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Prediction of creative thinking and emotional creativity based on Students Brain Executive Function of second-grade high school

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Abstract

Aim: Creativity is an essential element of cognition and thinking. Thinking is defined as the process of reorganizing or modifying the stored information and symbols in long-term memory. In this context, creativity is closely linked to analytical ability and the mind's capacity for visualization. The present study aims to predict creative thinking and emotional creativity based on executive brain functions among second-grade high school students in Jafarabad city. **Method:** The study employs a correlational methodology with descriptive characteristics and applied purposes. The statistical population consists of all male and female second-grade high school students in Jafarabad city, totaling 493 individuals. The sample size was determined Using Cochran's formula, resulting in the selection of 218 students. Standardized questionnaires for the Abedi Creative Thinking Questionnaire 2013, the Ivoril Emotional Creativity Questionnaire 1999, and the Questionnaire of Executive Functions of the Rescue Brain 2013 were used as data collection tools. **Finding:** The results of the reliability calculation of the questionnaires showed that Cronbach's alpha coefficient was estimated for creative thinking (0.84), emotional creativity (0.92), and brain executive function (0.79). which shows that the questionnaires are at an acceptable level. **Conclusion:** The data were analyzed using SPSS software, including descriptive and inferential analyses through tables, demographic charts, and regression analysis. The results suggest that executive brain function components can predict both creative thinking and emotional creativity.

Keywords: creative thinking, emotional creativity, executive brain function

Introduction

Today, flourishing and cultivating students' creativity is one of the most important goals of education and it is one of the most interesting and controversial topics in educational sciences and psychology. All the success and progress of a person depends on his dynamic and effective thinking and belief. Therefore, creativity is a mental process that enables people to think about new and practical ideas. One of the most complex and excellent manifestations of people's thinking is creative thinking (Petrie, van der Zanden, Meijer & Beghetto, 2020).

Creativity constitutes the foundational knowledge necessary for change and innovation. Rehamer and Brolin (1999) assert that the capacity to generate novel ideas and innovative products is a cognitive characteristic exclusive to humans. From this perspective, creativity emerges as a crucial component in the acceleration of scientific and technological innovations within society. Research supports that creativity and the extent to which creative thinking is applied will be a key feature of future innovative movements (PirKhayefi et al., 2009).

By looking at history, we find that the world has made fundamental changes in the hands of a few people who have creative thinking, and most of the progress of a society is owed to innovation and creative people. Due to this fact, many educational experts think that in today's changing world, teaching creativity and creating creativity in students is the heaviest and most important goal of any educational system (Makarova & Makarova, 2019).

Considering that today many teenagers do not have the necessary and basic abilities to face the problems of life and are vulnerable in the face of problems, the place and necessity of teaching thinking skills to teenage students to face the problems of today's world and to replace the methods and research-oriented scientific attitudes are very important instead of transferring and storing scientific facts (Opreaa, Stan & Andree, 2019).

The term "emotional creativity" was first introduced by April; it refers to an individual's ability to accurately perceive and express emotions uniquely and effectively in response to situational demands, as well as self-expression (i.e., authenticity) in an innovative way, thereby expanding thought patterns and improving interpersonal relationships (i.e., effectiveness). In this definition, innovation, effectiveness, and authenticity are considered the three primary elements of emotional creativity. Innovation encompasses the ability to transform ordinary emotions and generate novel emotional states that deviate from normative standards or create a new combination of common emotions. Effectiveness pertains to the coordination of creative responses with social and cultural contexts, enabling the establishment of desirable relationships with others (Oreil, 2007, as cited in Eslami-Rasekh and colleagues, 2012).

Creativity is a paramount aspect of knowledge that underlies any form of change and innovation. According to Rehamer and Brolin's (1999) perspective, humans possess the cognitive ability to generate novel concepts and innovative products. This notion offers a

crucial factor in advancing scientific development. Conversely, executive functions comprise a set of higher-order abilities that encompass self-regulation, inhibition, initiation, strategic planning, cognitive flexibility, and impulse control (Diamond and Willis, 1994). Neuroscience identifies functions such as organization, decision-making, working memory, retention and transformation, motor control, time perception, future prediction, reconstruction, inner speech, and problem-solving as among the most important executive functions. These functions play a pivotal role in human life, particularly in tasks related to learning and cognitive actions (Barkley, 1998; Welsh and Pennington, 1988; as cited in Alizadeh, 2006).

