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4 Sex-specific relations between different types of spatial play and mental rotation

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Abstract

The present study investigated relations between different types of spatial play at home and mental rotation ability in 236 (52% girls) 8-to-12-year-old children. Three types of spatial play were distinguished: construction activities, drawing/crafting activities, and outdoor activities. Overall, boys showed higher mental rotation performance compared to girls. Boys were more frequently engaged in construction and outdoor activities, while girls were more frequently engaged in drawing/crafting activities. Results of hierarchical regression analyses showed that after controlling for the effects of age, abstract reasoning, working memory, and socioeconomic status, participation in spatial play activities at home was related to mental rotation ability in boys, while this was not the case in girls. Importantly, only construction and drawing/crafting activities related to boys' mental rotation performance. These results emphasize the importance of further research into the sex-specific role of spatial play for spatial development, also in the years after kindergarten.

Introduction

Sex Differences in Spatial Ability

Spatial ability provides an essential foundation for the development of children's quantitative reasoning, such as mathematics (Nuttall, Casey, & Pezaris, 2005), and is highly predictive for their achievement in science and technology fields (Lubinski, 2010; Wai et al., 2009). Spatial ability is an umbrella term covering several abilities involving the mental representation and transformation of objects, such as rotation, scaling, perspective taking, and navigating. Of these different abilities, mental rotation is most extensively studied. Mental rotation is the ability to imagine the rotation of objects. Most mental rotation tasks require the participant to distinguish rotated from mirrored pictures of objects (e.g., Peters et al., 1995). It is the only spatial ability showing consistent sex differences, with men outperforming women (e.g., Voyer et al., 1995). Moreover, mental rotation is of interest because of its significant relations to STEM (science, technology, engineering, and math) achievement (e.g., Shea et al., 2001; Wai et al., 2009).

The sex difference in mental rotation emerges during the course of childhood (Levine et al., 2016) and is clearly manifest in children around ten years of age (Hoyek et al., 2012; Johnson & Meade, 1987; Neuburger et al., 2011; Claudia Quaiser-Pohl, Neuburger, Heil, Jansen, & Schmelter, 2014; Titze et al., 2010a). Numerous explanations for this sex difference are offered, ranging from biological and hormonal factors, to cognitive factors (e.g., differences in working memory and strategy use) and social-cultural factors (e.g., differences in spatial input, stereotyping) (for a review, see Levine et al., 2016). It is however not likely that these factors operate in isolation. Current developmental theories underline the importance of considering the complex ways that biological, cognitive and environmental factors interrelate to influence individual differences within and between the sexes (e.g., Bronfenbrenner & Morris, 2006; Halpern, 2013; Levine et al., 2016; Newcombe & Huttenlocher, 2003). The current study investigated the relations between spatial play at home and mental rotation ability in boys and girls between eight and twelve years old, while controlling for differences in general cognitive capacities and socioeconomic status. Importantly, the contributions of different types of spatial play activities were examined.

The Relation between Spatial Play and Spatial Ability

The observed spatial ability differences between boys and girls have often been attributed to sex differences in children's experience with spatial toys such as blocks and puzzles (e.g., Baenninger & Newcombe, 1995). Boys tend to play more with toys involving spatial components such as construction, manipulation, and movement (e.g., Lego, cars, trucks) than girls during the period of early (e.g., Jirout & Newcombe, 2015) and middle childhood (e.g., Cherney & London, 2006). Several studies showed a positive relation between children's play with spatial toys and their spatial performance. For example, Robert and Héroux (2004) measured spatial performance by a water level and embedded figures task. After controlling for differences in intelligence, they showed that in children between 9 and 15 years of age, spatial manipulation play (e.g., building forts, treehouses, and other structures) was more frequent in boys than in girls, and that this difference was related to differences in spatial ability. Similar results were found by Jirout and Newcombe (2015), who observed higher frequency of spatial play in kindergarten for boys than for girls, and a positive association between these spatial play experiences and scores on a spatial ability test (i.e., the WPPSI Block Design; Wechsler, 2012), while controlling for other aspects of ability. Importantly, Jirout and Newcombe showed that the relation between spatial play and spatial ability was specific for the play with blocks, puzzles and board games. Children's play with drawing materials, sound-producing toys, dolls, balls, cars, trucks, bikes, scooters and swing sets did not relate to their spatial ability. Other studies showed that even adult sex differences on spatial tasks can be related to the frequency of spatial activities that the participant had been engaged in as a child (e.g., Doyle, Voyer, & Cherney, 2012; Nazareth et al., 2013; Voyer, Nolan, & Voyer, 2000).

