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Demographic variations on spatial assembly skills: Evidence from Turkish preschoolers

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Abstract: This study examined how demographic factors relate to the spatial assembly skills of preschool children. The research included 270 children randomly selected from 25 preschools in Afyonkarahisar, Turkey. Spatial assembly skills were assessed using the Turkish-adapted Test of Spatial Assembly (TOSA), which includes two-dimensional (2D) and three-dimensional (3D) subtests. The findings revealed that girls significantly outperformed boys in the 2D subtest, while no gender difference observed in the 3D subtest. The order of birth and the number of children in the family had marginal associations with children's 2D performance, but parental age, education level or occupational groups did not display statistically significant relationships with children's spatial skills. Although these results suggest certain demographic patterns, causation cannot be inferred due to the descriptive design of this study. Environmental factors and individual experiences likely contribute to the differences observed. The limitations of this study include the cross-sectional nature of the data and the lack of a direct measurement on the home learning environment. The findings emphasize the importance of tailored educational interventions and family-focused strategies to foster early spatial skills of the children. Future research should adopt longitudinal designs and explore additional environmental variables to provide a more comprehensive understanding of the factors that shape the development of children's spatial skills.

Keywords: Spatial assembly, Preschool education, Demographic factors, Spatial skills

Introduction

Spatial skills refer to the ability to perceive, analyze and mentally manipulate objects and the relationships between them in one's environment (Uttal et al., 2013). These skills can enhance one person's abilities of problem solving and abstract thinking and are among the core cognitive abilities that develop in early childhood (Alkouri, 2022; Verdine et al., 2014). Early childhood is a critical period in which learning ability develops rapidly and cognitive foundations are established; therefore, fostering spatial skills during this phase is of great importance (Newcombe, 2010).

Spatial skills play a pivotal role, particularly in STEM (Science, Technology, Engineering and Mathematics) disciplines (Klyce & Ryker, 2024; Sorby et al., 2018; Zhu et al., 2023). STEM subjects require a high level of spatial thinking, such as mentally rotating three-dimensional objects, visualizing molecular structures or understanding abstract concepts (Uttal et al., 2024; Wai et al., 2009). Research indicates that fostering spatial skills at an early age through play-based activities, block play and navigation tasks can enhance children's success in STEM subjects and increase their interest in these areas (Casey et al., 2008; Kuhl et al., 2019; Li et al., 2023; Ramirez et al., 2012). In this context, the development of spatial skills in early childhood contributes not only at an individual

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level, but also to the scientific and technological progress of society (Levine et al., 2012; Uttal et al., 2013). Recent advancements in educational technology have opened new avenues to support early childhood education, particularly in fostering STEM-related skills. Mobile applications and coding platforms such as ScratchJr have demonstrated significant potential in promoting computational thinking and creativity in young learners (Kalogiannakis & Papadakis, 2017; Papadakis, 2020). Although these tools primarily focus on coding and problem-solving skills, they also contribute to foundational cognitive abilities such as spatial awareness and logical reasoning, which are closely linked to spatial skills. Furthermore, mobile devices and educational apps have been shown to enhance the learning experiences of pre-service teachers and provide them with innovative strategies for integrating STEM activities into the preschool classrooms (Kalogiannakis & Papadakis, 2020). These findings underline the transformative role of educational technology in broadening the scope of early childhood education and complementing traditional methods to foster key developmental skills.

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Birth order and the number of children in the family have also been frequently explored in research regarding their influence on spatial skills. Zajonc's Confluence Model (2001) suggests that first-born children receive more individualized attention, which positively influences their cognitive performance. Pavan (2016) reported that first-born children outperform their siblings in cognitive abilities, educational achievements and employment. Luo et al. (2022) observed that first-born children from low-risk families had early cognitive advantages, while later-born children from high-risk or language-minority families performed equally well or better. Adnan et al. (2022) emphasized the role of sibling interactions and birth order on educational outcomes, but pointed out that outcomes may vary across contexts.

In addition, Verdine et al. (2017) identified a significant association between socioeconomic status (SES) and spatial skills in early childhood, highlighting the importance of individual differences. Bower et al. (2020) reported that children of low-SES backgrounds respond particularly well to feedback provided during construction-based activities that help to improve spatial abilities. Polinsky et al. (2022) found that digital games played on touchscreen devices can enhance children's spatial skills, although this effect varies by age and gender.

In the Turkish context, research examining the relationship between demographic variables and spatial skills is limited. Gök Çolak (2021) identified significant differences in children's spatial thinking skills based on age, school attendance duration and maternal education level, but found no significant difference related to gender or paternal education level. The study also demonstrated that as children's age and school attendance increased, their spatial thinking scores improved. Similarly, Karadeniz (2015) found that map-based activities enhanced children's perception of spatial relationships and emphasized that the effects of these activities varied depending on individual characteristics. Karadeniz's findings highlighted the importance of designing activities that are tailored to children's developmental needs. Adak Özdemir (2011) showed that spatial skills training programs are effective in enhancing children's spatial perception and mental rotation abilities. While this study does not focus directly on demographic variables, it underscores the importance of considering individual differences when designing educational interventions. Evaluating the effects of such programs on children from families with different education levels may offer further insights into demographic factors.