Developmental investigations of executive functions have demonstrated that: a) these functions originate from the earliest stages of life, potentially concluding by the end of the initial year of life; b) they gradually develop and undergo substantial changes during the years between two to five years old, with children's executive function performance becoming quite comparable to that of adults around the age of 12; c) the success of children in executing executive functions can be determined based on the intricacy of explicit tasks; d) a differentiation can be established between the development of relatively "hot" emotional aspects of executive functions (linked with the orbitofrontal cortex) and "cooler" more cognitive aspects (associated with the lateral prefrontal cortex) (Zelazo & Muller, 2002); e) disruptions in epigenetic processes may result in difficulties in executive functions, and eventually, developmental disorders may be associated with impairments in certain aspects of executive functions (Zelazo & Muller, 2002).

With the information provided by this research, the forecast of creative thinking and emotional creativity among second-grade high school students was scrutinized based on their executive brain functions.

Emotional creativity and creative thinking

The concept of emotional creativity was originally introduced by April. It refers to the ability of individuals to effectively experience and express their emotions in a distinctive manner that facilitates addressing both personal and social demands. Furthermore, thinking has been analyzed and classified in various ways, with one perspective being that of Guilford. Guilford distinguishes between two main categories of thinking: convergent thinking and divergent thinking. Convergent thinking is associated with intelligence, whereas divergent thinking is a defining trait of creativity. These two aspects of thinking are essential to human cognition. The main difference between them is that convergent thinking leads to predetermined outcomes, where there is always a right or wrong answer, while divergent thinking generates a wide range of possible answers, each of which may be logically correct (Amiri, Asadi, 2007).In Guilford's theory, divergent thinking is composed of several different factors or characteristics. The factors or characteristics that make up divergent thinking are as follows:

1. Fluency (Mental): The generation of multiple thoughts at the same time.

2. Flexibility (Originality): The production of various and unconventional thoughts and solutions to a problem.
3. Originality (Novelty): The use of unique and new solutions.
4. Elaboration (Expansion): The production of details and determinations.
5. Combination: Putting together disparate thoughts.
6. Analysis: Breaking down symbolic structures into constituent elements.
7. Organization: Changing the shapes, functions, and uses of patterns.
8. Complexity: The ability to deal with various and related thoughts simultaneously (Guilford, 1987; as cited in Saif, 2008).

Education and Creativity

The organization of education and upbringing is of utmost importance in the cultivation of creativity in individuals. Following families, individuals spend a considerable amount of their lives in educational institutions. The advancement of any society is directly correlated to the activities that occur in schools, as it is through education that an individual's creativity is refined and honed. Therefore, the inefficiency of this system poses the greatest challenge to the emergence of creativity and innovation (Vakili & Amini, 2010, p. 186). "An investigation into the aims of education and upbringing at the beginning of the third millennium shows that handling complex individual and societal issues necessitates the development of individuals who can think creatively" (Sternberg, 1990, as cited in Aghai Esfahani et al., 2004, p. 40). "This is in contrast to the Iranian education and upbringing system, which, due to its centralized structure, has decreased the level of creativity, innovation, and novel ideas that are essential for the progress and productivity of any organization" (Feizi & Bashir, 2009, p. 97). "Gardner (1993) asserts that schools have a communal nature. Among these, appropriate communication and information technologies play a significant role in facilitating and transferring innovative communication at all levels and stages of education in schools. Gardner maintains that in this transfer, teachers must learn to take full advantage of educational opportunities and learn how to use new learning methods and processes to foster creativity in students" (PirKhayefi et al., 2010, p. 64).

Executive Brain Functions

Pennington and Ozonoff (1996) define executive functions as a distinct domain of abilities that encompasses several cognitive processes, including spatial organization, selective inhibition, response preparation, goal setting, planning, and flexibility. According to Barkley (1997), executive functions are self-regulatory actions that individuals undertake to exercise self-control. He posits that these actions comprise a set of behaviors that enable individuals to self-monitor, self-direct their behavior, and optimize future outcomes. In this way, individuals can exert control over their behavior over time, which is predicated on their perception of future events, allowing them to adjust and guide their ultimate response in a manner that leads to greater reinforcement. Barkley (1997) asserts that during development, self-regulatory behaviors become

progressively internalized and unconscious, with inner speech or private speech serving as a prime example of these processes (Alizadeh, 2006). A critical and pivotal aspect of comprehending executive functions and children's performance is acquiring a better understanding of the concept of flexibility/inflexibility (Zelazo et al., 2003). An additional way to grasp the relationship between self-centeredness and weak executive function suggests that similar cognitive changes occur in the emergence of multi-perspective perspectives, as well as changes in executive functions and levels of awareness (Zelazo, 2004). The results of the Principles and Zelazo's (2005) study also demonstrated that three-year-old children either use the first-person active perspective (for themselves) or the third-person passive perspective (for others). To execute a plan successfully, an individual must have an internal representation of a conditional action (i.e., the rule) and be able to comprehend when the condition has been met, allowing them to act (Alizadeh, 2006).

Components of Executive Functions

Executive functions are skills that help individuals make decisions, sustain attention, organize, plan, initiate, self-monitor, and be flexible in achieving goals. The components of executive functions are diverse and varied. Some of these functions are defined as follows by Dawson and Guare (2004):

Planning: The ability to create a roadmap to reach a goal or complete a task. Planning also includes the ability to make prioritization decisions.

Organization: The ability to arrange or order items systematically.

Time Management: The ability to estimate the time required, allocate time, and adhere to time constraints. It also involves an understanding of the importance of time.

Working Memory: The ability to hold information in mind while performing complex tasks. Working memory also includes the ability to use past experiences for the current situation and apply problem-solving strategies for the future.

Metacognition: The ability to monitor performance and self-evaluate (e.g., asking oneself questions).

Dawson and Guare (2004) believe that to achieve a goal, one must use a different method to guide and adjust behavior during a task, and therefore, executive functions are used for the following purposes:

A) Response Inhibition: The ability to think before acting. This ability helps individuals resist the temptation to engage in certain behaviors and, as a result, evaluate their behavior.

B) Emotional Self-Regulation: The ability to manage emotions to complete tasks, control, and direct behavior (hot and cool executive functions).

C) Flexibility: The ability to revise plans in the face of obstacles, new information, or errors. Flexibility includes adapting to changing conditions.

Assessment of Executive Functions

Accurate identification and assessment of impairments in executive functions are imperative for targeted intervention and treatment. It is of paramount importance to comprehend the root cause of executive function weaknesses. This is because executive functions may be impaired due to various reasons such as depression, anxiety, fatigue, or attention deficits. Once the cause of executive function impairment is identified, therapeutic intervention can be tailored based on psychotherapy or appropriate intervention methods (Dawson & Guare, 2004; Alizadeh, 2006). Formal and informal assessments are available for evaluating executive functions. Clinical interviews or specific questionnaires can be prepared concerning a child's abilities to perform tasks and responsibilities, given the substantial role that a child's daily activities and the judgments of parents and teachers play in assessing a child's performance in tasks and responsibilities at home and school. The Brief Executive Assessment (BRIEF) can be utilized in the realm of standardized tests. This assessment examines components such as inhibition, shifting, emotional control, initiation, working memory, planning, organization, and monitoring. The Wisconsin Card Sorting Test (WCST) is employed to evaluate cognitive flexibility (Dawson & Guare, 2004). It is important to note that a comprehensive assessment may involve a combination of clinical interviews, observations, questionnaires, and standardized tests to obtain a holistic understanding of an individual's executive functioning skills and potential areas of weakness.

Methods

The current investigation employed an applied research methodology with a descriptive orientation, utilizing a predictive correlational approach. The statistical population of interest consisted of both male and female high school students in Jafarabad County, amounting to a total of 493 individuals as per official Ministry of Education statistics. To determine an appropriate sample size, Cochran's formula was consulted, and, taking into account the population size of 218, a sample of 218 students was purposely selected. The sampling procedure implemented was multi-stage cluster sampling.

Data collection method:

The data in this study are collected through fieldwork.

Data collection tools:

In this research, the standard questionnaires listed below have been used for data collection.

Creative Thinking Questionnaire: The Abedi Creativity Test (CT) is a questionnaire for assessing creative thinking that is based on Torrance's theory. It was developed in Tehran by Abedi in 1984 and has undergone various revisions. Eventually, the 60-item version was formulated at the University of California by Abedi. The questionnaire's reliability has been consistently examined in previous studies and has been confirmed. In

the present study, reliability was assessed using Cronbach's alpha coefficient, which yielded a coefficient of 0.84, indicating acceptable reliability.

Emotional Creativity Questionnaire: The present instrument utilized in this study is a self-report measure in paper-and-pencil format. Its development and implementation can be traced back to the year 1989 when Thomas, in pursuit of his master's thesis, was responsible for its initial creation. Subsequent revisions were carried out by April and colleagues from 1991 to 1999. The fourth iteration marked a significant turning point for the questionnaire as changes and factor analysis were employed to refine it. The final version was eventually established by April and colleagues in the year 1999. This tool aims to assess emotional creativity across four distinct dimensions, namely, "readiness," "innovation," "efficacy," and "authenticity." A total of 30 items comprise the questionnaire, with "innovation" featuring eight items, "readiness" six items, "authenticity" nine items, and "efficacy" seven items. The measure's reliability has been scrutinized in previous research endeavors, and the results have been consistently positive. The current study employed Cronbach's alpha coefficient to assess the reliability of the questionnaire, yielding a coefficient of 0.92, which is deemed satisfactory.

