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Effects of Sport Participation on Scores of Spatial Ability Tests

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Abstract

Involvement in high spatial sport activities positively correlates with higher scores on spatial ability tests, possibly accounting for observed male advantages across the life span. The present study attempted to show a causal factor of experience for the early emergence of gender differences. Four Grade Three classes were assigned to 2 experimental conditions: high spatial (HS) sport activities and low spatial (LS) activities. Pre-treatment assessment of past experience predicted scores of spatial ability tests for males, but not for females. Female scores were correlated with coached activities. Data showed an effect on spatial ability test scores, resulting from treatment. Non-significant trends for male superiority on spatial tests were observed, suggesting a need for closer examination of causal factors over time.

Many approaches to general mental abilities identify spatial ability as a distinct component. Spatial abilities may be important for two areas of mental functioning: imagery and mathematical ability, especially for the understanding of geometry and algebra (Kolb and Wishaw, 1996). This aspect of ability is particularly interesting because it is often reported to show a significant gender difference. The present research considers possible explanations of that difference and offers an experimental test of one such theory.

Categories of Spatial Abilities

Linn and Petersen (1985) define three categories of spatial abilities. The first, 'spatial perception', is defined as the ability to determine spatial relations despite distracting information. The second category, 'mental rotation', is defined as the ability to rotate quickly and accurately two- or three-dimensional figures in imagination. Finally, 'spatial visualization' is defined as the ability to manipulate complex spatial information when several stages are needed to produce the correct solution.

Emergence of Gender Difference

There is general agreement that the gender-related differences observed in spatial abilities emerge early in childhood, around the age of seven or eight (Linn and Petersen, 1985; Johnson and Meade, 1987). Linn and Petersen (1985) drew four conclusions from 172 studies of spatial abilities in their meta-analyis. First, the gender differences observed arise on some types of spatial ability, but not others. Second, large differences are found only on measures of mental rotation. Third, smaller differences are found on measures of spatial perception. Finally, when differences are found, they can be detected across the life-span.

Theories of Gender Differences

Gender differences may be biologically based, or may derive from an individual's experience.

One theory of sex differences in spatial abilities attributes them to an X-linked genetic factor (Caplan et al., 1985). The hypothesis suggests that at least one of the genes controlling spatial ability is recessive and carried on the X-chromosome, a pattern well known from colour-blindness, which is more common in males. Accordingly, mother-son correlations of X-chromosome genes and spatial ability scores should be higher than mother-daughter ones; some degree of mother-daughter correlation should be present and no correlation between father and son scores should appear (Caplan et al., 1985).

Some researchers (Hartlage in 1970, Stafford in 1961) have found evidence for X linkage using spatial visualization measures (Linn and Petersen, 1985). Stafford and Harlage found mother-son correlations of .39 and Bock and Kolakowski found mother-son correlations of .20 (Caplan et al., 1985). Other researchers, such as Corely, Defries, Kuse and Vandenberg (1980), used spatial visualization measures and failed to support the theory of an X linked recessive major gene for spatial ability (Linn and Petersen, 1985). In any event, it seems likely that spatial ability depends on far more than a single gene.

Another theory attributing differences to biological factors is the timing of puberty theory. It was hypothesized that for girls, early maturation is associated with a feminine orientation and often reflected in more participation of feminine activities, which is disadvantageous for the development of spatial ability. Late maturation, on the other hand, is associated with a relatively masculine orientation, reflected in more participation of masculine activities, and more favorable to the development of spatial skills (Newcombe and Bandura, 1983). Newcombe and Bandura (1983) tested the effects of timing of puberty on spatial ability for 85 sixth-grade girls. The study showed a correlation of .22 between time of puberty and spatial ability (Newcombe and Bandura, 1983). The study suggests that masculine personality traits and interests are associated with spatial ability in girls. Early maturers were more feminine, as measured by the California Psychological Inventory, and less likely to participate in masculine sex-typed activities (Newcombe and Bandura, 1983).

