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ORIGINAL PAPER

Executive Function Training Through a Mindfulness-Based Neuroeducational Program in Elementary School Students

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Abstract

Objectives Cognitive processes underlying learning are essential for educational practice. Therapeutic interventions that incorporate mindfulness to enhance these processes are becoming increasingly popular, but few studies focused on the effectiveness of their application to the educational setting for the development of executive functioning. The objective of this study was to assess the effects of a neuroeducational program based on mindfulness techniques applied in the classroom on the executive functioning of second grade primary school students.

Method Forty-eight students were included, 25 in the passive control group and 23 in the intervention group. Participants were assessed before and after program implementation with the CARAS-R test to measure selective attention, the WISC-V Digits Span subtest to measure working memory, and the NEPSY-II Inhibition subtest to measure cognitive flexibility and inhibition.

Results Changes between pre- and post-intervention scores were analyzed separately for the control and experimental groups, and effect sizes were calculated to estimate the significance of the differences.

Conclusions Although both groups improved on the cognitive measures evaluated, our results indicate that the mindfulness-based program significantly improved students' working memory, inhibition, and cognitive flexibility. We conclude that this type of program can help teachers improve their educational practice with methodologies that promote the integral development of their students.

Preregistration This study is not preregistered.

Keywords Executive functions · Mindfulness · Education · Neuropsychology · Neuroeducation

Executive functions are considered high-level cognitive processes, but both their exact definition and measurement methods have been a source of controversy. In recent years, the model on executive functions proposed by Miyake et al. (2000) has become highly influential and has been supported by several additional studies (González-Andrade et al., 2022; Skei et al., 2023; Tabet et al., 2022). It identifies working memory, inhibitory control, and cognitive flexibility as central processes. Working memory refers to the brain's ability to maintain active information and manipulate it voluntarily. This function involves monitoring and encoding task-relevant information, as well as supervising information that remains active in memory. Inhibition, on the other hand, is related to the ability to deliberately control and repress a previously learned response to solve a task. Finally, cognitive flexibility refers to the ability to change the task when it is deemed necessary (Friedman et al., 2017; Miyake et al., 2000). Executive functions evolve slowly and progressively, and at different rates (Díaz & Guevara, 2016). They begin to develop from the first year of life, being noticeable around 6 months when the child self-controls their first simple movements, which gain in stability and subsequently mature, and develop regulating other cognitive resources. During this progressive development, the child may make mistakes that do not necessarily indicate executive dysfunction and may respond to a momentary loss of purpose and the consequent fall into automatic behaviors (Diamond, 2013).

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Executive functions are essential for a wide variety of functional tasks and their impairment can affect both academic and career success, the quality of relationships, and overall satisfaction with life.

Traditionally, educational precepts have been based on teachers' observation and interpretation of students. However, from a psychobiological point of view, we know that education is about the ability to shape student behavior through the acquisition of motor, emotional, and cognitive skills. This requires influencing and modifying the underlying brain processes (Ansari & Coch, 2006; Benarós et al., 2010; Dubinsky et al., 2019; Ferrero et al., 2016). From this perspective, the educational practices should not rely exclusively on the qualitative observation of students in the classroom but should incorporate lessons learned from the growing scientific research on brain functioning in relation to learning (Araya-Pizarro & Espinoza Pastén, 2020; Goswami, 2006). The scientific method can reveal the most effective techniques for the acquisition of knowledge according to the developmental age of students, allowing the construction of evidence-based neuroeducational programs. More research is needed to identify which programs are the most appropriate to enhance student learning (Goswami, 2006; Massonnié et al., 2020).