In contrast to previous studies showing positive relations between spatial play and spatial ability for both sexes, Dearing and colleagues (2012) reported a non-significant relationship between six-year-old girls' spatial activities at home and their spatial performance (i.e., WISC Block Design, a mental transformation and a mental rotation task). In children between 3 and 10 years of age, Connor and Serbin (1977) also showed that more frequent play with spatial toys (e.g., blocks, puzzles, balls, cars, large motor toys) was correlated with better spatial performance in boys, while this was not the case in girls. These studies suggest that the association between spatial play and spatial ability might be stronger for boys than for girls.

Controlling for SES and Cognitive Abilities

Spatial ability and spatial play do not only vary by children's sex, but also by the socioeconomic status (SES) of their family. In general, children from higher socioeconomic backgrounds outperform children from lower socioeconomic backgrounds on spatial tasks. Jirout and Newcombe (2015) for example, showed that middle and high SES children (aged 4 to 7) scored higher than children from low SES families on the Block Design test of the WPPSI. Less frequent play with spatial and numerical toys (i.e., board games, puzzles) has been observed in preschool children from lower SES families (Levine, Ratliff, Huttenlocher, & Cannon, 2012; Ramani & Siegler, 2008). Jirout and Newcombe (2015), however, did not report differences in spatial play activities between kindergartners from different SES groups. The importance of controlling for socioeconomic status is further highlighted by the study of Levine et al. (2005). They showed that the male spatial advantage varies across children from different socioeconomic backgrounds. Boys from middle- and high-SES backgrounds outperformed their female counterparts on spatial tasks, whereas boys and girls from a low SES group did not differ in their performance. Levine and colleagues hypothesized that in high SES environments boys may engage more often in spatially relevant activities than girls do. In low-SES environments however, boys and girls may engage in these activities at low and approximately equivalent levels.

In addition, when investigating the relation between spatial play and spatial ability, it is important to control for the effects of cognitive differences between children. Succeeding on a mental rotation task involves the temporary storage and processing of visual-spatial information. The participant has to maintain an active representation of the target figure, while simultaneously manipulating (i.e., transforming, rotating, comparing) different images in mind (Kaufman, 2007; Kosslyn et al., 1990). Especially abstract reasoning (i.e., the ability to encode, analyze, and operate on visual-spatial information) and working memory (i.e., the ability to hold and manipulate information over brief periods of time) may be important factors relating to sex differences in spatial ability. Positive relationships between these cognitive abilities and mental rotation have been observed in both adults and children (Karádi, Kallai, & Kovacs, 2001; Kaufman, 2007; Lehmann et al., 2014; Schweizer, Goldhammer, Rauch, & Moosbrugger, 2007; Wang & Carr, 2014).

