



# Computer Information Technology Based Digital Mindfulness Intervention on Executive Function of Fourth-Grade Students

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**Abstract.** In this study, four classes of primary school students in grade 4 in Beijing were randomly divided into intervention group and control group. The intervention group received an 11-week digital mindfulness intervention course, which foreign online mindfulness courses were used, played by computer, and presented by projector. Executive function and mindfulness level, strength and difficulty scale, adolescent multidimensional anxiety scale and academic achievement were measured before and after the intervention. Among them, the level of mindfulness, strength and difficulty scale, adolescent multidimensional anxiety scale and academic achievement were completed on computer. SPSS software was used to analyze all data. After 11 weeks of mindfulness intervention, repeated measures ANOVA showed that students in the mindfulness intervention group significantly improved their cognitive flexibility, inhibitory control and working memory. The level of mindfulness in the intervention group was significantly improved. However, there was no significant improvement in the total score of the strength and difficulty scale and other dimensions. The conclusion shows that the computer information technology based 11-week digital mindfulness intervention for primary school students is effective, so digital mindfulness intervention is a potentially effective and cost-effective way to improve executive function and mindfulness level of primary school students.

**Keywords:** digital mindfulness intervention · computer information technology · SPSS · primary school students · executive function

## 1 Introduction

Digital mindfulness interventions offer a promising path for teaching mindfulness in epidemic situations. Smartphone apps and web-based platforms for mindfulness can enhance its accessibility, personalization, standardization, and effectiveness of training [13]. Digital mindfulness interventions reduce geographic, logistical, and financial constraints, resulting in high-quality training [1]. In late 2019, Corona Virus Disease

2019 (COVID-19) outbreak occurred and quickly spread globally. It has caused varying degrees of physical and mental health effects in school children. There were negative effects on the physical and mental health of children and adolescents [17], and negative effects on executive functioning [11]; pandemic stressors early in life may also lead to neuropsychiatric disorders in adulthood and may trigger neuroinflammatory and behavioral disorders [4]. These challenges facing students urgently require schools to develop comprehensive programs that address the underlying cognitive and mental health needs of students. Numerous studies have shown that mindfulness interventions can improve working memory [15], can significantly increase cognitive flexibility in young children and elementary and middle school students [7, 10], improve problem behaviors [3], and improve depression and anxiety [8], as well as improve academic performance [14]. In today's pandemic, there is a need to explore the impact of using digital mindfulness interventions on primary and secondary school students.

Although there have been some achievements in mindfulness interventions, there are also some problems. Children and adolescents face great challenges in executive functioning, emotions, and behaviors, which are exacerbated by the pandemic. Few studies using mindfulness intervention for executive functioning in middle and upper elementary school students have been reported in China and abroad, and even fewer have used digital mindfulness intervention. In this paper, we used a digital mindfulness intervention to conduct an 11-week mindfulness intervention with fourth-grade primary school students to explore whether digital mindfulness interventions could improve executive functioning, improve problem behaviors, reduce anxiety, and improve academic performance.

## 2 Participates and Methods

### 2.1 Participates

A cluster sampling method was used to randomly divide four fourth grade classes of students in a Beijing primary school into an intervention group and a control group, each group including two classes. Four fourth grade classes were selected, with a total of 75 students. Excluding 5 students whose native language was not Chinese and 1 student who did not participate in the whole intervention, the valid sample size of this study was 69. The average age was 10.39 years old; 35 students in the intervention group, 18 girls (51.43%); 34 students in the control group, 17 girls (50%). The mindfulness course instructor had 7 years of experience in learning mindfulness practice and teaching mindfulness courses.

### 2.2 Measures

#### 2.2.1 Primary Outcome Variable: Execution Function

- (1) **Trail Making Test (TMT):** The TMT is used to test the cognitive flexibility of children.
- (2) **Stroop Test:** This test is a test of inhibition.

- (3) **Digit span test:** The test consists of a table of different digits, divided into digit parsimonious (2–10 digits) and backwards (2–8 digits), and digit backwards is a measure of working memory.

