Although some studies indicate male advantages in specific spatial tasks, such as three-dimensional mental rotation (Barel & Tzischinsky, 2017; Casey et al., 2017), other research suggests that spatial competence is more of a learned skill rather than an innate ability (D. C. Geary et al., 2000). Cochran & Wheatley (1989) found no gender differences in the frequency of strategy use, despite males tending to perform better in spatial tasks. Additionally, Bergner & Neubauer (2011) noted that differences in spatial skills could contribute to achievement gaps in mathematics, particularly in solving complex problems. Therefore, Casey et al. (2017) advocates for more inclusive educational interventions to reduce gender disparities in spatial skills from an early age.

In an effort to address this gap, Self & Golledge (1994) recommends that educators, particularly in the field of geography, adopt gender-neutral teaching methods to ensure that all students have equal opportunities to develop their spatial skills. Through a more inclusive and experience-based educational approach, females can gain learning opportunities equal to those of males, thereby reducing gender disparities in fields that rely on spatial abilities.

Educational interventions can also help reduce gender gaps in spatial ability. Training programs focused on mental rotation and spatial visualization have been shown to improve performance on spatial tasks, even among women who initially exhibit lower proficiency (Reilly et al., 2016). Other studies suggest that exposure to technology, such as the use of digital maps and computer-based navigation, can enhance spatial skills in both men and women (Kopcha et al., 2015).

Spatial ability has a significant impact on achievement in STEM fields. Studies indicate that mental rotation skills are a key predictor of success in mathematics and engineering (Bokhove & Redhead, 2025; Lombardi et al., 2019). Gender disparities in spatial ability may contribute to the underrepresentation of women in STEM, particularly due to stereotypes suggesting that women are less proficient in spatial and mathematical tasks (Bartlett & D. Camba, 2023).

METHOD

This study employed a quantitative approach, involving 78 students aged 15 to 17, consisting of 48 females and 30 males, who were randomly selected from three different schools in Bandung from August 27 to 29, 2024. The sampling process was conducted to ensure sufficient variation in spatial skills and students' career interests. The instrument used was a spatial ability test comprising 30 questions based on (Ramful et al., 2016), with a time limit of 18 minutes. Data analysis was performed using an Independent Samples t-Test to compare spatial ability test scores between male and female students and to determine whether there were significant differences between the two groups.

FINDINGS AND DISCUSSION

The following presents the descriptive analysis of students' spatial ability, categorized by gender (male and female). The analysis includes the sample size, mean score, standard deviation, standard error, and coefficient of variation, as shown in Table 1 below.

Table 1: Descriptive Analysis of Spatial Ability by Gender

	Group	N	Mean	SD	SE	CV
Spatial Ability	Female	48	13.125	3.425	0,494	0,261
	Male	30	15.667	4.751	0,867	0,303

Table 1 shows that the average score for males (15.667) is higher than that for females (13.125). However, score variability is also greater among males, as indicated by the standard deviation (4.751 vs. 3.425) and the coefficient of variation (0.303 vs. 0.261). Additionally, the smaller standard error for females (0.494) compared to males (0.867) suggests that the mean score for females is more stable. These results provide an initial overview of gender differences in spatial ability before conducting further analysis.

Further testing was conducted using an independent t-test, assuming normality and homogeneity of variance. If these assumptions were not met, a non-parametric test was used as an alternative, as shown in Table 2 and Table 3.

Table 2: Test of Normality

Residuals	W	p
Spatial Ability	0,983	0,377

Table 3: Test of Equality of Variances (Levene's)

	F	df_1	df_2	p
Spatial Ability	1.002	1	76	0,161

Based on Table 2, the normality test using the Shapiro-Wilk test yielded a W value of 0.983 with $p = 0.377$, which is greater than 0.05. This indicates that the residuals of spatial ability scores are normally distributed. Meanwhile, Table 3 presents the results of the homogeneity of variance test using Levene's test, with $F = 1.002$, $df_1 = 1$, $df_2 = 76$, and $p = 0.161$. Since the p-value is greater than 0.05, it can be concluded that the variance between groups is homogeneous. Therefore, the assumptions of normality and homogeneity of variance are met, allowing the analysis to proceed using the independent t-test.

Table 4: Independent Sample T-Test

	t	df	p
Spatial Ability	-2.742	76	0.008

The results of the Independent Samples *t*-Test indicate a significant difference in spatial ability between males and females, with males outperforming females. Wang & Carr (2014) and Zhang et al. (2024) found that males have better spatial working memory and employ more effective problem-solving strategies, which support higher performance in spatial tasks. From an environmental perspective, Rice et al. (1980) and Ogunkola & Knight (2019) demonstrated that males are more frequently exposed to activities that develop spatial skills, such as construction games and spatial technology-based tasks, contributing to their advantage. For further details, see Figure 1.

Figure 1: Violin Plot of Spatial Ability

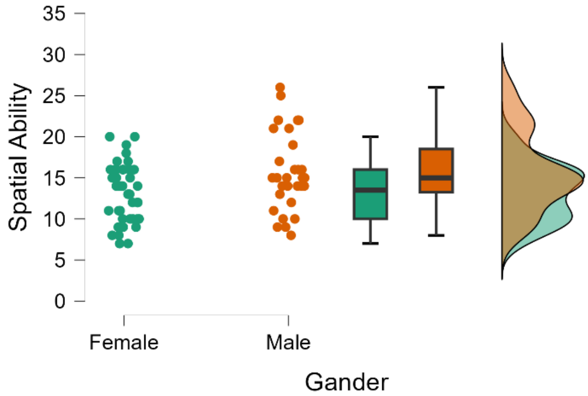

Figure 1 illustrates that, in general, males have a higher median spatial ability score than females, indicating a gender difference in spatial skills. This finding aligns with previous research showing that males tend to outperform females in various spatial tasks (Gilmartin & Pattont, 1984) and demonstrate greater proficiency in three-dimensional spatial abilities (D. Geary et al., 2001). Several studies have suggested that this advantage may stem from cognitive differences, such as enhanced visuospatial working memory and more efficient problem-solving strategies. Additionally, environmental factors, including exposure to spatially engaging activities such as construction-based games, video games, and sports that require spatial awareness, may contribute to the observed disparity. These experiences provide males with more opportunities to develop and refine their spatial reasoning abilities from an early age.

Moreover, the wider and more dispersed distribution of male scores, including several higher extreme values, supports the findings of Erskine et al. (2020), which suggest that males generally perform better in tasks involving mental rotation and spatial perception. This variation indicates that while some males exhibit exceptional spatial skills, others perform at levels comparable to or lower than females. The overlap between male and female distributions in this figure further highlights that spatial ability is not solely determined by gender. Some females demonstrate spatial skills on par with or even superior to their male counterparts, reinforcing the argument made by Govier & Salisbury (2000) that individual variation plays a crucial role. Additionally, recent studies suggest that with targeted training and exposure to spatially demanding tasks, females can improve their spatial abilities to levels comparable to those of males, further challenging the notion of an inherent gender-based advantage. Therefore, while Figure 1 supports the existence of a general male advantage in spatial ability, it also underscores the importance of considering individual differences, environmental influences, and learning experiences in shaping spatial skills.

On the other hand, several studies have identified additional factors beyond gender, such as individual differences, environment, and learning experiences, which also play a crucial role. Kopcha et al. (2015) found that individual variation in spatial skills may have a greater impact than gender differences in geospatial tasks, particularly in 2D and 3D environments. Furthermore, Joh (2016) revealed that without training, the gender gap in performance narrows, and in some cases, girls even outperform boys, suggesting that experience and the types of games played can influence spatial skills. Hyde et al. (2010) also emphasized that performance differences are not solely attributed to genetic factors but are also shaped by differential training. Additionally, Davis et al. (2021) demonstrated that findings on gender differences in spatial ability can vary depending on cultural contexts, particularly in non-industrial societies. Telaumbanua et al. (2024) found that while males generally outperform females in spatial visualization and mental rotation, females exhibit advantages in spatial orientation, a finding further supported by Aguilar et al. (2024), who discovered that young women excel in visualization tasks such as puzzle solving. Therefore, although males tend to have an advantage in specific aspects like mental rotation, the gender gap in spatial ability is not absolute and can be influenced by various external factors, including environment, learning experiences, and individual differences.

CONCLUSION

Descriptive analysis reveals that males generally outperform females in spatial ability, with a higher average score. However, this advantage comes with greater variability in male scores, suggesting that while some males excel significantly, others perform at a similar level to or even below their female counterparts. Tests for normality and homogeneity of variance confirm that the data meet the necessary assumptions for statistical analysis. The independent t-test further establishes a statistically significant difference between the two groups, affirming the tendency for males to have superior spatial ability on average. This finding aligns with prior research, which attributes male advantages in spatial reasoning to cognitive factors such as enhanced spatial memory and problem-solving strategies, as well as environmental exposure to spatially demanding activities like construction-based play and technology use.

Despite these findings, the overlap in score distributions underscores the importance of considering individual differences. While gender-related trends are evident, spatial ability is not solely determined by biological factors. Research suggests that environmental influences, learning experiences, and cultural contexts significantly impact the development of spatial skills. Some studies indicate that with appropriate training, the gender gap in spatial ability can be reduced or even eliminated. Additionally, females may exhibit strengths in specific spatial tasks, such as spatial orientation and visualization, challenging the notion of a universal male advantage. Given these complexities, efforts to bridge gender disparities in spatial ability should focus on providing equal opportunities for both genders to develop spatial skills through targeted educational strategies and enriched learning environments.

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