The Current Study

In the current study, the relation between spatial play at home and mental rotation ability was investigated, while controlling for individual differences in socioeconomic status and cognitive abilities (i.e., abstract reasoning and working memory). Whereas previous studies investigating the effects of spatial play on spatial ability mainly focused on young children around six years of age (e.g., Dearing et al., 2012; Jirout & Newcombe, 2015), the children in the current study were between eight and twelve years old. In this age window sex differences in mental rotation ability are generally clearly manifest (Hoyek et al., 2012; Johnson & Meade, 1987; Neuburger et al., 2011; Titze et al., 2010a). The current study differentiates between the types of spatial play. The study of Jirout and Newcombe (2015) showed that in kindergartners the relation between spatial play and spatial ability was present for the play with blocks, puzzles, board games, but not for play with other types of toys (e.g., drawing materials, cars, balls, bikes). We tested the hypothesis that also in older children different types of spatial activities relate differently to spatial ability. We expected to find: 1) sex differences in mental rotation ability, with boys outperforming girls (Hoyek et al., 2012; Johnson & Meade, 1987; Neuburger et al., 2011; Titze et al., 2010a; Voyer et al., 1995); 2) sex differences in spatial play, with boys participating more often in construction activities, and girls participating more often in drawing/crafting activities (e.g., Jirout & Newcombe, 2015); 3) sex differences in the relations between spatial play and mental rotation ability, with boys showing stronger relations between spatial play and mental rotation ability than girls (e.g., Connor & Serbin, 1977; Dearing et al., 2012), especially for construction activities (e.g., Jirout & Newcombe, 2015).

Methods

Participants

The total sample consisted of 236 children (124 girls) between 7.75 and 12.58 years of age (M = 9.94 years, SD = 1.20). On average, the boys (M = 9.97 years, SD = 1.16) were as old as the girls (M = 9.92 years, SD = 1.24): $F(1, 234) = 0.07$, $p = .79$. The children were recruited from seven regular elementary schools in the Netherlands. Parents gave written informed consent. All participants had normal or corrected-to normal vision. The Ethical Committee of the Faculty of Behavioral and Movement Sciences of Vrije Universiteit Amsterdam approved the research protocol.

Materials

Mental rotation. To assess mental rotation ability, we administered the Revised Vandenberg & Kuse Mental Rotations Test (Peters et al., 1995). The child received a booklet with 24 problems with three-dimensional cube constructions. Each problem consisted of a target object on the left and four objects on the right. The participant was required to determine which two (out of four) stimuli were rotations (and not mirror versions) of the target figure. In order to be sure that all participants understood the instructions (see also Hoyek et al., 2012), we practiced and discussed four example items in class. We also used a physical example item to show the children that all figures of a problem had the same constellation of cubes, but were rotated around the vertical axis. There were two sections with twelve problems each, with a time limit of four minutes per section. One point was given if the child identified *both* correct answers. The variable of interest was the total number of correct answers, with a maximum score of 24.

Abstract reasoning. To assess abstract reasoning, we used the Raven Standard Progressive Matrices (Raven SPM) (Raven et al., 2000). The Raven SPM consists of 60 items (arranged in five sets of 12), all of which involve completing a pattern or figure with a part missing by choosing the correct missing piece from among six or eight alternatives. Within each set, the items become increasingly more difficult. Children were required to solve as many analogical reasoning problems in 15 minutes. The variable of interest was the number of correct items.

Working memory. To assess working memory, we administered the computerized Mental Counters task (Huizinga et al., 2006), requiring children to retain numerical information active in their working memory while keeping track of the values of two 'counters'. The counters consisted of a horizontal line, above or below which squares appeared. Children were required to add 1 to the value of the counter when a square appeared above the line, and to subtract 1 when it appeared below the line. When any counter reached a given criterion value (e.g., '2' or '4'), participants had to press a button. Fifteen trials were presented, including series of five or seven consecutive squares, were presented. The variable of interest was the percentage of correct answers on the total number of trials.

Socioeconomic status. Socioeconomic status was assessed by the educational level of the parents. The educational level of parents is considered an important determinant of their work and economic circumstances, and indirectly, of their access to financial, human and social capital (Bradley & Corwyn, 2002). We asked parents to indicate for both the father and the mother the highest level of completed education on a scale from '1' 'primary education' to '8' 'post university education'. The complete scale is presented in Appendix A. The variable of interest was the mean of the score of the father and the score of the mother. A moderate correlation was observed between the educational level of the father and the mother (r = .38, p < .001). In cases where the educational level of only one of both parents was filled out (n = 10), we used that single score as the 'family score'.