### 2.2.2 Secondary Outcome Variables: Mindfulness Level, Emotional and Behavioral Problems, Anxiety, and Academic Achievement

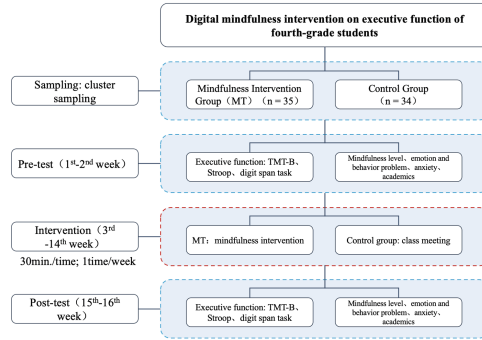
- (1) **Mindfulness level:** The levels of mindfulness were measured using the Five Facet Mindfulness Questionnaire (FFMQ), a 39-item scale developed by [2].
- (2) **Emotional and behavioral problems:** Students' emotional and behavioral problems were measured using the Chinese version of the Strengths and Difficulties Questionnaire (SDQ) (student version). The SDQ was proposed by [5]. In this study, the student self-assessment version was used by the students themselves.
- (3) **Anxiety:** Students' anxiety was measured using The Multidimensional Anxiety Scale for Children (MASC) [12].
- (4) **Academic achievement:** for math and English tests, the computerized adaptive test published by the Northwest Evaluation Commission were used.

## 2.3 Study Design

In this study, the effects of a digital mindfulness intervention on the executive functioning of fourth grade students were investigated using a “pre-test-intervention-post-test” approach (Fig. 1). The study was conducted as follows: first, the students were given a pre-test using computers in the first and second weeks, a mindfulness intervention using computerized multimedia from the third to the fourteenth weeks, and a post-test in the fifteenth and sixteenth weeks. The mindfulness intervention group conducted weekly sessions of 30 min each for 11 weeks. In addition, the mindfulness instructor would lead the students in the mindfulness intervention group to practice mindfulness twice a week according to the audio recording, with the length of the practice varying from 5 to 15 min depending on the content of the session. A post-test was administered within 2 weeks after the mindfulness intervention, and the content of the post-test was the same as the pre-test. The protocol of this study has been reviewed by the Ethics Committee of the Institute of Psychology, Chinese Academy of Sciences, and the ethical review approval number is H21009 (Fig. 1).

## 2.4 Intervention Plan

The mindfulness intervention program uses the Go to the now course, a foreign online platform, in an innovative format, mainly in the form of animations. It is played on the computer and viewed by the students through a projector. Each session begins with a 1–2 min review of the previous session, a 5 min computer recording to practice the mindfulness program from the previous session, and then the students watch the mindfulness program on the online platform using multimedia, the teacher and students discuss, the students complete the study sheets in class, and finally the computer recording is used to practice the mindfulness program in class. The overall time for a single session is about 30 min, which is ideal for practice in a classroom.



**Fig. 1.** Mindfulness intervention flow chart.

### 3 Results

#### 3.1 Test for Homogeneity of Each Variable Before Intervention in Both Groups

The data were analyzed using SPSS 26.0, and independent samples t-tests were used to test whether the subjects in the two groups were homogeneous. The results showed that there were no significant differences between the mindfulness intervention group and the control group on the Connected Test Task Response Time, Stroop Test Response Time and Breadth of Digit Backwards, Academic Achievement, Five Factor Positive Thinking Scale, Children’s Multidimensional Anxiety Inventory, and Strengths and Difficulties Questionnaire ( $p > .05$ ) (see Table 1).

#### 3.2 Changes in Scores of Each Variable Before and After Intervention in the Intervention and Control Groups

A 2 (group: intervention group, control group)  $\times$  2 (test time: pretest, posttest) repeated measures ANOVA was conducted to explore the effects of the mindfulness intervention on the primary outcome variable executive functioning, and the secondary outcome variables mindfulness level, emotional and behavioral problems, anxiety, and academic achievement, respectively.