Mercan (2019) found that the Early STEAM Future Preparation Program significantly improved preschool children's visual-spatial reasoning skills, with positive feedback from both teachers and parents regarding its effectiveness. Korkmaz (2017) highlighted that inquiry-based activities conducted in natural outdoor settings are more effective than classroom-based activities in enhancing children's geometric thinking skills, though their effects on spatial thinking skills are not statistically significant. Lastly, Çetin (2020) demonstrated that three-dimensional design activities conducted through synchronous online education significantly enhanced university students' spatial visualization abilities, suggesting the potential of such methods in improving spatial skills across diverse contexts. Additionally, Küçükay and Yenilmez (2021) examined the spatial skills and anxiety levels of students in rural areas and indirectly discussed how demographic variables may influence spatial skills.

In Turkey, research on early childhood education often relies on small and homogeneous samples, which limits the generalizability of results and leaves significant knowledge gaps in the field. Existing studies tend to focus on isolated demographic variables such as age or maternal education without considering the combined influence of multiple factors. Critically, no comprehensive study has systematically investigated how gender, birth order, number of siblings, parental occupation, parental education level and parental age collectively shape spatial assembly skills in preschool-aged children. This lack of integration hinders a holistic understanding of the interplay between demographic characteristics and cognitive development in early childhood. While international research underscores the importance of spatial skills for STEM education and long-term academic success, there is a notable absence of studies exploring these relationships in Turkey's unique sociocultural and educational context. Addressing this gap is crucial, as culturally relevant insights are essential for designing effective early intervention strategies and educational policies tailored to diverse populations. This study aims to fill this gap by providing a comprehensive analysis of the demographic factors influencing the spatial assembly skills of Turkish preschoolers. By adopting a descriptive research framework, this study not only contributes to the global literature but also offers practical implications for optimizing early childhood education policies in Turkey. The results are expected to support the development of family-centered programs and targeted interventions that promote spatial skills, laying a foundation for equitable and effective STEM education initiatives.

This study aims to examine how preschool children's spatial assembly skills vary according to specific demographic variables in Turkey. Within a descriptive research framework, the study addresses the following questions:

- What are the descriptive patterns of the scores obtained by preschool children in the two-dimensional (2D) and three-dimensional (3D) subtests of the Test of Spatial Assembly (TOSA)?
- Is there a significant difference in children's spatial assembly skills as a function of gender?
- Is there a significant difference in children's spatial assembly skills based on birth order?
- Is there a significant difference in children's spatial assembly skills based on the number of children in the family?
- Is there a significant difference in children's spatial assembly skills based on parental age groups?
- Is there a significant difference in children's spatial assembly skills based on parental education levels?
- Is there a significant difference in children's spatial assembly skills based on parental occupation groups?

The rationale behind these research questions stems from the need to understand how various demographic factors contribute to the development of spatial skill in early childhood, a critical period for cognitive growth. Gender differences, for instance, have been inconsistently reported in the literature, warranting further exploration of their role in two-dimensional and three-dimensional spatial tasks. Birth order and family size are hypothesized to influence cognitive outcomes due to variations in parental attention and resource allocation, yet their specific effects on spatial skills remain underexplored. Parental demographics, including age, education and occupation, have been linked to differences in the home learning environments, which are known to impact early cognitive abilities. By examining these variables collectively, this study seeks to provide a comprehensive perspective on the factors that shape preschool children's spatial assembly skills, thereby addressing a significant gap in the existing literature.

Method

Research design

This study was designed as a descriptive research study aimed at examining how preschool children's spatial assembly skills vary according to specific demographic variables. A quantitative research approach was employed, and children's spatial skills were assessed using a standardized measurement tool. Descriptive research is frequently used to reveal existing conditions and to examine individuals' performance based on specific variables (Creswell & Creswell, 2018). In this study, the dependent variable is spatial assembly skills, while the independent variables include demographic factors such as gender, birth order, number of children in the family, parental age, educational level and occupational groups. The study was conducted using a cross-sectional design in which data was collected from a group of participants within a specific time frame. This design allowed for the description and analysis of demographic variations in children's spatial assembly skills.

Population and sample

The population of this study consisted of preschool children enrolled in public and private preschools in Afyonkarahisar and its districts, Turkey. To determine the sample size, the researchers referred to Krejcie and Morgan's (1970) table, aiming for a 95% confidence level. Accordingly, a sample of 270 children was considered sufficient for this study. Participants were randomly selected to ensure that every child in the population had an equal chance of being selected. Only children with typical development confirmed by teachers and school records were included in the study. Written parental consent was obtained prior to participation. Factors such as age, school type and accessibility of the researchers were considered in the sampling process.

Table 1. Demographic characteristics of the participants (N = 270)

Characteristic	Category	N	%
Child's Gender	Girl	124	45.9
	Boy	146	54.1
Birth Order	Firstborn	167	61.9
	Middle	13	4.8
	Lastborn	90	33.3
Number of Children in the Family	1 Child	130	48.1
	2 Children	114	42.2
	3 Children	19	7.0
	4 or More Children	7	2.6
Mother's Age	Under 29	68	25.2
	30-39	190	70.4
	40-49	12	4.4
Father's Age	Under 29	29	10.7
	30-39	198	73.3
	40-49	42	15.6
	50 and Above	1	0.4
Mother's Education	Primary/Secondary	15	5.6
	High School	70	25.9
	University	175	64.8
	Postgraduate	10	3.7
Father's Education	Primary/Secondary	14	5.2
	High School	64	23.7
	University	176	65.2
	Postgraduate	16	5.9
Mother's Occupation	Homemaker	83	30.7
	Civil Servant	118	43.7
	Worker	8	3.0
	Self-Employed	14	5.2
	Other	47	17.4
Father's Occupation	Civil Servant	114	42.2
	Worker	24	8.9
	Self-Employed	50	18.5
	Other	82	30.4
School Type	Public	203	75.19
	Private	67	24.81

Data collection tools

General Information Form: In this study, a General Information Form was used to collect the fundamental demographic data of the participating children and their families. The form was prepared by the researchers and included questions aimed at identifying variables such as gender, number of siblings, birth order, parental education level, occupation and age. To ensure content validity, the form was reviewed by three experts specializing in early childhood education and educational psychology. These experts provided feedback on the clarity, relevance and comprehensiveness of the questions, which was incorporated into the final version of the form.