Participation in different types of spatial play. Parents completed a questionnaire to indicate how often their child participated in different spatial play activities at home. The questionnaire was based on the Spatial Activity Questionnaire designed by Dearing and colleagues (2012). Parents were asked to indicate on a 5-point Likert scale (from '1' 'never' to '5' 'many times per week') how often their child participated in 23 different leisure activities in the past six months. Eight 'distractor' activities were not used in the analyses as they were non-spatial in nature (e.g., watching television, playing with dolls, and playing a musical instrument). The remaining fifteen items were divided into three categories. The first category was labeled *'construction activities'* and comprised five items (Cronbach's alpha = .86). Example items are 'Plays with construction toys, such as buildings blocks or Legos' and 'Uses kits to build models (such as airplanes, animals, dinosaurs, doll houses)'. The second category concerned '*drawing/crafting activities'* (5 items, Cronbach's alpha = .74). Example items are 'Colors, paints, or draws free hand (not filling-in outlines)' and 'Does arts and crafts projects (such as making jewelry, stringing beads, or using play dough/clay)'. The third category involved *'outdoor activities'* (5 items, Cronbach's alpha = .65). Example items are 'Climbs trees' and 'Plays in parks or green spaces'. As the reliability analysis showed that deleting one of the items of this scale (i.e., 'Doing ball sports such as football, tennis, and hockey') would led to an increase of Cronbach's alpha to .70, this item was omitted from the scale. A complete list of the items is included in Appendix B. The variables of interest were the means of the scale items, with a maximum score of 5, and with higher scores indicating more frequent participation in that specific type of spatial activity.

Procedure

Parents received an information letter and active consent form, which were distributed by the schools. A pen-and-paper questionnaire on child- and family characteristics and children's spatial activities at home was attached to this form. Testing at schools comprised two sessions. The administration of the tasks was standardized, and all children received the same instructions and uniform testing conditions. The first session was a group session and took about 45 minutes. Each child sat at its own desk in the classroom and worked alone. After a short oral introduction about the background and procedure of the study, the children completed the Mental Rotation Test (Peters et al., 1995) and the Raven abstract reasoning measure (Raven et al., 2000). During the same week, the children received an individual session (10 minutes), taking place in a quiet room in the school. In this session, the computerized working memory test (Huizinga et al., 2006) was administered.

Data Analysis

First, using multivariate analyses of variance, we investigated sex differences in mental rotation, the three types of spatial activity, socioeconomic status, abstract reasoning, and working memory, while controlling for the effects of age. Second, we computed bivariate correlations between these variables. To answer the main question on the relations between the different types of spatial play and spatial ability, we performed two hierarchical regression analyses, one for the boys and one for the girls, with mental rotation as dependent variable. In the first step, we added age, socioeconomic status, abstract reasoning, and working memory as the control variables. In the second step we included the three different types of spatial play activities. To assess whether these activities significantly contributed to the prediction of mental rotation, we investigated the difference in explained variance (R^2) between the model with and the model without the spatial play activities. To assess the relative contribution of each of the three types of activity we compared the size of the standardized regression coefficients.

For 236 children, data on mental rotation and abstract reasoning were available. For six children (2 boys, 4 girls) there were no accurate working memory data due to computer failure. The parents of nine children (3 boys, 6 girls) did not complete the spatial activity questionnaire, and seventeen parents (7 boys, 10 girls) did not provide information on their educational level. Complete data were available for 213 children (103 boys, 110 girls). Little MCAR's test revealed that the data were missing completely at random: $\chi^2(21) = 27.32$, $p = .16$.

Results

Sex Differences

First, we investigated differences between boys and girls on the mental rotation measure, the spatial activity measures and the control variables (i.e., abstract reasoning, working memory, SES), while controlling for the effects of age. Table 4.1 provides the uncorrected means and standard deviations of these variables, separately for boys and girls. Multivariate analyses of variance with sex as independent variable and age as covariate revealed large significant effects of sex, F (7, 204) = 28.85, p < .001, η_p^2 = .50, and age, F (7, 204) = 7.93, p < .001, η^2 = .21.

