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Spatial Experiences of High Academic Achievers: Insights From a Developmental Perspective

Lisa Marie Weckbacher[1] **and Yukari Okamoto**[1]

Abstract

The study explored the relationship between types of spatial experiences and spatial abilities among 13- to 14-year-old high academic achievers. Each participant completed two spatial tasks and a survey assessing favored spatial activities across five categories (computers, toys, sports, music, and art) and three developmental periods (early childhood, middle childhood, and adolescence). The first phase of analysis determined the percentage of favorite activities by category and developmental period; the second phase examined how participants with the highest scores on each spatial measure differed in their experiences. Findings showed that certain activities (e.g., playing video games and soccer) tended to reemerge across periods and be linked to strong spatial skills. Implications for nurturing high achievers' potential to succeed in spatially demanding careers are discussed.

Keywords

cognition, high academic achievers, high school students, mental rotation, spatial ability, spatial activities, spatial experiences, spatial skills, verbal-spatial ability

The development of spatial ability, generally defined as the ability to create and manipulate visual images, is believed to involve an intricate mix of environmental influences (Baenninger & Newcombe, 1995). In the effort to detangle this complexity, one avenue of research that has yielded some valuable insights pertains to the role of spatial

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experience, notably, participation in spatially oriented activities. Such knowledge is important to know in determining whether and to what extent certain experiential factors can actually help improve spatial thinking (Terlecki & Newcombe, 2005).

In general, the movement toward identifying a relationship between spatial experience and spatial ability has historically focused on gender differences. Within this body of literature, most studies involved exploring the connection among a limited sample of spatial experiences with students who are typically drawn from university settings (e.g., Eliot & Czarnolewski, 2007; Ginn & Pickens, 2005; Newcombe, Bandura, & Taylor, 1983; Ozel, Larue, & Molinaro, 2004; Signorella, Krupa, Jamison, & Lyons, 1986; Voyer, Nolan, & Voyer, 2000). The findings are encouraging in that they suggest a link between spatial-activity participation and an individual's spatial capabilities. However, few studies have examined the potential benefits of spatial experience in relation to individual interests and opportunities that change over time. Furthermore, most of these studies are not necessarily applicable to highly select samples of students whose academic talents might help them to succeed in spatially demanding careers.

Domains of Spatial Experience and Related Measures

Domains of spatial experience include activities specific to computers (Cherney, 2008; Ginn & Pickens, 2005; Greenfield, Brannon, & Lohr, 1994; Terlecki & Newcombe, 2005), toys (Casey et al., 2008; Serbin & Connor, 1979; Voyer et al., 2000), sports (Hult & Brous, 1986; Ozel et al., 2004), music (Costa-Giomi, 1999; Rauscher, 1999), and art (Chan, 2007; Newcombe et al., 1983). In most of these studies, the assessment of spatial-activity participation is coupled with some type of spatial ability measure to determine whether an association exists between the two.

For example, Terlecki and Newcombe (2005) examined spatial experiences with computers and related activities in a sample of nearly 1,300 undergraduate students. Men and women's reported computer experiences revealed that participants with higher levels of experience (especially men) tended to score significantly higher on Vandenberg and Kuse's (1978) Mental Rotations Test (MRT). Within men and women, higher levels of computer experiences significantly correlated with stronger MRT performance. Serbin and Connor (1979), who conducted one of the earliest studies on the relationship between spatial experience and spatial ability, reported that playing with masculine toys (e.g., blocks) related to the development of spatial skills. Further support regarding the potential benefits of block play emerged in Casey et al.'s (2008) more recent investigation of block-building interventions to develop spatial reasoning skills in kindergarteners.

With respect to sports, Ozel et al.'s (2004) findings showed that consistent participation in sporting activities, such as soccer and swimming, was related to males' increased performance in the ability to discriminate and mentally rotate objects. That is, athletes compared with nonathletes, seem to possess some advantage in their ability to transform spatial information that may very well be linked to enhanced spatial processing experience. Similarly, Costa-Giomi (1999) argued that musicians, in contrast to nonmusicians, differ in their development of specific cognitive abilities, spatial ability for one. In her study, children who persisted and participated more actively in the process of learning the piano demonstrated improvement in spatial ability. Though the improvement was temporary, the findings shed light on how the quality of participation is certainly a factor to consider.

