Effectiveness of Deductive Reasoning and Visuospatial Skills on Academic Achievement

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Abstract— Academic achievements are considered to be the benchmarks for entering in the next level of schooling and poor performance in academic skills reflects in the future of students. Academic achievement can be varied because of multiple reason and cognitive abilities play a major role among them. The present study aimed to assess the effects of few of the cognitive skills such as deductive reasoning, visuospatial attention, and visuospatial memory on academic achievement. There were 40 children within the age range of 5 to 7 years who participated in the study. Based on the academic performance in the annual examination, the participants were grouped into two. There were three tasks, each task designed to tackle different cognitive perspectives. The first task was odd one out intended to check deductive reasoning. Visuo-spatial memory was analyzed as second task where tokens were presented in complexity ascending order. Lastly, posner cueing was adapted to measure spatial attention based on the reaction time. Results showed that deductive reasoning and visuospatial memory skills were reduced in academically poor performing children, while the other group scored better scores in these tasks. Also, academically well performing students group had reduced reaction time of valid and invalid tokens for the spatial attention task which was prolonged in the opposite group. Correlation was assessed between their cognitive skills and the relationships between the variables were positive in both academic groups, however the strength of correlation was varied among the compared pairs.

Keywords: Reasoning, Visuospatial, Attention, Memory, Academics

I. INTRODUCTION

"Academic achievement is the performance in school in a standardized series of educational tests. The term is more generally used to describe performance in the subjects of the curriculum" (Sekar & Lawrence, 2016). It also measures the final numerical scores of basic subjects taught in that academic year. As it is the benchmark for the passing criteria to the next class, it is mandatory for students to achieve good marks in the final exam.

Spoken language communication can be acquired effortlessly during the typical developmental period which does not really require any formal instruction. However, academic skills must be taught through explicit school settings over a period of time. It is necessary to have adequate cognitive abilities in the child when they are exposed to the world of academics to understand instructions and perform tasks appropriately. Whoever is lacking cognitive skills such as reasoning, memory and executive functions will have poor academic achievement. There is a need of identifying the source of inabilities as early as possible, since it can hinder the individual from achieving better in life.

Deductive reasoning is one of the reasoning skills where rules need to be applied to the knowledge and it opens a path to attain logical conclusion. It can be any modality of representation such as visual, auditory or tactile and the processing can be varied accordingly. Visual representation along with dimensional variation induces the activation of visual area of brain along with frontal and parietal lobe, whereas in the case of language involvement, semantics and phonology need to be identified. This could be possible only with efficient retrieval of stored information which is logically related to the current situation (Mangal, 2002). Hence, it is not a single level process, rather it requires the involvement of multiple cognitive functions such as critical thinking and problem solving (Tsai & Samarapungavan, 2009). General reasoning abilities considered to be the strong predictor of academic achievement (Kuhn & Holling 2009; Oloyede, 2012).

Visuospatial memory (VSM) is a part of Baddeley's multi component model working memory, where the information stored for a shorter duration of time and process the information within immediate effect (Baddelry, 1986, 2000). It acts as a system to generate, manipulate, and maintain the visual and spatial information (Gathercole & Baddeley, 1993). There has been research to understand the underlying connection between the visuospatial memory and academic skills in school going children. But, there were no homogeneity between the reports which studied the effect of visuospatial memory on academic skills.

One group of researchers believes that there is a positive association between poor VSM and dyslexia diagnosis (Gathercole, Brown & Pickering, 2003). There is another study which is in consensus with this notion and reported of inadequate VSM even in adult dyslexic patients (Franceschini, Gori, Ruffino, Pedrolli & Facoetti, 2012). Similarly, there were other findings which explains VSM as predictive parameter for reading difficulties (Burggraaf, Frens, Hooge, & van der Geest, 2018) and higher level reading is significantly associated with development of VSM in children (Pham & Hasson, 2014). Another belief explains that VSM and academic skills are two entities which are not associated in any manner. Therefore, children with reading difficulties can have good VSM (Swanson & Jerman, 2006).