Executive *Functions Brain Questionnaire*: The present questionnaire was developed and standardized by Najati in the year 2013. It encompasses a total of thirty items along with seven distinct components, namely memory, inhibitory control, selective attention, decision-making, planning, sustained attention, social cognition, and cognitive flexibility. The consistency and accuracy of this questionnaire have been examined in previous studies and have been substantiated. In the current analysis, the reliability of the questionnaire was assessed using Cronbach's alpha coefficient, which resulted in a value of 0.79, indicating acceptable reliability.

Research Execution Method

Upon obtaining the necessary authorizations from the University's Research Deputy, the process was initiated by submitting the questionnaires to the Provincial Department of Education for their approval. The questionnaire items were meticulously reviewed by the esteemed Research and Development Group, who subsequently stamped all the questionnaires with their seal of approval. These questionnaires were then introduced to the Education Department of Jafarabad City for collaboration and notification to schools and the Inspectorate. Subsequently, a clustered multistage sampling technique was employed to select a sample of 109 female students and 109 male students from different schools. The selected students were then requested to complete the aforementioned questionnaires.

Data Analysis

In the course of this study, after collating the requisite data, the information was recorded within SPSS software version 18 for analysis. The process of data analysis was

bifurcated into two distinct segments. Firstly, a comprehensive evaluation of descriptive data was undertaken, comprising the calculation of the mean and the generation of an assortment of charts and graphs. Secondly, an inferential analysis of the data was executed, with this particular section relying upon the utilization of the Pearson correlation test and multiple regression analysis.

Results

Demographic Information of Participants

the distribution of respondents by gender. According to the provided data in the frequency distribution table, 50% of the respondents are female, and 50% are male.

Descriptive Findings

Table 1 presents the descriptive statistics of participants' scores by research variables, including emotional creativity, executive brain functions, and creative thinking.

Table 1: Descriptive Statistics of Participants' Scores by Research Variables
Variable

Variable	Components	Mean	Standard Deviation	Minimum Score	Maximum Score
Emotional Creativity	Readiness	93.3	69.0	86.1	94.4
	Innovation	91.2	93.1	93.1	93.3
	Effectiveness	100.3	80.1	60.1	60.4
	Authenticity	127.3	50.1	00.5	00.1
	Total Emotional Creativity	100.3	26.2	11.4	21.2
Executive Brain Functions	Memory	68.3	00.2	00.5	00.2
	Mastery Control and Selective Attention	28.3	33.2	83. 2	83.4
	Decision-Making	39.3	00.2	60.2	60.4
	Planning	49.3	00.2	67.2	67.4
	Sustained Attention	24.3	67.1	67.1	67.4
	Social Cognition	12.3	00.1	67.1	67.4
	Cognitive Flexibility	34.3	00.2	00.5	00.2
	Total Executive Brain Functions	36.3	70.2	08.2	08.4
Creative Thinking	Fluid	12.56	69.43	43	63
	Expansion	32.25	79.34	14	33
	Initiative	13.39	20.48	28	48
	Flexibility	83.27	08.34	20	33
	Total Creative Thinking	148.4	79.12	119	169

Inferential Analysis of Data

The research hypothesis was analyzed using multiple regression and Pearson correlation tests. Before proceeding to test the hypotheses and their analysis, it is necessary to determine the normality of the variables to decide whether to use parametric or non-parametric tests. Non-parametric statistical tests do not require specific assumptions, while parametric tests do require certain assumptions, and if these assumptions are not met, they cannot be applied. One of the most critical assumptions for parametric tests is the normal distribution of variable data. Parametric tests are typically based on means and standard deviations, and when the data distribution is not normal, these statistics do not accurately reflect the true nature of the data. To assess the normality of the distribution of research variables, the Kolmogorov-Smirnov test was employed. The Kolmogorov-Smirnov test compares the null hypothesis of data normality to the alternative hypothesis of non-normality. If the level of significance is greater than the test's error rate, the assumption of data normality is accepted. The results of the Kolmogorov-Smirnov test for assessing the normality of variable distributions are presented show that considering that the significance level of the Kolmogorov-Smirnov test is greater than the error value of 0.05, the assumption of normality for the tested variables is not significant at the 0.05 level. Therefore, it can be concluded that the examined data meet the conditions of normality, and the conditions for using "parametric" tests are satisfied. Thus, the mean can be used as the central indicator in statistical decisions. Consequently, Pearson correlation and multiple regression tests can be employed for hypothesis testing.