Further support for this view comes from Chan's (2007) study of gender differences in Chinese gifted students' self-reported spatial experiences. Chan constructed a scale that consisted of six items; three of the items pertained to in-school extracurricular activities (e.g., receiving awards in drawing or designing) whereas the other three items pertained to extracurricular activities in outdoor events (e.g., evidence of good map reading or sense of direction). Chan claimed that these two types of items measure students' visual-arts experience and spatial-orientation experience, respectively. Students were asked to rate the degree to which each of the six items was descriptive of them ranging from 1 (*least descriptive*) to 5 (*most descriptive*). Findings showed gender differences in spatial ability (notably mental rotation, in favor of males) and spatial experience (males reported greater involvement in spatial-orientation activities). Contrary to what Chan hypothesized, effect sizes of these gender differences turned out to be relatively modest thus weakening any strong support for the idea that gender differences in spatial experience may somehow influence gender differences in spatial ability. Chan concluded that a more valid approach to assessing the role of spatial experience might be to ask students about their time spent engaging in a wider sampling of activities. In other words, taking the duration of participation into account, rather than just involvement per se, may help to more clearly decipher the reason why some spatial experiences may be more beneficial than others.

In sum, the majority of findings are consistent in that differential spatial experiences stemming from childhood into later years tend to be significantly related to higher levels of spatial ability. Research to date, however, continues to be largely limited to the study of gender as well as a restricted sampling of spatial experiences that do not fully consider the quality of experience.

Measures of Spatial Experience

In studies geared toward obtaining a more cumulative sampling of spatial experience, assessment approaches tend to involve self-evaluation of activity preferences and/or frequency of participation within a broad developmental period (or periods). For instance, Voyer et al.'s (2000) activity questionnaire is based on two categories of childhood activities: toys and sports. In their study, participants were asked to rank their top-10 toys and top-10 sports in terms of the amount of time spent with each activity as a child. Newcombe et al.'s (1983) Spatial Activities Questionnaire involves ranking the degree of participation for 81 sports (e.g., baseball, figure skating) and art (e.g., knitting, building models) activities among adolescents and young adults.

Given the widespread interest in the impact of computer usage (including video games) on spatial ability, Terlecki and Newcombe (2005) developed the Survey of

Spatial Representation and Activities. This instrument is a 17-item questionnaire that includes open-ended and multiple-choice questions. The questions are mainly geared toward assessing the frequency of computer, video game, and map usage as well as perceived difficulty related to their usage. Though the description of the survey does not specify age appropriateness, the items imply that it is targeted toward adolescents and adults (e.g., What type of computer software do you own or use? How proficient or skilled do you believe you are at using maps?). Eliot and Czarnolewski's (2007) Everyday Spatial Behavioral Questionnaire, also targeted toward adolescents and adults, emerged as the most recently developed instrument designed to quantify difficulty *and* frequency of spatial experience across a variety of contexts (e.g., driving and accurate drawing).

Assessing participation in spatial activities raises concerns pertaining to the reliability of the information shared. To determine whether such participation is related to spatial ability, researchers have chosen to focus on the frequency of participation in either the childhood (Voyer et al., 2000) or the adolescent/early adulthood years (Newcombe et al., 1983). Perhaps due to using retrospective measures, Baenninger and Newcombe (1989) argued that the recollection of participation in spatial activities (particularly during childhood) may be inaccurate or selective. Moreover, the frequency of participation may bear little influence in comparison with when participation occurred. For example, participation in spatial activities during the preschool years (e.g., playing with Legos) in comparison with adolescence (e.g., skateboarding) may be more apt to nurture spatial development.