There is a growing body of literature addressing the potential benefits of mindfulness-based interventions. Recently, several meta-analyses have examined mindfulness in evidence-based interventions, with promising though inconclusive results. They have identified benefits for sleep quality (Rusch et al., 2019), eating disorders (Sala et al., 2020), depression, anxiety/stress, addictive disorders (Dunning et al., 2019; Goldberg et al., 2018), and chronic pain (Hanley et al., 2024; Hilton et al., 2017; Pérez-Fernández et al., 2022). On the other hand, a smaller group of studies have linked mindfulness practice with cognition. In the non-clinical adult population and in people over 60 years of age, there seems to be a small significant positive effect on executive function and working memory (Whitfield et al., 2022). Moreover, a French team of researchers conducted a meta-analysis on mindfulness and cognition, finding that it improved sustained attention and cognitive flexibility (Bulzacka et al., 2018). However, the meta-analysis by Dunning et al. (2019) on the effects of mindfulness-based interventions on cognition and mental health in child and adolescent populations showed clear benefits only in mindfulness, depression, and anxiety/stress, with active control group randomized controlled trial (RCT) studies and inconclusive effects on cognition (attention and executive functions). In pediatric populations, studies have mainly focused on clinical attention deficit hyperactivity disorder (ADHD) population, with partially positive results (Oliva et al., 2021). Improvements are identified against inactive controls, but not in comparison with other therapies. It is concluded that the practice of mindfulness can assist in ADHD therapy, but not replace existing treatments and therapies. All these meta-analyses highlight the poor methodological quality of many of the studies reviewed and the need for further research with more rigorous methodologies. Regarding mindfulness in the educational setting, some studies have analyzed its use to promote emotional well-being, self-esteem, and motivation to learn; however, little research has focused on assessing the effects of mindfulness on executive functions in the classroom (Bartos et al., 2021; Bockmann & Yu, 2022; Cohen et al., 2021; Flook et al., 2010, 2013; Rose & Lomas, 2020; Sharma & Palomares-Fernandez, 2023; Tortella et al., 2021; Weed et al., 2022). Existing literature points to the need to study its efficacy in schools through more rigorous research designs that minimize bias and produce high-quality evidence to guide school practice (Millett et al., 2021; Phan et al., 2022; Phillips & Mychailyszyn, 2022).

Currently, there is a growing body of research focusing on the use of mindfulness as an intervention for deficits in executive functions and it is recommended to develop proposals to determine which components of executive functions enhance mindfulness-based programs and which one provides the greatest benefit (Geronimi et al., 2020; Liebherr et al., 2024; Martin, 2024). Therefore, it is desirable to develop neuroeducational programs that help primary school students to optimize these processes. To our knowledge, none has been developed that uses mindfulness techniques for the improvement of executive functions. Consequently, an intervention program based on mindfulness in the educational context could be of great benefit not only for enhancing students' executive functions but could also impact academic performance.

In summary, there are currently several studies on the contribution of mindfulness to emotional management and attention, but there are fewer that analyze the impact of mindfulness on executive functions in the school context (Bartos et al., 2021; Cohen et al., 2021; Tortella et al., 2021; Sharma & Pomares-Fernandez, 2023; Van Ede & Nobre, 2023). The aim of this study was to evaluate whether a neuroeducational intervention program based on mindfulness techniques improves selective attention or capacity of selecting, and prioritizing the relevant contents, working memory, inhibition, and cognitive flexibility in a group of second grade students.

Method

Participants

A quasi-experimental design was used, specifically a pretest–posttest design including a passive control group. The selection of both experimental and control groups was not random but respected the school's own division of classes. A total of 48 students in the second year of primary school participated in this study. Of these, 25 received traditional classes, while the other 23 participated in the neuroeducational program, in sessions of approximately 45 min, 3 days a week for 10 weeks (total of 30 sessions). The inclusion criteria were (a) being 7–8 years old, and (b) having consent of the interested parties and their parents or legal guardians. Students with any type of neurodevelopmental disorder, psychopathological disorder, or diagnosed maturational delay were excluded. The intervention group consisted of 10 males and 13 females with a mean age of 7.29 ± 0.41. The control group had a mean age of 7.60 ± 0.46 years, and consisted of 10 boys and 15 girls.

Procedure

First, we requested permission from the school administration to carry out the study and communicated with families to obtain their informed consent. Once obtained, the families were informed of the study through a participant document that provided information about the research project, the responsible researchers and their contacts, the objective of the study, the study's inclusion and exclusion criteria, information about the participation in the study (duration, timing, characteristics of the neuroeducational program), the benefits and risks of participation, how to express agreement, or refusal to participate, the confidentiality of participation, no financial compensation for participation, the possibility of abandoning the study at any time, and information on the use of the data obtained in the research. Likewise, the family could contact the research team at any time to resolve any questions. Once the family had been informed of all these previous aspects of the study, they signed an informed consent to participate in the study.