Test of Spatial Assembly (TOSA): The Test of Spatial Assembly (TOSA) was developed by Verdine et al. (2014) and adapted into Turkish for preschool children by Yıldız (2024) following validity and reliability analyses. The TOSA is a comprehensive assessment tool designed to evaluate children's spatial skills and understand individual differences in early childhood. It includes two subtests: a two-dimensional (2D) subtest and a three-dimensional (3D) subtest. For example, in the 2D subtest, children are asked to replicate geometric shapes using provided puzzle pieces, with the focus on adjacency and alignment. In the 3D subtest, children construct vertical structures using blocks, with the score based on accuracy in replication of the target design. Examples given in Figures 1 and Figure 2 below illustrate how TOSA assesses fine motor skills, spatial reasoning and problem-solving abilities.

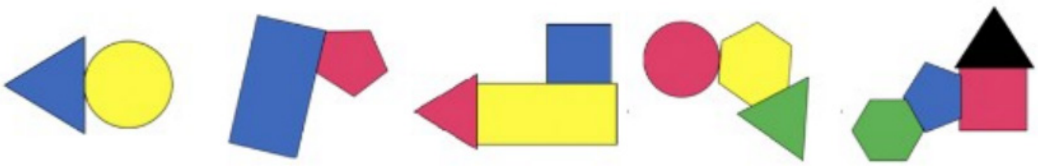

Figure 1. Shapes in the 2D subtest of the test of spatial assembly

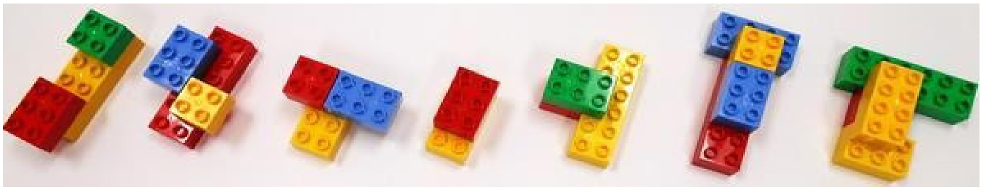

Figure 2. Models to be constructed in the 3D subtest of the test of spatial assembly

The Turkish adaptation of TOSA aims to measure different levels of spatial skills through its two subtests. During implementation, the children's individual performance was carefully observed, the target designs were photographed and the results were evaluated using standardized criteria. The 2D subtest assessed the children's ability to accurately replicate geometric shapes, while the 3D subtest evaluated their ability to construct target structures using blocks. To ensure that the children were comfortable and able to concentrate, the test was conducted in a quiet and suitable environment, with no time limitations. Sample items were presented at the beginning to help children understand the task before proceeding to the test items. The scoring system for the 2D subtest is based on criteria such as the adjacency of pieces, horizontal and vertical alignment accuracy and relative positioning. The children's designs were evaluated based on their similarity to the target models. The 3D subtest focuses on spatial relationships such as vertical alignment, rotation and displacement to assess children's three-dimensional perception and motor skills. Each subtest was scored using a standardized system to ensure consistency and accuracy.

The validity and reliability analyses conducted during the Turkish adaptation confirmed that TOSA is a suitable measurement tool for Turkish children. The overall reliability coefficient of Cronbach's alpha for the 2D subtest was calculated to be 0.889, indicating a high level of internal consistency. The item-total correlation coefficients for the 2D subtest ranged between 0.349 and 0.722, demonstrating that each item sufficiently represented the overall test. Similarly, the 3D subtest had an overall Cronbach's alpha reliability coefficient of 0.889, with item-total correlation coefficients ranging from 0.319 to 0.616. These results confirm the reliability of both subtests in assessing the spatial skills of Turkish children.

The construct validity of the TOSA was also examined in the context of the Turkish adaptation. The results of factor analysis for the 2D subtest revealed three dimensions—adjacency of pieces, horizontal and vertical alignment and relative positioning—that represent different aspects of spatial skills. The 3D subtest, on the other hand, is structured around vertical alignment, rotation and displacement, highlighting the evaluation of block placement skills.

In summary, the Test of Spatial Assembly is an effective tool for assessing spatial skills in early childhood and has been introduced into the Turkish education system with strong validity and reliability findings. Its high reliability coefficients and construct validity support its usability in both scientific research and educational practise. TOSA provides valuable insights into individual differences and serves as an important tool for evaluating children's potential in STEM-related areas. For this research, the reliability analyses of the TOSA yielded a Cronbach's α = 0.85 for the 2D subtest and a Cronbach's α = 0.83 for the 3D subtest. These values further confirm the reliability of the TOSA as a measurement tool for this study (Tabachnick & Fidell, 2013).

Data collection

The data collection for this study was conducted in compliance with ethical guidelines and relevant legal regulations. Approval was obtained from the Afyon Kocatepe University Ethics Committee for Scientific Research and Publication (Approval Date: 29.11.2022, No: 143364), as well as permission from the Ministry of National Education and the Ministry of Family and Social Services.

