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Genetic Architecture of Working Memory Cognitive Function of Twins

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Authors' contributions

This work was carried out in collaboration between both authors. Author Annu designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author BD managed the analyses of the study and managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

The twin research has provided a deep understanding of the influence of genetic and the environment on cognitive functions. The contribution of genetic material accounted for 50-65% in the variations of working memory cognitive functions of twins. To conduct twin study 100 pairs of twins from two districts, namely: Bhiwani (N = 90) and Hisar (N = 110) of Haryana State, were taken. The working memory cognitive functions of twins were measured using the Wechsler Intelligence Scale for Children- Revised (WISC-R). Heritability estimate was used to examine the genes that contributed to shaping the cognitive functions of twins. The result of heritability estimates revealed that the heritability estimates of working memory cognitive functions namely: digit span (62%), maze (58%) and arithmetic (58%) in Bhiwani district and Hisar district, were 57%, 51% and 54% for digit span, maze, and arithmetic respectively. The findings elucidated that the working memory cognitive functions were more influenced by genetic architecture than the environmental factors. The monozygotic twins were more correlated in their general cognitive abilities than the dizygotic twins.

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1. INTRODUCTION

Working memory is a system of cognition which is responsible for temporarily holding available information for processing. It is included in the cognitive functions, the set of cognitive processes that are necessary for the cognitive control of behaviour [1]. [2] Reported that genes whose alleles differently influence working memory.

Heritability is a mathematical statistics that usually captures how much of the variation of a trait that is attributed to genetic differences. It does not respond to either capture how many genes are involved or how much of the trait relies exclusively on the genome. The heritability estimates for working memory revealed that the genetic contribution was around 65 percent for the variations in working memory of twins and the influence of environmental factors was less than the genetic factors through using twin and genome-wide analytic approaches [3].

The human genome is made up of some 20,300 and all genes may present genetic variants [4]. [5] found out 148 novels independent genes that are directly associated with general cognitive functions. The genes that affect only one cognitive ability that affects all kind of cognitive abilities so that genes are highly pleiotropic that affect cognitive abilities [6]. Cognitive functions such as working memory, cognitive control, and intelligence develop through the movement of the brain. [7] Provided compelling evidence across four longitudinal studies that changed in everyday cognitive activity with variation in multiple aspects of cognitive function.

Twins are not a simple *tabula rasa* like once thought, since they are conditioned by their genome to an extent. The environment is also a significant factor for their cognitive functions, intelligence. The brain is malleable and can be changed through daily experiences that change cognitive functions; its formation and functioning are based on a genetic substrate that influences it to a moderate or high degree [1]. Twins studies showed that identical twins have identical IQs since their genetic constitution is the same, or it could be because they have the same experiences. A little bit of variation in IQ could be attributed to different environmental factors. But in case of the formation of dizygotic twins (DZ), genetically these twins are just like ordinary brothers and sisters, sharing 50% genetic constitution, and they are only special in that they share the mother's womb [8].

[9] Observed genetic architecture of diverse cognitive functions in children and adolescents including the magnitude of common genetic effects and patterns of shared and unique genetic influences. [10] Investigated that genetic and environmental influences on the functional neural connection were a crucial step toward developing intermediate phenotypes between genes and cognitive functions. The results revealed that genetic influence was moderate, and shared environmental influence was weak-to-moderate across the neural connection in the brain.

[11] Revealed that intelligence quotient was determined by several factors that included both genetic as well as non-genetic factors. Even though genetic factors played a major role in determining IQ, various other modifiable environmental influences could influence the IQ of an individual. Nature and nurture worked together in determining human intelligence. Moreover the genetic played a significant role in the IQ of the individual and environmental circumstances also affect IQ.

2. MATERIALS AND METHODS

Study Design: The objective of the twin study design was to analyze the genetic and environmental impact on the working memory cognitive abilities of twins. To conduct this study mainly two districts were selected randomly namely: Bhiwani (N = 90) and Hisar (N = 110) of Haryana state. To assess the working memory cognitive functions of twins, a total of 100 pairs of twins were selected from two districts with the age group 6-to-8 years.

Data collection: The data was collected by the following methods namely: assessment, interview, observation, and questionnaire method from the twins to gather information.

Tool: The cognition of twins was examined by The WISC-R [12]. The working memory subsets included digit span, maze, and arithmetic.

Statistical Analysis: The software SPSS (Statistical Package for the Social Sciences) was used for statistical analysis. Mean, Standard

Deviation, z-test, and the heritable estimate was used to meet the objectives of the study. Heritability estimates (h2) were calculated by the following formula given by [13], h2= 2(RMz- RDz) Where, h2 is the heritability estimate, RMz is the correlation coefficient for monozygotic twin pairs and RDz is the correlation coefficient for dizygotic twins. The correlation coefficient was used to find the correlation between the working memories of twins.