Hypothesis Testing

The hypothesis that creative thinking and emotional creativity of second-grade high school students can be predicted based on brain executive functions was tested.

Creative Thinking

Table 2: Regression Coefficients for Creative Thinking Based on Brain Executive Function Components

Model	R	R^2	Adjusted R^2	Standard Error of the Estimate
1	1 0.459	0.210	0.184	22.896

The results in Table 2 show that 18% of the total variance in creative thinking is explained based on the components of brain executive functions.

Table 3: ANOVA Test to Examine the Significance of the Regression Model

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	F	Significance Level
Regression	2.932	7	0.419	7.991	0.000
Residual	11.009	210	0.052		
Total	13.941	217			

The results in Table 3 indicate that the regression model for creative thinking based on the components of brain executive functions is significant ($p < 0.000$, $F = 7.991$).

Table 4: Regression Coefficients for Creative Thinking Based on Brain Executive Function Components

Dependent Variable	Predictor Variables	Beta	SEB	b	t	Sig
Creative Thinking	Constant	2.904	0.167		17.369	0.001
	Memory	0.097	0.029	0.263	3.323	0.001
	Control and Selective Attention	0.117	0.038	0.252	3.077	0.002
	Decision Making	0.049	0.031	0.118	1.547	0.123
	Planning	0.026	0.031	0.064	0.849	0.397
	Sustained Attention	0.071	0.026	0.204	2.767	0.006
	Social Cognition	0.078	0.022	0.234	3.467	0.001
	Cognitive Flexibility	0.157	0.033	0.469	4.779	0.001

The results in Table 4 indicate that among the components of brain executive functions, the components of memory, control and selective attention, sustained attention, social cognition, and cognitive flexibility predict creative thinking.

Emotional Creativity

Table 5: Regression Coefficients for Emotional Creativity Based on Brain Executive Function Components

Model	R	R^2	Adjusted R^2	Standard Error of the Estimate
1	0.513	0.263	0.239	0.40673

The results in Table 5 show that 26% of the total variance in emotional creativity is explained based on the components of brain executive functions

Table 6: ANOVA Test to Examine the Significance of the Regression Model

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	F	Significance Level
Regression	12.403	7	1.772	10.711	0.000
Residual	34.740	210	0.165		
Total	47.143	217			

The results in Table 6 indicate that the regression model for emotional creativity based on the components of brain executive functions is significant ($p < 0.000$, $F = 10.711$).

Table 7: Regression Coefficients for Emotional Creativity Based on Brain Executive Function Components

Dependent Variable	Predictor Variables	Beta	SEB	b	t	Sig
Creative Thinking	Constant	2.042	0.297		6.876	0.001
	Memory	0.283	0.052	0.420	5.488	0.001
	Control and Selective Attention	0.041	0.068	0.048	0.609	0.543
	Decision Making	0.003	0.056	0.003	0.045	0.964
	Planning	0.061	0.055	0.081	1.119	0.265
	Sustained Attention	0.063	0.046	0.098	1.375	0.171
	Social Cognition	0.162	0.040	0.266	4.077	0.001
	Cognitive Flexibility	0.107	0.058	0.175	1.842	0.067

The results in Table 7 show that among the components of brain executive functions, the components of memory and social cognition predict emotional creativity.

Discussion

The present study aimed to predict the creative thinking and emotional creativity of second-grade high school students based on brain executive functions. The research results showed that both creative thinking and emotional creativity of second-grade high school students can be predicted based on brain executive functions. The findings of this study indicate that brain executive functions can predict the creative thinking and emotional creativity of students.

Conclusion

In examining the relationship between emotional creativity and brain executive functions, it can be noted that creativity requires both freedom and a lack of mental structure in dealing with issues and phenomena, as well as the need for prior experiences, knowledge, and awareness, which are part of brain executive functions. Previous research in this area by Babakhani and Balvardi (2018) on the relationship between creativity and executive functions, Ahrary and colleagues (2018) on predicting students' creativity based on executive functions, Kamarda and colleagues (2017) on executive functions and creativity according to Ivcevic and Brackett (2007) also align with the results of the current research and confirm its findings. Considering the results of the present research on the effect of brain executive functions on creative thinking and emotional creativity, it is recommended to hold special educational workshops in schools to increase students' awareness of brain executive functions. Finally, for further research, it is suggested to

investigate strategies for enhancing brain executive functions among students. Additionally, it is recommended to conduct similar research in other regions of the country and compare the results with those of the present study.

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