The data was collected during the spring semester of the 2024 academic year, between February and April. Prior to data collection, the families of the participating children were informed in detail about the purpose, scope and methods of the study as well as the confidentiality of the data to be collected. Written informed consent forms were obtained from the parents, who were assured that their children's participation was entirely voluntary and that they could withdraw from the study at any time without any consequences. During the test implementation, the children were also given clear explanations in a child-friendly manner to ensure their voluntary participation. The process was introduced as a playful activity to avoid any anxiety. Children who did not want to participate were excluded from the study.

The demographic data were collected using the General Information Form, which was completed by the researchers based on the personal development records of the children provided by the schools. Spatial assembly skills were assessed in quiet, distraction-free environments such as empty classrooms or meeting rooms equipped only with test materials, a table and chairs. The researchers sat face-to-face with each child and introduced the test as a game: "Now we will play a game together using these shape cards and blocks. I will take pictures of what you build so I don't forget them." Sample items were used to familiarize the children with the test before proceeding with the two-dimensional (2D) subtest. The test duration was optimized based on individual differences and attention spans, with sessions lasting approximately 15-25 minutes. A supportive and encouraging environment was maintained to ensure that each child felt comfortable throughout the process. Children who showed discomfort or chose not to continue were allowed to stop the test without any pressure. The confidentiality of the collected data was strictly maintained. The participants' identities were anonymized and the data was used solely for research purposes. The researchers adhered to standardized protocols during the entire data collection process to ensure reliable and valid assessments of the children's spatial assembly skills while respecting ethical principles at every stage.

Data analysis

The data collected in this study were analyzed using non-parametric statistical tests due to the violation of normality assumptions. Normality was assessed through statistical indicators and the results showed significant deviations from a normal distribution in both the two-dimensional (2D) and three-dimensional (3D) subtests. In particular, the Shapiro-Wilk test revealed p-values below the significance level of 0.05, and the values for skewness and kurtosis indicated non-symmetrical and non-normal distributions. Based on these findings, it was deemed appropriate to use non-parametric methods (Field, 2013; Pallant, 2020). The Kruskal-Wallis H test and Mann-Whitney U test were employed to evaluate differences in spatial assembly skills (dependent variable) across the demographic factors (independent variables). Analyses were conducted using SPSS, and a significance level of $p < 0.05$ was adopted. Non-parametric tests were chosen for their robustness in situations where distributional assumptions are violated and for their reliability, particularly in studies with smaller sample sizes or skewed data (Field, 2013). The results are presented with group comparisons, including mean ranks and p-values, to determine whether significant differences exist between groups.

Results

This section presents the results of the study, focusing on how demographic variables influence the spatial assembly skills of preschool children. The data was analyzed based on gender, birth order, number of children in the family, parental age, educational level and occupational groups. The differences in the scores obtained from the two-dimensional (2D) and three-dimensional (3D) subtests of the spatial assembly test were examined using non-parametric statistical methods. The differences between the groups were analyzed using non-parametric tests. In particular, the Kruskal-Wallis H test was employed to evaluate differences across multiple groups, while the Mann-Whitney U test was used for pairwise comparisons. The results are explained in detail alongside relevant tables and statistical results. Table 1 provides the descriptive statistics for the scores obtained by the preschool children in the TOSA 2D and 3D subtests.

Table 2 shows the descriptive statistics for the scores obtained by the preschool children in the TOSA 2D and 3D subtests. The results indicate that the mean score for the TOSA 2D subtest is 21.45 (SD = 7.81), with scores ranging from 2 to 35. Similarly, the mean score for the TOSA 3D subtest is 23.98 (SD = 10.09), with scores ranging from 1 to 52. These results suggest that preschool children generally perform slightly better on the three-dimensional tasks compared to the two-dimensional tasks, as reflected in the higher mean score for the 3D subtest. The variability in scores, as indicated by the standard deviations, demonstrates a broad range of spatial assembly skills of the children in the sample. This descriptive data provides a foundation for understanding how demographic factors and other variables may influence performance on spatial assembly tasks. As per the second research question, Table 3 presents the results of the Mann-Whitney U test, which was conducted to analyze the differences in scores from the TOSA 2D and TOSA 3D subtests based on the gender variable.

Table 2. Descriptive statistics for TOSA 2D and 3D subtests (N = 270)

Subtest	Mean	SD	Min.	Max.
TOSA 2D	21.45	7.81	2	35
TOSA 3D	23.98	10.09	1	52

Table 3 presents the results of the Mann-Whitney U test conducted to examine gender-based differences in the total scores of the TOSA 2D (two-dimensional) and TOSA 3D (three-dimensional) subtests. The mean scores ($\bar{X}$) for girls and boys were compared to determine whether gender is associated with variations in spatial assembly skills. The results indicate that in the TOSA 2D subtest, girls ($\bar{X}$ = 22.73) scored significantly higher than boys ($\bar{X}$ = 20.34), with this difference reaching statistical significance (U = 15616.0, p = 0.017). This result suggests that girls outperformed boys in two-dimensional spatial assembly tasks. In contrast, for the TOSA 3D subtest, the mean scores for girls ($\bar{X}$ = 24.06) and boys ($\bar{X}$ = 23.90) were very similar, and no statistically significant difference was observed (U = 14102.5, p = 0.524). This finding indicates that gender-specific differences are not apparent in three-dimensional spatial assembly tasks. These results suggest that the observed gender-based differences may vary depending on the type and dimensionality of the task, with girls demonstrating an advantage in two-dimensional tasks, while showing comparable performance to boys in three-dimensional tasks.