The biological theories are not consistent in their findings and often not supported by researchers. Correlations that do support these theories tend to be small, suggesting an alternate factor may successfully explain sex differences in spatial ability.

In contrast to the biologically based theories are experiential or social theories. Spatial ability differences may be attributed to the involvement of girls and boys in different activities. Lunneborg (1982) assessed the extent the sexes differed in activities performed at school/work or in leisure activities requiring spatial ability. Self-reports indicated that men participated in more leisure-time activities requiring spatial ability. Men more often worked with machines, assembled things, and engaged in games and sports; women used spatial ability more for driving, organizing things, and artistic endeavors. However, both sexes identified sports as the leisure activity requiring the greatest spatial ability (Lunneborg, 1982). In a follow-up study Lunneborg (1984) found men's self-ratings of everyday spatial abilities were significantly higher than women's. Although the follow-up study supported previous findings that men participate in more activities requiring high spatial ability, it is important to note that these were essentially correlational studies between different forms of self-reports of spatial performance and not actual measure of everyday spatial abilities (Lunneborg, 1984).

Pellegrini & Smith (1998) suggest that the immediate benefits of physical play are linked with cognitive developments. Pellegrini and Smith (1998) define three kinds of play. The first type of play, stereotype rhythmic movement, peaks in infancy. The second, exercise play, peaks during the preschool years. The last kind of play, rough and tumble play, peaks in middle childhood. The latter form of play described by Pellegrini and Smith (1998) appears to reflect gender differences, with greater prevalence in males.

Conner & Serbin (1977) observed masculine and feminine activity preference scales based on frequencies of play behaviour in the classroom. In particular, masculine and feminine activity preferences were correlated with three cognitive measures to determine the extent to which sex typing is associated with general intellectual development or visual-spatial ability (Conner & Serbin, 1977). Results suggested: (a) many children have already learned to avoid opposite-sex activities by the time they enter nursery school; (b) sex-role learning during the preschool period appears to involve increasing attention to same-sex activities; and (c) the development of visual-spatial ability in boys is related to involvement in masculine activities (Conner & Serbin, 1977).

After reviewing the articles of Pellegrini & Smith (1998) and Conner and Serbin (1977), Bjorklund & Brown (1998) suggest that increased play is related to increased learning. Physical play, particularly in boys, often involves activities that require eye-hand coordination, such as playing football, climbing trees, or playing on gymnastic equipment. One hypothesis about the nature of gender differences in spatial abilities is that boys' greater experience with such activities promotes the development of spatial cognition to a higher level than seen in girls (Bjorklund & Brown, 1998).

Conclusion

In light of the past research, it would be expected that a correlation between past experience in high spatial sports and spatial ability tests scores could be replicated. As well, it would be assumed that the more activities, involving formal training/coaching, that participants were involved in, the higher their test scores would be. By increasing the physical spatial experience through treatment (e.g., sports), it would be assumed that this experience would generalize to improve all cognitive spatial ability, resulting in an increase in scores on paper-and-pencil spatial ability tests, thus providing empirical evidence of an experiential factor to spatial ability. If gender differences exist, favoring males on pretest spatial ability test scores, as the literature would predict, this difference would be narrowed or totally eliminated by providing the same experience to the female participants.

Studies (Hult & Brous, 1986; Lunneborg, 1982; Conner & Serbin, 1977; Bjorklund & Brown, 1998) indicate a relationship between activities and spatial ability. This could mean that increased involvement in activities requiring high spatial ability could increase spatial ability test scores; however, all of the research has been correlational. It is necessary to demonstrate a causal effect experimentally. This is the intent of the present study. If activity patterns are at the root of observed gender differences, it should be possible to reduce or eliminate the differences by providing the same activity to all subjects.

Method

Subjects

Participants were 110 children, mean age of 8 years 7months, from four Grade 3 classes of local elementary schools.

Procedure

A mixed within-and-between-group design was used. The schools participating in the experiment were assigned to either the high-spatial (HS) treatment group or the low-spatial (LS) treatment group.