##### 3.2.1 Analysis of Variance for Repeated Measures of Cognitive Flexibility in the Intervention and Control Groups

A 2 (group: intervention, control)  $\times$  2 (test time: pretest, posttest) repeated measures ANOVA on the TMT-B task found a significant interaction ( $F_{(1, 67)} = 8.71, p = .004, \eta^2_p = 0.115$ ). Simple effects analysis revealed that at the group level, the intervention and control groups were not significantly different in the baseline condition ( $p = .778$ ) and the response time was significantly lower in the intervention group than in the control group at the posttest ( $p = .014$ ). At the test time level, the intervention group had a significantly lower reaction time at posttest than at pretest ( $p = .022$ ), and the control group had a non-significant difference between the reaction time at posttest and pretest ( $p = .072$ ). The results suggest that the intervention group was better able to perform the TMT-B task after training than before training.

### 3.2.2 Analysis of Variance for Repeated Measures of Inhibition Control in the Intervention and Control Groups

A 2 (group: intervention group, control group)  $\times$  2 (test time: pretest, posttest) repeated measures ANOVA on the Stroop effect found a significant interaction ( $F_{(1, 67)} = 6.89$ ,  $p = .011$ ,  $\eta^2_p = .093$ ) (Table 1). Simple effects analysis revealed that at the group level, the intervention and control groups were not significantly different in the baseline condition ( $p = .647$ ), and the posttest intervention group had significantly lower response times than the control group ( $p = .033$ ). At the test time level, the posttest reaction time was significantly lower in the intervention group than in the pretest ( $p = .003$ ), and the posttest was not significantly different from the pretest in the control group ( $p = .499$ ). The results suggest that the intervention group was better able to perform the Stroop task after training than before training.

### 3.2.3 Analysis of Variance for Repeated Measures of Working Memory in the Intervention and Control Groups

A repeated-measures ANOVA on back count-backward doing 2 (group: intervention, control)  $\times$  2 (test time: pretest, posttest) found a significant interaction ( $F_{(1, 67)} = 10.70$ ,  $p = .002$ ,  $\eta^2_p = 0.138$ ). A simple effects analysis revealed that at the group level, the difference between the intervention and control group scores was not significant in the baseline condition ( $p = .982$ ) and significantly higher in the posttest intervention group than in the control group ( $p = .002$ ). At the test time level, posttest scores were significantly higher in the intervention group than in the pretest ( $p < .001$ ), and posttest and pretest scores were not significantly different in the control group ( $p = .827$ ).

### 3.2.4 Analysis of Variance for Repeated Measures of the Intervention and Control Groups at the Level of Mindfulness

A 2 (group: intervention group, control group)  $\times$  2 (test time: pretest, posttest) repeated measures ANOVA was done on the total mindfulness level score. The results showed a significant interaction ( $F_{(1, 63)} = 50.66$ ,  $p < .001$ ,  $\eta^2_p = 0.45$ ) (Table 1). Simple effects analysis showed that at the group level, the difference between the intervention and control groups was not significant at the pretest ( $p = .511$ ), and the intervention group had a significantly higher total score at the level of mindfulness at the posttest than the control group ( $p = .001$ ). At the time level, the intervention group scored significantly higher on the posttest than on the pretest ( $p < .001$ ), and the control group did not differ significantly between the posttest and pretest scores ( $p = .109$ ).

### 3.2.5 Analysis of Variance for Repeated Measures of Anxiety in the Intervention and Control Groups

A 2 (group: intervention, control)  $\times$  2 (test time: pretest, posttest) repeated measures ANOVA on the total anxiety scale scores showed a nonsignificant interaction ( $F_{(1, 60)} = 0.36$ ,  $p = .549$ ,  $\eta^2_p = 0.006$ ), a nonsignificant main effect of time ( $F_{(1, 60)} = 0.18$ ,  $p = .672$ ,  $\eta^2_p = 0.003$ ), and a group main effect was not significant ( $F_{(1, 60)} = 0.11$ ,  $p = .742$ ,  $\eta^2_p = 0.02$ ) (Table 1).