Table 3. Mann-Whitney U test results for gender differences in TOSA subtests (N = 270)

Gender	N	TOSA 2D (Mean ± SD)	U-Statistic (2D)	p-Value (2D)	TOSA 3D (Mean ± SD)	U-Statistic (3D)	p-Value (3D)
Girls	124	20.34 ± 8.46	15616.0	0.0169	23.90 ± 10.49	14102.5	0.5244
Boys	146	22.73 ± 6.81	15616.0	0.0169	24.06 ± 9.65	14102.5	0.5244

Table 4. Kruskal-Wallis H test results for TOSA 2D and TOSA 3D scores based on birth order (N=270)

Variable	Birth Order	Test	$\bar{X}$	SD	H	p
Birth Order	First-born	TOSA 2D	16.50	4.21	5.92	0.052
		TOSA 3D	21.94	5.87	1.76	0.415
	Middle	TOSA 2D	22.69	6.34	5.92	0.052
		TOSA 3D	24.29	6.02	1.76	0.415
	Last-born	TOSA 2D	21.19	5.88	5.92	0.052
		TOSA 3D	23.97	5.90	1.76	0.415

$p < 0.05$

Table 4 presents the results of the Kruskal-Wallis H test conducted to examine the differences in TOSA 2D and TOSA 3D scores based on birth order. For the TOSA 2D subtest, there was a marginally significant difference between the birth order groups (H = 5.92, p = 0.052). The mean score of the first-born children ($\bar{X}$ = 16.50, SD = 4.21) was lower compared to the other groups, suggesting a potential association between birth order and performance on two-dimensional spatial assembly. However, since the p-value is slightly above the threshold of 0.05, this result cannot be considered statistically significant. For the TOSA 3D subtest, no significant difference was found among the birth order groups (H = 1.76, p = 0.415). The mean scores across all groups were relatively similar, indicating that birth order does not appear to influence performance on three-dimensional spatial assembly tasks. These findings suggest that while birth order may have a slight association with performance on two-dimensional spatial tasks, no such relationship is observed for three-dimensional tasks. Further research with larger samples may help clarify these observations.

Table 5 displays the results of the Kruskal-Wallis H test conducted to examine the differences in TOSA 2D and TOSA 3D scores based on the number of children in the family. For the TOSA 2D subtest, a statistically significant difference was found among the groups (H = 9.354, p = 0.025). The mean score for the group of families with 4 or more children ($\bar{X}$ = 9.83, SD = 7.88) was noticeably lower compared to families with fewer children. This result suggests that having more children in the family may be associated with the reduced performance in two-dimensional spatial assembly tasks. Potential explanations include the division of parental resources and reduced frequency of parent-child interactions in larger families. In contrast, for the TOSA 3D subtest, no significant differences were found between the groups (H = 4.317, p = 0.229). However, it is noteworthy that the mean score for the group of families with 4 or more children ($\bar{X}$= 16.50, SD = 4.64) was still lower than those of other groups, albeit not to a statistically significant extent. These findings highlight that the number of children in the family may have a stronger association with two-dimensional spatial skills (TOSA 2D), while three-dimensional spatial skills (TOSA 3D) appear to be less affected. Further research could explore the role of family dynamics, such as the resource allocation and the interaction quality, in shaping children's spatial abilities.

Table 5. Kruskal-Wallis H test results for TOSA 2D and TOSA 3D scores based on number of children in the family (N=270)

Variable	Number of Children	Test	$\bar{X}$	SD	H	p
Number of Children in the Family	1 child	TOSA 2D	21.72	7.50	9.354	0.025
		TOSA 3D	23.73	9.25	4.317	0.229
	2 children	TOSA 2D	21.55	7.82	9.354	0.025
		TOSA 3D	24.49	11.06	4.317	0.229
	3 children	TOSA 2D	22.10	8.08	9.354	0.025
		TOSA 3D	24.38	9.77	4.317	0.229
	4 or more	TOSA 2D	9.83	7.88	9.354	0.025
		TOSA 3D	16.50	4.64	4.317	0.229

$p < 0.05$

Table 6 presents the results of Kruskal-Wallis H test for TOSA 2D and TOSA 3D scores across different maternal and paternal age groups. The findings indicate that for both TOSA 2D and TOSA 3D subtests, no statistically significant difference was observed between maternal age groups (H = 0.031, p = 0.985 for TOSA 2D; H = 0.469, p = 0.791 for TOSA 3D). This result suggests that maternal age does not appear to influence children's spatial assembly performance. Similarly, no significant difference was found across paternal age groups in either subtest (H = 1.005, p = 0.800 for TOSA 2D; H = 2.118, p = 0.548 for TOSA 3D). The mean scores for all paternal age groups were relatively similar, indicating that paternal age does not have a significant association with children's spatial assembly skills. Overall, these results suggest that parental age is not a determining factor for children's performance of TOSA 2D and TOSA 3D. Further studies may consider other factors, such as parenting practices and family environment, which may play a more prominent role in children's cognitive and spatial development.