A letter was sent to parents to inform them of the experiment and provide a contact number in case more information was required before the children were involved in the study. A questionnaire was filled out by each student to assess past experience in 13 activities; football, softball, basketball, hockey/ringette, figure skating, skiing, soccer, tennis, bowling, dancing, gymnastics, curling and swimming. It also assessed the extent of participation in organized sports (those involving coaching or training through an organization such as the YMCA, Sault Gym Club, Ontario Hockey Association, etc.).

Pre-testing for spatial abilities was conducted using seven paper-and-pencil tests adapted by Johnson & Meade (1987) for use with children of this age. These tests had been selected so as to span a range of tasks and difficulties in accord with the following criteria: a) instructions could be made sufficiently clear and simple for use with children, b) cognitive operations on the test items were reasonably simple, and c) the items were likely to be intrinsically interesting to children (Johnson and Meade, 1987).

The first test, Flags, presents pairs of American flags in various orientations, to be judged same or different. The second, Mental Rotations, presents pairs of three-dimensional Shepard-Metzler block figures for a same-different response. The third, Cubes, presents pairs of three-dimensional cubes bearing different designs on each face. A 'same' response is correct if the two pictures could, after one or more rotations in three-dimensions, depict the same cube. The fourth, Hands, presents pictures of hands for a right-left discrimination. The fifth test, Blocks, presents stacks of blocks, and requires the determination of the number of blocks including those hidden from view. The sixth test, Spatial Relations, presents a fragment of a square in the stem. The student must select from four alternatives which piece, when properly rotated, completes the square. The seventh test, Hidden Figures, presents a simple line drawing in the stem. The student must select which one of three alternatives contains the unrotated stem figure (Johnson and Meade, 1987).

The spatial ability testing was conducted over a two-day period; Flags, Hands, Blocks and Spatial Relations on the first day, Hidden Figures, Cubes and Mental Rotations on the second day. Each test session lasted approximately 1/2 hour. The tests were explained, using the instructions from Johnson and Meade (1987) and several tests (Flags, Blocks, Cubes and Mental Rotations) were demonstrated with models. Practice items were completed prior to testing.

Baseline measures of skill mastery were assessed for all participants. Four stations, set up in the gymnasium, were used to assess participants' skill at throwing a ball to a target, basketball shots on a net, shooting a hockey ball on a net and catching a football. The ball-throwing station had an inner target 0.67 m x 0.67 m and an outside target 1m x 1m taped to a wall. Participants threw a small street hockey ball from a distance of 3.67 metres. A score of 2 was given for hitting the inner target and a score of

1 was given for hitting the outside target. Each participant was allowed five throws. The basketball station consisted of a child's Fisher Price basketball net and small basketball. Each participant was given five attempts to get the ball in the net from a distance of 3 metres. A score of 2 was given for getting the ball in the net and a score of 1 for hitting the rim. The hockey station consisted of a child-size hockey net with a 3.67 m x 3.67m target hung from the middle of the top crossbar, floor hockey stick and small street hockey ball. The participants were given five attempts and received a score of 2 for hitting the target and a score of 1 for getting the ball in the net. The football station consisted of a pillow football approximately one foot in length. The participants were thrown the ball from a distance of 5 metres and given a score of 2 if they caught the ball and a score of 1 if they touched the ball with their hands but fumbled the catch. One throw was aimed at the center of their body and two throws to each side of their body; one shoulder height and one waist height.

Participation in HS or LS activities was conducted for one week, consisting of two Phys-Ed sessions. Each group was instructed and supervised by two volunteers and myself. Activities were identified as either high-spatial or low-spatial by 4^{th-}year psychology students of Algoma University College with an inter-rater reliability of 85%. High-spatial activities were identified using the operational definition: making an object go to a specific targeted area or effectively catching an object thrown. The definition is not comprehensive of all spatial abilities, but closely approximates Linn and Petersen's (1985) 'spatial perception' definition. HS activities consisted of basketball passing skills, hockey skills, and ball-throwing/target activities. LS activities, not meeting the high spatial definition, concentrated on endurance, balance and speed (e.g., relay races). All of the activities, both HS and LS, met Ontario Education Curriculum standards.

