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Statistical Analysis Of The Impact Of The Rubik's Cube On Spatial Intelligence

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Abstract
This study explores the impact of solving the Rubik's Cube on spatial reasoning abilities using inferential statistical methods. Within a sample of 30 participants there existed two cohorts, cubers (n = 15) and non-cubers (n = 15). A two-sample t-test was employed to analyse the outcomes after both groups completed a standardized spatial reasoning test. The findings suggested that cubers scored far higher in spatial reasoning (M = 72.74%) compared to non-cubers (M = 56.63%) because the t-statistic equaled 2.962 as p = 0.006, also this indicates a statistically important difference. Cubers' mean solving duration and spatial cognition skill underwent a further correlational investigation. Pearson's correlation yielded r ≈ -0.675, implying a modest inverse association, with faster solve times linked to superior spatial reasoning scores. These outcomes reveal that routine interaction using the Rubik's Cube may elevate spatial intelligence. Individuals can resolve predicaments in a more optimal fashion through consistent participation. The study ascertains the Rubik's Cube possesses potential utility within education plus training as an affordable cognitive instrument.

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I. Introduction

In the information-filled world of today, abilities such as spatial thinking are more vital than ever before. Spatial reasoning or spatial intelligence is the ability to imagine, visualize and differentiate objects in two or three dimensions. It gives us the ability to understand, manipulate and modify complex data and translate concepts into concrete ideas [1] (Spatial Reasoning: an often overlooked key asset, 2024). Spatial thinking has a profound influence on our everyday choice-making and problem-solving.

One of the instruments that have provoked spatial thinking is the 3x3 Rubik's Cube—a 3D puzzle invented by Ernő Rubik in 1974. Originally intended to be a learning tool for spatial geometry, the Rubik's Cube has evolved to be an international phenomenon, with over 350 million units sold worldwide. Apart from its enjoyment and cultural appeal, cubing requires the application of fundamental thinking capabilities: visual acuity, pattern detection, algorithmic reasoning, and, importantly, spatial intuition. This renders the Rubik's Cube not only a popular toy, but also an extremely valuable instrument for mental training. Solving the Rubik's cube requires sophisticated mental processes—imagining spatial changes, executing multi-step procedures, and anticipating movements— all directly associated with spatial thinking. This makes the cube a potentially strong, affordable, and accessible method of cognitive enrichment.

This study seeks to explore the correlation between the ability to solve Rubik's Cube and spatial reasoning through inferential statistical techniques. It aims to understand how interactive, logic-driven devices can enhance our mental capabilities, particularly spatial reasoning. In today's world it can be helpful to investigate whether a hands-on brain teaser can be a cheap means of shaping essential mental capacities. This can, in the long term, help in learning, training, and self-improvement.

II. Objectives Of Study

1. To compare the spatial reasoning abilities (by using a spatial reasoning test) of individuals who regularly solve the Rubik's Cube (cubers) with those who do not (non-cubers), using a two-tail t-test analysis to determine whether a statistically significant difference exists between the two groups.
2. To determine whether there is a correlation between spatial reasoning abilities and the time taken to solve the Rubik's cube, using the Pearson correlation model.

III. Limitations Of Project

Sample Size And Diversity:

The study may be limited by a relatively small or homogenous sample group, which could affect the generalizing of the results to broader populations with varied backgrounds.

Validity Of The Spatial Reasoning Test Used:

The spatial reasoning test used in this study may not fully capture the all the dimensions of spatial reasoning. Additionally, factors such as environment, text anxiety, familiarness will the question etc. might skew the test.

Variability In Methods Used To Solve The Cube:

For the seconds objective, that is to check the correlation between solve time and spatial reasoning test, various method used to solve the cube such as CFOP vs. the beginner method might change the time taken to solve the cube. As a result, the correlation test may not accurately show the relation between speed and test scores.

IV. Scope Of Study

This study focuses on exploring the relationship between Rubik's Cube solving and spatial reasoning abilities among individuals aged approximately 10 to 55 years. It encompasses two primary areas: comparing the spatial reasoning skills of regular Rubik's Cube solvers with those who do not engage in cube-solving, and evaluating whether there is any significant statistical correlation between speed of solving the Rubik's cube and spatial reasoning abilities.