Table 7 presents the results of Kruskal-Wallis H test conducted to examine the differences in TOSA 2D and TOSA 3D scores based on maternal and paternal education levels. For the maternal education groups, the results show no statistically significant difference in scores of TOSA 2D (H = 0.777, p = 0.855) or TOSA 3D (H = 3.221, p = 0.359). However, it is notable that the children whose mothers had high school education exhibited the highest mean scores in the TOSA 3D subtest ($\bar{X}$ = 25.21, SD = 10.59). In contrast, children of mothers with postgraduate education had the lowest scores in both TOSA 2D ($\bar{X}$ = 20.50, SD = 9.47) and TOSA 3D ($\bar{X}$= 21.80, SD = 8.16). Similarly, for the paternal education groups, no significant difference was found in scores of either TOSA 2D (H = 2.746, p = 0.433) or TOSA 3D (H = 0.745, p = 0.862). Despite the lack of a statistical significance, children of fathers with postgraduate education achieved the highest mean scores in the TOSA 2D subtest ($\bar{X}$ = 23.47, SD = 8.53), while children of fathers with university education had the highest mean scores in the TOSA 3D subtest ($\bar{X}$= 24.36, SD = 10.34). Although the results do not demonstrate statistically significant differences, the observed variations suggest that parental education levels may be associated with the minor fluctuations of children's spatial assembly skills. These findings need further investigation to explore the potential influence of parental education levels on children's cognitive development, particularly in spatial tasks.

Table 6. Kruskal-Wallis H test results for TOSA 2D and TOSA 3D scores based on maternal and paternal age groups (N=270)

Variable	Age Group	Test	$\bar{X}$	SD	H	p
Maternal Age	29 and below	TOSA 2D	21.22	8.16	0.031	0.985
		TOSA 3D	24.07	10.44	0.469	0.791
	30-39 years	TOSA 2D	21.49	7.78	0.031	0.985
		TOSA 3D	24.04	10.03	0.469	0.791
	40-49 years	TOSA 2D	22.12	6.83	0.031	0.985
		TOSA 3D	22.56	9.56	0.469	0.791
Paternal Age	29 years or below	TOSA 2D	20.60	8.61	1.005	0.800
		TOSA 3D	23.49	11.24	2.118	0.548
	30-39 years	TOSA 2D	21.38	7.90	1.005	0.800
		TOSA 3D	23.63	9.66	2.118	0.548
	40-49 years	TOSA 2D	22.46	6.84	1.005	0.800
		TOSA 3D	26.17	11.35	2.118	0.548
	50 and above	TOSA 2D	21.00	6,90	1.005	0.800
		TOSA 3D	20.00	7,80	2.118	0.548

$p < 0.05$

Table 7. Kruskal-Wallis H test results for TOSA 2D and TOSA 3D scores based on maternal and paternal educational levels (N=270)

Variable	Educational Level	Test	$\bar{X}$	SD	H	p
Maternal Education	Primary/Secondary	TOSA 2D	21.67	7.05	0.777	0.855
		TOSA 3D	22.11	12.81	3.221	0.359
	High School	TOSA 2D	22.07	7.15	0.777	0.855
		TOSA 3D	25.21	10.59	3.221	0.359
	University	TOSA 2D	21.23	8.08	0.777	0.855
		TOSA 3D	23.74	9.72	3.221	0.359
	Postgraduate	TOSA 2D	20.50	9.47	0.777	0.855
		TOSA 3D	21.80	8.16	3.221	0.359
Paternal Education	Primary/Secondary	TOSA 2D	22.71	7.89	2.746	0.433
		TOSA 3D	24.00	10.75	0.745	0.862
	High School	TOSA 2D	21.69	7.03	2.746	0.433
		TOSA 3D	23.37	9.85	0.745	0.862
	University	TOSA 2D	21.16	7.98	2.746	0.433
		TOSA 3D	24.36	10.34	0.745	0.862
	Postgraduate	TOSA 2D	23.47	8.53	2.746	0.433
		TOSA 3D	22.21	8.11	0.745	0.862

p < 0.05

Table 8 displays the results of Kruskal-Wallis H test analyzing the differences in scores of TOSA 2D and TOSA 3D based on maternal and paternal occupation groups. For maternal occupation, the results indicate no statistically significant difference among the groups for scores of TOSA 2D (H = 5.876, p = 0.208) or TOSA 3D (H = 1.582, p = 0.812). However, children of workers achieved the highest mean score in the TOSA 2D subtest ($\bar{X}$ = 24.30, SD = 4.06), while children of civil servants obtained the highest mean score in the TOSA 3D subtest ($\bar{X}$ = 24.57, SD = 10.03). Children of self-employed mothers had the lowest mean score in the TOSA 2D subtest ($\bar{X}$ = 19.00, SD = 7.47). For paternal occupation, no statistically significant difference was found for scores of TOSA 2D (H = 6.391, p = 0.094) or TOSA 3D (H = 0.240, p = 0.970). Nonetheless, children of workers achieved the highest mean score in the TOSA 3D subtest ($\bar{X}$ = 24.41, SD = 12.21), while children of civil servants had relatively higher mean scores in TOSA

2D ($\bar{X}$ = 21.84, SD = 8.35). Although the differences were not statistically significant, the slight variations in mean scores suggest that maternal and paternal occupation might be associated with minor differences in children's spatial assembly skills. These trends can be further investigated to examine the underlying factors, such as parental engagement, socioeconomic resources and availability of educational support, that might explain these variations.