Following treatment, each student was post-tested for spatial ability and skill mastery. Post-test assessment of spatial ability was completed, using the same seven paper-and-pencil spatial ability tests that were administered at pre-testing. The students did not obtain feedback on pre-test scores and practice effects would have been equally distributed between the two treatment groups, and should not favor one or the other. Skill mastery was post-tested using the same physical assessment (four stations in gymnasium) used at pre-testing.

Results

Spatial Ability. Total scores of spatial tests were summed across each participant's seven spatial test scores to create a composite index of individual test performance reflecting a general component of spatial ability. Difference scores were created by subtracting pretest scores from post-test scores and these change scores were analyzed using a one-way analysis of variance (ANOVA) with Spatial Task (HS vs. LS) as the sole factor. The analysis indicated a simple effect for the HS task, $F = 21.87$ $(1,91)$, $p < 0.01$; the relevant means and standard deviations are presented in Table 1.1.

In light of past research suggesting sex differences in spatial ability, we conducted a one-way analysis of variance was conducted on the HS and LS adjusted scores, to indicate sex differences within each treatment. There were no significant sex differences observed for either the HS or LS group; $F = 0.000$ $(1,43)$, $p = 0.962$ and $F = 2.57$ $(1, 47)$, $p = 0.116$, respectively. The means and standard deviations for these analyses are given in Table 1.1. Children in the HS condition showed greater gains in spatial ability, which is illustrated in Figure 1.1.

Insert Table 1.1 and Figure 1 here.

There were serendipitous findings of a significant difference between the schools involved in the HS and LS treatment groups for pre-test paper-and-pencil spatial ability test scores. The two schools involved in the HS group had significantly lower pre-test scores than the two schools involved in the LS group, $F = 7.03$ (3,102), $p = 0.000$. School 1 and 2 were involved in the HS condition and school 3 and 4 were involved in the LS condition. Means (standard deviations shown in parentheses) for schools 1 through 4 were 67.04 (9.30), 71.46 (14.02), 82.54 (11.85), and 77.25 (14.43), respectively.

The variable of the schools was partialled out in order to match the sample groups and reduce the error term, thus having a clearer test of the original hypotheses. Further analyses of the spatial tests were conducted with adjusted scores in analysis of covariance (ANCOVA). Spatial condition (HS vs. LS) and sex (female vs. male) were assessed for main effects and interactions on analysis of variance for the total test difference, using the adjusted scores. There was a significant main effect for spatial treatment, $F = 8.08$ (1,91), $p = 0.006$. The magnitude of this effect, using omega squared (ω^2) calculations, was 0.06. The main effect for sex was insignificant, $F = 0.22$ (1,91), $p = 0.644$. The interaction effect for spatial condition and sex was insignificant, F = 0.22 (1,91), p = 0.641.

Post-hoc comparisons were conducted in order to further investigate the differences of pre-test between the two treatment groups. The groups significantly differed in reported experience on the questionnaire, t = -2.34, p = 0.021. The HS group reported less experience in high spatial sports. The mean score (standard deviation in parentheses) for the HS and LS groups were 24.92 (4.89) and 27.59 (6.70), respectively.

In addition to the analyses on the total measure of general spatial ability, measured by the total test differences, we sought to analyze the effects of spatial task in each of the categories of spatial ability, provided by Linn and Petersen (1985). Two of the three categories, Mental Rotation and Spatial Visualization, described tests used in this study. We summed the difference-scores of Hands, Mental Rotations, and Flags to create a Mental Rotation Category. Blocks, Spatial Relations, Hidden Figure, and Cubes were included in the Spatial Visualization Category.

