Mindfulness Training Enhances Attention and Executive Function in 3–4-Year-Old Children: Postprint

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Abstract

Mindfulness training refers to a psychological intervention method in which individuals focus their attention on present-moment experiences. Previous studies have shown that mindfulness training can promote the development of attention, executive function, emotion regulation, etc., but the mechanism by which mindfulness training affects psychological development in young children is not clear. Therefore, to examine the effects of mindfulness training on attention and executive function in 3-4-year-old children: A pre-post test design was adopted; the mindfulness group received mindfulness training twice a week, 20-30 minutes each time, for a total of 12 sessions; the control group did not receive any training. Results showed: C1) In terms of attention, there was no significant difference between the mindfulness group and the control group in the pre-test; after training, the sustained attention scores of children in the mindfulness group were significantly higher than those in the control group. C2) In terms of executive function, there were no significant differences in pre-test scores between the mindfulness group and the experimental group in inhibitory control, cognitive flexibility, and working memory; after training, the scores of children in the mindfulness group for inhibitory control and cognitive flexibility were significantly better than those in the control group, while there was no significant difference in working memory between the two groups. The study demonstrates that mindfulness training promotes the development of attention and executive function in 3-4-year-old children, and in terms of executive function, it mainly manifests as improvements in inhibitory control and cognitive flexibility.

Full Text

Mindfulness Training Enhances Attention and Executive Function in 3- to 4-Year-Old Children

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Abstract

Mindfulness training is a psychological intervention that involves focusing attention on present-moment experiences. Previous research has demonstrated that mindfulness training can promote the development of attention, executive function, and emotion regulation, yet the mechanisms underlying its effects on early childhood development remain unclear. To investigate the impact of mindfulness training on attention and executive function in 3- to 4-year-old children, we employed a pretest-posttest design. The mindfulness group received 12 sessions of mindfulness training (twice weekly, 20–30 minutes per session), while the control group received no intervention. Results revealed: (1) For attention, no significant difference existed between groups at pretest, but posttest scores for sustained attention were significantly higher in the mindfulness group than in the control group. (2) For executive function, no significant pretest differences emerged between groups on inhibitory control, cognitive flexibility, or working memory. At posttest, the mindfulness group demonstrated significantly better performance on inhibitory control and cognitive flexibility compared to the control group, whereas working memory did not differ significantly between groups. These findings indicate that mindfulness training promotes the development of attention and executive function in 3- to 4-year-old children, with particular benefits for inhibitory control and cognitive flexibility.

Keywords: mindfulness training; 3- to 4-year-old children; attention; executive function
Classification Code: B844.1

1. Introduction

Mindfulness refers to the practice of purposefully maintaining attention on present-moment experiences with a non-judgmental attitude (Kabat-Zinn, 2003). Two core components are emphasized: first, concentrating attention on the current moment, and second, accepting present events without judgment (Bishop et al., 2004; Kabat-Zinn, 1994). Mindfulness training, therefore, represents a psychological intervention that cultivates present-moment attentional focus (Lutz, Slagter, Dunne, & Davidson, 2008). Beyond improving emotional regulation, mindfulness training enhances cognitive abilities. Robins et al. (2012) found that mindfulness training effectively improved emotional regulation capabilities, while Zeidan et al. (2010) used electrical stimulation to induce pain and discovered that just three days of mindfulness training

significantly reduced reported pain levels. Brooker et al. (2014) reported that four weeks of mindfulness training produced significant improvements in perceived stress, sleep quality, and self-identity.

Rueda et al. (2012) proposed that short-term meditation training can enhance attention, cognitive control, and cognitive switching abilities (Klingberg et al., 2005; Rothbart, McCandliss, Saccomanno, & Posner, 2005; Rueda, Checa, & Cómbita, 2012). Mrazek et al. (2013) randomly assigned 48 undergraduates to either a mindfulness group (two weeks of mindfulness training, four sessions per week, 45 minutes each) or a control group (nutrition education with the same schedule). Results showed the mindfulness group exhibited better attentional focus and cognitive performance. Wang et al. (2012) assigned 31 college students to mindfulness and control groups, using Stroop and prospective memory tasks to examine cognitive mechanisms. They found the mindfulness group outperformed the control group on both tasks. Westbrook et al. (2013) demonstrated that brief mindfulness training significantly improved executive function (Weijer-Bergsma, Formsma, Bruin, & Bögels, 2012; Westbrook et al., 2013). Additionally, Good et al. (2015) found that mindfulness training enhanced attention stability in adolescents (Good, Lyddy, & Glomb, 2015; Semple, Lee, Rosa, & Miller, 2010; Smallwood & Schooler, 2015). Zeidan et al. (2010) conducted four days of mindfulness training with university students (M age = 20 years) and observed significant improvements in both attention and executive function. Collectively, these studies demonstrate that mindfulness training enhances cognitive abilities, though research on young children remains scarce, and mechanistic studies are particularly limited. Therefore, the present study employed a pretest-posttest experimental design with control group to examine the effects of mindfulness training on attention and executive function in 3- to 4-year-old children and explore potential mechanisms, providing theoretical support for clinical psychological interventions.

From the perspective of mindfulness mechanisms, cognitive abilities—especially attention and executive function—play crucial roles. Deikman (1963, 2000) conceptualized mindfulness as a process of automatization and de-automatization, where automatization refers to behavioral steps disappearing from conscious awareness through repetition, and de-automatization involves regaining awareness of these internal steps. Attention, switching ability, and inhibitory control are essential in this process (Deikman, 2000; Deikman, 1963). Kabat-Zinn (2003) proposed that mindfulness involves using self-discipline techniques to achieve effective attentional control as a form of self-relaxation. In other words, mindfulness training primarily targets attention and cognition (Kabat-Zinn, 2003), enhancing cognitive abilities related to controlling external interference, switching, and attention (Ivanovski & Malhi, 2007).

An alternative perspective suggests that mindfulness influences cognitive development by improving sensory integration (Tang, Tang, Tang, & Lewis-Peacock, 2017). Zheng et al. (1991) identified ages 3–6 as a critical period for sensory integration development, which occurs in two phases: (1) a primary stage in-

volving perception, balance, hand-eye coordination, attention, and emotional stability; and (2) an advanced stage encompassing sustained attention, learning ability, self-control, and mental switching (Zheng & Li, 1991). We can therefore infer that sensory integration development in 3- to 4-year-olds is closely related to attention and executive function development. Research indicates that sensory integration deficits impair attention, memory, and control, leading to reduced sensitivity, memory decline, inattention, and poor self-control (Huang, Li, & Wang, 2002). In other words, mindfulness training may enhance attention, self-control, and mental switching by promoting sensory integration development (Friese, Ostafin, & Loschelder, 2017; Lee & Orsillo, 2014; Modesto-Lowe, Farahmand, Chaplin, & Sarro, 2015). Cameron et al. (2015) found that visual integration training effectively improved executive function (inhibitory control, cognitive flexibility, working memory). Therefore, this study examined changes in attention and executive function before and after training, designing a series of mindfulness training courses based on the cognitive developmental characteristics of 3- to 4-year-olds to investigate the effects and psychological mechanisms of mindfulness training on attention and executive function.

Mindfulness is a psychological process of directing attention to specific objects such as breath, sounds, or visual perceptions (Black, Milam, Sussman, & Johnson, 2012). This process comprises three subcomponents: sustained attention, attentional switching, and attentional control (Bishop et al., 2010; Brown & Ryan, 2003; Shapiro, Carlson, Astin, & Freedman, 2010). Josefsson et al. (2014) used an experimental-control design to examine mindfulness training effects on attention, with the experimental group completing five weekly one-hour sessions and the control group receiving relaxation training. Results showed significant attention improvements after five mindfulness sessions. Another perspective holds that mindfulness requires multiple cognitive abilities to adjust one's mental state according to the instructor's guidance, involving inhibitory control, cognitive flexibility, and other capacities (Ying & Wang, 2012; Moore & Malinowski, 2009; Moore, 2013), making it a strategy for enhancing executive function (Thurman & Torsney, 2014). Riggs et al. (2015) found that children with higher mindfulness awareness scores demonstrated better executive function, particularly in inhibitory control and working memory. In summary, while mindfulness training improves attention and executive function, most research has focused on adults or adolescents, with few experimental studies investigating whether mindfulness training can enhance these abilities in young children or exploring underlying mechanisms.

Early childhood represents a critical period for psychological development and a sensitive window for many psychological capacities (Deloache, Eisenberg, & Siegler, 2010; Piaget, 1981). Lenroot and Giedd (2006) proposed that ages 3–6 constitute a key period for cognitive development and peak brain development. Tang et al. (2012) noted that mindfulness training can improve neural circuit transmission in the anterior cingulate cortex (ACC) and autonomic nervous system (ANS). Numerous studies show that after mindfulness training, individuals exhibit significant prefrontal cortex activation compared to controls when

completing tasks requiring attentional control, attentional switching, cognitive flexibility, self-monitoring, planning, inhibitory control, and working memory (Roth, Randolph, Koven, & Isquith, 2006; Wood & Smith, 2008). Lenroot and Giedd (2006) identified ages 3–6 as both a critical period for cognitive development and peak brain development, during which the brain exhibits strong behavioral plasticity and sensitivity (Lenroot et al., 2009; Pascual-Leone, Amedi, Fregni, & Merabet, 2005). Additionally, ages 3–6 are crucial for attention and executive function development. Research indicates that ages 3–4 mark the initial stage for attention development, with attentional shifting and allocation still immature and highly plastic (Ruff, Capozzoli, & Weissberg, 1998; Pan & Ma, 2009). Zelazo et al. (2013) found that ages 3–5 represent the most rapid developmental period for executive function, particularly in inhibitory control and cognitive flexibility (Zelazo et al., 2013; Yang & Song, 2003). Therefore, investigating whether mindfulness training can promote attention and executive function development in 3- to 4-year-olds and exploring the underlying psychological mechanisms holds important practical value.

In summary, this study employed mindfulness training methods using familiar body parts (vision, hearing, touch, balance) to guide children in focusing attention on specific areas and subsequently training executive function. Using a pretest-posttest experimental-control group design, we examined the effects and psychological mechanisms of mindfulness training on attention and executive function in 3- to 4-year-olds. We used the classic "Find Animals" task to assess attention, the "Peach Heart/Flower" task for inhibitory control, the Dimensional Change Card Sort (DCCS) task for cognitive flexibility, and the Wechsler Picture Memory task for working memory. The mindfulness group completed 12 sessions (twice weekly, 20–30 minutes each, six children per session), while the control group participated in normal classroom activities without training. We predicted that mindfulness training would enhance attention and executive function in 3- to 4-year-olds, with significant improvements in attention and executive function (primarily inhibitory control and cognitive flexibility) compared to the control group, and possible effects on working memory.

2. Method

2.1 Participants

We randomly selected 60 children aged 3–4 years from a kindergarten in Chongqing. During posttest data collection, four children were unable to complete the tests and four were absent due to illness, leaving a final sample of 52 children (26 in the mindfulness group, 26 in the control group). The mindfulness group ranged from 41.69 to 51.42 months (M = 46.08 months, SD = 1.12 months) with 13 boys and 13 girls. The control group ranged from 41.98 to 53.98 months (M = 47.59 months, SD = 3.60 months) with 13 boys and 13 girls. The 3-year-old subgroup ranged from 41.69 to 45.11 months (M = 43.57 months, SD = 1.10 months) with 8 boys and 8 girls. The 4-year-old subgroup ranged from 45.14 to 53.98 months (M = 48.48 months, SD = 2.27

months) with 18 boys and 18 girls. All children were right-handed with normal intellectual, visual, and auditory development. Each child received a small gift upon completion. Parental informed consent was obtained for all participants.

2.2 Experimental Design

We employed a 2 × 2 mixed design with group (mindfulness vs. control) as a between-subjects factor and test time (pretest vs. posttest) as a within-subjects factor. Neither group had prior similar training experience. The interval between pretest and posttest was approximately 2.5 months, with identical tasks administered at both time points. The mindfulness group participated in 12 sessions (twice weekly, 20–30 minutes each, six children per session), while the control group engaged in normal classroom activities without training.

All testing was conducted on Dell Achievement 3667-R1308 computers with 19.5-inch color monitors (1024 × 768 resolution, 60 Hz refresh rate, true color). Children sat approximately 60 cm from the screen, with all stimuli presented centrally on a white background. Testing occurred in a behavioral observation laboratory, lasting approximately 30 minutes including 1–2 minute breaks between tasks. Task order was: attention (5 minutes), inhibitory control (6 minutes), cognitive flexibility (5 minutes), and working memory (3 minutes). Data were analyzed using SPSS 21.0.

2.3 Experimental Tasks

Attention refers to the ability to focus and direct mental activity (Eldar, Ricon, & Barhaim, 2008). We used the Find Animals task developed by Breckenridge et al. (2007) to measure sustained attention in 3- to 6-year-olds. The procedure involved presenting a series of pictures containing animals and non-animals on a computer screen. Children verbally reported "animal" when seeing target stimuli (e.g., elephants, tigers, ducks) and made no response to non-targets. The experimenter provided prompts if children missed four consecutive targets. Each trial sequence was: fixation cross "+" (1800 ms) followed by stimulus picture (200 ms) (see Figure 1 [Figure 1: see original paper]). We recorded correct responses, errors (reports to non-targets), and prompts. The attention score was calculated as: correct responses minus errors minus prompts.

Executive Function (EF) refers to a set of higher-order cognitive abilities for conscious and effective control of thought and behavior, including inhibitory control, cognitive switching, and working memory (Oh & Lewis, 2008).

Inhibitory Control is the ability to suppress dominant responses (Aron, Robbins, & Poldrack, 2014). We used the "Peach Heart/Flower" task developed by Davidson (2006) to measure preschoolers' inhibitory control. The procedure was: children were told that "peach heart" or "flower" pictures would appear randomly on the left or right side of the screen. They were instructed to point left whenever seeing a "peach heart" and right whenever seeing a "flower," regardless of stimulus location (Davidson, Amso, Anderson, & Diamond, 2006).

Each trial sequence was: fixation cross "+" (500 ms) followed by stimulus picture (8000 ms), with 20 trials total. We recorded mean accuracy (see Figure 2 [Figure 2: see original paper]).

Cognitive Flexibility refers to mental switching ability—the capacity to shift from one dominant response to another to adapt to changing situations (Davidson et al., 2006). We used the standard 3- to 5-year-old version of the Dimensional Change Card Sort (DCCS) task developed by Zelazo et al. (2006). Children were shown cards varying in shape and color. They first sorted by shape for six trials, then by color for six trials, then by shape again (Zelazo, 2006; Zelazo et al., 2003). Each trial sequence was: background (800 ms) → fixation cross "+" (1000 ms) → stimulus picture (1000 ms) → response screen (8000 ms), with 36 trials total. We recorded response accuracy (see Figure 3 [Figure 3: see original paper]).

Working Memory is a system for temporarily storing and manipulating information (Baddeley, 1982; Baddeley, 2013). We used the Picture Memory task from the Wechsler Preschool and Primary Scale of Intelligence (WPPSI-IV) (Wechsler, 2003). Children viewed one or more pictures for 3–5 seconds, then identified previously presented pictures from a response card. For example, after seeing an apple for 3 seconds, children pointed to the apple from a set containing an apple and a safety helmet. Correct responses scored 1 point; errors scored 0. Testing terminated after four consecutive errors. Picture sets ranged from 1–7 items (3-second presentation for one item, 5 seconds for two or more items), with difficulty increasing with set size. The working memory score was the number of correct responses (maximum = 35) (see Figure 4 [Figure 4: see original paper]).

2.4 Mindfulness Training Method

Based on Kabat-Zinn et al. (2005), we designed a developmentally appropriate mindfulness curriculum for 3- to 4-year-olds incorporating three phases—"breath and attention," "body sensation and movement," and "awareness of mental activity" (Kim, Sun, Jung, & Ko, 2005; Wu & Zheng, 2008)—integrated with the two-stage model of sensory integration development (Zheng, 1991). The program consisted of 12 sessions (twice weekly, 20–30 minutes each, six children per session). The three phases were: (1) Breath and Attention: learning abdominal breathing and focusing attention on bodily sensations; (2) Body Sensation and Movement: experiencing coordinated body movements; and (3) Awareness of Mental Activity: relaxing emotions and mindfully perceiving each body part. Specific lessons are detailed in Table 1 . Instructors encouraged active participation, guiding children to experience and engage with the present moment using encouraging, open, and accepting attitudes.

3. Results

Descriptive statistics for pretest and posttest scores on attention and executive function are presented in Table 2 . No significant pretest differences emerged between groups on attention, inhibitory control, cognitive flexibility, or working memory (all ps > 0.05). To examine mindfulness training effects, we conducted 2 (group: mindfulness vs. control) $\times$ 2 (test time: pretest vs. posttest) repeated measures ANOVAs.

Attention. The ANOVA on attention scores revealed a significant group $\times$ test time interaction, $F(1, 50) = 14.42$, $p < 0.001$, $^2 = 0.22$. Simple effects analysis showed no pretest difference between groups ($p > 0.05$), but posttest scores were significantly higher in the mindfulness group than the control group ($p < 0.05$) (see Figure 1 [Figure 1: see original paper]). These results demonstrate that mindfulness training significantly improved attention in 3- to 4-year-old children.

Inhibitory Control. The ANOVA on inhibitory control scores revealed a significant group $\times$ test time interaction, $F(1, 50) = 9.03$, $p < 0.01$, $^2 = 0.15$. Simple effects analysis showed no pretest difference ($p > 0.05$), but posttest scores were significantly higher in the mindfulness group ($p < 0.001$) (see Figure 2 [Figure 2: see original paper]). These findings indicate that mindfulness training significantly enhanced inhibitory control.

Cognitive Flexibility. The ANOVA on cognitive flexibility scores revealed a significant group $\times$ test time interaction, $F(1, 50) = 5.24$, $p < 0.05$, $^2 = 0.10$. Simple effects analysis showed no pretest difference ($p > 0.05$), but posttest scores were significantly higher in the mindfulness group ($p < 0.001$) (see Figure 3 [Figure 3: see original paper]). These results demonstrate that mindfulness training significantly promoted cognitive flexibility development.

Working Memory. The ANOVA on working memory scores revealed a significant main effect of test time, $F(1, 50) = 10.75$, $p < 0.01$, $^2 = 0.21$, but no significant main effect of group, $F(1, 50) = 0.27$, $p > 0.05$, and no significant interaction, $F(1, 50) = 1.30$, $p = 0.26$. LSD post-hoc tests showed that posttest scores were significantly higher than pretest scores across both groups (M_{diff} = 3.07, $p < 0.01$). These findings suggest that mindfulness training did not specifically enhance working memory development in this age group.

To examine potential age (3 vs. 4 years) and gender differences in training effects, we conducted independent samples t-tests on change scores (posttest minus pretest) for each measure. No significant age differences emerged in improvements on attention, inhibitory control, cognitive flexibility, or working memory (all ps > 0.05). Similarly, no significant gender differences were found in training-related improvements (all ps > 0.05).

In summary, using the Find Animals task for attention, the Peach Heart/Flower task for inhibitory control, the DCCS task for cognitive flexibility, and the Wechsler Picture Memory task for working memory, we found that after 12

mindfulness training sessions, the mindfulness group showed significantly higher posttest scores than the control group on attention, inhibitory control, and cognitive flexibility, but not on working memory. These results indicate that mindfulness training effectively enhanced attention, inhibitory control, and cognitive flexibility in 3- to 4-year-old children, but did not significantly improve working memory.

4. Discussion

4.1 Effects of Mindfulness Training on Attention

The present study found no pretest difference in attention scores between groups, but posttest scores were significantly higher in the mindfulness group, indicating that mindfulness training promoted attention development in 3- to 4-year-olds. Previous research has established close relationships between mindfulness and attention, as reflected in the Zen concept that "mindfulness is a mental state of focusing on an object" (Purser & Milillo, 2015), which aligns with attentional mechanisms. Mindfulness training is a method of concentrated attention training that involves consciously and purposefully focusing on the present moment with an open, non-judgmental attitude (Brown & Pinel, 2003; Kabat-Zinn, 2003). Zheng et al. (1991) identified ages 3–6 as a period of rapid sensory integration development, with 3- to 4-year-olds developing primary integration skills (balance, hand-eye coordination) and 4-year-olds gradually developing advanced integration (sustained attention, self-control, mental switching). Previous research has shown that sensory integration development promotes cognitive abilities including attention in preschoolers (Mao, 2009). The current study integrated sensory integration principles with mindfulness concepts, and results showed that 12 sessions of mindfulness training significantly improved attention in the mindfulness group compared to controls. This suggests that mindfulness training may enhance attention in 3- to 4-year-olds through sensory integration development.

Mindfulness involves directing attention to specific objects such as breath, sounds, or visual perceptions (Black, Milam, Sussman, & Johnson, 2012). Our training guided children to focus on breathing, surrounding sounds, different smells, and body parts, using familiar bodily sensations to anchor attention and thereby improve attentional capacity. Ma (2013) similarly found that mindfulness training improves attention by focusing on the present moment and adjusting one's state to fit the situation. Previous research demonstrates that mindfulness training enhances attention and reduces problem behaviors (Biegel, Brown, Shapiro, & Schubert, 2009; Semple, Lee, Rosa, & Miller, 2010), improves classroom attention and reduces distraction (Mrazek, Smallwood, & Schooler, 2012), and promotes attentional stability (Razza, Bergen-Cico, & Raymond, 2015).

4.2 Effects of Mindfulness Training on Executive Function

The study found no pretest differences between groups on executive function measures. After 12 mindfulness training sessions, the mindfulness group showed significantly higher posttest scores than the control group on inhibitory control and cognitive flexibility, but not on working memory. These findings indicate that mindfulness training improved executive function in 3- to 4-year-olds, primarily in inhibitory control and cognitive flexibility. Previous research has shown that mindfulness training promotes executive function development (Zelazo & Lyons, 2012). Biegel et al. (2009) found improved inhibitory control, and Westbrook et al. (2013) demonstrated enhanced executive function following mindfulness training. A longitudinal study showed that 12 weeks of mindfulness training produced better performance on inhibitory control and cognitive flexibility compared to controls (Flook, Goldberg, Pinger, & Davidson, 2015). Research indicates that ages 3–4 represent a critical period for advanced sensory integration development (attention concentration, self-control, mental switching) (Mao, 2009). Mindfulness training requires children to control emotions and thoughts to follow the instructor's guidance (Borders, Earleywine, & Jajodia, 2010), engaging not only attention but also inhibitory control, cognitive flexibility, and working memory to continuously adjust one's state to the present moment (Ying & Wang, 2012; Moore & Malinowski, 2009; Moore, 2013). In our study, children had to inhibit irrelevant information and flexibly shift attention to specific body parts or objects, effectively promoting inhibitory control and cognitive flexibility (Zoogman, Goldberg, Hoyt, & Miller, 2015; Black, 2015). Thus, mindfulness training effectively enhanced attention and executive function (particularly inhibitory control and cognitive flexibility) in 3- to 4-year-olds.

Although the mindfulness group showed greater improvement in working memory than the control group, the difference was not significant. Several factors may explain this null finding. First, it may relate to the developmental level and characteristics of working memory in this young age group. Previous studies demonstrating mindfulness training effects on working memory involved adolescents (e.g., M age = 12.9 years; Riggs et al., 2015) or college students (e.g., M age = 20.83 years; Mrazek et al., 2013). However, working memory research indicates that while its precursors emerge around 4.5–6.5 months (Reznick, Morrow, Goldman, & Snyder, 2004), working memory components are not fully developed until after age 4 (Alloway et al., 2005). Therefore, mindfulness training may have limited capacity to enhance working memory in 3- to 4-year-olds. Second, the training curriculum may have contributed, as it focused primarily on attention and cognitive flexibility (breath and attention phase), inhibitory control and cognitive flexibility (body sensation and movement phase), and attention and inhibitory control (awareness of mental activity phase), with minimal emphasis on working memory. This may have reduced training effects on working memory. Third, training intensity (frequency and duration) may matter. Our data showed the mindfulness group's improvement exceeded the control group's, though not significantly. Future research could increase training frequency and

duration with process monitoring to examine developmental trajectories. In conclusion, whether mindfulness training can effectively improve working memory in young children requires further investigation considering developmental characteristics, curriculum content, and training intensity.

In summary, this study systematically examined the effects of mindfulness training on attention and executive function in 3- to 4-year-olds using standard experimental paradigms and explored underlying psychological mechanisms. Results demonstrated that mindfulness training enhanced attention, inhibitory control, and cognitive flexibility, providing a novel approach for early training of attention and executive function with important theoretical and practical implications. However, this study used a no-treatment control rather than an active control, leaving unclear whether non-specific factors influenced results. Future research should employ active control groups (e.g., relaxation training) to isolate the specific effects of mindfulness training on attention and executive function in 3- to 4-year-old children.

This study developed a developmentally appropriate mindfulness curriculum for 3- to 4-year-olds. Results showed that 12 sessions of mindfulness training effectively enhanced attention and executive function, with improvements in executive function primarily manifested in inhibitory control and cognitive flexibility.

References

[1] Alloway, T. P., Gathercole, S. E., Adams, A. M., