Journal of Child and Family Studies (2018) 27:2632–2642
https://doi.org/10.1007/s10826-018-1073-9

ORIGINAL PAPER

The Effects of Mindfulness Practice on Attentional Functions Among Primary School Children

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Published online: 6 April 2018

Abstract
In recent years, many studies have shown the positive impact of mindfulness training on multiple measures of physical and mental well-being in clinical and nonclinical populations. Although it is believed that many of the positive effects of mindfulness training are mediated by its effects on attention, few studies have explored the effectiveness of mindfulness on attention in children. The present study aimed to examine the effects of mindfulness practice on sustained and selective attention in elementary school children. The study included 101 third, fourth and fifth graders. The mindfulness group consisted of 58 fourth grade pupils. Attention assessment included the Computerized Continuous Performance Task and the Conjunctive Visual Search Task, measuring sustained and selective attention, respectively. Measurements were collected before the beginning and after the end of a 10-week mindfulness workshop. The mindfulness workshop was delivered in small groups of 3–4 pupils, allowing personal care. A significant improvement in both attentional tasks was obtained in the experimental group. The impact of effectively improving children's attention, and specifically reducing impulsivity, and the possibility to do it effectively using mindfulness is discussed. Finally, the limitations of the current study and suggestion for further research are mentioned.

Keywords Mindfulness · Children · Sustained attention · Selective attention · Impulsivity

Introduction

In recent years, interest has grown in the benefits mindfulness-based training can offer in physical and mental well-being in clinical and nonclinical populations, including reduced anxiety (Kabat-Zinn et al. 1992), depression (Kumar et al. 2008), stress (Chiesa and Serretti 2009), avoidance and rumination (Kumar et al. 2008), cognitive reactivity (Raes et al. 2009) and sleep disturbances (Carlson and Garland 2005; Winbush et al. 2007). It is believed that many of the positive effects of mindfulness training are mediated by its effects on attention (Brown et al. 2007; Carmody 2009; Hölzel et al. 2011; Malinowski 2013; Posner et al. 2015; Shapiro et al. 2006; Tang et al. 2015). A central feature of mindfulness-based interventions is that they teach the trainees to control the direction of their attention, so that it becomes focused on experiences of the present moment (e.g. one's breathing) while being resilient to distraction by other, internal or external events. This is exemplified by the most widely used operational definition of mindfulness as: "the awareness that emerges through paying attention on purpose, in the present moment, and nonjudgmentally, to the unfolding of experience moment by moment" (Kabat-Zinn 2003, p. 145). Accordingly, the improvement of attentional skills, and in particular of attention regulation, features centrally in most conceptualizations of mindfulness training (Hölzel et al. 2011; Lutz et al. 2008; Malinowski 2013; Slagter et al. 2011; Tang and Posner 2009; Wallace and Shapiro 2006). Posner et al. (2015) argued that mindfulness training yields similar attentional improvements to those of network training, which trains specific brain attention networks by practicing cognitive tasks thought to engage these networks. According to these authors, mindfulness training develops a brain state that may influence these and other attentional networks (Hillman et al. 2008; Hölzel et al. 2011; Tang et al. 2007 2014; Tang et al. 2012a).

Research assessing the ability of mindfulness to improve attentional abilities in adults has yielded mixed results (for a

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review, see Chiesa et al. 2010), possibly owing to the use of different protocols in each study, ranging from a few hours of practice (e.g. Wenk-Sormaz 2005), through 8 weeks Mindfulness Based Stress Reduction (MBSR) (e.g. MacCoon et al. 2014) to 3 months retreats (e.g. MacLean et al. 2010). Among the studies supporting the effects of mindfulness meditation on attentional processes, there are reports on improvements in sustained attention (Lutz et al. 2009; MacLean et al. 2010; Morrison et al. 2014; Semple 2010), attention regulation (Tang et al. 2007; Wenk-Sormaz 2005), selective attention (Jensen et al. 2012), and orienting of attention (Jha et al. 2007), as well as in changes in neural activity and underlying neural architecture (Malinowski 2013; Moore et al. 2012). Importantly, it has been claimed that mindfulness improves the ability to disengage attention from unexpected and emotionally charged stimuli (Bögels et al. 2010). Other studies, however, have found no differences between controls and participants in mindfulness workshops in sustained attention (MacCoon et al. 2014), attention regulation (Jha et al. 2007; Semple 2010), orienting of attention (Tang et al. 2007) or alerting of attention (Jha et al. 2007; Tang et al. 2007).