Analysis of covariance (ANCOVA) was implemented, with the variables of School, Experience and Age partialled out. A main effect for spatial treatment was observed for the Mental Rotation Category, F = 5.86 (1,90), p = 0.018. No main effect for sex was observed, F = 0.15 1,90), p = 0.701, in this category and there were no interaction effects for spatial treatment and sex, F = 0.16 (1,90), p = 0.689. The Spatial Visualization Category was analyzed in the same manner and there were no significant findings. The main effect for spatial treatment and sex was insignificant, F = 2.09 (1, 90), p =0.152; F =0.06 (1, 90), p = 0.811, respectively. There was no spatial treatment and sex interaction observed, F = 0.000 (1, 90), p = 0.952. The relevant scores for these analyses are given in Table 1.2. Total test difference scores were analyzed with these covariates and there was a significant main effect for spatial treatment observed, $F = 5.86$ (1, 90), $p = 0.018$. There was no significant main effect of sex, $F = 0.15$ (1,90), $p = 0.701$, and no interaction observed, $F = 0.16$ (1,90), $p = 0.689$.

Insert Table 1.2 here.

Correlations. Past experience in high spatial activity (e.g., sports) correlated with the total scores of the seven paper-and-pencil pretest spatial ability tests, $r = 0.327$, $p = 0.001$, but did not correlate with each individual test. Table 1.3 shows individual correlations with experience and each of the seven tests. Past experience correlated with spatial ability test scores for males ($r = 0.394$, $p = 0.002$), but not for females ($r = 0.233$, $p = 0.119$). Regression analysis showed that past experience, as measured by the questionnaire, significantly accounted for 15.5% of the variability of male scores, and only 5.4% of female variability. No significant correlation was found for overall scores of activities that involved coaching/training and spatial ability test scores ($r = 0.153$, $p = 0.122$). There was, however, a significant correlation for activities involving coaching and spatial ability for females ($r = 0.490$, $p = 0.000$), but not for males ($r = 0.248$, $p = 0.060$).

Insert Table 1.3 here.

Discussion.

The correlation results support similar findings of Hult and Brous (1986) that have shown a positive correlation between athletic skills and spatial abilities. Predictive value of past experience for spatial ability test scores, for males only, may reflect the content of activities being assessed. These activities may not be representative of many female activities that would involve spatial ability, such as working with puzzles, skipping rope, baton twirling, ping pong, making jewelry, or playing with Lego blocks. The fact that more males participated in the activities assessed by the questionnaire would account for the positive correlation found for males, but not females. The small percentage of variability of spatial ability, attributed to past experience in high spatial sports, suggests that future research include a broader assessment of children's activities that may yield more support to the experiential theories of spatial ability.

Coaching/training of high spatial sport activities significantly related to female scores on spatial ability tests, but not males. This finding may reflect the stereo-typing of activities, in that, unless females are involved in organized sports, they may not participate in these activities because of stereo-typing. Assessment of interests, rather than experience, may give further support to this idea and would help rule out self-selection, resulting from ability, perception of sex-typed activities, or the availability of the activity, as a possibility.

The effect found for treatment indicates the experimental design used in the present study is advantageous to research in this area. Most of the prior research has been correlational and this study could be considered a pilot study, showing the effectiveness of providing relative activities for the development of spatial ability, thus providing evidence of causation for the experiential theories. Future research would benefit to use designs intended to show causation to support these theories. The experiment was conducted over a short period of time, only two Phys Ed periods, and in light of this, these findings are impressive.

The baseline difference for the treatment groups was problematic. Given the significant difference in treatment pretest spatial ability test scores, one could speculate that the observed effect of treatment was a statistical regression. The testing instrument, namely the seven spatial ability tests, have been adapted for use with children of this age by Johnson and Meade (1987). Care must be taken to assure that the children comprehend the test items and understand the nature of the required response. The point being; these tests have not consistently been used in the research to measure spatial ability in young children and may not be reliable measures. Future research, using these spatial ability tests, may lend support to their reliability and rule out instrumental effects.

The post-hoc findings, of a significant difference in reported past experience of the HS group, indicates that providing these children with similar experience allows for an increase in scores, equal to that of the LS group, that report more previous experience with these types of activity. This finding would support the correlational evidence for the relationship of past experience in high spatial activity and spatial ability test scores.