More than two decades ago, Baenninger and Newcombe (1989) recommended the use of a questionnaire to assess spatial-activity participation across several different periods of childhood given how children's interests are likely to change with time. Despite this recommendation, no such studies have been conducted thus far. In other words, the scope of experiences in most works to date tends to be limited to a few categories of activities (e.g., toys and sports) that do not fully capture the potential benefits of spatial experience with time. More specifically, the study of how spatial experiences within the context of narrowly defined developmental periods (e.g., early childhood, middle childhood, and adolescence) may relate to spatial thinking has yet to be explored. This line of inquiry takes into account that interest and participation in types of spatial activities are likely to change over the course of development, and as a result, may vary across different age groups. Consequently, a more comprehensive sampling of spatial experiences seems necessary to more accurately reflect the "experience-ability relationship" (Chan, 2007), mainly if different populations of people are called to question.

Spatial Ability Among High Academic Achievers

Spatial ability's unique influence on broad areas of academic performance (e.g., Rohde & Thompson, 2007) has drawn some attention to its importance among samples of high academic achievers, notably the mathematically gifted. By comparison, most studies that explore the relationship between strength in spatial ability and academic achievement pertain mainly to performance in mathematics. Moreover, these studies tend to focus on or incorporate samples of gifted students in some way. This may be partly due to the line of findings that clearly support how strength in types of spatial skills is a key factor in mathematics achievement (e.g., Benbow & Minor, 1990; Reichel, 1997; Stumpf, 1994; Stumpf & Eliot, 1995; Webb, Lubinski, & Benbow, 2007). These skills, such as pattern recognition, visual transformation, and mental rotation to name just a few, reflect the cognitive profile of the mathematically gifted. In addition to this well-established finding that the mathematically gifted are inclined to be spatially adept, they do show qualitatively different profiles in this respect. For instance, Stumpf and Eliot's (1995) comparison of mathematically gifted males and females revealed a male advantage on most recognition- and manipulation-type tasks with mental rotation representing the largest effect size. Females, however, tended to do significantly better than males on visual memory tasks, or tasks that involve perceptual speed in relation to spatial problem-solving processes.

Outside the realm of gender differences, other studies that have focused on spatial ability in relation to giftedness contribute toward further defining unique characteristics of spatial strength. One example is Hermelin and O'Connor's (1986) comparison of artistically versus mathematically gifted adolescents' ability to develop spatial representations when solving different types of spatial problems. They found that whereas artistically gifted children were particularly at good constructive imagination on the basis of minimal perceptual cues, mathematically gifted children were particularly good in their ability to process verbal-spatial information (e.g., "How many squares of the same size will I need to make a bigger square?") in their problem-solving efforts. That is, mathematically gifted children's ability to think about space seems to strengthen their capacity to translate verbal propositions into well-defined spatial representations. Another example pertains to van Garderen and Montague's (2003) observation that the tendency to develop schematic rather than pictorial representations sets apart gifted students from their less-capable peers (i.e., students who are average achievers and students with special needs) with respect to successful solution attempts when solving a problem. Whereas schematic representations involve spatial relationships among problem parts, pictorial representations simply encode the overall visual appearance of an object (or objects) in a problem. In sum, gifted students solved more problems correctly than students from the other two groups largely due to their sophisticated use of spatial images that incorporate essential elements of a problem to achieve success.

Research Questions

The current study provides some early insights from a developmental perspective into how a broader range of spatial experiences relates to the spatial ability of students outside the college population, in this case, high academic achievers drawn from a high school setting. The following research questions were therefore posed:

Research Question 1: How do high academic achievers' favored spatial activities vary from early childhood into adolescence?

Research Question 2: How do differences in favored activities from early childhood into adolescence relate to strong spatial skills among high academic achievers?

Method

Participants

Originally, 43 seventh- and eighth-grade students ranging from 13 to 14 years of age consented to participate in the study. The students had been drawn from an elite college preparatory institution in southern California dedicated to educating high-achieving students. The students were predominantly Caucasian. Given the significant fee for enrollment and the surrounding affluent neighborhood, they can be considered children of upper-middle class families.

Of the 43 students, 14 (5 boys, 9 girls) met the criteria as high achieving to be included in the study. These 14 participants identified as high achieving demonstrated mastery of quantitative and/or verbal skills based on the most recently administered standardized achievement test, or grades if test scores were not available. The achievement test, formally known as the Comprehensive Testing Program 4 (CTP 4), is a nationally administered test designed specifically for private schools that are members of the Educational Records Bureau. A student had to obtain either a stanine score of 9 on the Mathematics 1 and 2 or Verbal Reasoning subtests, or a grade point average (GPA) of 4.0 and higher in the most recent mathematics or English/language arts courses to be classified as a high academic achiever.

Materials

Two tasks measured spatial ability. The first, Vandenberg and Kuse's (1978) MRT is a nonverbal paper-and-pencil spatial task. The MRT originated from Shepard and Metzler's (1971) computerized version using two-dimensional drawings of three-dimensional objects. The MRT may be administered to children but has been most frequently cited with adolescents and adults across a wide range of intellectual ability, including gifted youth (e.g., Stumpf & Eliot, 1995). In large samples, Vandenberg and Kuse reported that the MRT displayed substantial internal consistency (.88) and test–retest reliability (.83).

The MRT measures ability in determining a match between a primary object and two of four objects presented at different angles. Each object is an abstract configuration of 10 blocks. Two of the four rotated objects are the same as the primary object in each problem. In terms of scoring, two credits are awarded if the 2 items chosen are correct *or* one credit if only 1 item is chosen and correct. To control for guessing, no credit is awarded if 2 items are chosen but only 1 is correct. In total, the task consists of 20 items. The maximum score is 40.

The second task is a revised version of Hermelin and O'Connor's (1986) measure of verbal-spatial ability. They administered the task to 12- to 14-year-old children who were identified as gifted in mathematics or art. Reliability data were not provided, and the usage of this task seemed to be limited to Hermelin and O'Connor's study. In contrast to the MRT, it measures ability to solve verbal presentations of problems that may involve the use of varied spatial skills rather than just one (e.g., mental rotation). Of the 12 original questions, 10 were chosen for the current study. Several of the 10 questions were then revised in collaboration with fellow faculty and doctoral candidates. Sample items include (a) "How many diagonals can be drawn on the surface of a cube?" (b) "If I take a lowercase 'b' and rotate it clockwise until it was upside down, what letter will it be now?" and (c) "The midpoints of two opposite sides of a square are joined together by a straight line. What will result?" For two questions, there is more than one possible answer, but only one credit is awarded per question if an answer is correct. The maximum score is 10.

The Youth Activities Survey (see Table 1) was developed for the present study. The survey consists of 70 spatially oriented activities partly drawn from questionnaires used in prior research (i.e., Newcombe et al., 1983; Voyer et al., 2000). The determination for additional items was based on an analysis of the nature of each activity grounded in literature on spatial activities. In comparison, the Youth Activities Survey entails a broader range of spatial activities categorically grouped as follows: computers (14 items), toys (16 items), sports (24 items), music (6 items), and art (10 items). Moreover, this survey, unlike its counterparts, incorporates the duration of participation in activities across the early childhood (0-5 years), middle childhood (6-11 years), and adolescent years (12+ years). It is to be completed with a parent to assist in the recollection of activities from earlier years. Basically, participants were asked to rank their three most favorite activities (i.e., 1 = *most favorite*, 2 = *second most favorite*, 3 = *third most favorite*) within each category for each developmental period. For example, under the category "sports," a participant may choose martial arts, soccer, and baseball as his favorite activities during middle childhood. If soccer is first in rank, then it is interpreted as the most favorite activity of the three for that specific duration of time. If none of the activities listed applies, the participant is free to provide up to three additional activities to each categorical list (under "other") and then rank accordingly.

Procedure

Participants returned the surveys to mathematics and English teachers prior to testing. Both spatial tasks were then group administered within a classroom setting. To ease the anxiety of the participants, the verbal-spatial task was administered first considering it is not openly timed. Instructions for the verbal-spatial task were read aloud to the participants. A sample question was included at the end of the instructions to familiarize

Table 1. Youth Activities Survey Items by Category

Computers	Toys	Sports	Music	Art
Research	Blocks	Badminton	Reading	Drawing
Word processing	Lincoln logs	Baseball	Writing	Painting
Graphic design	Tinker toys	Basketball	String	Sculpting
Browsing	Climb/ride	Golf	Piano	Pottery
Online shopping	Modeling clay	Hockey	Drums	Knitting
Online chatting	Model kits	Figure skating	Brass	Embroidery
Email	Puzzles	Racquetball		Jewelry
Playing games	Board games	Cycling		Crafts
Designing games	Ring toss	Soccer		Paper-folding
Installing software	Croquet	Tennis		
Designing software	Musical	Volleyball		
Building computers	Jump rope	Martial arts		
Repairing computers	Darts	Bowling		
Computer classes	Marbles	Football		
	Jax	Hopscotch		
	Baton twirling	High jumping		
		Lacrosse		
		Skiing		
		Skateboarding		
		Ping pong		
		Riding horses		
		Pool		
		Squash		
		Track and field		

the participants with the type of questions to follow. Each of the 10 questions was read twice allowing 5 s to respond after each verbal presentation. If necessary, a question was read a third time allowing 5 s to follow before moving on to the next question. Following the 10th and final question, any question was repeated once on request.

The participants were asked to read the instructions for the MRT. To their knowledge, participants were timed for 3 min to read the instructions and complete the sample problems. Afterwards, the task then consists of two parts divided into 10 problems apiece. Participants had 3 min to complete each part.

Results

The data underwent two phases of analysis. The first phase primarily involved calculating frequency counts that were converted to percentages of ranked activities relative to each of the five categories and three developmental periods. For the second phase, the

Table 2. Most Favored Spatial Activities by Category and Developmental Period (N = 14)

	Developmental period		
Category	Early childhood (%)	Middle childhood (%)	Adolescence (%)
Computers (14)			
Video games	64[a]	50[a]	14
Online chat	0	0	36[a]
Toys (16)			
Blocks	21[a]	21[a]	7
Climbing/riding	21[a]	21[a]	21
Board games	7	21[a]	50[a]
Sports (24)			
Soccer	50[a]	50[a]	43[a]
Music (6)			
Piano	29[a]	43[a]	21[a]
String instrument	0	0	21[a]
Art (10)			
Drawing	36[a]	43[a]	29[a]

Note: The total number of activities for each category within the Youth Activities Survey is in parentheses.
[a]The activities with the highest frequency counts for each developmental period.

most favored activities (ranked as 1) of those participants with the highest scores on each spatial measure were compared to determine whether and how their spatial experiences differ relative to each type of skill.

Favorite Spatial Activities in Early Childhood, Middle Childhood, and Adolescence

The most favored activities, or activities ranked as 1, are reported in Table 2. As can be seen, a relatively narrow grouping of activities emerged as most favorite activities in comparison with the total number of activities within each category: computers, sports, and art in particular.

Activities with the highest frequency counts also tended to emerge as most favorite activities in more than one developmental period with the exception of online chatting, string instrument, drums, listening to music, and painting. Table 3 is a slightly different presentation of Table 2. The most favorite activities with the highest frequency counts are listed categorically across the three developmental periods highlighting an even narrower group of activities chosen from the 70 items total.

Activities ranked as 2 or 3 (i.e., second most favorite and third most favorite, respectively) generally showed a broader spectrum of favored activities. Of these activities, a

Table 3. Most Favored Spatial Activities With the Highest Frequency Counts (*N* = 14)

	Developmental period		
Category	Early childhood	Middle childhood	Adolescence
Computers	Video games	Video games	Online chat
Toys	Blocks	Blocks	Board games
	Climbing/riding	Climbing/riding	
Sports	Soccer	Soccer	Soccer
Music	Piano	Piano	Piano
			String
			Listening
Art	Drawing	Drawing	Drawing
	Painting		

Table 4. Top-Three Spatial Activities by Category and Developmental Period (*N* = 14)

	Developmental period		
Category	Early childhood	Middle childhood	Adolescence
Computers	Video games (71%)	Video games (86%)	Online chat (64%)
Toys	Blocks (50%)	Climbing/Riding (100%)	Board games (93%)
Sports	Soccer (71%)	Soccer (71%)	Soccer (57%)
			Basketball (57%)
Music	Piano (43%)	Piano (64%)	Piano (64%)
Art	Drawing (86%)	Drawing (64%)	Drawing (64%)

Note: The percentages in parentheses represent the highest frequency counts of the activities that were ranked as most favorite, second most favorite, or third most favorite.

number of them reemerged as second and third favorites (e.g., video games, blocks, soccer, piano, drawing) across all three developmental periods. Table 4 lists the activities ranked as 1, 2, or 3 (or the top three) with the highest percentage within each category for each developmental period. Aside from toys, a clear pattern of favored activities surfaced within each category indicating that the duration of participation for most of these activities likely extended into more than one developmental period for most participants.