Less research has been conducted in children; however, the results, which are based on cognitive tests or parents' and/or teachers' reports, seem promising. Improvements after mindfulness practice were reported in sustained attention (Berto and Barbiero 2014; Napoli et al. 2005), attention regulation (Felver et al. 2017; Flook et al. 2010), orienting of attention (Felver et al. 2017; Napoli et al. 2005), alerting of attention (Felver et al. 2017) and in parents' reports of attention problems (Semple et al. 2010). However, other studies did not reveal significant effects of mindfulness practice on attention (e. g., no changes in sustained attention, Napoli et al. 2005).

There are several reasons for aiming to increase attentional skills in children. Recent national surveys in the U.S. have documented an increase in the prevalence of attention deficit hyperactivity disorder (ADHD) among children during the past decade (e.g. Boyle et al. 2011), and there is a concern that the growing internet and mobile phone usage may exacerbate attentional problems (Hadlington 2015; Ralph et al. 2014). Consistent evidence suggests that attention related skills such as task persistence and self-regulation, and the ability to control and sustain attention, are vitally important for school success (Janus and Duku 2007), predict academic achievement during preschool and the early elementary grades (Alexander et al. 1993; Duncan et al. 2007; Smith-Donald et al. 2007), and have a central role in psychosocial development (Eisenberg et al. 2004). In addition, there is a comorbidity between attention deficit and anxiety (Bowen et al. 2008), and anxiety is related to behavioral problems (Woltering and Lewis 2013) and reduced academic performance (Seipp 1991). Given that mindfulness training may provide a simple and efficient method to train attention (MacLean et al. 2010; Tang et al. 2012b), additional studies would reveal the potential of mindfulness to improve attention in educational settings.

Attentional deficits represent a pivotal problem among this population. Some studies have evaluated the feasibility and effectiveness of mindfulness training for children and adolescents with ADHD with promising results. Most of these studies have combined training for children with parallel mindful parenting training (e.g. Bögels et al. 2008; Haydicky et al. 2012; Singh et al. 2009; van der Oord et al. 2012). In a recent review, Mitchell et al. (2015) summarized studies aimed at the assessment of mindfulness training in the ADHD population, separately for children and adolescents and for adults. Findings among both children and adolescent samples and among adult samples have shown promising results suggesting that mindfulness training among the ADHD population is feasible and acceptable. However, most of the studies suffer from methodological issues, limiting generalizability and indicating the need for larger, more methodologically rigorous trials.

The purpose of the present study was to investigate the impact of mindfulness practices on attention in elementary school children. We tested the participants before and after mindfulness training, in comparison to peers who did not practice meditation. We tested the effects of mindfulness training on sustained attention and selective attention. We hypothesized that the training would improve attentional functions of children in the experimental group only.

Method

Participants

The study included 101 third, fourth and fifth graders from an elementary school in central Tel Aviv. The experimental group consisted of 58 fourth grade pupils, 30 boys and 28 girls, from two fourth grade classes (of 24 and 34 children), with ages ranging from 9.6 to 10.7 years (mean = 10.1, std. dev. = 0.3). Since the school principal did not agree to administer the mindfulness workshop to only part of the children in the fourth grade, the control group consisted of 43 pupils from third and fifth grade classes (Mean age = 10.17, std. dev. = 1.01). The third grade class was randomly selected between three classes, and the fifth grade class randomly selected between two. The third graders included 22 pupils, 11 boys and 11 girls, with ages ranging from 8.7 to 9.8 years (mean = 9.23, std. dev. = 0.33). The fifth grade group included 21 pupils, 9 boys and 12 girls, with ages ranging from 10.6 to 11. 7 years (mean = 11.11, std. dev. = 0.35). Children received no compensation for participation in the study. No exclusion criteria were applied, as the chief

scientist of the Israeli Ministry of Education does not allow the gathering of any information (e.g. academic or health related) about children from the school authorities. With alpha set at 0.05, a sample size of 21 per group (the size of the smallest group in this study) provides 76% power to detect an effect size of $d = 0.4$.