The research is limited to assessing spatial reasoning through a standardized test provided by AssessmentDay [3] (AssessmentDay, n.d.). It does not attempt to explore other cognitive abilities such as memory, logical reasoning, or verbal intelligence. The study applies inferential statistical tools such as two-sample and Pearson's correlation to analyze the data and draw meaningful conclusions about potential correlations and improvements.

V. Importance Of Study

In an era where cognitive flexibility and problem-solving skills are increasingly valued, understanding how simple, accessible tools can enhance specific cognitive functions holds immense educational and psychological significance. This study explores the Rubik's Cube not just as a puzzle or recreational activity, but as a potential instrument for cognitive development, specifically, for the enhancement of spatial reasoning skills.

Spatial reasoning is a foundational component of learning in disciplines such as mathematics, engineering, architecture, and the visual arts. Improving this skill can lead to better academic performance, stronger critical thinking abilities, and more effective real-world decision-making. By examining the relationship between Rubik's Cube solving and spatial reasoning, this study aims to highlight an affordable, engaging, and widely available method for cognitive training. The findings from this research may provide valuable insights for educators, cognitive psychologists, and curriculum developers seeking innovative, low-cost tools to integrate into learning environments.

VI. Review Of Literature

A study by Newcombe, in 2010 [4] (Newcombe, 2010) concluded that spatial thinking is essential for grasping abstract concepts, specifically in mathematics and science. She empahsised on the need for spatial training tools in early education, claiming that spatial skills can be nurtured rather than being purely innate.

A study by Sorby, in 2009 [5] (Sorby, 2009) analysed the impact of spatial training in engineering students, and found that regular exercises such as mental rotation, 3D visualization, and object manipulation significantly improved spatial reasoning and academic performance in the subjects of the study.

Jirout & Newcombe, in 2015 [6] (Jirout JJ & Newcombe NS , 2015), "Building Blocks for Developing Spatial Skills: Evidence from a Large, Representative U.S. Sample" — published in *Psychological Science.* The research found that children who frequently engaged in structured block play (such as LEGO or building blocks) developed significantly higher spatial visualization and mental rotation abilities than those who did not. The study concluded that hands-on, manipulative tasks can serve as powerful tools for early cognitive development.

VII. Data Collection Methodology

The data for this study was collected through a using a spatial reasoning test provided by AssessmentDay [3] (AssessmentDay, n.d.).

For the first objective, the sample of participants who were selected were divided into 2 groups- cubers and non-cubers. Every participant in the sample was asked to complete the spatial reasoning test mentioned above, which was scored out of twelve. The scores were later converted into percentages and the results of the two groups were compared to see if there was any statistically significant difference.

For, the second objective, the cubers in the sample were asked to perform 5 solves, and the average of these solves was taken, in seconds (excluding the millisecond part). A Pearson correlation analysis was applied to this data to assess if there is a relationship between the spatial reasoning scores achieved initially, and average solving speed (lower time = higher speed).

Each test was timed, and participants were instructed not to use calculators, internet resources, or assistance from others. Scores were recorded and anonymized to protect participant privacy.

The collected data was organized using spreadsheet software and later statistical analysis tools are used to perform inferential testing, including two-tailed t test and Pearson's correlation model.

VIII. Mathematical Tools Used

Two-Sample T-Test

The two-sample independent t-test is employed to compare the means of two independent groups — cubers and non-cubers — to test the first hypothesis of whether there is a significant difference in spatial reasoning ability.

Interpretation:

- A significant result ($p < 0.05$) would suggest that Rubik's Cube solvers outperform non-solvers in spatial reasoning.
- An insignificant result would imply no meaningful difference in average scores between the two groups.

Pearson Correlation Model

The Pearson correlation model, also known as the Pearson correlation coefficient, measures the strength and direction of the linear relationship between two continuous variables. It is a statistical measure that provides a value between -1 and +1, indicating the degree to which the variables are related.

The range of the values received by using the Pearson Correlation method are as follows:

- +1: A perfect positive linear relationship. As one variable increases, the other increases proportionally.
- -1: A perfect negative linear relationship. As one variable increases, the other decreases proportionally.
- 0: No linear relationship between the variables.

IX. Data Analysis

Objective-1:

To compare the spatial reasoning abilities of people who solve the Rubik's cube regularly (cubers) and people who cannot solve the Rubik's cube (non-cubers), to check if there is any statistically significant difference, by using a two-tail t-test.

For the purpose of this objective, 2 random samples of 15 cubers and 15 non-cubers were selected, and were given a spatial reasoning test [3] (AssessmentDay, n.d.). The test was scored out of 12 and was converted into a percentage and tabulated in the table below.

CUBERS:		
Participant ID	Score (out of 12)	Percentage (%)
P-01	10	83.3
P-02	9	75
P-03	7	58.3
P-04	8	66.6
P-05	9	75
P-06	8	66.6
P-07	7	58.3
P-08	11	91.6
P-09	11	91.6
P-10	5	41.6
P-11	10	83.3
P-12	10	83.3
P-13	9	75
P-14	7	58.3
P-15	10	83.3

NON-CUBERS:		
Participant ID	Score (out of 12)	Percentage (%)
P-01	5	41.6
P-02	6	50
P-03	7	58.3
P-04	12	100
P-05	8	66.6
P-06	5	41.6
P-07	7	58.3
P-08	5	41.6
P-09	6	50
P-10	9	75
P-11	7	58.3
P-12	7	58.3
P-13	7	58.3
P-14	6	50
P-15	5	41.6

A two-sample t-test will be conducted for the scores above, to determine if there is any statistically significant difference in the spatial reasoning abilities between cubers and non-cubers.

First we set up the null and alternate hypothesis.
Null hypothesis: There is NO statistically significant difference between the performance between the cubers and non-cubers sample, in the spatial reasoning test.
Alternate hypothesis: There is a statistically significant difference between the performance between the cubers and non-cubers sample, in the spatial reasoning test.

Next, we calculate the mean and the standard deviations of the two samples will be calculated, in order to find the t-statistic.
We will use a two-tailed test at $\alpha = 0.05$.

CUBERS:

Participant ID	Score (out of 12)	Percentage (%)
P-01	10	83.3
P-02	9	75
P-03	7	58.3
P-04	8	66.6
P-05	9	75
P-06	8	66.6
P-07	7	58.3
P-08	11	91.6
P-09	11	91.6
P-10	5	41.6
P-11	10	83.3
P-12	10	83.3
P-13	9	75
P-14	7	58.3
P-15	10	83.3
	AVERAGE SCORE	**72.74**
	STANDARD DEVIATION	**14.25135583**

NON-CUBERS:

Participant ID	Score (out of 12)	Percentage (%)
P-01	5	41.6
P-02	6	50
P-03	7	58.3
P-04	12	100
P-05	8	66.6
P-06	5	41.6
P-07	7	58.3
P-08	5	41.6
P-09	6	50
P-10	9	75
P-11	7	58.3
P-12	7	58.3
P-13	7	58.3
P-14	6	50
P-15	5	41.6
	AVERAGE	**56.63333333**
	STANDARD DEVIATION	**15.50859976**

t-statistic = $\frac{\overline{x_1} - \overline{x_2}}{\sqrt{(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2})}}$
$\overline{x_1}$ = 72.74
$\overline{x_2}$ = 56.63
s_1 = 14.251
s_2 = 15.508
$n_1 = n_2 = 15$

t-statistic = $\frac{72.74-56.63}{\sqrt{\frac{203.091}{15} + \frac{240.498}{15}}}$
t-statistic = $\frac{16.11}{\sqrt{13.5394 + 16.0332}}$
t-statistic = $\frac{16.11}{\sqrt{29.5726}}$
t-statistic = $\frac{16.11}{5.438}$
t-statistic = 2.962

N = 30 (15 cubers and 15 non-cubers)
Degree of freedom = (N-1) = 30-1 = 29
The p value is calculated using a p value calculator [2] (GraphPad Software, n.d.).
The two-tail p value was found to be 0.00600.0060 < 0.05.

This implies that there is a statistically significant difference between the spatial reasoning abilities of individuals who can solve the cube, as compared to individuals who cannot solve the Rubik's cube. Thus, we can reject the null hypothesis, which stated that there is NO statistically significant difference between the performance between the cubers and non-cubers sample, in the spatial reasoning test. People who solve the Rubik's Cube regularly (cubers) score significantly higher in spatial reasoning tests compared to those who don't. This supports the idea that practicing the cube may enhance spatial reasoning skills.

Objective-2:

To determine whether there is a correlation between spatial reasoning abilities and the time taken to solve the Rubik's cube, using the Pearson correlation model.

For this objective, 15 participant who know how to solve the Rubik's cube were selected, and were given a Spatial Reasoning test [3] (AssessmentDay, n.d.). The test was scored out of 12. The scores out of 12 were converted in percentages, which was used for the analysis. Furthermore, participants were made to solve the cube 5 times, and the average solve time in seconds (excluding the milliseconds part) was taken into consideration. The table below shows the scores of the individual participants, along with the average solve time in seconds.

Participant ID	Score (out of 12)	Percentage (%)	Average solve time (seconds)
P-01	10	83.3	34
P-02	9	75	46
P-03	7	58.3	122
P-04	8	66.6	182
P-05	9	75	96
P-06	8	66.6	18
P-07	7	58.3	89
P-08	11	91.6	42
P-09	11	91.6	48
P-10	5	41.6	167
P-11	10	83.3	24
P-12	10	83.3	29
P-13	9	75	42
P-14	7	58.3	62
P-15	10	83.3	35

A Pearson correlation model will be used to find whether there is any statistically significant correlation between the percentages scored in the spatial reasoning test, and the average solve time in seconds, of the Rubik's cube.

If the final correlation value (r) < 0, then we can say that there is a negative correlation between the two variables, implying that the speed at which the Rubik's cube can be solved has a statistically significant impact on the spatial reasoning abilities of individuals, i.e., less the time taken to solve the Rubik's cube, higher the spatial reasoning abilities, and vice versa.

If the final correlation value (r) > 0, then we can say that there is a positive correlation between the two variables, implying that the speed at which the Rubik's cube can be solved has a statistically significant impact on the spatial reasoning abilities of individuals, i.e., more the time taken to solve the Rubik's cube, higher the spatial reasoning abilities, and vice versa.

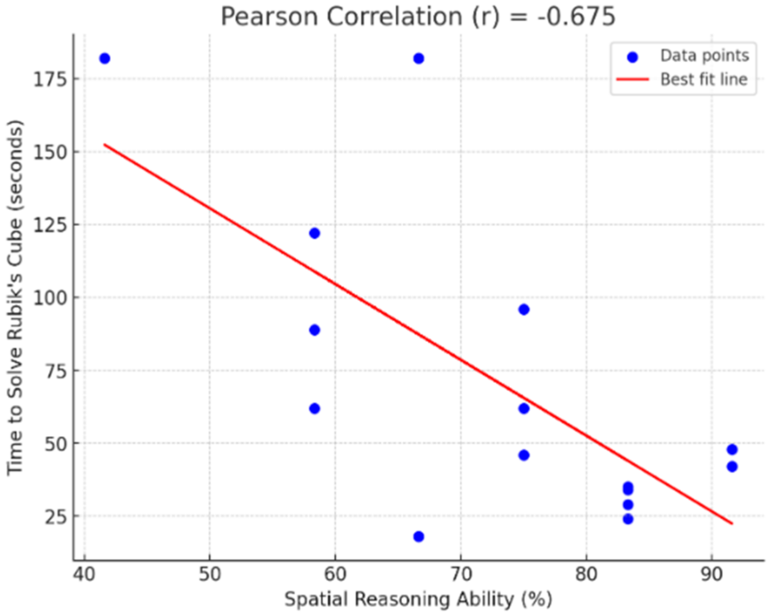
Participant ID	Prcentages (X)	Average time for solve (Y)	X-Mean of X	Y-Mean of Y	(X-Mean of X) (Y-Mean of Y)	(X-Mean of X)^2	(Y-Mean of Y)^2
P-01	83.3	34	10.56	-35.06666667	-370.304	111.5136	1229.671111
P-02	75	46	2.26	-23.06666667	-52.13066667	5.1076	532.0711111
P-03	58.3	122	-14.44	52.93333333	-764.3573333	208.5136	2801.937778
P-04	66.6	182	-6.14	112.9333333	-693.4106667	37.6996	12753.93778
P-05	75	96	2.26	26.93333333	60.86933333	5.1076	725.4044444
P-06	66.6	18	-6.14	-51.06666667	313.5493333	37.6996	2607.804444
P-07	58.3	89	-14.44	19.93333333	-287.8373333	208.5136	397.3377778
P-08	91.6	42	18.86	-27.06666667	-510.4773333	355.6996	732.6044444
P-09	91.6	48	18.86	-21.06666667	-397.3173333	355.6996	443.8044444
P-10	41.6	167	-31.14	97.93333333	-3049.644	969.6996	9590.937778
P-11	83.3	24	10.56	-45.06666667	-475.904	111.5136	2031.004444
P-12	83.3	29	10.56	-40.06666667	-423.104	111.5136	1605.337778
P-13	75	42	2.26	-27.06666667	-61.17066667	5.1076	732.6044444
P-14	58.3	62	-14.44	-7.066666667	102.0426667	208.5136	49.93777778
P-15	83.3	35	10.56	-34.06666667	-359.744	111.5136	1160.537778
AVERAGES	72.74	69.06666667		SUM	-6968.94	2843.416	37394.93333

If the final correlation value (r) is = 0, then we can say that there is no correlation between the two variables, implying that the speed at which the Rubik's cube does not have a statistically significant impact on the spatial reasoning abilities of individuals, i.e., more or less the time taken to solve the Rubik's cube, does not affect the spatial reasoning abilities.

Pearson Correlation Coefficient (r) = $\frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})2*\sum(y-\bar{y})2}}$

$r = \frac{-6968.94}{\sqrt{2843.416}*\sqrt{37394.933}}$

$r = \frac{-6968.94}{53.32369079*193.3776952}$



$$r = \frac{-6968.94}{53.32369079 * 193.3776952}$$

$$r = \frac{-6968.94}{10311.61242}$$

r = -0.675834167941 ≈ -0.675

r = -0.675834167941 ≈ -0.675

Final Pearson Correlation

The final value of $r \approx -0.675$. This suggests a moderate negative correlation, $r < 0$ ($-0.675 < 0$). This implies that as the average time taken to solve the Rubik's reduces, there is an increase in Spatial reasoning levels amongst individuals. The moderate negative correlation between the 2 variables here (average solve time and spatial reasoning level) also suggests that time taken to solve the Rubik's cube may not be the only factor contributing to spatial reasoning levels, although it may be a significant factor contributing to the same.

X. Results, Conclusion And Final Recommendations

Results

OBJECTIVE-1: Two-Sample t-Test (Cubers vs. Non-Cubers)

- Mean Spatial Reasoning Score (Cubers): 72.74%
- Mean Spatial Reasoning Score (Non-Cubers): 56.63%
- Standard Deviations: 14.25 (cubers), 15.51 (non-cubers)
- Sample Size (each group): 15
- t-statistic: 2.962
- Degrees of Freedom: 29
- p-value: 0.006

Since the p-value is less than the significance level ($\alpha = 0.05$), the null hypothesis was rejected. This means there is a statistically significant difference in spatial reasoning scores between cubers and non-cubers. Cubers outperformed non-cubers in the spatial reasoning test.

OBJECTVE-2: Pearson Correlation (Solve Time vs. Spatial Reasoning)

Pearson Correlation Coefficient (r) ≈ -0.675

This value indicates a moderate negative correlation between cube-solving speed and spatial reasoning ability. In other words, as the time taken to solve the Rubik's Cube decreases, the spatial reasoning score increases.

This suggests that faster cubers tend to have stronger spatial reasoning skills. However, since the correlation is moderate (not strong), it also implies that while solve time may be a contributing factor, it is likely not the only one.

Conclusion

The findings of this study demonstrate that individuals who solve the Rubik's Cube regularly tend to have significantly higher spatial reasoning abilities than those who do not. This supports the hypothesis that engaging with the Rubik's Cube enhances spatial intelligence.

Furthermore, the negative correlation between solve time and spatial test performance suggests that individuals who solve the cube faster may possess higher/better spatial skills. However, this relationship is moderate, indicating that other factors (such as prior exposure to spatial tasks, general intelligence, or method used) may also influence performance.

Final Suggestions:

Based on the findings of this study, it is suggested that individuals consider incorporating the Rubik's Cube into learning environments as it is an affordable and effective tool for improving spatial reasoning. Regular cube-solving engages learners in visual thinking, pattern recognition, and problem-solving, which may contribute to higher spatial reasoning abilities. As the results showed a significant difference in spatial reasoning scores between cubers and non-cubers, the Rubik's Cube can be used not just as a recreational activity but as a structured cognitive training method to improve mental agility and academic performance.

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