Mental rotation. For mental rotation, a significant univariate effect of sex was observed, F (1, 210) = 20.06, p < .001, η_p^2 = .09, while controlling for the positive effects of age, F (1, 210) = 23.03, p < .001, η_p^2 = .10. In line with the expectations, boys had higher mental rotation scores than girls. Also when adding abstract reasoning as an additional control variable (F (1, 232) = 32.84, p < .001, η_p^2 = .12), the effect of sex remained significant: F (1, 232) = 28.63, p < .001, η_p^2 = .11.

Table 4.1. Sex Differences on Mental Rotation, the Spatial Activities, and the Control Variables, Uncorrected for Age Effects

			Boys (n = 103)		Girls (n = 110)		
	Min	Max	*M*	*SD*	*M*	*SD*	*d*
Mental rotation	0	22	9.20	5.23	6.45	3.93	0.59
Construction activities	0	4.60	2.44	0.79	1.52	0.60	1.31
Drawing/crafting activities	1	4.80	2.20	0.77	2.53	0.72	0.44
Outdoor activities	1.25	5	2.96	0.76	2.58	0.72	0.51
Abstract reasoning	14	51	34.89	7.57	36.13	6.94	0.17
Working memory	6.25	100	70.02	19.28	63.73	22.71	0.30
Socioeconomic status	1	8	4.67	1.42	4.64	1.39	0.02

Note. Cohen's *d*: .20 = small effect, .50 = medium effect, .80 = large effect.

Spatial activities. Sex differences in the three different types of spatial activity were investigated, with age as control variable. For construction activities, there was a large significant effect of sex, F (1, 210) = 94.22, p < .001, η_p^2 = .31. Boys participated more frequently in construction activities compared to girls, while controlling for the negative relation between age and construction activities, F (1, 210) = 53.75, p < .001, η_p^2 = .20. For drawing/crafting activities, there was a small significant effect of sex, F (1, 210) = 10.82, p = .001, η_p^2 = .05. Girls participated more frequently in drawing/crafting activities compared to boys, while controlling for the negative relation between age and drawing/crafting activities, F (1, 210) = 6.31, p = .01, η_p^2 = .03. For outdoor activities, there was a moderate significant effect of sex, F (1, 210) = 14.47, p < .001, η_p^2 = .06. Boys participated more frequently in outdoor activities compared to girls, while controlling for the non-significant relation between age and outdoor activities, F (1, 210) = 2.23, p = 14. Sex differences on the individual items can be found in Appendix B.

Control variables. For abstract reasoning, the effect of sex was not significant, F (1, 210) = 2.03, p = .16, while controlling for the positive effects of age, F (1, 210) = 28.66, p < .001, η_p^2 = .12. As expected, there were no differences in abstract reasoning between boys and girls. For working memory, the effect of sex was significant, F (1, 210) = 4.64, p = .03, while controlling for the positive effects of age, F (1, 210) = 8.19, p = .01, η_p^2 = .04. Unexpectedly, boys outperformed girls on the working memory measure. For socioeconomic status there were, in line with the expectations, no differences between the sexes, F (1, 210) = 0.03, p = .88, and no relations with age: F (1, 210) = 0.17, p = .68.

Summarizing, boys outperformed girls on the mental rotation and working memory measure, and participated more frequently in construction and outdoor activities at home compared to girls. Girls participated more frequently in drawing/crafting activities compared to boys. No sex differences in abstract reasoning and socioeconomic status were observed.

Relations Between the Spatial Play Activities and Mental Rotation

Correlations. Preliminary to the hierarchical regression analyses, we computed bivariate Pearson correlations between mental rotation and the predictor variables, separately for boys and girls (see Table 4.2). In both sexes mental rotation varied as a function of age: the older the children, the higher the scores on the MRT. Regarding the spatial activities, construction and drawing/crafting activities were positively related to mental rotation in boys, but no relation between outdoor activities and mental rotation was observed. In girls, there were no significant relations between the three types of spatial activity and mental rotation. Regarding the control factors, abstract reasoning was positively associated with mental rotation in both boys and girls. Interestingly, working memory was significantly related to mental rotation in girls, but not in boys. In addition, there were strong relations between abstract reasoning and working memory.