Procedure

The attention tasks were performed over 2 days, between 9:00 and 13:30, in the school's computer room. On both days the number of experimental and control participants was balanced. Commonly, attention tests are administered individually in a quiet environment. However, due to the fact that the tests had to be administered in the school, to a large number of children in a short period of time, participants were tested in groups of 12, divided into three groups of four, with each group under the supervision of another experimenter. The non-personalized administration was most probably the reason for some participants not understanding the task properly, and accordingly having to be discarded. Experimenters explained the tasks to be performed and ensured that the children understood. Each attentional task was preceded by two training sessions, the first performed by the experimenter in front of four children, and the second by each participant. During training, participants received a feedback sound for error (beep). During the tests, no feedback was provided. Children were instructed to work quietly, respond as quickly and accurately as possible, and remain in the room until all children completed the tasks. All children performed the CPT first. As indicated above, The CPT was performed without interruption, whilst in the search task, participants had the option to take short breaks at the end of each series. The full duration of each session was about 30 min. Computerized attention software and data were removed from school computers at the end of each measurement round.

The study was conducted in accordance with ethical guidelines for human subjects at Tel Aviv University and approved by the chief scientist of the Israeli Ministry of Education. Participants' parents provided signed consent for their children's participation in the study, and children were told that they could cease their participation in the study at any time. No children participated in the study without parental consent. Parents were given contact information to obtain further details about the study. Parents and pupils were presented with and affirmed a confidentiality commitment.

Workshop

For 10 weeks, the experimental group participated in a weekly workshop, held at school at 10 a.m, while children in the control group studied as usual. The program was delivered during the second half of the school year by students from Tel Aviv University, who participated in a mindfulness training practicum in which during the first semester they were first trained to practice themselves, and then to deliver the practice to children [for a detailed protocol, see (Tarrasch 2014)]. Accordingly, the instructors had only basic proficiency in teaching mindfulness to children. Each session lasted approximately 45 min, in small groups of 3–4 pupils, which allowed personal attention. The groups were spread at different locations in the schoolyard, trying to separate as much as possible between them, in order to allow some privacy. Blankets were used on the floor in order to set the "borders" for each group. The conditions were far from ideal in terms of noise and distractions. However, in spite of this fact, the workshops functioned well. The teacher of the practicum was present at school throughout the workshop. Each week he joined two of the groups, and at the end of each meeting all students congregated to share their experiences, discuss difficulties and receive feedback.

The children's mindfulness training was based on mindfulness principles and the Mindfulness Based Stress Reduction (MBSR) method. Students worked based on a protocol in which each session included the practice of three specific exercises, aiming at raising the children's awareness of physical processes, feelings and thoughts. The exercises used are listed and described in Table 1.

The adaptation of the program to children was based on several principles, aiming to gamify and personalize the practice, especially during the first sessions. The exercises were short, lasting between 5 and 10 min., and followed by a discussion allowing children to share their difficulties, feelings and discoveries. The length of the exercises increased from session to session throughout the semester. The exercises included challenges, such as balancing a bottle on the top of the head while practicing mindful walking or mindful eating with eyes closed aiming to guess the color of a little candy, only by its taste. If the children were uncalmed they were asked to run as fast as they could for one minute, then stop, freeze and feel the breathing and the heart beats, and only then practice mindful walking. Mindful walking could be held as a contest where the last child arriving would be the winner. Yoga practice was accompanied by drawn instructions with the caricature of a lion. Children were asked in the first times to imagine that they are animals and even imitate voices of animals while practicing the different positions (e.g the sound of a snake while in the snake position). In comparison to adults, the exercises were more physical and playful. In cases where children had problems to concentrate, short games were played, before continuing with the protocol. The protocol was flexible enough to allow changes in accordance with

Table 1 Exercises used and their description

Exercise	Description
Breathing awareness	Children are trained to pay attention to each inhalation and exhalation with aids such as counting breaths
Mindful eating	Participants are instructed to slowly smell, hear, and eat cut fruits
Walking meditation	Mindful slow walking noticing the lifting, moving and placing of each leg over the ground, with focused attention on body sensations and/or breathing
Listening to the here and now	Entailing deliberate focused observation of sensory inputs in the present moment, including elements such as the chair you are sitting on, the room you are in, the time of day, smells and sounds
Basic yoga	The sun salutation
Imagining one's own safe peaceful place	Vividly visualizing it and paying attention to all its details
Meditation bubble	Each thought that arrives enters a bubble, rises up, and disappears when the bubble bursts, with the child invited to wait curiously for the next thought

the mood and concentration level at each session. Homework sometimes included asking the children to teach their parents an exercise.

