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Effect of mindfulness practices on executive functions of elementary school students

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Abstract
The study aimed to evaluate the impact of mindfulness exercises on the executive functions of elementary school students. A group of 100 female students from second and third grades, who met specific criteria (average IQ, right-handedness, no physical or mental illnesses, and no psychological or psychiatric interventions), were divided into experimental and control groups through cluster sampling. The experimental group, with an average age of 97.12±3.48 months, participated in eight one-hour mindfulness exercise sessions, while the control group, averaging 96.18±3.33 months in age, received no such intervention. Assessments were conducted using working memory tests, continuous performance tests, and Wisconsin card sorting tests both before and after the intervention. Analysis of the data with ANCOVA revealed significant improvements in the mindfulness group's forward and backward memory scores and total memory scores ($P<0.01$), as well as the perseveration dimension of cognitive flexibility ($P<0.05$) and a notable enhancement in the response time for attention ($P<0.01$). These results support prior research affirming the positive effects of mindfulness on executive functions, although the limited number of sessions may have restricted the significance of impacts in certain areas.

Keywords: Cognition, mindfulness, executive functions

Introduction
Adapting to the complexities of today's world requires the ability to sift through unnecessary information and concentrate on the more significant elements of our surroundings. The critical role of selective attention in managing cognitive operations is well-recognized. It aids in identifying and choosing suitable responses by eliminating irrelevant environmental details and channeling cognitive efforts towards processing information pertinent to immediate objectives. (Dimond & Lee, 2011).

Hence, mindfulness is closely linked with attention and cognitive flexibility, as the essence of mindfulness involves directing focus toward present experiences, implicitly requiring both these cognitive abilities (Moore & Malinowsky, 2009). Cognitive flexibility refers to the capacity to employ various cognitive strategies to navigate novel and unforeseen circumstances, a skill inherently connected to the processes of attention. This ability allows us to filter out irrelevant details and concentrate our focus on achieving objectives. Consequently, mindfulness practice, which emphasizes the non-judgmental awareness of the present moment as derived from meditation, involves managing our focus and discarding inappropriate reactions, embodying the principles of cognitive flexibility.

In the context of mindfulness, it is proposed that such practices enhance the self-regulation of attention (Bishop, 2004). Elementary school children often face greater challenges than older students in absorbing new lessons and maintaining focus on learning activities. Thus, it's crucial for them to develop the ability to concentrate on new information provided by their teachers and disregard distractions.

Numerous research efforts have explored the impact of mindfulness on overall executive functions, focusing on areas such as attention, memory, and psychological flexibility. Despite this extensive research, there remains a gap in understanding how mindfulness affects various aspects of executive functions, especially among elementary school students in Iran. This study seeks to fill this gap by assessing the impact of mindfulness training on the executive functions of female second and third graders (Flook *et al*., 2010; Diamond & Lee, 2011; Teper & Inzlicht, 2013) [16]

Methods
Research design
This study utilized an experimental design, incorporating both pretest and posttest measures, along with a control group for comparison.

Sample
The study targeted students from elementary schools in Jaipur City of Rajsthan. Initially, five Elementary School were chosen from Jaipur for the first stage of sampling. From these schools, four classes—two from the second grade and two from the third grade—were selected. Subsequently, 100 female students were chosen from these classes based on specific inclusion and exclusion criteria. These students were then randomly divided into experimental (n=50, mean age 97.12±3.48 months, average IQ 111.0±1.43) and control groups (mean age 96.18±3.33 months, average IQ 111.18±1.52). The inclusion criteria specified an IQ range of 100-115 and right-handedness, while the exclusion criteria ruled out any students with psychological disorders, physical illnesses, or those undergoing psychiatric or psychological treatments.

Research tools
1. Wechsler Intelligence Scale for Children (Weschler, 1981) [17].
2. Wisconsin Card Sorting Test (1948)
3. Continuous Performance Task (2000)

Procedure

Following coordination with the Education Department and the selection of participants, written informed consent was secured from both the parents and the participants themselves, with an assurance that participants could withdraw from the program at any time. Prior to initiating the intervention, each participant was individually assessed using three research instruments. The intervention, conducted by a professional trained in mindfulness techniques, spanned over 8 weeks with sessions lasting 2 hours each week. Tailored to be age-appropriate, the program incorporated exercises and games designed to enhance self-awareness through the engagement of the five primary senses. Post-intervention, the research tools were administered once more to each participant. The collected data were then subjected to a one-way analysis of covariance (ANCOVA) for analysis, utilizing SPSS software version 21.

Results

Following the collection of data, analysis was conducted using SPSS, with findings presented through both descriptive and inferential statistical methods. Descriptive statistics for all variables across the three groups were detailed in the analytical segment, with the testing of assumptions conducted via a one-way analysis of covariance (ANCOVA). Descriptive statistics for pretest and posttest variables are displayed in Table 1, employing covariance analysis to determine the impact of mindfulness on various executive function facets.