Differences in Favored Activities Relative to Strength in Spatial Ability

A Spearman's rank correlation test determined that the relationship between scores on the MRT and the verbal-spatial task was negative ($\rho = -.32$) but not significant. The

Table 5. Descriptive Statistics for the Mental Rotations Test and the Verbal-Spatial Task

	M (*SD*)
Mental Rotations Test	
Total sample (N = 14)	15.36 (6.08)
High scorers (n = 5)	20.80 (2.59)
Verbal-spatial task	
Total sample (N = 14)	6.43 (1.99)
High scorers (n = 5)	10.90 (4.90)

means and standard deviations regarding performance for all participants (N = 14) on both spatial ability tasks are listed in Table 5. For the MRT, the Cronbach's alpha coefficient was .69, and for the verbal-spatial task, the coefficient was .58.[1]

An even divide of scores identified participants as either high (n = 7) or low scorers (n = 7) on the MRT and the verbal-spatial tasks. Within these subgroups, two participants scored high on both tasks, and two participants scored low on both tasks. These participants were therefore removed from subsequent analyses that solely involved comparing high scorers on each task separately. The respective means and standard deviations are also listed in Table 5. The high scorers on the MRT (n = 5) consisted of three boys and two girls; high scorers on the verbal-spatial task (n = 5) consisted of one boy and four girls.

The descriptive analysis that follows only considered activities most highly favored to more strongly determine how certain spatial activities may be linked to strong spatial skills. Beginning with computers, four out of five high scorers on the MRT chose video games as their most favored spatial activity for early childhood and middle childhood. In regards to sports, a majority of these participants elected soccer as the most favored activity for different developmental periods but in two cases, soccer represented all three. Similarly, drawing emerged as the favored activity for two high scorers across all three periods, and for two other scorers, it emerged for two consecutive periods. Most of these high scorers also chose piano and/or drums as their instruments of choice for different developmental periods, though in three cases, these choices also represented consecutive periods of time. Most favorite toy activities revealed greater variability compared with the other four categories; however, blocks and climbing/riding toys surfaced more frequently than others (e.g., puzzles and board games).

Most favorite activities among high scorers on the verbal-spatial task revealed less of a clear pattern across all five categories. To begin, favored activities in regards to computers included video games along with graphic design, online chatting, and research for school/related activities across a mix of developmental periods. Toys followed suit in that blocks emerged a few times but in addition to climbing/riding, board games, Tinker toys, and a few items listed under "other" (e.g., books, dolls, and dress-up). With the exception of books, two of these activities, blocks and board games, represented favorite activities for three participants across two consecutive periods. (One participant's choice is questionable given his choice of blocks as the most highly favored adolescent toy.) Similarly, sports choices ranged in that soccer, basketball, and softball closely tied as most favored with a slight preference toward soccer overall. Compared with computers and toys, sports activities showed slightly more continuity across developmental periods. Finally, music and art activities represented two extremes. Favored music activities (e.g., drums, brass, piano, string and "other") varied most whereas favored art activities varied least (e.g., drawing, painting, and crafts). Listening and/or singing, listed under "other," fell into more than one developmental period for three participants. Crafts, followed by painting and then drawing, also fell into more than one developmental period but for all five participants.

Discussion

As a step toward building a developmental perspective of how spatial experience relates to spatial ability, the current study serves to narrow the scope of study to higher achieving students rather than gender differences alone. Though no causal ordering between experience and ability can be drawn, the findings are nonetheless valuable in that they add support to previous research in two ways: (a) Certain spatial experiences seem to be more strongly related to spatial ability compared with others and (b) these experiences tend to vary with strength in types of spatial skills.