**Table 1.** Analysis of variance for repeated measurements of pre and post measurements in the intervention and control groups

	Intervention group (n = 35)		Control group (n = 34)		<i>F</i>	<i>p</i>
	Pre-test	Post-test	Pre-test	Post-test		
TMT-B	50.56 ± 18.00	42.88 ± 20.24	49.39 ± 16.38	55.46 ± 21.34	8.71**	.004
Stroop	14.51 ± 11.83	9.64 ± 9.30	13.32 ± 9.55	14.42 ± 8.93	6.89*	.011
Digit span test	4.26 ± 1.63	5.43 ± 1.85	4.26 ± 1.05	4.21 ± 1.27	10.74**	.002
FFMQ	104.31 ± 22.94	124.50 ± 25.44	108.24 ± 24.94	104.39 ± 23.32	50.66***	< .001
MASC	48.48 ± 13.51	46.81 ± 11.66	48.48 ± 14.28	48.77 ± 13.85	0.36	.549
SDQ	14.94 ± 6.13	14.94 ± 5.53	14.97 ± 5.84	15.27 ± 6.22	0.04	.835
Academic	0.01 ± 0.820	-0.06 ± 0.84	-0.01 ± 1.07	0.06 ± 1.04	3.152	.080

Note: \*  $p < 0.05$  \*\*  $p < 0.01$  \*\*\*  $p < 0.001$

### 3.2.6 Analysis of Variance for Repeated Measures of Emotion and Behavior in the Intervention and Control Groups

The results of the repeated measures ANOVA showed that after 11 weeks of training, the strengths and difficulties questionnaire total score interaction was not significant, the time main effect was not significant, and the group main effect was not significant (see Table 1).

### 3.2.7 Analysis of Variance for Repeated Measures of Academic Achievement for the Intervention and Control Groups

Results of the repeated measures ANOVA showed that the interaction was not significant ( $F_{(1,67)} = 3.152$ ,  $p = .080$ ), the main effect of time was not significant ( $F_{(1,67)} = 0.001$ ,  $p = .980$ ), and the main effect of group was not significant ( $F_{(1,67)} = 0.049$ ,  $p = .826$ ).

## 4 Discussion

This study showed that the use of a digital mindfulness intervention enhanced executive functioning in the intervention group, with improvements in mindfulness levels, but did not significantly improve in other areas. In this study, the mindfulness intervention allowed elementary school students to focus their attention on breathing, food, surrounding sounds, and various parts of the body through changes in their familiar bodies to focus on specific objects. The mindfulness exercises of positive breathing, positive action, and positive eating require practitioners to use a variety of cognitive abilities to adjust their state of consciousness and then follow guided meditation, a process that facilitates the training of abilities such as cognitive flexibility and inhibitory control [9].

The subjects of this study were fourth grade students in a bilingual primary school, aged between 10–11 years old, and fourth grade students are in a critical period of

prefrontal cortex development. A study found that by the ages of 10 and 11, the structure of executive functions gradually stabilized and had largely stabilized [6]. This suggests that the mindfulness intervention is appropriate and effective for fourth grade students in bilingual schools where executive functioning is stabilizing.

Regarding the level of mindfulness, the five-factor mindfulness scores on the posttest were significantly higher in the intervention group than in the control group, and the intervention group showed a significant increase in the level of mindfulness, while the control group didn't. This is consistent with domestic researchers' research on 12 weeks of mindfulness education for elementary school students, where students' mindfulness levels increased to some extent on all dimensions and total scores [18].

In the present study, anxiety status did not improve significantly, which is different from existing studies. A possible reason for this is the low anxiety scores and the absence of anxiety symptoms in the students in the baseline situation. Future recommendations are for large samples, increasing the duration of intervention, increasing the number of interventions, and adding parent or teacher questionnaires, etc.

In terms of academic achievement, the results showed no significant improvement in the intervention group, which is inconsistent with existing research [16]. One reason for the lack of significant improvement in academic achievement in the current study may be the use of adaptive testing in both English and math, and the possibility that a weekly intervention was not sufficient to significantly improve academic achievement.

## 5 Conclusion

In conclusion, an 11-week digital mindfulness intervention increased fourth grade students' levels of mindfulness. The intervention improved inhibitory control, cognitive flexibility, and working memory, but no significant changes were seen in total difficulty scores. The mindfulness intervention did not significantly improve anxiety levels or academic achievement. This study provides important evidence for the improvement of mindfulness intervention on the executive functioning and other aspects of elementary school students in bilingual schools, and also provides new directions for future mindfulness intervention research.

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