Prior to data analysis, tests for normality (using the Wilks-Shapiro test), homogeneity of regression slopes, and variance equality (using Levene's test) were performed for each aspect of working memory. Upon satisfying these prerequisites, ANCOVA was utilized to evaluate the influence of mindfulness on memory components, as outlined in Table 2.

Table 2 reveals that, after adjusting for pretest memory scores, a notable difference emerged between the experimental and control groups in posttest outcomes (P=0.001, F=18.78). The effect size indicated that mindfulness practices enhanced forward memory, backward memory, and digit-letter memory by approximately 39%, 48%, and 28%, respectively, underscoring the positive impact of mindfulness on working memory capabilities.

To ascertain the effect of mindfulness on cognitive flexibility, ANCOVA was again employed, with its findings presented in Table 3. However, this analysis was preceded by verifying the assumptions of normality (Wilks-Shapiro test), homogeneity of regression slopes, and error variance equality (Levene's test) for each dimension of cognitive flexibility. Table 3 demonstrates that, after adjusting for pretest scores of preservation, a significant disparity was observed between the experimental and control groups in their posttest results (P=0.04, F=4.41), indicating the effectiveness of mindfulness in enhancing cognitive flexibility.

The effect size, as measured by Eta squared, indicates that mindfulness accounts for approximately 13% of the variance in perseveration, suggesting that mindfulness practices lead to a noticeable reduction in perseveration, thereby having a relatively significant impact. However, after controlling for the pretest scores of errors in the Wisconsin Card Sorting Test (WCST) (P=0.14, F=2.22), no significant differences were found between the experimental and control groups in the posttest scores. This implies that mindfulness practices did not significantly alter the number of errors made on the WCST.

Table 1: Descriptive statistics of aspects of memory, cognitive flexibility, and attention

Variable		Group	Mean	SD	Mean	SD
Memory	Forward	Experimental	10.31	1.88	12.87	1.92
		Control	9.75	2.38	9.75	2.74
	Backward	Experimental	8.50	1.89	11.68	3.32
		Control	8.56	1.89	8.75	2.26
	Digit leter	Experimental	15.50	3.65	18.87	3.05
		Control	14.75	3.67	15.12	3.51
Cognitive flexibility	Preservation	Experimental	23.31	12.57	16.31	9.65
		Control	17.43	7.87	20.56	9.16
	Error	Experimental	25.81	14.12	20.87	14.60
		Control	16.68	10.46	14.31	9.42
Attention	Commission	Experimental	14.25	26.93	4.81	9.67
		Control	2.93	4.99	3.25	3.35
	Omission	Experimental	3.93	4.22	1.93	2.11
		Control	1.43	2.25	1.12	1.14
	Correct	Experimental	133.06	26.97	143.25	11.12
		Control	146.25	3.51	145.25	4.09
	Time	Experimental	620.87	84.61	666.75	81.10
		Control	619.25	73.39	558.87	88.20

Table 2: Analysis of covariance of effectiveness of mindfulness on memory

Variable	Reference	SS	df	Mean	F	P-Value	R^2
Forward memory	Pre-test	80.59	1	80.59	26.51	0.001	0.48
	Group	57.09	1	57.09	18.78	0.001	0.39
Digit & leter	Pre-test	98.76	1	98.76	12.63	0.001	0.30
	Group	90.31	1	90.31	11.55	0.002	0.28
Backward memory	Pre-test	61.91	1	61.91	9.94	0.004	0.25
	Group	71.25	1	71.25	11.44	0.001	0.48

Table 3: Analysis of covariance for the effects of mindfulness on cognitive flexibility

Variable	Reference	SS	df	MS	F	P-value	ETA.S
Preservation	Pre-test	535.40	1	535.40	7.31	0.001	0.20
	Group	323.14	1	323.14	4.41	0.04	0.13
Total error	Pre-test	322.74	1	322.74	2.22	0.14	0.07
	Group	120.75	1	120.75	0.83	0.37	0.03

To assess the impact of mindfulness on attention, an ANCOVA was employed. Prior to data analysis, the assumptions of normality (using the Wilks-Shapiro test), homogeneity of regression slopes, and error variance equality (using Levene's test) were verified for each aspect of attention. The ANCOVA results for attention dimensions are detailed in Table 4.

Table 4 illustrates that, after adjusting for pretest commission errors (F=1.52, P=0.23), no significant differences were observed between the experimental and control groups in their posttest outcomes (P=0.05, F=0.81), indicating that mindfulness did not significantly affect commission errors. Similarly, for omission errors, after accounting for pretest scores (P=0.01, F=7.24), the posttest comparison showed no significant differences between groups (P=0.67, F=0.18).