Socioeconomic status was positively related to abstract reasoning (boys and girls) and to working memory (only boys), but not to mental rotation (boys and girls). In addition, socioeconomic status was positively related to construction activities in girls, but not in boys: the higher the socioeconomic status of the family, the more frequently girls participated in construction activities at home. In girls, but not in boys, age was negatively related to the spatial activities: with increasing age, girls participated in fewer spatial activities at home.

Table 4.2. Pearson Correlations Among Mental Rotation and the Predictor Variables

	1	2	3	4	5	6	7	8
1. Mental rotation	-	.31**	.03	.11	.15	.44**	.31**	.07
2. Age	.29**	-	.25**	.26**	.16	.33**	.28**	.02
3. Construction activities	.31**	.10	-	.53**	.47**	.07	.01	.19*
4. Drawing/crafting activities	.20*	.10	.51**	-	.49**	.13	.05	.05
5. Outdoor activities	.05	.007	.47**	.31**	-	.003	.05	.04
6. Abstract reasoning	.40**	.37*	.02	.02	.06	-	.45**	.34**
7. Working memory	.18	.12	.06	.05	.04	.55**	-	.19
8. Socioeconomic status	.12	.03	.15	.14	.02	.45**	.36**	-

Note. The values below the diagonal represent the values for the boys, the values above the diagonal are the values for the girls. *$p < .05$. ** $p < .01$

Hierarchical regression analyses. To answer the research question regarding the contributions of the different types of spatial activity to mental rotation in boys and girls, two hierarchical regression analyses were performed, one for the boys and one for the girls. Age, SES, abstract reasoning, and working memory were included as control variables in the first step (see Table 4.3 for the results of the analysis).

The total regression model of the boys accounted for 33% of the variance in mental rotation, the model of the girls predicted 27%. In both boys and girls, age and abstract reasoning were positively related to mental rotation. Higher age and better abstract reasoning ability were associated with higher mental rotation scores. Working memory and socioeconomic status were no significant predictors of mental rotation. Interestingly, the inclusion of the three spatial activity variables the second step led to a significant increase in explained variance in mental rotation in boys (i.e, $\Delta R^2 = 0.11$, $p = .002$), but not in girls (i.e., $\Delta R^2 = 0.02$, $p = .37$). When inspecting the contributions of the individual predictors, significant positive relations between construction activities and mental rotation and between drawing/crafting activities and mental rotation were observed in boys. This indicates that more frequent participation in construction and drawing/crafting activities was related to higher mental rotation scores. Participation in construction activities was more strongly related to mental rotation than participation in drawing/crafting activities. In the girls, none of the spatial activities contributed significantly to the model.

In summary, the results of the hierarchical regression analyses indicated that children's participation in spatial play at home (i.e., construction and drawing/crafting activities) was associated with mental rotation performance in boys, but not in girls.

Table 4.3. Hierarchical Regression Analyses Predicting Mental Rotation from the Spatial Activities and Control Variables

	Boys		Girls	
Predictor	ΔR^2	β	ΔR^2	β
Step 1	.22***		.25***	
Age		.22*		.15
Socioeconomic status		-.08		-.12
Abstract reasoning		.38**		.40***
Working memory		-.04		.11
Step 2	.11**		.02	
Construction activities		.32**		.09
Drawing/crafting activities		.09*		.06
Outdoor activities		-.11		-.18
Total R^2	.33***		.27***	
n	103		110	

Note. Constant in the model of the boys: *B(SD)*= -12.13(4.57), t = -2.66, p = .009. Constant in the model of the girls: *B(SD)*= -5.24(3.71), t = -1.41, p = .16.

*p < .05. ** p < .01. *** p < .001.

Discussion

The main aim of the present study was to investigate the relations between spatial play at home and mental rotation ability in eight- to twelve-year-old children, while controlling for differences between children in socioeconomic status and general cognitive abilities. Importantly, a distinction between three different types of spatial play was made: construction activities, drawing/crafting activities, and outdoor activities.