The significant increase in paper-and-pencil spatial ability test scores for mental rotation tests, for the HS group, indicate that this cognitive ability can be generalized from experience. This was not the case for spatial visualization. Linn and Petersen (1985) suggest that spatial visualization, which requires more complicated manipulation of information, is equally difficult for both males and females and may depend more on cognitive development that has not fully developed in children of this age. The involvement of more complicated cognitive manipulation of information may not quickly generalize from experience for spatial visualization, as would seem to be the case for mental rotation.

The treatment in the present study was manipulated for a short period of time and future research would benefit to manipulate activities for a longer period. This would allow for more effective assessment of whether spatial visualization could be generalized from experience of relative activities.

The idea that involvement in these physical activities could generalize to cognitive development of spatial ability would provide implications for educational techniques to improve spatial skills of children through more involvement of sport participation in the education curriculum, as well as increasing the activities through child-rearing practices.

Contrary to previous research, we failed to confirm the longstanding findings of significant gender differences on spatial ability test scores, especially the mental rotation tests. The latter test show the largest sex differences in previous research and may actually reflect a change in child-rearing practices over the years. Much of the literature dates to the 1970s (Conner and Serbin, 1977) and 1980s (Lunnborg, 1982; Newcombe and Bandura, 1983; Lunnborg, 1984; Linn and Petersen, 1985; Caplan et al., 1985; Hult and Brous, 1986) and may not be representative of changes already taking place within this new generation of children. A re-evaluation of past research is suggested to rule out cohort effects as an explanation for these contradictions. In light of the changes taking place in child-rearing practices, future research aimed at assessing the changes in spatial abilities among children would be warranted.

References

Bjorklund, David F. and Brown, Rhonda Douglas (1998). "Physical play and cognitive development: Integrating activity, cognition, and education". Child Development, Vol. 69 (3), 604-606.

The effects of spatial ability may be a result of past experience and the types of play children are exposed to. Cognitive developments may be facilitated with rough and tumble play during childhood.

Conner, Jane M. and Serbin, Lisa A. (1977). "Behaviourally Based Maculine- and Feminine-Activity-Preference Scales for Preschoolers: Correlates with Other Classroom Behaviours and Cognitive Tests". Child Development, Vol. 48, 1411-1416.

Observational intervals of 10 sec alternated with recording intervals of 5 sec. Each subject's behaviour was recorded on six to 10 occasions during the free-play period each day. Three cognitive test were given to the children, the vocabulary and block design sub-scales of the Wechsler Preschool and Primary Scale of Intelligence (WPPSI) and the Preschool Embedded Figure Test (PEFT). Results suggest the development of visual-spatial ability in boys is related to involvement in masculine activities. The advantages of a behaviourally based definition of masculine and feminine activity preference are discussed. Vocabulary scores from the WPPSI suggest that verbal intelligence may play a role in the degree to which preschoolers learn to conform to sex stereotypes.

Hult, Richard E. JR. and Brous, Cornelia W. (1986). "Spatial Visualization: Athletic Skills and Sex Differences". Perceptual and Motor Skills, Vol. 63, 163-168.

Development of spatial visualization may be more highly related to development of sport skills involving manipulation of visual images. This observation related to women more than men. It did not seem to matter for men, as seen by higher DAT scores.

Hyde, Janet Shibley (1981). "How Large Are Cognitive Gender Differences?" American Psychologist, Vol. 36, No. 8, 892-901.

Gender differences appear to account for 1-5% of the population variance, but the known differences in abilities are still too small to explain the observed occupational differences. Meta-analysis explaining some of the difficulties of replication of gender differences in spatial abilities (e.g., selection of the data set, statistical analysis, and sampling), and gives recommendations of further research (sufficient information for the use of ω^2 and *d* to be calculated).

Johnson, Edward S. and Meade, Ann C. (1987). "Developmental Patterns of Spatial Ability: An Early Sex Difference". Child Development Vol. 58, 725-740.