Furthermore, after controlling for pretest scores of correct responses (P=0.14, F=2.26) and response times (P=0.96, F=0.002), the findings revealed no significant change in correct responses between the groups at posttest (P=0.79, F=0.07). However, a significant difference was found in response times between the groups (P=0.001, F=12.53), with mindfulness leading to a 30% improvement in response speed, as indicated by the effect size.

These results suggest that while mindfulness practices did not significantly impact the various dimensions of attention such as commission and omission errors or the number of correct responses, they did effectively reduce response time by about 30%.

Table 4: Analysis of covariance for the effects of mindfulness on attention

Variable	Reference	SS	df	MS	F	P	ETA.S
Commission	Pre-test	78.33	1	78.33	1.52	0.23	0.05
	Group	2.81	1	2.81	0.05	0.81	0.002
Omission	Pre-test	17.33	1	17.33	7.24	0.01	0.20
	Group	0.44	1	0.44	0.18	0.67	0.006
Correct response	Pre-test	152.34	1	152.34	2.26	0.14	0.07
	Group	4.89	1	4.89	0.07	0.79	0.002
Time of response	Pre-test	17.44	1	17.44	0.002	0.96	0.001
	Group	93058.67	1	93058.67	12.53	0.001	0.30

Discussion

This research investigated the impact of mindfulness training on the executive functions of female students in the second and third grades of elementary school. Findings indicate that mindfulness training notably improves working memory and certain aspects of cognitive flexibility, yet does not significantly influence attentional components. Unlike prior research that often focused on a single executive function and highlighted the benefits of mindfulness, this study provides a broader perspective by evaluating multiple dimensions of executive functions and their responsiveness to mindfulness practices, including its effects on enhancing executive functions and behavioral regulation (Raes, Bruyneel, Loeys, Moerkerke, & De Raedt, 2015; Flook *et al*., 2010).

The findings present mixed outcomes regarding the influence of attention within working memory, as this study did not yield evidence to support an enhancement in attention through mindfulness practices. A potential reason for this discrepancy might relate to the different modalities of information processing, like visual and auditory, that underpin attention maintenance; however, our investigation was limited to visual processing. It's conceivable that mindfulness practices could enhance other forms of attention, such as divided and focused attention. This possibility aligns with the observed potential benefits on working memory detailed in the initial results, which necessitate both divided and focused attention. Another consideration is the variety of mindfulness practices that are age-specific and their differential effects on attention sustainability. Hence, there's a need to explore how different mindfulness practices might influence attention across various age groups.

The Wisconsin Card Sorting Test serves as a measure for assessing cognitive flexibility. During this test, participants are instructed to sort cards according to certain criteria (e.g., shape) and are provided with feedback, either affirming or negating their choices. Upon receiving negative feedback, participants must discern a new categorization principle (e.g., color). The ability to effectively transition between these rules demonstrates cognitive flexibility, necessitating the suppression of previously relevant mental strategies. Errors of perseveration occur when a participant continues to apply an outdated rule despite repeated indications of its ineffectiveness (Alvarez & Emory, 2006) [1].

Perseveration is the key symptom of frontal lobe dysfunction and is related to reduction of flexibility (Alvarez & Emory, 2006) [1]. With more activity in the frontal lobe, preservation errors of research sample reduce. Ultimately, regarding the effectiveness of mindfulness on attention, the findings of the study showed no significant change, which was not consistent with the previous findings (Napooli *et al*., 2005; Jha, Krompinger, & Baime, 2007) [8].

According to Luria's (1986) model on the development of attention, children in the early stages of schooling require more sessions focused on prefrontal cortex activities. In our study, limitations on the number and length of sessions were encountered due to the impracticality of having students participate in the intervention program more than three times a week without missing classroom time. Additionally, logistical constraints prevented families from bringing their children to the program outside of school hours. Therefore, future studies should employ more extensive tools and mindfulness protocols to derive conclusive results. Another challenge was the hesitancy of parents to cooperate, likely due to the novelty and unfamiliarity of the intervention, not recognizing its potential benefits. To address this, we recommend that school psychologists organize informational sessions for parents to highlight the value of psychological interventions in enhancing behavior, reducing stress, and boosting executive functions, assuring them of the safety and absence of adverse effects. Psychologists should themselves be well-informed about these interventions before discussing them with parents.

This study suggests that further evaluations of the intervention's effectiveness should consider the age and grade levels of students, possibly incorporating newer versions of mindfulness and attention protocols (MAPs). Additionally, there's a recommendation to enhance working memory and cognitive flexibility not only in clinical populations for therapeutic purposes but also in nonclinical groups to bolster executive function skills.

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