After each exercise, children shared their experiences and feelings. Children were asked to practice at home as much as possible; however, no means of ensuring that they did so were applied. Each workshop opened with a brief conversation about the previous session and about practice at home. The discussions between the exercises were planned such that different topics were discussed throughout the sessions, aiming at strengthening different qualities. Session by session content is presented in Table 2. For an example of a session, see Table 3.

Table 2 Session by session content

Week	Session content
1	Introduction. What is mindfulness? How to practice?
2	How to cope with stressful situations
3	Awareness to our reactions in challenging situations
4	Automatic pilot. Learning to chooses our reactions in challenging situations
5	Develop the ability to concentrate
6	Further development of the ability to concentrate
7	Explore ways to integrate mindfulness in everyday life
8	Further integration of mindfulness in everyday life
9	How to be more attentive to friends and others
10	Wrap-up, and motivation to keep practicing

Table 3 Example of a session: Session 2

Exercise	Length
Welcome and discussion of the home exercise during the past week: Mindful eating of the first bite at each dinner and sharing the experiences with the family.	5 min.
Imagining one's own safe peaceful place	8 min.
Sharing the experiences of the own safe peaceful place, and how it can help us in coping with stressful situations	5 min.
Practice of breathing awareness	8 min.
Sharing the experiences during breathing awareness, and commenting on how stress affects the breathing rate and depth	6 min.
Mindful eating	6 min.
Sharing experiences during mindful eating. Wrap-up, and homework explanation: Practice during the week the own safe peaceful place, draw it, and vividly remember it in stressful situations	7 min.

Measures

The dependent measures were derived from two computerized tasks of attention from a set developed by Tsal et al. (2005).

Continuous performance task

The first, designed to measure sustained attention, was the Computerized Continuous Performance Task (CPT), based on Rosvold et al. (1956). During the CPT, a single stimulus appears for 100 msec. on a computer screen with a black background, at varying intervals of 1000, 1500, 2000, or 2500 msec. Stimuli appear in the center of the screen, as different geometric shapes of different colors. Stimuli size ranged from 2.5 to 2.7 cm in height and 2.6 to 3.0 cm in width. Sixteen different combinations of colors and shapes were used, including squares, circles, triangles and stars in red, blue, green or yellow.

Each participant was presented with a total of 320 trials, preceded by 15 training trials. The total length of the task was 12 min without a break. Participants were asked to respond as quickly and accurately as possible to the predefined target of a red square, by pressing the spacebar with the index finger of the dominant hand. The target appeared in 30% of trials. Participants were instructed not to respond to stimuli that differed from the target in terms of shape, color or both. 17.5% of the trials contained non-red squares,

17.5% presented red, non-square geometric shapes, and 35% presented geometric shapes which differed in both color and shape from the target stimulus. The different stimuli appeared in a randomized manner on the computer screen, independently of the participant's response.

This task has been shown to have high test-retest and internal reliability, as well as convergent and divergent (discriminant) validity (Shalev et al. 2011). Three measures were used in the current study: (a) proportion of commissions, namely trials in which participants responded to a non-target stimulus; false alarms (a high commission rate indicates the subject's tendency to impulsivity (Gross-Tsur et al. 2006)); (b) proportion of omissions, namely trials in which participants did not respond to the target; misses of the target (a high omissions rate indicates inattention (Allan and Lonigan 2015; Riccio et al. 2001)); and (c) the standard deviation of reaction times in responding to the target, which measure lapses in sustained attention (Tsal et al. 2005). A low standard deviation indicates a homogeneous performance, i.e. that the reaction time was consistent throughout the task, indicative of a high sustained attention.

Dissociations between commissions and omissions have been reported (Allan and Lonigan 2015; Brocki and Bohlin 2004; López-Vicente et al. 2014). More than 15% commissions and/or more than 30% omissions and/or reaction time (RT) std. dev. greater than 200 msec. in the CPT test indicate a performance below that expected due to attentional deficits at this age, i.e., children with such performance either did not understand the task, or performed it in an unattended way, not related to attentional deficits. Therefore, children that performed above these values were excluded from the analyses (8 children—4 boys and 3 girls from fourth grade, and 1 girl from third grade). The final number of participants with valid data in this task was 42 children in the control and 51 children in the mindfulness group.