Second, the two second grade classes participating in the study underwent a pretest. One of the classes was then administered the neuroeducational program (experimental group) while the other continued with its traditional sessions (passive control group). The experimental group was chosen intentionally according to availability in the classroom. The program was carried out in sessions of approximately 45 min for 10 weeks (30 sessions), and the sessions were held during school hours, although a series of activities were also proposed to be carried out at home during the weekend. After the implementation of the program, a posttest evaluation was carried out to both groups.

Following the indications of Greenland (2010), we developed a neuroeducational program based on mindfulness techniques to enhance selective attention, working memory, inhibition, and cognitive flexibility. The program consisted of 30 sessions of approximately 45 min, and was conducted three times per week (Monday, Wednesday, and Thursday) for 10 weeks. Each session was focused on working one of the aforementioned cognitive processes and the difficulty of the tasks gradually increased over the weeks. All sessions were held during school hours (see Supplementary Information). The assessments were conducted by two professionals with extensive experience in neuropsychological evaluations. The mindfulness intervention sessions were carried out by an expert in neuroeducation.

Measures

The instruments used for their measurement and the scoring. The dependent variables measured in the study are visual selective attention, measured by the CARAS-R test; working memory, measured by the WISC-V Digit subtest; inhibition and cognitive flexibility, measured by the NEPSY-II Inhibition subtest. The independent variable is the effect of the program, measured by the pretest–posttest change in all dependent variables.

The Test of perception of differences-revised (CARAS-R) was used to assess visual selective attention, the ability to perceive, quickly and accurately, similarities and differences, providing a measure of selective attention. Students are presented with a template containing 60 graphic items. Each item consists of three faces drawn schematically (round face with eyes, eyebrows, mouth, and hair). The objective is for the child to determine which face is different from the other two and to cross it out. The time to complete the test is 3 min. The test can be administered individually or collectively. The test has been normed on a national sample of over 12,000 schoolchildren (Thurstone & Yela, 2012). Hits and net hits (A–E) scoring was analyzed.

The Digits Span subtest of the Wechsler Intelligence Scale for Children (WISC-V) was used to assess working memory and involved the memorization of numerical sequences. The WISC-V assesses intelligence in a population aged 6 years to 16 years and 11 months and is composed of five primary index scales and four ancillary index scales. The progressive digit memory test requires the subject to repeat the numbers that an examiner says aloud respecting the order. Conversely, the inverse digit memory test requires the subject to repeat the numbers in reverse order to that followed by the examiner. The test has a total duration of approximately 10 min (Wechsler, 2015). Direct, inverse, and total scoring were analyzed.

Finally, the Inhibition subtest of the NEPSY-II was used. The NEPSY II neuropsychological assessment battery has been designed and validated to assess neuropsychological development in children between 3 and 16 years of age. It has three modalities of activities (naming, inhibition, and switching), which allows the assessment of attention and other aspects related to executive function such as inhibitory control and cognitive flexibility. In this study, we specifically use the subtest to assess inhibition for the population aged 5 to 16 years, which allows us to obtain measures for two constructs, inhibition and flexibility. To perform the test, the student must, in front of a series of geometric figures (circles and squares) or arrows (black and white), say the name of each geometric figure, or the direction of each arrow (naming mode). Then, the child has to give an alternative response (inhibition) and, finally, the child must change his/her behavior according to a characteristic of the stimulus presented (switching – cognitive change/flexibility). In this way, we estimate the capacity of children from 7 years of age to inhibit automatic responses, and their ability to switch between different types of responses (Korkman et al., 2007). Inhibition – time, inhibition – total errors, inhibition – combined scaled score, change – time, change – total errors, and change – combined scaled scoring was analyzed.