Types of Spatial Experiences: A Developmental Perspective

Previous research has shown that participation in types of spatial activities is positively related to performance on spatial tasks (e.g., Ginn & Pickens, 2005; Newcombe et al., 1983; Signorella et al., 1986; Voyer et al., 2000). For instance, a fair amount of research to date lends support to the benefits of video games (e.g., Cherney, 2008), block play (e.g., Casey et al., 2008), and piano instruction (e.g., Costa-Giomi, 1999) to help delineate the "experience-ability relationship" (Chan, 2007). Less research exists that targets specific sports (e.g., Hult & Brous, 1986) and art-related activities (e.g., Eliot & Czarnolewski, 2007). However, a broad interpretation of findings is in line with the three previous categories, which suggests that participation in either sports or art activities tends to be associated with enhanced spatial performance. Taken together, the findings are still generally limited in terms of explaining how certain developmental periods may more or less influence interests and opportunities in spatial activities that change from the early childhood to the adolescent years.

The pattern of findings in the current study adds further support to prior research (Voyer et al., 2000) in that students identified with strong spatial ability tended to favor some activities more than others. Unlike Chan (2007) and Voyer et al.'s (2000) spatial-activity measures that ask participants to respectively rate or rank each item listed, the Youth Activities Survey took a different approach partly recommended in each of these works. That is, with the Youth Activities Survey, participants were able to *choose* their favored activities from robust, categorically defined lists. It is worthy to note that the students' choices strongly paralleled the types of activities that previous studies identified as potentially influential. Some of these activities included video games, block play, soccer, piano, and drawing among a few others.

From a developmental perspective, toy-related activities reflected the greatest degree of change across developmental periods, which was not surprising considering that block play and climbing/riding toys are unlikely to be popular among most adolescents. Activities related to computers, sports, music, and art remained less variable from one period to another. Of greater significance is that a number of choices remained the same across two sometimes three developmental periods. This implies that the duration of participation is likely a key factor in the relationship between spatial experience and spatial ability. In other words, longer periods of participation, or accumulating experience, should be considered in evaluating just how spatial experience relates to spatial ability. Until now, less attention has been paid to the duration of participation, especially within the context of well-defined developmental periods that may very well aid the recollection of participation from early years.

Spatial Experience in Relation to Types of Spatial Ability

Of those studies that have found a relationship between spatial experience and spatial ability, many of the spatial tasks assessed skill in mental rotation (e.g., Cherney, 2008; Ginn & Pickens, 2005; Ozel et al., 2004; Terlecki & Newcombe, 2005; Voyer et al., 2000; Webb et al., 2007). No known studies to date has explored the relationship between spatial experience and verbal-spatial ability, which is an added hallmark to the present work. In comparing the students who scored high on mental rotation with those who scored high on the verbal-spatial task, some overlap of favored activities emerged in that certain activities represented both groups (e.g., video games, blocks, soccer, piano, and drawing). However, favored spatial activities among students with strong mental rotation ability represented clearer, more consistent patterns of interest. Greater variability in spatial experiences more strongly characterized the verbal-spatial group overall.

The differences in reported favored experiences may be reflected in the negative correlation between performance on the mental rotation task and that on the verbal-spatial task. Though nonsignificant, the direction of the relation is still important. It suggests that the tasks are measuring different types of spatial ability. Whereas Vandenberg and Kuse's (1978) MRT assesses mental rotation only, the verbal-spatial task seems somewhat eclectic in the types of spatial skills that may be required to solve each item. That is, the type of spatial thinking involved in solving some of the items (e.g., "How many diagonals can be drawn on the surface of a cube?") may be quite different from others (e.g., "The midpoints of two opposite sides of a square are joined together by a straight line. What will result?"). Consequently, the greater variety of differences in favored experiences among students with strong verbal-spatial ability may very well reflect this broader spectrum of experiences from an early age. However, strength in mental rotation is a specific type of spatial ability that may develop as a result of certain experiences over significant periods of time.

Limitations

There are a few noteworthy limitations to address. The total number of students who completed the survey is likely too narrow to draw any reliable conclusions in regards to whether or not these favored spatial activities represent higher achieving students in general. Considering that the school site is located in an affluent area, it is quite possible that participation in a number of the activities reported may be a stronger reflection of afforded opportunities among the upper-middle class rather than personal choice. If participation is driven by personal choice, it is still unknown whether the participants with strong spatial skills were simply drawn to spatial activities from the onset. In other words, spatial experience may not necessarily nurture the development of strong spatial skills; it could very well reflect a self-selection process (Newcombe et al., 1983; Voyer et al., 2000).

Two issues surround the Youth Activities Survey. For one, the survey requires parental participation to assist in the recollection of activities, especially from the early childhood years. It is possible that parents may encourage their children to select activities that are perhaps more socially desirable than others. For example, of the upper-middle class parents who participated in the current study, some may have encouraged their children to express favoritism toward activities like playing the piano, when in fact it may not have been a favored activity growing up. Instead, it may just be a childhood or adolescent experience not all that favored. An alternative may be to directly administer the Youth Activities Survey to the participants but ask their parents to complete an open-ended questionnaire on the early childhood years only. Differences between the survey and questionnaire responses could help determine the overall benefits of either approach.

The second issue pertaining to the Youth Activities Survey involves age. The survey is designed to assess favored activities across three developmental periods that extend to 12 years of age and beyond. The participants ranged from 13- to -14-year-olds, which is closer to the earlier adolescent years than later. From a developmental perspective, it can be argued that to assess the role of spatial experience into adolescence, future studies should assess older adolescents (e.g., 17-18 years of age) as well. As interests and opportunities are likely to change with time, a good deal of valuable information can be lost if accumulating experiences throughout such critical years are not taken into account.

Implications and Future Research

Efforts in the United States to motivate and prepare young scientists and engineers to meet the needs of its high-tech economy are a concern (Armstrong, 2003; National Science Board, 2009). A large proportion of scientific, technology, engineering, and mathematics (commonly referred to as STEM) departments of U.S. graduate schools consist of high-caliber foreign students who remain in the United States after graduation to work and often contribute toward the U.S. research enterprise. Despite this overseas dependence, efforts to improve U.S. students' interest and required skills to succeed in STEM careers remain a concern.

In a report from the United States Government Accountability Office, Ashby (2006) emphasized the decline in the number of conferred degrees in STEM fields from 32% to 27% in the academic years 1994-1995 and 2003-2004, respectively. Suggestions to encourage enrollment in STEM fields continue to include outreach and mentoring in order for the United States to keep pace within a rapidly evolving global economy (National Science Board, 2009). Along these lines, Bharucha (2008) argued that there is a sense of urgency in the United States with respect to how other countries, mainly China and India, are producing professionals in STEM fields far more effectively. For example, in 2008, China as well as India produced far more than double the number of graduating engineers compared with the United States (Hughes, 2009). The immediate question that comes to mind then is, "What are they doing that the United States is not?" The latter part of the question is far easier to answer. Spatial ability, a key component of high-level development in scientific and engineering domains, has long been relegated to a secondary status relative to verbal and quantitative abilities. Consequently, there has been great neglect in identifying and nurturing high-spatial individuals in the U.S. educational system (Mann, 2005; Shea, Lubinski, & Benbow, 2001). One might argue then that targeting young students with exceptional spatial skills may help to produce students with promise for STEM fields (Webb et al., 2007). By doing so, these skills can continue to be honed through experiences that nurture spatial thinking over the course of development.

The present study is a starting point toward unraveling the relationship between spatial experience and spatial ability among high-achieving youth who hold promise for developing math–science expertise. By examining this relationship from a developmental perspective, there is movement toward supporting the idea that the benefits of certain spatial experiences may vary with age, particularly if these experiences extend from one developmental period into another. Given that the Youth Activities Survey is the first instrument designed to assess spatial-activity participation relative to multiple developmental periods, the next step would be to determine whether the same patterns of experiences emerge among individuals who are considered to be average or less-than-average achievers. Moreover, continued study of how certain spatial experiences differentially relate to types of spatial thinking is in need. Such efforts could lend further support toward modifying educational practices that can help meet the current demand of STEM fields in the United States.

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Note

1. The lower Cronbach's alpha coefficient for the verbal-spatial task may be indicating that more than one construct is being measured.

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