3. Results

3.1 Cognitive Dimensions of Twins in Two Districts

As presented in Table 1 there were highly significant differences in mean values for cognitive dimensions, namely, digit span (Z=2.67**), arithmetic (Z=2.90**) of twins of the Bhiwani and Hisar districts. The significant (0.05%) differences were found between twins of Bhiwani and Hisar district on dimensions of cognitive namely; mazes (Z=2.11*). Twins at Bhiwani district performed better for all the same mentioned dimensions as compared to their counterparts from Hisar district.

3.2 Heritability Estimates for Working Memory Cognitive Functions of Twins Over Districts

Table 2 portrays the heritability estimates for working memory cognitive functions of twins in both districts namely: Bhiwani and Hisar. The heritability estimates for working memory cognitive functions namely: digit span (62%), maze (58%), and arithmetic (58%) in the Bhiwani district. The data indicated that the remaining 38 percent variance in digit span working memory

Table 1. Cognitive dimensions of twins in two districts (N=200)

Cognitive Dimensions	Bhiwani (n=90) Mean±SD	Hisar (n=110) Mean±SD	Z Value
Digit Span	9.10±2.62	8.15±2.35	2.67**
Mazes	5.50±2.31	4.82±2.22	2.11*
Arithmetic	2.10±0.75	1.80±0.70	2.90**

***,*: Significant at 0.05% and 0.01%, respectively*

Table 2. Heritability estimates for working memory cognitive functions of twins over districts

Working memory cognitive functions	Heritability (%)	
	Bhiwani	Hisar
Digit span	62	57
Mazes	58	51
Arithmetic	58	54

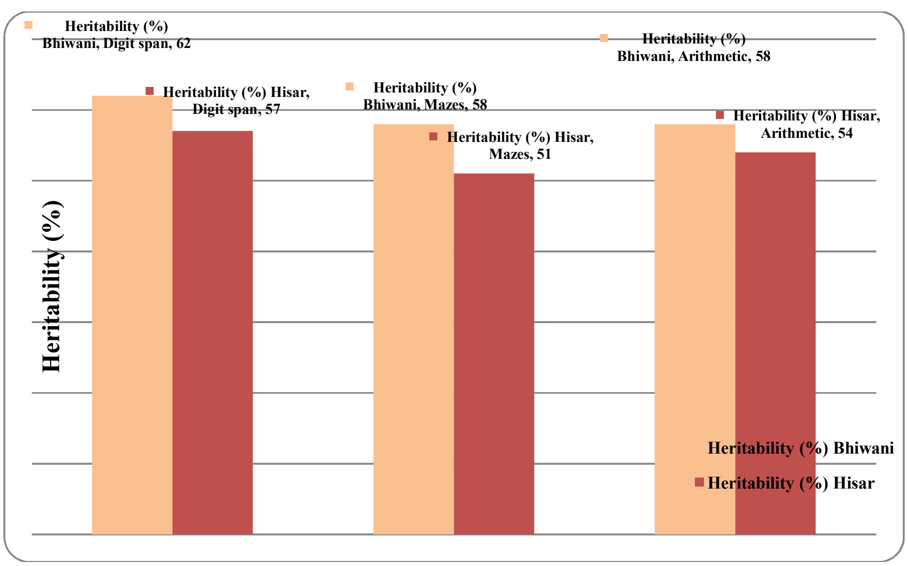

Fig. 1. Heritability estimates for working memory of twins over districts

cognitive functions were due to environmental factors. Further, the data portrait that 42 percent and 42 percent variance in maze and arithmetic respectively were due to environmental circumstances. In Hisar district, the heritability estimates for digit span, maze, and arithmetic were 57 percent, 51 percent, and 54 percent respectively. The indicated that the remaining 43 percent variance in digit span was due to environmental factors and 49 percent and 46 percent in maze and arithmetic respectively contributed to environmental situations. The heritability estimates revealed that more genetic influence on digit span working memory followed by maze and arithmetic working memory cognitive functions in the Bhiwani district. In Hisar district, the heritability estimates accounted for the digit span was highest (57%) followed by arithmetic that was 54% and heritability was lowest for the maze that was 51%. The genetic influence was more on digit span followed by arithmetic and maze working memory cognitive functions in Hisar district.

3.3 Correlation Coefficient among Monozygotic and Dizygotic Twins for Their Working Memory

Table 3 provided the information regarding the correlation coefficient among monozygotic and dizygotic twins for working memory in Bhiwani and Hisar district. The data in table 3 portrays that the correlation coefficient among monozygotic twins for working memory namely: digit span, maze, and arithmetic was r=0.78, r=0.62, and r=0.75 in Bhiwani district. Among dizygotic twins, the correlation coefficient for digit span (r=0.47), maze (r=0.33), and arithmetic (r=0.47) in the Bhiwani district. Further the correlation coefficient among monozygotic twins was for working memory namely: digit span (0.75), maze (r=0.68), and arithmetic (r=0.73) in Hisar district. Among dizygotic twins, the correlation coefficient was for digit span (0.46), maze (r=0.42), and arithmetic (r=0.46) in Hisar district. The data indicated that monozygotic

Table 3. Correlation coefficient of monozygotic and dizygotic twins for their working memory