Table 8. Kruskal-Wallis H test results for TOSA 2D and TOSA 3D scores based on maternal and paternal occupation groups (N=270)

Variable	Occupation	Test	$\bar{X}$	SD	H	p
Maternal Occupation	Homemaker	TOSA 2D	22.13	7.79	5.876	0.208
		TOSA 3D	23.96	11.15	1.582	0.812
	Civil Servant	TOSA 2D	21.55	7.94	5.876	0.208
		TOSA 3D	24.57	10.03	1.582	0.812
	Worker	TOSA 2D	24.30	4.06	5.876	0.208
		TOSA 3D	22.00	6.22	1.582	0.812
	Self Employed	TOSA 2D	19.00	7.47	5.876	0.208
		TOSA 3D	23.59	4.77	1.582	0.812
	Other	TOSA 2D	20.23	8.01	5.876	0.208
		TOSA 3D	22.95	10.08	1.582	0.812
Paternal Occupation	Civil Servant	TOSA 2D	21.84	8.35	6.391	0.094
		TOSA 3D	24.25	10.65	0.240	0.970
	Worker	TOSA 2D	22.52	7.65	6.391	0.094
		TOSA 3D	24.41	12.21	0.240	0.970
	Self Employed	TOSA 2D	22.08	7.93	6.391	0.094
		TOSA 3D	23.89	9.76	0.240	0.970
	Other	TOSA 2D	20.23	6.96	6.391	0.094
		TOSA 3D	23.52	8.90	0.240	0.970

$p < 0.05$

Discussion

This study examined how gender, birth order, number of children in the family, parental age, education level, and occupational groups correspond to the differences in preschool children's spatial assembly skills. The results demonstrated that gender and the number of children in the family were particularly associated with variations in children's spatial skills, while parental age, education level, and occupation did not produce significant difference.

Our findings revealed that girls performed significantly better than boys on the TOSA 2D subtest; however, no significant difference was observed between genders on the TOSA 3D subtest. This result aligns with previous studies that highlighted girls' early advantage in fine motor skills (Levine et al., 2012), which may provide them with an edge in two-dimensional tasks requiring precision and attention to detail. This discrepancy could also reflect girls' greater exposure to activities that develop two-dimensional spatial skills, such as puzzles or drawing. Nevertheless, the literature frequently emphasizes the inconsistency of gender differences in spatial skills. For instance, Tzuriel and Egozi (2010) suggested that training can reduce gender differences in spatial abilities, while Gök Çolak (2021) reported that there is no substantial role of gender in spatial skill performance.

The finding of no gender difference in the TOSA 3D subtest aligns with the studies suggesting that spatial abilities—particularly those requiring mental rotation—are sensitive to environmental experiences and opportunities (Aaten et al., 2011; Levine et al., 2012). While there also some studies highlight male advantages in mental rotation tasks (Moore & Johnson, 2008; Quinn & Liben, 2008), findings by Frick et al. (2014) indicate that these differences tend to diminish with age. This variability in gender-related spatial performance further underscores the impact of education and experience. Spatial skills are malleable and responsive to targeted interventions, suggesting that gender-based disparities, if present, can be mitigated through appropriate educational programs (Joh, 2016; Tzuriel & Egozi, 2010). In summary, the superior performance of girls in the 2D subtest highlights the significance of fine motor skills in two-dimensional spatial tasks. Conversely, the absence of differences in the 3D subtest suggests the potential of educational and environmental factors to balance gender disparities. These findings emphasize the critical role of structured educational programs in promoting the development of spatial skills, particularly in early childhood when these abilities are most susceptible to external influences. These findings may also underscore the significant role of preschool education in fostering children's foundational cognitive and motor skills, which provides equal opportunities for children to develop spatial abilities.

In our study, birth order demonstrated a marginally significant association with the performance on TOSA 2D subtest, in which the first-born children scored lower compared to other groups ($p = 0.052$). However, no significant difference was observed in the performance on TOSA 3D subtest ($p = 0.415$). This finding suggests that the role of birth order in the development of children's spatial skills may be limited. The lower performance of first-born children in the TOSA 2D subtest supports previous studies indicating that spatial skills are more effectively developed through free play and creative activities (Levine et al., 2012; Verdine et al., 2017). The literature on birth order and cognitive skills presents conflicting findings. While Zajonc's (2001) Confluence Model highlights cognitive advantages for first-born children, the absence of such advantages in spatial skills suggests that these abilities may develop through distinct mechanisms. Studies by Aaten et al. (2011) and Culver and Dunham (1969) further indicate that three-dimensional spatial skills are less influenced by birth order, emphasizing the role of alternative developmental factors. These findings underscore the complexity of spatial skill development, which appears to be more strongly associated with environmental and biological factors. The results of our study suggest that the variation in spatial skills associated with birth order requires further investigation with larger and more diverse samples. In particular, aspects such as family dynamics, socioeconomic status and the quality of parent-child interactions should be examined more comprehensively to clarify their role in the development of children's spatial skills (Luo et al., 2022).

In our study, children from the family with four or more children performed significantly lower on the TOSA 2D subtest. This result may be attributed to the division of resources and reduced frequency of parent-child interactions within larger families. Previous research aligns with this interpretation, suggesting that parents with more children may have limited capacity to provide individualized support, which can negatively impact children's cognitive development (Zajonc, 2001; Pavan, 2016). Socioeconomic status may also mediate this correlation. For example, Luo et al. (2022) found that the impact of sibling count on cognitive performance was more obvious in families with lower socioeconomic status. In this context, both resource constraints and reduced individualized attention in larger families may hinder the development of children’s spatial skills. Although demographic variables such as birth order and the number of children in the family showed notable associations with spatial assembly skills, it is important to consider other environmental and contextual factors. For instance, firstborn children might benefit from more focused parental attention, while children in larger families could gain different advantages from sibling interactions. These findings highlight the complexity of factors influencing spatial abilities and suggest that demographic variables alone cannot fully explain the observed differences.