Similar to visuospatial memory, visuospatial attention (VSA) plays significant role in academic skills development. Visuospatial attention engrosses by identifying a stimulus among the visually presented counter parts on the basis of its spatial location. Further, this spotted location requires higher cognitive processing (Vecera, & Rizzo, 2003). Multiple tests were used throughout history to understand the relation of visuospatial attention and reading abilities in school going children. And the findings showed children with reduced VSA, who were diagnosed with poor reading skills, also seen improvement of performance across developmental period (Commodari & Guarnera, 2005; Stevensa & Bavelier, 2011)

As a whole, both visuospatial abilities including memory and attention have impact on academic performance. There are two related hypotheses: the first one explains the relation visuospatial abilities and academic performance such as mathematics-related tasks; the second hypothesis was dealt with the indirect relationship between visuospatial ability and academic achievement via other cognitive abilities (Liu, Wei, Chen, Hugo & Zhao, 2021).

The present study aims to find the effect of deductive reasoning, VSM and VSA on 1st standard English Medium school going children. Though there are varied types of reasoning, current study concentrates only on deductive reasoning, since it has the maximum contribution on academic accomplishments than other six components of reasoning abilities (Bhat, 2016; Gómez-Veiga, Vila, Duque, & García, 2018). Even VSM has been studied before and shown significant effect on academic skills, present study included in the tasks to see the mother tongue involvement as the phonological factor could change the transparency degree of VSM (Franceschini, Gori, Ruffino, Pedrolli & Facoetti, 2012). VSA has been studied previously in children to assess the effect on reading whereas the RT of valid and invalid tokens yet to study. As students, there is a requirement of avoiding unwanted token which distract the impromptu legitimate material presented to them. Inability to attend the valid material reduces the efficiency of the individuals and the speed of recognition also majorly accountable in this. Similarly, present study tried to analyze the correlation between deductive reasoning, visuospatial memory and visuospatial attention in academically good and poor students. There are the possibilities of harmony in the development of these parameters as all of them are come under the cognitive skills. However, the robustness of the correlation is questionable where the academic performances of the participants were varied across group.

II. METHOD

1) Participants: There were 40 children with an age range of 5 to 7 years (mean age= 6.1 years) who participated in the study. All of them were studying in first Standard English medium school and were observed to have similar economical background. Based on the academic performance and teacher's evaluation, subjects were categorized in to two groups, one group of children who scored more than 80% and other group of children had less than 50% total marks in the annual examination based on the curriculum. Gender was not considered as exclusion criteria and informed consent was procured from guardian prior to data collection.
2) Tasks: There were three tasks, each task designed to tackle different cognitive perspectives. There first task was odd one out and intended to check deductive reasoning. There were 15 tokens and each token comprised of four words. Visuo-spatial memory was analyzed as second task where three tokens of two, three and four pictures were exhibited. Lastly, posner cueing was adapted to measure spatial attention based on the reaction time.
3) Procedure: Participants were instructed ahead regarding the data collection procedures and asked to perform the same in a quiet room individually. Task one was based on paper and pen and participants were enlightened to mark words which are not matched to the group of other words in the same row. There were 15 rows of four words and performance was analyzed as sum of correct answers at the end of the task. Following to that, subjects were seated in front of computer screen and displayed images of fish in a pot. There were 27, 2X3 slides including three iterations of two, three and four picture representation where each slide followed by an empty slide for participant to show the retrieved image. Participants were provided a trial for the task with single image and asked to point the columns according to the images visualized.

Posner cueing was administered as a standard method using psytoolkit online version and asked the participant to focus on the computer screen. They had instructed that there will be a green point on the centre of the monitor and need to fix focus on that point. Target stimulus was appeared on either right or left boxes of this central point after a brief period of time of cue appearance. Participants were asked to be keen on the target and respond immediately after it appeared of the screen as pressing specific keys according to the side of target shown. Reaction time (RT) was measured for each response and automatically system calculated valid and invalid responses separately.

III. RESULTS

The study aimed to see the effect of academic performance on few cognitive functions such as deductive reasoning, visuospatial memory and spatial attention. Descriptive statistics showed variations between children who performed poor in school in comparison to bright students as per the teachers. As shown in the table 1, deductive reasoning and visuospatial memory were quite less in academically poor children, whoever other group scored better scores in these tasks. In the good academic students, reaction time of valid and invalid tokens was reduced for the spatial attention task which was prolonged in the opposite group.