Data show gender-related differences to emerge at age 11, in favor of males. Age of emergence of gender differences is different for white males and females than for black males and females. This is an indication that differences may emerge as a result of socio-cultural factors rather than biological factors.

Linn, Marcia C. and Petersen, Anne C. (1985). "Emergence and characterization of sex differences in spatial ability: a meta-analysis". Child Development Vol.56, 1479-1498.

Results of a meta-analysis suggest a) that sex differences arise on some types of spatial ability but not others, b) that large sex differences are found only on measures of mental rotation, c) that smaller sex differences are found on measures of spatial perception, and d) that, when sex differences are found, they can be detected across the life span.

Lunneborg, Patricia W (1982). "Sex differences in self-assessed, everyday spatial abilities". Perceptual and Motor Skills, Vol. 55, 200-202.

Survey assessed differences between activities of men and women. There was no difference between school/work activities, but a difference was observed for leisure time activities; men reported higher involvement of activities that required high spatial abilities (working with machinery, assembling things, and engaging in games and sports). Both sexes reported sports as the activity they thought required the highest level of spatial ability.

Lunneborg, Patricia W (1984). "Sex differences in self-assessed, everyday spatial abilities: Differential practice or self-esteem?" Perceptual and Motor Skills, Vol. 58, 213-214.

Extension of earlier study which supported the findings of men reporting more time spent playing visual games, working with machines, engaging in sports, and driving a car. Men's estimates of spatial performance were higher than women's estimates.

Pellegrini, A. D. and Smith, Peter K. (1998). "Physical Activity Play: The Nature and Function of a Neglected Aspect of Play". Child Development, Vol. 69, Number 3, 577-598.

Literature review considering the nature and possible developmental functions of physical activity play, defined as a playful context combined with a dimension of physical vigor. Three kinds of play are distinguished: (1) rhythmic sterotypies peaking in infancy; (2) exercise play peaking during the preschool years; and (3) rough-and-tumble play peaking in middle childhood. Gender differences (greater prevalence in males) characterize the latter 2 forms. Function is considered in terms of beneficial immediate and deferred consequences in physical, cognitive, and social domains.

Appendix

Table 1.1

Means, Standard Deviations and One-way Analysis of Variance for Effects of Spatial Condition on Pretest and Post-test Difference Scores

Condition	M	SD	F	η^2
HS/LS			21.87 (1,91)	0.196
High Spatial	6.34	11.43		
Female	6.26	13.6		
Male	6.43	9.57		
Low Spatial	-5.10	11.99		
Female	-8.47	10.25		
Male	-2.90	12.68		

Note. η^2 = effect size

Table 1.2

Analysis of Covariance of Categories of Spatial Ability with School, Experience and Age as Covariates

Source	df	Adj SS	Adj MS	F (p)
MR Category				
HS / LS	1	316.18	316.18	4.26 (0.042)
Sex	1	7.62	7.62	0.10 (0.794)
HS / LS * Sex	1	24.72	24.72	0.33 (0.565)
Error	84	6230.50	74.17	
Total	90			
SV Category				
HS / LS	1	95.46	95.46	2.09 (0.152)
Sex	1	2.64	2.64	0.06 (0.811)
HS / LS * Sex	1	0.17	0.17	0.00 (0.952)
Error	84	3844.60		
Total	90			

Table 1.3

Correlations (Pearson) of Past Experience in High Spatial Sports and Spatial Ability Pretest Scores

	Flags	M R	Cubes	Hands	Blocks	S R	Hidden
Pretest	0.138	0.052	0.282*	0.138	0.112	0.177	0.296*
Female	0.159	0.146	0.361*	0.124	-0.113	0.019	0.314*
Male	0.277	-0.016	0.180	0.148	0.276*	0.292*	0.283*

Note. M R = Mental Rotations, S R = Spatial Relations

* $p =< 0.05$

Figure 1

Mean Pre-test and Post-test Spatial Ability Test Scores