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Brief Research Report

Visuo-Spatial Abilities across Age Groups: A Cross-Sectional Study

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ABSTRACT

Although the visuo-spatial ability is one of the major components of fluid intelligence, it has not been explored much. Moreover, the researchers who have explored this area have restricted with one or two age groups but have not explored across different age groups. The objective of this study is to examine the differences in the visuo-spatial abilities of children, adolescents, young, and middle-aged adults and also the gender difference in them. This is a cross-sectional study comprising of four different age groups such as children, adolescents, young adults and middle-aged adults with 30 participants each (a total of 120 participants) with 56 males and 64 females. The visuo-spatial ability is measured using the Block Design Test (BDT) taken from Weschler's intelligence scales- WISC-IV and WAIS-IV. The statistical techniques used are t-test, and ANOVA. The results showed significant differences in the visuo-spatial abilities of different age groups and a curvilinear pattern was obtained with children displaying the least ability, followed by middle-aged adults, adolescents, and young adults. Unlike the other components of fluid intelligence, like working memory and processing speed that show significant gender differences, this study did not find any gender difference in the visuo-spatial abilities of individuals.

Keywords: *Visuo-spatial abilities, block design test, children, adolescents, young adults, and middle-aged adults.*

INTRODUCTION

The human brain that is responsible for several cognitive abilities undergoes enormous changes from childhood to adulthood (Crone, 2009). The competence of a person is known with his intellectual abilities which is comprised of not one or two, but a combination of different cognitive abilities. These cognitive abilities fall under two broad categories of intelligence such as fluid intelligence and crystallized intelligence, as originally proposed by Cattell and Horn, (1963). A number of intelligence measures are correlated with the performance on the Block Design tests (BDT), a measure of visuo-spatial abilities, suggesting that these tests assess important aspects of intellectual functioning (Salthouse, 1987; Koenis et al., 2015).

BDT is a multifaceted asset that seems to measure multiple cognitive functioning. Block design is a performance test and involves detailed focused processing (Muth et al., 2014), which is regarded to be a first of its kind to assess visuo-spatial ability (Johansson & Wahlin, 1998). It not only measures the non-verbal abstract conceptualization (Sattler, 1974) and spatial visualisation (Sattler, 1974; .Kaufman, 2001) but, performance on such tasks are considered to be the predictors of cognitive functioning such as spatial measures (Groth-Marnat & Teal, 2000) and general intellectual measures (Snow et al., 1984; Shea et al, 2001).

Visuo spatial abilities are essentially important for independent functioning as they aid in numerous activities such as perceiving objects visually and locating them in space which help us to navigate our environment safely (de Bruin et al., 2016). Visuo-spatial abilities are a combination of different types of cognitive abilities (Burggraaf, 2018). These are grouped under three spatial task categories such as spatial perception, spatial visualization, and mental manipulation of two- and three-dimensional objects (Heyes et al., 2012). Visuo-spatial abilities are assessed as part of a comprehensive neuropsychological evaluation (Zink et al., 2018) and also for the research purpose that is driven out of inquisitiveness. The components involved in visuo-spatial tests include tasks that involve recognition of patterns and understanding the dimensions (Johansson & Wahlin, 1998). Some of the typical visuospatial tasks are Block Design, Mental Rotation, figure disembedding and Navon Figures (Muth et al., 2014), copying figures, reproducing geometric designs (Lezak et al., 2012), constructing patterns using blocks (BD; PsychCorp, 2008; Wechsler, 1955). While some researchers consider BDT to be a measure of fluid spatial ability (Schretlen et al., 2000), others consider it to be a visuo-spatial test that measures abstract reasoning, an important component of fluid reasoning (Stevenson & Gernsbacher, 2013), or fluid intelligence (WAIS-IV, Bugg et al., 2006). BDT is found to be highly correlated with general intelligence, which is referred to as the fluid intelligence by some researchers (Marshalek et al., 1983; Snow et al.,1984).

Apart from contributing significantly to the spatial and perceptual organization factor, the findings from the factor analytical studies of Wechsler scales have shown the block design test to be the fourth-best measure of general intelligence "g" among the 12 subtests and the best estimate of "g" among the performance scale subtests (Maxwell, 1959; Cohen, 1959). This is one of the reason that it is being used widely in all of the popular measures of intelligence (Shah & Frith, 1993).

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The performance tasks that test the intelligence or its components such as visuo-spatial tasks, processing speed, or mental manipulations are the tests to assess cognitive functioning. This functioning is the outcome of various cognitive processes that develop and mature at different points of time as an individual grows (Burggraaf, 2018). The developmental stages of childhood and adolescence are characterized by both the development of the brain as well as cognitive processes. This brain development and cognitive maturation occur in parallel during childhood and adolescence (Casey et al., 2000) to which the intellectual functioning is strongly associated (Koenis et al., 2015). As this cognitive function continues to mature until late adolescence or the young adulthood (Casey et al., 2005; Crone et al., 2006), it is appealing to study the performance in the non-verbal visuospatial domain due to its high demand on cognitive reasoning (Burggraaf, 2018).

There are varieties of cognitive tasks, whose timing of maturation also vary from tasks to tasks (Diamond, 2002). While the areas responsible for the sensory and motor processes mature early during the childhood, the cognitive functions that involve top-down approach mature during late adolescence (Casey et al., 2005).

As the maturation of different cognitive processes vary with age, a large emphasis has been laid on age differences on the performances of different cognitive tasks such as processing speed (Sheppard & Vernon, 2008; Nettelbeck & Burns, 2010), working memory (Johnson et al., 2010; Pliatsikas, et al., 2019), and visuo spatial abilities (Wahlin et al., 1993). A number of cross-sectional studies have reported age related decline beginning in the young adulthood and continuing gradually throughout the lifespan (de Bruin et al., 2016; Verhaeghen & Salthouse, 1997), in the general visualization (Gv) and Fluid Reasoning (Gf) tasks (Horn & Cattell, 1966; Horn & Hofer, 1992). The performance of older individuals on the block design tests have been found to be significantly lower than the young individuals (Wahlin et al., 1993) which is similar to the results of other cognitive tasks mentioned earlier. Apart from age difference, performance in some cognitive tasks such as processing speed (Burns, &Nettelbeck, 2005; Camarata, & Woodcock, 2006), and working memory (Harness et al., 2008; An et al., 2018) display gender differences also. Consistent with similar cognitive tasks, studies on BDT have also shown gender difference in favour of males (Colom et al., 2002; Ronnlund & Nilsson, 2006), which has also been revealed from the standardized sample of WAIS-R and WAIS III (Lynn, 1998). Contrarily, few recent studies have shown little or no gender difference in the performance of visuo-spatial tasks. The gender difference, if seen at all, is small and occurs in tasks that involve mental rotation (Luciana et al., 2005).

The other versions of visuospatial tasks such as one minute DOT and two-minute DOT have also shown absence of gender difference (Killgore & Gogel, 2014; Burggraaf et al., 2015; Burggraaf et al., 2018). This study aims at exploring the visuo-spatial abilities of children, adolescents, young adults and middle-aged adults with respect to differences in their performance across varying ages and gender.

METHOD

Participants

The participants included in this study were taken from four different age groups such as children (9-11 years old), adolescence (12-19 years old), young adults (20-35 years old) and middle-aged adults (36-55 years old) with each group consisting of 30 participants. The sample comprised of 120 participants with 56 males and 64 females. Sampling technique adopted was purposive sampling, a non-random sampling technique, but as the data was normally distributed, parametric tests were used to analyse the data. The participants were selected based on the inclusion criteria that were set by the researcher. They were required to have normal vision and motor functioning to perform the task. The participants were tested for vision using Ishihara colour blindness test and were also checked for motor functioning like finger movements and object lifting ability by asking the participants to squeeze a sponge ball and lift the cubes given. Based on these inclusion criteria, 30 participants were taken for each of the four age groups. All the participants were taken from Bengaluru, India. Children and adolescents were taken from a Central Board of Secondary Education (CBSE) school, and permission for their participation was sought from the Headmistress of the school. The informed consent was also obtained from the young and middle-aged adults who were willing to participate in the study.

Materials

The Block Design Test (BDT) used in this study is a sub-test of the Wechsler scales –that is designed for both children (WISC-IV) and adults (WAIS-IV). BDT is included as one of the core subtests in its perceptual reasoning index. The test requires the participants to view a picture and recreate a two-dimensional pattern using a set of white and red blocks within a specified time limit for each pattern. The raw scores obtained by the participants are then converted to their respective age-based scaled scores as per the manual.

Procedure

The participants had given their consent prior to the test. They were individually administered in a distraction free space. The first two trials given as sample items in the manual were demonstrated to the participants and were clearly instructed about the time limit also. Every trial was stopped once the participant had crossed the stipulated time limit and the test was stopped when the given consecutive number of failures was reached by the participants. The scores for every trial were given based on the time taken by the participant in making the right pattern as mentioned in the manual.

Statistical analysis

The software used to analyze the data statistically was IBM SPSS version. 22. Kolmogrov- Smirnov test was used to check the normal distribution of the data. The test statistic obtained was 0.103 and as the data was normally distributed, parametric tests such as t-test and Analysis of Variance (ANOVA) were employed, to find the difference between the groups based on gender and age respectively.

Results

The results were obtained after analyzing the data with appropriate statistical techniques. The gender difference in the performance of Block design test was found using the t-test and the difference across the four different age groups was found using ANOVA. The results obtained are as follows.

Table: 1 Gender difference in the visuo spatial abilities.

	Gender difference		*t-value*	*p*
	M	SD		
Male (N=56)	11.2679	2.895	1.611	0.11
Female (N=64)	10.4531	2.642		

Significance Level: 0.05

The Table1 shows difference between males and females in their visuo-spatial abilities which is measured using the Weschler's block design test (BDT). The obtained *t (118) = 1.611* is not significant at 0.05 level indicating that both males (*N= 56; M=11.2679; SD= 2.895*) and females (*N=64;M=10.4531; SD=2.642*) are similar with respect to their visuo-spatial abilities and do not have any significant difference.

Table 2: Difference in Visuo-spatial ability among different age groups

	N	M	SD	F	Sig.
Children	30	7.9000	1.18467	142.530	0.000
Adolescents	30	11.8000	0.80516		
Young Adults	30	14.3333	1.42232		
Middle Adults	30	9.3000	1.64317		

It is clear from the ANOVA table, that there are significant differences between all the four groups in their visuo-spatial abilities with $p<0.05$.

From the Post hoc comparisons, the differences between all the four groups obtained are found to be significant. It is found that the children have obtained the lowest score in the visuo-spatial abilities than all the other three groups. The mean score of children *(M=7.900; SD= 1.184)* is significantly lower than the adolescents *(M=11.80; SD=0.805)*, young adults *(M=14.33; SD= 1.422)*, and middle-aged adults *(M=9.300; SD=1.643)*.

Adolescents, whose mean score is *(M=11.80; SD=0.805)*, have significantly higher visuo-spatial ability than the children *(M=7.900; SD= 1.184)*, and the middle-aged adults *(M=9.300; SD=1.643)*, but not the young adults *(M=14.33; SD= 1.422)*. These differences are significant at p<0.05 (p=0.00).

Taking young adults into consideration, it was found that they have outperformed all the other groups with significant differences. The young adults have scored the highest *(M=14.33; SD= 1.422)* among all the four groups, indicating to have the highest visuo-spatial abilities than children *(M=7.900; SD= 1.184)*, adolescents *(M=11.80; SD=0.805)*, and the middle-aged adults *(M=9.300; SD=1.643)*.

When middle-aged adults *(M=9.300; SD=1.643)* are taken into account, they have lower visuo-spatial ability than adolescents *(M=11.80; SD=0.805)*, and young adults *(M=14.33; SD= 1.422)* but higher ability than children *(M=7.900; SD= 1.184)*.

DISCUSSION

The intellectual abilities are measured using a wide range of cognitive tasks involving both crystallized and fluid intelligence. Such tasks require the ability of abstract reasoning, generating, transforming and manipulating different types of novel information in real time, that involve both sensory and motor functions such as working memory, attention, visuo-spatial skills, and many more. One such task is block design test, which is used in this cross-sectional study to assess the differences in the visuo-spatial abilities of children, adolescence, young adults and middle-aged adults. The difference in the performance across different age groups and gender has been explored in this study using block design test (BDT), which is quite a good measure of visuo-spatial abilities.

It is observed from the table 1. that there is no significant gender difference in the visuo-spatial abilities across ages and is supported by researchers (Killgore & Gogel, 2014; Burggraaf et al., 2015; Burggraaf et al., 2018). It is reported by some researchers that gender difference in visuo-spatial abilities exist, only when the task at hand involves mental rotation and the reason being the difference in applying different weightage to the geometrical reference cues (Collaer & Nelson, 2002; Holden et al., 2015).

The age related difference in visuo-spatial abilities has also been an important concern for cognitive researchers. A large emphasis has been laid on the age differences in cross sectional data by Wechsler and other researchers (Kaufman, 2001) and a considerable gradual decline from early to late adulthood has also been reported (Kaufman et al.,1989). From the table (2), the results show a curvilinear pattern in the performance of visuospatial abilities with children being at the lower extreme of the curve, that begins to increase gradually through adolescence upto late adolescence or young adulthood, where the performance is at its peak, followed by a gradual decrease beginning in the middle adulthood period. The increase in performance that begins with adolescence is supported by researchers such as Shah and Frith (1993). Also, Burggraaf et al., 2015 and 2018 have reported a similar increase in performance through late adolescence.

It is concluded that the young adults have the highest visuo-spatial abilities, followed by adolescents, middle-aged adults, and children, attributing the rise in performance during adolescence and young adulthood to the areas associated with the cognitive functions, in particular those that involve the top-down approach like BDT, that mature during the late adolescence (Casey et al., 2005; Burggraaf, 2018).

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