	Academic performance							
	Poor				Good			
	DR per	VSMper	RT valid	RT invalid	Oper	VSMper	RT Valid	RT invalid
Mean	51.33	75.00	684.40	752.40	93.33	87.50	568.90	667.40
STD	22.23	26.64	159.10	128.59	7.69	10.57	197.86	206.40

*DRper: Deductive reasoning percentage; VSMper: Visuospatial memory, RT: Reaction time

Table 1: Mean and standard deviations of performance of different tasks across academic performances

Further statistical evaluation was carried out to see the effect of academic performance on cognitive skills. Nonparametric tests were used since the normality assumption was violated. The Mann-Whitney U test showed a significant effect of academic performance in deductive reasoning and valid RT. Participants who had good academic history scored higher mean score for deductive reasoning and valid tokens of VSA tasks than the group who had poor academic background. However, there was no significant effect of academics on visuospatial memory and invalid RT of VSA. /Z/ and p values are given in table 2 for further understanding. Wilcoxon signed rank test was administered to analyze the validity of the token in RT in both groups and conventionally found to have significant effect in both groups i.e. poor [/Z/= 2.397, p=0.017] and good [/Z/= 2.805, p=0.005] where participants had taken comparatively less time to respond for valid tokens than invalid.

	/Z/	p Value
DRper	3.585	0.000*
VSMper	0.964	0.335
RT valid	1.965	0.049*
RT invalid	1.663	0.096

* Significantly different (p< 0.05)

*DRper: Deductive reasoning percentage; VSMper: Visuospatial memory, RT: Reaction time

Table 2: Effect of academic performance across different tasks

Correlation analyses between the parameters were administered using Pearson correlation and the coefficients of comparisons are given the table 3. As it seen, the relationships between the variables were positive in both academic groups, however the strength of correlation was varied among the compared pairs. With obvious reason, there was a very strong relationship between spatial attention RT of valid and invalid variables where Pearson correlation coefficient r was 0.936 for students of academically poor group and r=0.977 for counter group. Similarly, valid RT of spatial attention was in very strong relationship with deductive reasoning in both poor (r=0.728) and good (r=0.722) academic groups. Weak positive relationship was observed between visuospatial memory and deductive reasoning where the Pearson correlation coefficient r was less than 0.5. VSM was in weak positive relationship with VSA, where the r value was less than 0.3. Though the performances of both groups were significantly different, the relationship within the group was moreover similar in pattern.

	Poor			Good		
	DRper	VSMper	RT valid	DRper	VSMper	RT valid
DRper	1			1		
VSMper	0.383	1		0.227	1	
RT valid	0.728	0.293	1	0.722	0.259	1
RT invalid	0.579	0.332	0.936	0.650	0.191	0.977

*DRper: Deductive reasoning percentage; VSMper: Visuospatial memory, RT: Reaction time

Table 3: Correlation coefficients of compared parameters

IV. Discussion

Present study aimed to see the effect of academic performance on few cognitive skills. Participants who had good academic performance scored higher mean score for valid tokens of VSA tasks than the group who had poor academic background. But RT taken to respond for invalid tokens of VSA was not significantly different between the groups. Children who were good at curriculum given inclusive attention to valid tokens and they had taken less time to choose appropriate tokens. Consecutively, they were reluctant to attend invalid tokens as fast as valid tokens shows the precision of attention which lead them to perform better in overall academics. However, children who had poor curriculum score had overall reduction of RT for the VSA as it reflected in their academics. They had difficulty to follow visually presented information in the class especially notes written on the board which is a daily class routine. As a whole, it was evident that VSA had a direct influence with the academic achievement of the student atleast in the early ages of schooling and it is incongruent with the previous reports (Shea, Lubinski & Benbow, 2001; Wai, Lubinski & Benbow, 2009; Hodgkiss, Gilligan, Tolmie & Thomas, 2018; Liu, et al, 2021). However most of the studies in the past emphasized on the relationship between VSA and reading abilities (Facoetti, Paganoni, Turatto, Marazola & Mascetti, 2000; Boonen, Wesel, Jolles & van der Schoot, 2014; Cui, Zhang, Wan, Chen, Zeng & Zhou, 2019), and it is deviant from the present study where the present study dealt with overall performance of the children which included not only reading but also other academic skills. Similarly, VSA have been proved to be an influencing parameter for arithmetic skills (Agrillo, Piffer & Adriano, 2003; Gilligan, Flouri & Farran, 2017; Geer, Quinn & Ganley, 2019; Xie, Zhang, Chan & Xin, 2020), where arithmetic was a part of academic skills considered for the present study. These disparities can be explained based on the pathway explained by Liu et al (2021), where the relationship extent from visuospatial ability to arithmetic ability to reading ability, then to academic achievement. Even though, reading and arithmetic skills did not focus separately in the study, they were intuitive with the last stage of the pathway i.e. academic achievement.