Data Analyses

The analyses were performed using SPSS statistical software version 25.0 for Windows. The following analysis strategy was used. First, a descriptive study of central tendency and dispersion of the dependent variables was conducted. Second, a normality test: The normality of the dependent variables was tested separately for the control and experimental groups using the Shapiro–Wilk test. Third, the initial equivalence of the groups was assessed by comparing pretest scores using the Mann–Whitney *U* test. Fourth, separate analyses were conducted for pretest and posttest scores using the Wilcoxon test. Finally, using the rank-biserial correlation statistic, the significant results of the statistical tests were accompanied by effect sizes to estimate the magnitude of the differences (Tomczak & Tomczak, 2014). This effect size is interpreted similarly to a correlation coefficient. Additionally, differences in effect sizes between experimental and control groups were studied using the *z*-test. Following Lenhard and Lenhard (2016), effect sizes based on Cohen's *d* were transformed to correlation coefficients. According to Hattie (2008), effect sizes in the educational field are contextualized with an average of 0.2. Effects above this value are considered large, indicating a higher impact than usual in education. Effects between 0.1 and 0.2 are equivalent to those produced by teacher or school characteristics, and are also noteworthy.

Results

Table 1 shows the descriptive results of the pretest and posttest evaluations for the cognitive variables. The initial values of the two groups appear similar from a descriptive perspective. However, in some variables, there are significant differences between the control and experimental groups (Table 3).

Table 2 presents the results of the normality test, indicating that most variables do not achieve normality in the distribution of scores. Consequently, nonparametric statistics were used in the inference tests.

To check the initial equivalence of the groups, pretest scores between the experimental and control groups were compared. As shown in Table 3, there are statistically significant initial differences between the groups in the variables Inhibition – combined scaled score, Inhibition – time, and Inhibition – total errors, with large effect sizes (values above 0.20). Consequently, intra-group comparisons were carried out.

A comparison of intra-group changes was made using the Wilcoxon test for each group separately. Table 4 shows the improvement in attention in the control group, with large effect sizes for the variables of Hits and Net hits ($r = –0.59$). In the experimental group, the trend of improvement in attention is not significant.

Regarding working memory, the experimental group achieved significant changes in all variables, with large effect sizes (values above –0.90 in the Digits Total score). In contrast, the control group did not exhibit statistically significant changes in these variables, although the effect size for Digits Inverse and Total score indicates a worsening in the posttest.

Regarding flexibility, both groups significantly increased their posttest scores for the variables Change – combined scaled score and Inhibition – time, with the experimental group achieving nearly double the effect size in the former. The experimental group also shows a significant increase in the score for Inhibition – combined scaled score, with a large effect size ($r = -0.84$). Although no significant results are identified for the control group, the effect size indicates a considerable improvement in this variable.

A notable aspect of the intervention's effects on the flexibility variables in the experimental group is the significant decrease in total errors for both Inhibition and Change, with large effect sizes (values of 0.87 and 0.96, respectively).

The effect sizes observed in this study have important educational implications. For instance, the large effect sizes in improvements in working memory in the experimental group suggest that the mindfulness-based neuroeducational program can significantly enhance cognitive functions critical for academic success. The improvements in flexibility and attention, although less pronounced, also indicate potential benefits for classroom performance, particularly in tasks requiring sustained attention and cognitive flexibility. These findings, where effect sizes above 0.20 (Hattie, 2008), are considered substantial and indicative of meaningful educational interventions.