Conjunctive visual search task

The second task, the Conjunctive Visual Search Task based on Treisman and Gelade (1980), aimed to evaluate selective attention. The task was to search for a target defined as a specific conjunction of color and shape. The target was a blue square (0.8 cm in side) appearing among an equal number of red squares (0.8 cm in side) and blue circles (0.8 cm in diameter). There were four display sizes of 4, 8, 16, or 32 items, which were equally frequent and randomly intermixed within a block. The items were randomly positioned within a 7×6 matrix subtending 9.5 cm in width and 8 cm in height. Half of the displays contained a target. Each display was preceded by a 100-ms white central fixation cross and remained on until response. Participants were required to respond as quickly and accurately as possible, with their right finger to the presence of the target and with their left finger to its absence. There were five 40-trial blocks, each preceded by 10 practice trials. The total length of the task was 12 min. The accuracy level for each of the displays was calculated. Reduction in performance as a function of increased display size served as a measure of selective attention deficits (Tsal et al. 2005). This task has been shown to have good divergent validity (Shalev et al. 2010). Internal reliability was assessed by correlating the accuracy of the first and second half of the test, separately for each of the combinations of display size (8, 16 and 32), target inclusion (with or without target) and time of measurement (before and after the mindfulness workshop). Pearson correlations were significant ($p < .001$) and ranged between .37 and .78. The exclusion rational in this task was similar to the one employed in the CPT test: participants with low accuracy levels were discarded, as such bad performance can only reflect misunderstanding the task rather than attentional or cognitive deficits. Accordingly, participants with less than 85, 75 or 65% accuracy in trials with 8, 16 or 32 item-displays respectively were not included in the analyses (11 children—5 boys and 5 girls from fourth grade, and 1 girl from third grade). The final number of participants with valid data in this task was 42 children in the control and 48 children in the mindfulness group.

Data Analyses

Experimental and control participants performed both attention tasks prior to the mindfulness workshop training and after its completion. The initial measurement was carried out during the week preceding the first workshop, and the second during the week following the final workshop. In order to assess differences between the two groups in the pre-measures, one-way ANCOVAs were performed, with age as a covariate. In order to assess the effects of the workshop on sustained and selective attention, repeated measures ANCOVAs were performed, comparing the performance of the control and mindfulness groups, before and after the workshop, controlling for age.

Specifically, for analyses of the CPT data, separate $2 \times (2)$ ANCOVAs were performed for commissions, omissions and reaction time standard deviations with the within-subjects effects of time of measurement (before and after the workshop), the between-subjects factor of group (mindfulness vs. control) and age as a covariate. Significant effects were followed by Tukey Honest Significant Difference (HSD) post-hoc comparisons.

For the analysis of the conjunctive visual search task, accuracy levels were assessed using a $2 \times (2 \times 2 \times 3)$ repeated measurements ANOVA, with the within-subjects factors of time of measurement (pre vs. post workshop) target inclusion (with vs. without target) and item displays

(8,16,32; 4 item-displays were not used because of ceiling effect in percent accuracy), the between-subject factor of group (mindfulness vs. control) and age as a covariate. Since low order interactions are nested within higher order interactions, only the highest order interaction is presented and followed by Tukey's HSD post-hoc comparisons.

Results

Table 4 presents the means and standard deviations of the dependent measures, in the pre- and post-measures, separately for the mindfulness and control groups.

Sustained Attention

One-way ANCOVAs comparing pre-measures, revealed a significantly larger percent of commissions in the mindfulness group as compared to the control group, $F(1,90) = 5.93$, $p < .05$). No significant differences were obtained for the percent of omissions or standard deviation of response time.

Repeated measures ANCOVAs on percent of commissions yielded a significant effect of time, $F(1,90) = 5.25$, $p < .05$, $\eta_p^2 = .02$, and a significant interaction between time and group, $F(1,90) = 12.72$, $p < .01$, $\eta_p^2 = .124$. As can be seen in Fig. 1, Tukey's HSD revealed a significant reduction in the commissions rate in the mindfulness group only ($p < .001$, Cohen's $d = 0.89$).

Repeated measures ANCOVAs performed on the percent of omissions yielded only a significant effect of time, $F(1,90) = 5.01$, $p < .05$, $\eta_p^2 = .05$), with a decrease in omissions in the second administration as compared to the first one. ANOVA of standard deviation of the response time yielded no significant outcomes.