In accordance with previous studies investigating mental rotation in similar age groups (e.g., Geiser, Lehmann, Corth, & Eid, 2008; Hoyek et al., 2012; Titze et al., 2010a), boys had higher scores on the mental rotation test compared to girls. As hypothesized, boys were more frequently engaged in spatial construction activities than girls, while girls were more frequently engaged in drawing/crafting activities (Jirout & Newcombe, 2015). In addition, boys participated more often in spatial outdoor activities compared to girls.

To investigate the relations between the different types of spatial play and mental rotation ability, hierarchical regression analyses were performed, separately for boys and girls. Interestingly, the results showed additive effects for spatial play, above the effects of SES and the cognitive factors, in the boys, but not in the girls. Inspection of the contributions of the different types of spatial play showed that construction activities were most strongly related to boys' mental rotation performance. Also drawing/crafting activities were related to their mental rotation performance, but to a lesser degree. Outdoor spatial activities were not related to mental rotation.

The finding that spatial play was related to mental rotation in boys, but not in girls is in contrast with previous studies showing that the relation between spatial input and spatial ability is independent of sex (e.g., Doyle et al., 2012; Jirout & Newcombe, 2015; Uttal et al., 2013). However, the results corroborate with the findings of Connor and Serbin (1977) showing only positive relations between spatial play and ability in boys, and with the findings of Dearing and colleagues (2012), demonstrating a non-significant relation between spatial play and spatial ability in young girls. These results emphasize the importance of considering the social context in which spatial learning occurs. Not only cognitive information processes relate to differences in successful spatial performance, but also the spatial play experiences children have at home. The finding that girls are less frequently engaged in such activities at home, may be a strong argument for the integration of this type of activities in the school curriculum, also in the higher grades of elementary school.

This study clearly showed that the different types of spatial play are differently related to boys' mental rotation performance. The strongest relations were found for construction activities, including the play with blocks and model kits. This is in line with the findings of Jirout and Newcombe (2015) in younger children, and with training studies showing positive effects of construction activities on spatial ability (e.g., Bruce & Hawes, 2015; Casey et al., 2008). Smaller, but significant relations, were found for drawing and crafting activities. In line, previous intervention studies with paper folding activities showed positive effects on mental rotation in middle school boys (Boakes, 2009) and in adults (Jaušovec & Jaušovec, 2012). Both construction and drawing/crafting activities involve the representation and active manipulation of 2D and 3D objects in space, which may be helpful practice for the development of mental rotation ability.

The significant relation between the quantity of spatial play and mental rotation in boys but not in girls, may be explained by sex differences in the quality of spatial play. That is, the boys might have practiced the spatial activities in qualitatively richer ways compared to the girls. The study of Levine and colleagues (2012) provides evidence for differences in the quality of spatial play between boys and girls. In their study with preschoolers boys played with more difficult puzzles than girls. In addition, the parents of the boys were more strongly engaged in the puzzle play compared to the parents of the girls and provided them with more spatial language. Future studies should take the quality of spatial play into account, for example by assessing the complexity of children's building constructions (for an example of a scoring system see Casey, Pezaris, & Bassi, 2012; M. A. Roberts, Franzen, Furuseth, & Fuller, 1995) or by encoding spatial language use during such activities (see for example Levine et al., 2012).

A question that remains unanswered is *why* boys participated more frequently in spatial activities compared to girls. Differences might be affected by gender stereotyping and the social acceptability of toys and activities. For example, parents were found to encourage boys more than girls to participate in spatial activities (Caldera, Huston, & O'Brien, 1989). In another study with 10- and 12-year-olds, both boys and girls held the common stereotype that spatial play activities are more appropriate for boys than for girls and that boys are more skilled in these activities (Vander Heyden, van Atteveldt, Huizinga, & Jolles, 2016). Another influence on the choice of spatial play activities may be the level of spatial ability itself: Children with higher levels of spatial ability may seek more spatial activities in their free time than children with low levels of spatial ability. Our correlational study cannot rule out this possibility, but many studies using a training study design have demonstrated the causal effects of spatial input on spatial ability (e.g., Uttal et al., 2013).