Table 1 Descriptive analysis of study variables

Group	Cognitive domain	Instrument	Scoring	Pretest					Posttest				
				Average	Deviation	Median	Min	Max	Average	Deviation	Median	Min	Max
Control	Visual selective attention	CARAS-R	Hits	48.04	11.23	50	12	60	51.73	10.28	55.5	17	60
			Net hits	43.46	14.08	46	0	60	47.59	13.24	53	6	60
	Working memory	WISC-V Digits	Direct – score	7.32	1.46	8	5	12	7.24	1.16	7	5	9
			Inverse – score	6.84	1.62	7	4	9	6.16	1.65	6	4	9
			Total score	18.88	3.22	19	12	26	17.52	2.70	18	11	21
	Inhibition and cognitive flexibility	NEPSY-II Inhibition subtest	IC scaled score	10.60	3.38	11	1	14	11.64	3.31	12	4	17
			CC scaled score	9.52	2.73	10	4	15	10.96	3.76	11	2	16
			Inhibition – time	9.22	2.56	9	3	13	11.24	3.54	12	3	17
			Inhibition – E	4.22	4.7	3	0	21	3.24	2.96	3	0	11
			Change – time	9.87	1.96	10	7	13	11.36	2.78	11	5	15
			Change – E	11.83	6.58	10	5	26	9.60	7.73	9	0	33
Experimental	Visual selective attention	CARAS-R	Hits	46.77	11.09	52	18	57	47.28	9.02	48	30	60
			Net hits	43.22	11.30	46	12	54	45.19	10.59	48	21	60
	Working memory	WISC-V Digits	Direct – score	7.78	1.78	8	4	11	9.14	2.17	9	6	15
			Inverse – score	6.35	1.67	7	4	10	6.35	1.67	9	4	12
			Total score	19.17	4.12	19	12	29	25.33	5.82	25	15	37
	Inhibition and cognitive flexibility	NEPSY-II Inhibition	IC scaled score	8.61	3.26	8	3	16	12.43	1.66	13	8	15
			CC scaled score	9.09	3.33	9	3	15	11.80	2.89	12	7	15
			Inhibition – time	7.65	2.40	7	4	16	10.14	2.01	10	7	14
			Inhibition – E	6.96	4.97	7	0	17	1.95	1.43	2	0	6
			Change – time	10,00	2.92	10	5	19	10.48	2.18	11	6	14
			Change – E	14.43	10.21	11	4	44	6.48	4.09	6	1	17

IC inhibition – combined scaled score; *CC* inhibition – combined scaled score; *E* total errors

Table 2 Shapiro–Wilk normality tests on pretest and posttest scores by group

Instrument	Scoring	Group*	Pretest			Posttest		
			n	Shapiro–Wilk	*p*	*n*	Shapiro–Wilk	*p*
CARAS-R	Hits	C	24	0.86	0.00	22	0.710	0.00
		E	22	0.80	0.00	21	0.946	0.29
	Net hits	C	24	0.87	0.01	22	0.790	0.00
		E	22	0.83	0.00	21	0.946	0.26
WISC-V Digits	Direct – score	C	25	0.85	0.00	25	0.910	0.03
		E	23	0.94	0.14	21	0.928	0.12
	Inverse – score	C	25	0.91	0.03	25	0.914	0.04
		E	23	0.92	0.05	21	0.887	0.02
	Total score	C	25	0.96	0.49	25	0.923	0.06
		E	23	0.97	0.58	21	0.974	0.83
NEPSY-II Inhibition	IC scaled score	C	23	0.87	0.01	25	0.941	0.15
		E	23	0.95	0.27	21	0.919	0.08
	CC scaled score	C	23	0.97	0.63	25	0.948	0.23
		E	23	0.97	0.54	21	0.879	0.01
	Inhibition – time	C	23	0.95	0.23	25	0.973	0.72
		E	23	0.83	0.00	21	0.957	0.47
	Inhibition – E	C	23	0.77	0.00	25	0.876	0.01
		E	23	0.95	0.28	21	0.902	0.04
	Change – time	C	23	0.93	0.09	25	0.930	0.09
		E	23	0.93	0.09	21	0.965	0.62
	Change – E	C	23	0.86	0.00	25	0.843	0.00
		E	23	0.87	0.01	21	0.940	0.22

*C control; E experimental; IC inhibition – combined scaled score; CC inhibition – combined scaled score; E total errors

Table 3 Initial differences between control and experimental groups with Mann–Whitney *U* test and effect size

Instrument	Scoring	Mann–Whitney *U*	*p*	Effect size (rank biserial correlation)
CARAS-R	Hits	249	0.74	0.06
	Net hits	257	0.87	0.03
WISC-V Digits	Direct – score	242	0.33	0.16
	Inverse – score	234	0.26	0.19
	Total score	288	1.00	0.00
NEPSY-II Inhibition	IC scaled score	159	0.02	0.40
	CC scaled score	242	0.62	0.09
	Inhibition – time	148	0.01	0.44
	Inhibition – E	168	0.03	0.37
	Change – time	262	0.97	0.01
	Change – E	242	0.63	0.09

IC inhibition – combined scaled score; *CC* inhibition – combined scaled score; *E* total errors

Discussion

The aim of this work was to evaluate whether a neuroeducational intervention program based on mindfulness techniques could improve cognitive processes related to the executive function such as attention, working memory, cognitive flexibility, and inhibition, our main hypothesis being that such a program would allow students to obtain relatively better scores in selective attention, cognitive flexibility, and working memory competencies (DiCarlo et al., 2020; Haberlin & O Grady, 2017; Wood et al.,

Table 4 Pretest and posttest differences with the Wilcoxon *W* test by group and effect size

Cognitive domain	Instrument	Scoring	Control			Experimental			*Z* (*p*) *Dif r*
			Wilcoxon *W*	*p*	Effect size*	Wilcoxon *W*	*p*	Effect size (*r*)*	
Visual selective attention	CARAS-R	Hits	43.00	0.02	−0.59	108.00	0.93	0.029	−2.29 ($p=0.01$)
		Net hits	31.00	0.03	−0.59	91.00	0.40	−0.21	−1.52 ($p=0.06$)
Working memory	WISC-V Digits	Direct – score	82.00	0.80	0.07	3.00	0.00	−0.96	−6.37 ($p<.001$)
		Inverse – score	165.00	0.09	0.43	18.50	0.00	−0.78	−4.90 ($p<.001$)
		Total score	169.50	0.06	0.47	3.00	0.00	−0.97	−8.33 ($p<.001$)
Inhibition and cognitive flexibility	NEPSY-II Inhibition	IC scaled score	56.00	0.07	−0.47	16.50	0.00	−0.84	2.35 ($p<.001$)
		CC scaled score	54.50	0.03	−0.53	15.50	0.00	−0.85	2.19 ($p=0.01$)
		Inhibition – time	9.00	0.00	−0.92	24.50	0.01	−0.74	−2.10 ($p=0.02$)
		Inhibition – E	113.00	0.24	0.32	178.50	0.00	0.88	−3.36 ($p<.001$)
		Change – time	12.50	0.00	−0.87	70.50	0.52	−0.18	−4.87 ($p<.001$)
		Change – E	148.00	0.26	0.28	187.00	0.00	0.97	−5.75 ($p<.001$)

IC inhibition – combined scaled score; *CC* inhibition – combined scaled score; *E* total errors; *Z*(*p*) indicates *Z*-test and the associated probabilities; *Dif r* indicates that this *Z*-test is regarding the difference between the effect sizes of the control and experimental groups

*Negative values indicate a higher score on the posttest

2018). As mentioned earlier, executive functions are high-level cognitive processes, whose main components, according to the model by Miyake et al. (2000), are working memory, inhibitory control, and cognitive flexibility.

We performed a comparison of age, sex, and cognitive variables between the experimental group and the control group. Both were equivalent in age and sex, and the only cognitive variables showing significant differences between groups in the pretest were Inhibition – combined scaled score, Inhibition – time, and Inhibition – total errors. This analysis allowed us to ascertain the baseline cognitive characteristics and associated needs of the groups. On the other hand, the posttest evaluation showed differences between groups in both attention and working memory, which could indicate that students in both groups experienced improvements in some variables independently of having received the mindfulness-based program. This is an interesting fact because it allows us to conclude that traditional school training also helps developing cognitive processes which foster the acquisition of knowledge and skills (Dirlikov et al., 2014; Menezes et al., 2015; Sonuga-Barke & Coghill, 2014).

On the other hand, considering the differences in pretest–posttest scores between groups, the results indicate that the experimental group obtained a better score in the variables of working memory, and although its working memory score was already higher in the pretest than that of the control group, the program significantly improved it. However, the observed improvements in attention within the control group, but not in the experimental group, may appear paradoxical, given that mindfulness interventions are generally aimed at enhancing attentional control. This may be because we could not control for this group performing other activities with effects on attention in parallel. Likewise, although not statistically significant, the control group already had a higher score in attention in the pretest, meaning that it had a tendency to obtain better results in this cognitive process. In conclusion, the data seem to indicate that the mindfulness-based intervention improves complex processes related to executive functions, such as working memory, inhibition, and cognitive flexibility (Flook et al., 2010) did not significantly improve attention. Additionally, although the control group improved in attention and inhibition, the experimental group improved in working memory, inhibition, and flexibility, which shows that the neuroeducational program promoted an improvement trend in these executive processes. This upgrade may be explained by the selection of tasks for the program, which may have required a greater involvement of higher-level executive processes in the field of metacognition. It is not uncommon to find improvement of executive functions in mindfulness-based educational interventions (Wood et al., 2018).

Limitations and Future Directions

Future projects should continue to evaluate the effectiveness of this type of programs, as they undoubtedly have a direct and positive impact on cognitive development, learning, and academic performance (Huguet et al., 2017). This study had several limitations. One of them was related to the duration of the program, since although the duration and timing of the intervention program is based on recommendations and previous studies (Crompton et al., 2024; Siebelink et al., 2021), we believe better results would be obtained with a longer program. Including neuroeducational programs with this approach throughout the entire academic year would help enhance the benefits in the short, medium, and long term.

Also, conducting the posttest in June may have affected the results, since at this time of the year the students are more tired and the weather is adverse, which may induce a state of lower concentration and thus underestimate the results of the tests (Anderko et al., 2020; Wang & Liu, 2024). It would be advisable to conduct the posttest in May, which could be reflected in better performance on attentional tasks.

In future studies, it would be advisable to the extent possible, to carry out these neuroeducational programs from the beginning of the school year trying to carry out the activities during the early hours of the morning and carry out assessment throughout the course to learn about the improvements of the interventions at different times of the school year. Finally, we were unable to control, first, the activities that we proposed to the experimental group to be carried out at home during the weekend; and second, the activities performed by the control group which could improve cognitive processes, which hindered the quantification of the program's effect. For subsequent interventions, we suggest monitoring these activities parallel to the intervention program itself and designing a more extensive program (time and schedule) that incorporates a greater number of activities to work on attention, since this has been the process with the worst results. In addition, we suggest including joint sessions with students and families to improve control over external activities, and enhance the benefits of the program and enhance control over external activities by keeping a detailed log of both experimental and control group activities outside the intervention sessions.

At the statistical level, to minimize interference with the normal functioning of the school, the selection of the groups was not random since the groups assigned was based on the class division to which each student belongs. As specified in evidence-based medicine studies, randomized controlled trials (RCTs), although desirable for research, may not be appropriate for all questions due to the reality of the context and variables to be studied (Fletcher, 2009; Swanson et al., 2010). However, in future research, it is advisable to implement a randomized controlled trial (RCT) design to eliminate selection bias and enhance internal validity, or to enlarge the sample and randomize it, in order to test the reliability of these results. Reliabilities could not be calculated for the sample because individual responses to each test item were not available. Only the total scores for each dimension were accessed. In future studies, it is recommended to include more information on the reliability and validity of the measures.

We also suggest performing statistical analyses to control for sociodemographic variables with a view to better assessing the effect size of the differences, as well as conducting a medium- and long-term follow-up (between 6 months and 1 year) of the program's effects to check whether its positive effects are maintained. Measurement variables could be included to check if the effects effectively translate into greater autonomy, and better execution of daily activities requiring attention and executive functions (Laatsch et al., 2020). Finally, we recommended incorporating long-term follow-up assessments to evaluate the sustained impact of the mindfulness intervention over time. Also, it would be interesting to implement mixed-methods approaches, combining quantitative and qualitative data, to understand the intervention's effects comprehensively. Despite the aforementioned limitations, to our knowledge, this is one of the few studies developing a neuroeducational intervention program based on mindfulness that has been shown to help improve processes related to executive functioning. In the future, similar intervention programs in the classroom could be helpful for teachers to enhance their educational practice by adopting new methodologies that favor the integral development of their students.

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Data Availability Data are available from the corresponding author upon email request.

Declarations

Ethics Approval This study was conducted in strict accordance with Helsinki Declaration and it has been approved by the Ethics Committee of the Hospital Clínico San Carlos with registration number 21/422-E.

Informed Consent Informed consent was requested from the school to conduct the study. Subsequently, families were informed about the study and provided with the information sheet and informed consent form for their signature prior to commencing any procedures.

Use of Artificial Intelligence No artificial intelligence was used in this study.

Conflict of Interest The authors declare no competing interests.

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