Selective Attention

One-way ANCOVAs comparing pre-measures, revealed a significantly higher accuracy in the mindfulness group as compared to the control group for trials including 8 displays, with ($F(1,90) = 4.38$, $p < .05$) and without target ($F(1,90) = 4.57$, $p < .05$). No significant differences were obtained for trials including 16 or 32 displays.

Although main effects and lower order interaction were obtained in repeated measures ANCOVAs, they are not presented since a significant four-way interaction was obtained between group, time of measurement, item-displays and target inclusion ($F(2,174) = 3.25$, $p < 0.05$, $\eta_p^2 = .04$). As Fig. 2 depicts, a significant improvement in accuracy between the pre and post measures for trials with target including 16 displays was observed in the mindfulness group ($p < .05$, Cohen's $d = 0.46$), and for trials with target including 32 displays in the control ($p < .05$, Cohen's $d = 0.31$) and the mindfulness group ($p < .0001$, Cohen's $d = 0.85$).

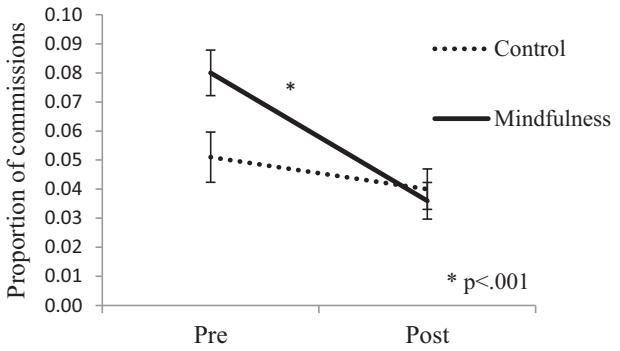

Fig. 1 Two-way interaction between time and group on the number of commissions in the CPT test ▶

Table 4 Means and standard deviations of the dependent variables, in the pre- and post-measures, separately for the mindfulness and control groups

	Mindfulness group				Control group			
	Pre		Post		Pre		Post	
Measure	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Commissions %	8.11	6.29	3.63	4.58	5.00	5.08	3.94	4.46
Omissions %	2.22	3.07	1.80	2.81	1.78	2.84	2.03	3.15
S.D. of response time	99.30	26.15	102.09	34.66	90.88	22.02	94.75	28.94
Acc. 8 disp. with target	0.98	0.03	0.98	0.03	0.97	0.05	0.98	0.04
Acc. 16 disp. with target	0.93	0.07	0.97	0.03	0.95	0.06	0.95	0.07
Acc. 32 disp. with target	0.87	0.10	0.96	0.05	0.87	0.11	0.91	0.10
Acc. 8 disp. without target	0.98	0.03	0.98	0.03	0.97	0.04	0.97	0.05
Acc. 16 disp. without target	0.99	0.03	0.99	0.03	0.98	0.04	0.98	0.03
Acc. 32 disp. without target	0.97	0.04	0.99	0.02	0.98	0.04	0.99	0.03

S. D. standard deviation, *Acc* accuracy level, *dis* number of displays

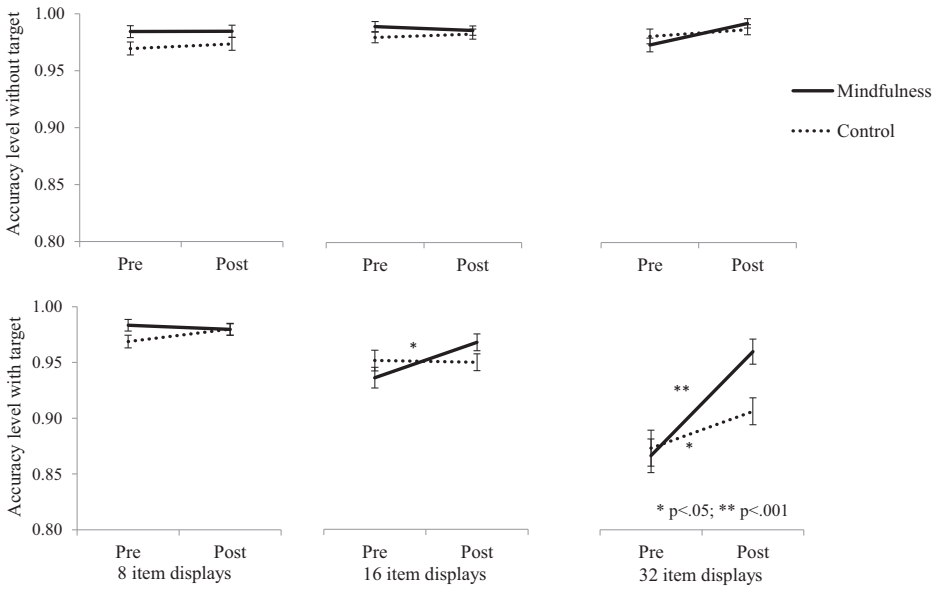

Fig. 2 Four-way interaction between group, time of measurement, item-displays and target inclusion on accuracy proportion in the search task assessing selective attention

Discussion

The results of the present study suggest that the mindfulness workshop in elementary school children was effective in improving attentional capacities, as measured by the CPT and Conjunctive Visual Search Task. Specifically, a significant reduction in the commissions' rate, while performing the CPT was obtained among children in the mindfulness group only. In the Conjunctive Visual Search Task, a significant improvement in accuracy in displays including 16 items was obtained only among children in the mindfulness group, while a significant improvement in displays including 32 items was obtained in both groups, but in a larger manner among children in the mindfulness group.

On average, all children showed an improvement from the first to the second measure, consistent with studies showing that children's attentional capacities improve with maturation (Betts et al. 2006; Brodeur and Pond 2001; Conners et al. 2003; Klenberg et al. 2001). However, for the commissions rate, this maturation effect was significant only for children in the mindfulness group, and for the selective attention task, it was more pronounced in the mindfulness group. It is important to mention that the two groups differed in the pre-measures, maybe due to the fact that the control group was composed of children in the 3rd and 5th grade, while the mindfulness group of children in 4th grade. Accordingly, the results must be considered with caution. However, the advantage of the statistical approach used in our study is that it assesses the differences between pre- and post-measures between the groups. So, the fact that significant interactions were obtained means that regardless of original differences, the change differs between the groups.

Commissions rate measures the ability to inhibit responses, and an increased rate is indicative of impulsive behavior and hyperactivity (Egeland and Kovalik-Gran 2010). A pivotal aspect of impulsivity is rapid, unplanned reactions to stimuli before complete processing of information (Moeller et al. 2001). The cultivation of mindfulness, to the contrary, precludes impulsive thought and behavior through the maintenance of attention in the present moment and the qualities of acceptance, openness, and curiosity (Stratton 2006). In fact, one of the emphases in mindfulness training is on enabling the individual to react with less impulsivity and more self-control (Diamond and Lee 2011), and dispositional mindfulness is correlated with impulsivity (Peters et al. 2011). Thus, it is possible that mindfulness-induced reduction in impulsivity in our group of children reflects a lowering in the commissions rate while performing the CPT task. We found no improvement in errors of omission, which reflect inattention (Allan and Lonigan 2015; Epstein et al. 2003). The most likely reason for the lack of significant differences in our study is a floor effect, as the numbers of omissions in the pretest were already very low (avg. 2.0%, median 1.0%), as compared to commissions (avg 6.7%, median 4.9%).

The Conjunctive Visual Search Task measures selective attention which is the ability of focusing on the significant and ignoring the insignificant (Tsal et al. 2005). It reflects the efficacy of top-down processing (Treisman and Gelade 1980) and enables us to focus awareness on objects and events that are relevant to our immediate goals. Interestingly, selective attention mechanisms can be decomposed into distinct mental operations; namely, disengaging attention from the current focus, orienting attention to a new locus, and selectively modulating new stimulus inputs (Hopfinger et al. 2000). This description of selective

attention processes very closely resembles the attentional processes involved in mindfulness, as presented in the model of Malinowski (2013). According to Malinowski, during the process of meditation, the meditator focuses on an object such as breathing, a phase that requires sustained attention. As soon as the mind loses the focus on the object, mind wandering occurs. The meditator will respond to mind wandering by activation of the executive attention system and return to the meditation object while utilizing orienting of attention. Thus, the practice of mindfulness may have improved selective attention, as reflected in a better performance in the Conjunctive Visual Search Task.

The present results support previous findings that children can benefit from the positive effects of mindfulness meditation on attentional processes (Berto and Barbiero 2014; Felver et al. 2017; Flook et al. 2010; Napoli et al. 2005). Although the number of programs offering mindfulness-based interventions in children has grown during the past 5 years, few have specifically assessed the effects of mindfulness on attention. At a more general level, the present results support the theories that view attention as a mediator of the effects of mindfulness practice (e.g. Malinowski 2013; Tang et al. 2015).

An improvement in selective attention and impulsivity in elementary school children may have important implications for their functioning and well-being. Better attentional skills may mediate improvements in academic achievements, as self-regulation has been shown to improve school-readiness (Willis and Dinehart 2014) and help develop concentration and self-awareness, which result in higher academic competence (Biegel and Brown 2009; Weare 2013). Indeed, attention related skills such as task persistence and self-regulation have been associated with academic achievement (Duncan et al. 2007), and mindfulness training has been found to improve academic performance (Beauchemin et al. 2008; Byrne et al. 2013). Some of these effects could be related to reduced anxiety, as anxiety impairs attention (Eysenck et al. 2007), is negatively correlated with self-regulation (Buckner et al. 2009) and interferes with academic performance (Seipp 1991).

Although the present study targeted regular children (and most probably included a percentage of children with ADHD), the evident improvements in attention may have special relevance for children with attentional deficits. ADHD symptoms negatively affect academic achievements, academic self-perception and future orientation in children, as shown in a longitudinal study conducted by Scholtens et al. (2013). Less efficient functioning in the measures used in the present study has been observed in children with ADHD as compared to normal children. Therefore, the capacity of mindfulness training to improve these measures in the present study suggests that such training may be beneficial for children with ADHD. Children with ADHD commonly receive pharmacological treatments that often involve unpleasant side effects (Charach et al. 2014) and whose long-term effectiveness is questionable (MTA Cooperative Group 2004). Mindfulness practice provides an efficient non-pharmacological alternative that many children can practice, especially after adapting the exercises to their developmental and attentional characteristics. Therefore, future studies should assess attentional improvements following mindfulness practice specifically on children diagnosed with ADHD.

The special conditions of the workshop administration in the current study require special attention. On the one hand, the setting was exceptional in terms of the small number of children in each group, allowing very personal and dedicated teaching. On the other hand, the instructors had a short training and most had no previous experience in mindfulness practice. Furthermore, the workshop was held in a noisy, "non-sterile" setting, without any special conditions. The encouraging results of the present study in spite of the minimal conditions in terms of training and location shed light on the feasibility and scalability of mindfulness practice among schoolchildren. Additional studies including similar conditions but in larger groups of children will help defining the minimal requirements needed to effectively implement mindfulness in the educational system.

Limitations

The study had several limitations. First, the selection of the control group was not ideal, as the mindfulness group was composed of children from fourth grade whilst the controls were from third or fifth grades. The lack of randomization within the same grade threatens the internal validity of the results, particularly since attentional capacities are age-dependent (Betts et al. 2006; Conners et al. 2003; Klenberg et al. 2001). Therefore, although we used a pre-post design that overcomes this pitfall at least partly, by assessing differences among the groups rather than absolute values, the conclusions should be considered with caution. Second, the study lacked an active control group, receiving personal contact, as did the mindfulness group. The assessment of the effectiveness of the workshop was conducted by means of objective attentional tests only. No data was collected from teachers or parents with regards to their perception of "real life" attention following the intervention. Additional tests measuring changes in other relevant domains (e.g., anxiety, behavioral problems and academic achievements) would help validate the results, while assessing predictions regarding the role of mediating and moderating variables, based on leading theories in the field. Although the amount of time that children practiced at home may have affected their outcomes, we had no means to assess its extent. It is most unlikely that children practiced at home substantially,

but the information on their practice could have enriched the results and discussion. Home practice follow-up should be collected in future research. Finally, as we did not collect socioeconomic details regarding the sample, our results cannot be related to social or economic status. A meaningful future direction would be to see if these results could be replicated across social (and minority) groups.

Compliance with Ethical Standards

Conflict of Interest The author declare that he has no conflict of interest.

Ethical Approval All procedures performed in the current study were in accordance with the ethical standards of the Tel Aviv University research committee and the chief scientist of the Israeli Ministry of Education.

Informed Consent Informed consent was obtained from all individual participants' parents included in the study.

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