In conclusion, the present study shows that sex differences in 8- to 12-year-old children's spatial ability are related to differences in the frequency in which boys and girls participate in specific types of spatial play at home. In boys, more frequent participation in construction and drawing/crafting activities was associated with better spatial performance. In girls, the frequency of participation in spatial activities was not related to better performance. These findings underline the importance of investigating individual differences in spatial development from an transactional perspective, considering the interrelations between child and environmental factors (e.g., Bronfenbrenner & Morris, 2006; Halpern, 2013; Newcombe & Huttenlocher, 2003). As previously established for the development of language and mathematics, this study demonstrates the important associations between spatial play in the home environment and spatial skills, also in the years after kindergarten. Nevertheless, more research is needed to reveal the mechanisms contributing to the sex differences in spatial activity participation. Parents and teachers should be aware of their role in encouraging girls to make 'cross-gender' toy choices (Freeman, 2007). In addition, they may be educated about promising toys and activities which provide girls opportunities to practice their spatial skills (Neuburger, Ruthsatz, Jansen, Heil, & Quaiser-Pohl, 2013; Verdine, Golinkoff, Hirsh-Pasek, & Newcombe, 2014).

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Appendix A

Educational levels in the parental education questionnaire
1. Primary education
2. Lower vocational education
3. Pre-vocational education
4. Secondary vocational education
5. Senior general secondary education or Pre-university education
6. Higher vocational education/University of professional education
7. University
8. Post-university education

Appendix B

Scores (*M*, *SD*) on the Spatial Activity Questionnaire for Boys and Girls, Sex Differences tested with Multivariate Analyses of Variance With Bonferroni Correction, with Cohen's *d* as Measure of Effect Size

	Construction activities	Boys	Girls	*F* (1,206)	*d*
1	Uses tools (such as hammer or screwdriver) to make things or takes things apart to see how they work (such as a broken flashlight or toy)	2.36 (1.02)	1.40 (0.63)	61.79**	1.13
2	Sets up play environments with toy furniture, toys buildings, train tracks or building blocks	2.50 (1.23)	1.64 (0.95)	29.76**	0.78
3	Builds race tracks on the ground	2.38 (1.04)	1.25 (0.55)	89.37**	1.36
4	Uses kits to build models (such as airplanes, animals, dinosaurs, doll houses)	1.87 (0.96)	1.25 (0.54)	29.82**	0.80
5	Plays with construction toys (such as building blocks, Legos, magnet sets)	3.02 (1.23)	1.94 (1.09)	43.07**	0.93

Drawing/crafting activities		Boys	Girls	*F* (1,206)	*d*
1	Does arts and crafts projects (such as making jewelry, stringing beads, or using play dough/clay)	2.08 (1.00)	3.23 (1.05)	64.03**	1.12
2	Colors, paints, or draws free hand (not filling-in outlines)	2.38 (1.07)	3.25 (1.11)	32.45**	0.80
3	Draws maps (such as treasure hunt maps)	2.12 (1.07)	1.86 (1.05)	2.81	0.25
4	Draws plans for houses, forts, castles, or other buildings or layouts	2.36 (1.12)	2.21 (1.03)	1.06	0.14
5	Folds or cuts paper to make 3-d objects (such as origami, paper airplanes)	1.94 (1.03)	1.93 (0.94)	0.01	0.01
Outdoor activities					
1	Plays in parks or green spaces	3.69 (0.87)	3.77 (0.80)	0.27	0.10
2	Explores woods, streams, ponds, or beaches or searches for plants, bugs, or animals outdoors	2.53 (1.08)	2.27 (0.98)	2.65	0.25
3	Climbs trees	2.73 (1.11)	2.27 (1.11)	9.05*	0.41
4	Builds dams, forts, tree houses, snow tunnels or other structures outdoors when the weather permits	2.77 (1.17)	2.06 (1.01)	22.31**	0.65

Note. Multivariate effect of sex: $F(14,193) = 18.35$, $p < .001$. Cohen's *d*: .20 = small effect, .50 = medium effect, .80 = large effect. *$p < .01$; ** $p < .001$.