Present study results showed that children who had good academic performance scored higher mean score for deductive reasoning than the group who had poor academic skills. This evidence is in agreement with the results of previous study by Klauer and Phye (2008) where they reported that improved classroom performance of assigned subjects in direct relationship with greater reasoning abilities. Greiff and Neubert (2014) explained it as association between reasoning abilities (both inductive and deductive) and fluid intelligence which involved in understanding and solving novel complex problems. Gómez-Veiga et al (2018) also reported similar results where they had tested various levels of deductive reasoning tasks and showed a positive interconnection between academic performance and deductive reasoning. Though there was inconsonance, 1 source of difficulty only tested with easier evaluation task in the present study, also there was no intelligence evaluation included in the method as inclusion criteria. Besides, reasoning abilities studied in higher grade students and reports showed similar results where effect size of DR was significantly higher than other types of reasoning (Bhat, 2016; Vani, 2018)

Present study did not identify any significant effect of academic performance on visuospatial abilities in initial class students of primary school. This relationship between VSM and academic achievement of younger children had been reported in previous studies (Gathercole & Pickering, 2000; Alloway & Alloway, 2010). However, overall academic performance in the present study was based on the yearly academic examination which was not established in the earlier studies where they given priority to reading and mathematics. Furthermore, Giofrè, Donolato and Mammarella (2018) explained that visuospatial memory was related to mathematics and verbal memory was in relation with reading. Weak positive relationship was observed between visuospatial memory and deductive reasoning in the results of present study. Though there was positive relationship which was incongruent with previous studies, the strength of correlation was distinct where they found to have stronger correlation between these two parameters (Kane, et al., 2004; Shipstead & Yonehiro, 2016). This discrepancy can be reasoned as age factor and the participants included in the present study were younger as compared to the middle aged school children in the previous studies.

There were strong positive correlation noticed between RT of valid visuospatial attention task and deductive reasoning as the tokens for the deductive reasoning skills were presented visually and visuospatial attention should work to read the material presented to the participants (Johnson-Laird, 1999). However, the anatomical sites of excitation for these skills were entirely different (Monge, Greenwood, Parasuraman, & Strenziok, 2016). The strong positive correlation can be possible as the neurophysiologic process is an integrated function and there can be the possibility of inter connection between the sites and dynamic configured neural system works for certain tasks (Goel, 2017). Even though VSM and VSA usually were consider under the class of visuospatial skills, the relationship was weak between them. As it explains in Duncan's integrated competition hypothesis that there is one selection mechanism that acts to select items for both attention and working memory systems (Duncan et al., 1996). But the magnitude of excitation of one skill during the process of other skill not explored and future direction can consider the vagueness.

V. Conclusion

This study results showed that deductive reasoning, visuospatial attention and visuospatial memory were inter related to some extent and all these cognitive skills are required to be intact for better academic achievement. Understanding all these emphasize the importance of multidimensional assessment of children for their cognitive abilities. Along with basic role of intelligence tests at school, present study findings highlights that deductive reasoning and visuospatial abilities might be as important at school as standard intelligence tests. Also, these skills can a relevant source of information to infer about subsequent school success/failure or to diagnose learning difficulties. Furthermore, the study will provide helpful information about the potential assessment and treatment by special educator, speech language pathologist and educational psychologist.

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