Our findings showed no significant difference in children's spatial skills based on maternal or paternal age. This result aligns with previous research suggesting that parental age plays a relatively minor role in children's cognitive development compared to other factors. Levine et al. (2012) noted that parental age does not exert a direct influence; while the quality of parent-child interactions and the environmental stimuli provided are more critical determinants. Our findings suggest that children of both younger and older parents can access equal opportunities for spatial skill development. Nevertheless, the variation caused by parental age may be shaped by indirect factors such as socioeconomic status, education level and parenting practices. Earlier studies highlighted that the effect of parental age is closely related to the quality of time that parents spend with their children and the educational opportunities they provide (Newcombe, 2010). Therefore, demographic variables such as parental age should not be considered isolatedly but rather evaluated collectively with environmental and educational factors.

Our study also revealed that maternal and paternal education levels did not lead to statistically significant differences in children’s spatial assembly skills. However, findings in the literature on this topic remain inconsistent. Gök Çolak (2021) reported that children whose mothers had a bachelor’s or graduate degree displayed higher spatial thinking skills, while studies by Köse (2005) and Değirmenci (2014) suggested that the influence of parental education on children's spatial skills is limited. Similarly, findings regarding paternal education are inconsistent. Levine et al. (2012) found a positive but non-significant association, while Şahin Arı (2007) reported that higher paternal education levels could enhance children’s visual perception skills. These results suggest that the influence of parental education levels might be moderated by other factors, such as the time that parents allocate to their children, the use of spatial language, and engagement in spatial activities (Pruden et al., 2011; Casey et al., 2014). Thomson et al. (2020) further highlighted that spatial support provided by fathers can particularly benefit girls’ mathematics achievement. Overall, the relationship between parental education levels and children’s spatial skills appears complex, necessitating consideration of additional environmental and individual factors.

Our study revealed that maternal and paternal occupations did not have a direct influence on children’s spatial assembly skills. This finding aligns with literature suggesting that the quality of time that parents spend with their children and the educational opportunities provided are more influential than parents' occupational status (Pruden et al., 2011; Casey et al., 2014). Parental occupation often indirectly shapes children’s development through socioeconomic status, work hours and environmental stimuli provided at home, regardless of the specific occupation (Levine et al., 2012). For example, Thomson et al. (2020) highlighted that high-quality spatial support provided by fathers could significantly enhance girls' mathematical achievements. The lack of a clear influence from parental occupations observed in our study suggests that individual parenting practices play a more decisive role than general occupational patterns. Future studies could further investigate how environmental and familial contexts interact with demographic factors to shape children's spatial abilities.

Conclusion and recommendations

This study investigated the demographic variables influencing spatial assembly skills in preschool children. The findings revealed that variables such as gender, birth order, number of children in the family, parental age, education level and occupational groups differ in their impact on children's spatial assembly skills across specific dimensions and contexts. Notably, gender was found to have influence on two-dimensional spatial skills, with girls outperforming boys, while no significant difference was observed in three-dimensional tasks. This suggests that educational opportunities and environmental experiences play a critical role in the development of these skills. A decline in spatial performance was observed as the number of children in the family increased, which might be attributed to divided resources and reduced parent-child interactions. Parental age, education level and occupation were found to have limited effects, indicating that their influence might be mediated by other variables. Environmental factors, such as parental involvement, home learning environments and access to resources, may also play a crucial role in shaping children's spatial skills. Future research should aim to investigate the relative influence of these factors. To summarize, this study contributes to the growing body of literature on children's spatial development by highlighting the interplay between demographic variables and early education. It provides a basis for future research exploring the mechanisms underlying these associations. These findings also align with broader educational goals by emphasizing the importance of fostering spatial reasoning skills in early childhood as a precursor to STEM-related competencies.

These findings emphasize the importance of considering both individual differences and environmental and educational factors in the development of children's spatial skills. Early childhood education programs should incorporate play-based activities and structured interventions designed to support children's spatial development. Educators and policymakers must provide materials and activities tailored to children's individual needs to foster these skills effectively. Additionally, awareness programs and parental guidance initiatives can enable families to better support their children's cognitive development.

There are several limitations of this study. First, the sample was limited to a specific geographic region, which restricts the generalizability of the results. Second, the cross-sectional design used in data collection does not allow for the evaluation on the long-term impact of demographic variables. The assessment tool for spatial skills evaluation focused on specific sub-dimensions, potentially excluding other aspects of spatial ability. Furthermore, factors such as the quality of parent-child interactions and the influence of socioeconomic context were not examined in sufficient depth. Meanwhile, it is important to note that this study does not establish causal relationships, but rather highlights variations in spatial abilities across demographic groups, offering a descriptive analysis of these differences.

Future studies should include larger and more diverse samples and employ longitudinal designs to evaluate the long-term effects of demographic variables on spatial skills. Further research should explore the roles of parent-child interactions, socioeconomic factors, and cultural differences in greater detail. Experimental studies comparing the effectiveness of different educational programs on spatial skills can also provide valuable insights for developing targeted intervention strategies. Such research can contribute to a deeper understanding of individual differences and help formulate inclusive and effective policies to enhance children's spatial skills.

Authors' contributions

Umit Unsal Kaya: Conceptualization (lead); methodology (lead); formal analysis (lead); writing – review and editing (equal); supervision (lead). Ozgün Uyanık Aktulun: Data collection (lead); writing – original draft (supporting); literature review (lead); writing – review and editing (equal). Merve Yıldız: Software (lead); methodology (supporting); data collection (supporting); writing – original draft (equal); writing – review and editing (equal).

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Institutional review board statement

This research follows the guidelines of the Declaration of Helsinki and has been approved by the Institutional Review Board (Ethics Committee) of Afyon Kocatepe University (protocol code 143364 and approval date 29.11.2022).

Informed consent statement

Informed parental consents were secured for all participating children prior to data collection.

Conflict of interest

The authors declare no conflict of interest.

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