Working memory cognitive functions	Correlation Coefficient (r)			
	Bhiwani		Hisar	
	Monozygotic	Dizygotic	Monozygotic	Dizygotic
Digit Span	0.78	0.47	0.75	0.46
Maze	0.62	0.33	0.68	0.42
Arithmetic	0.75	0.47	0.73	0.46

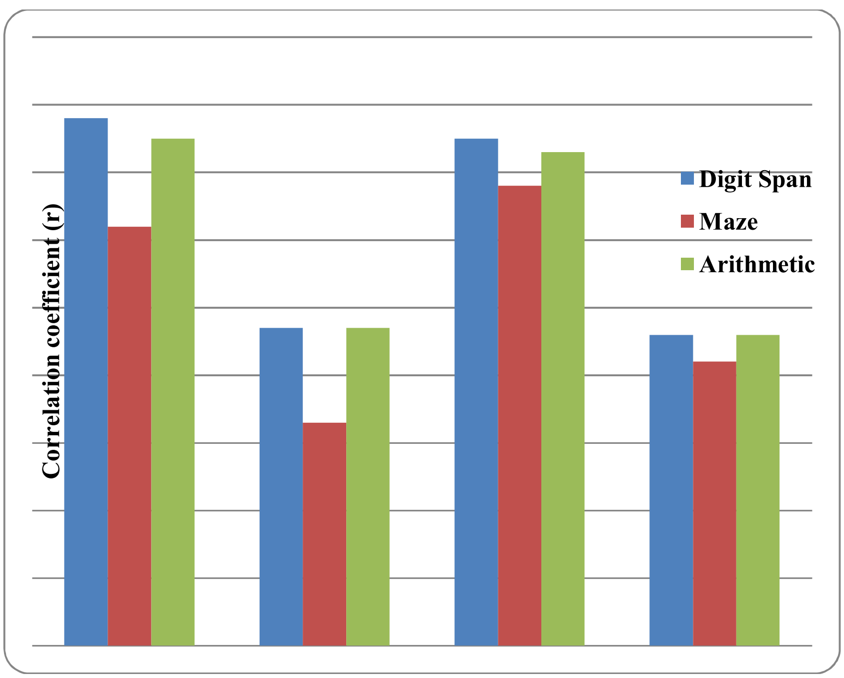

Fig. 2. Correlation coefficient of monozygotic and dizygotic twins for their working memeory

twins were more correlated with each other in working memory as compared to dizygotic twins in both Bhiwani and Hisar district.

4. DISCUSSION

A twin study was conducted to analyze the genetic and environmental influence on cognitive functions and assessed the four cognitive domains of the Wechsler scale and found that the heritability estimate for working memory cognitive functions was ranging from 50-65 percent [14]. The behaviour genetic studies of twins examined the genetic influence on different cognitive functions and concluded that the working memory cognitive abilities were more heritable and influence of genetics capturing half of the variations in cognitive functions of twins [15].

Another study to analyze the genetic and environmental influence on cognitive functions and concluded that the variations in working memory cognitive functions were due to genetic factors that contributed around 50 percent [16]. The genetic influence on working memory cognitive functions was 50% and the remaining 50 percent variations in working memory cognitive functions were due to environmental situations [17]. The study was conducted to examine the genetic influence on working memory-related task and concluded that the genes accounted for up to 65 percent variance in working memory cognitive abilities [18].

[19] Supported that genetic difference between people accounts for 50% to 70% of the variation in performance on tests of cognitive abilities. [20] Indicated that genetic influences account for over 60% of the variance in the cognitive outcome of twins, with environmental influences accounting for the remaining variance. [21] Conducted a meta-analysis of cross-sectional twin and family studies of specific cognitive and concluded that patterns of age differences in heritability estimates across cognitive domains.

[22] Studied that fraternal twins, or dizygotic twins, shared exactly half their genes. They were not as optimal as identical twins to make out the degrees of genetic influence, but they were a very good basis for comparison for identical twins. The monozygotic twins were more correlated than dizygotic twins in general cognitive functions. [23] Examined the correlation between monozygotic and dizygotic twins and concluded that the correlation is higher in monozygotic (>0.8) than in dizygotic twins (≈0.6).

5. CONCLUSION

Genes are the supplier of specific traits such as cognitive functions. Twin studies explain variations in individual working memory cognitive functions.

The genes are responsible for the substantial heritability of working memory cognitive functions of twins. Heritability estimate provides valuable information regarding the influence of genetics on working memory cognitive functions of twins. Based on twins' study, it was concluded that genetic play a significant role in shaping the working memory cognitive functions of twins as compared to the environmental circumstances of twins in early developmental years. Monozygotic twins were more correlated with working memory cognitive functions as compared to dizygotic twins.

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CONSENT AND ETHICAL APPROVAL

The experiments on twins were carried out in accordance with relevant guidelines and regulations. Informed consent was obtained from all twins and their parents. All experimental protocols were approved by Institution advisory Committee at Chaudhary Charan Singh Haryana Agricultural University and were performed in accordance with the guidelines formulated by the advisory committee.

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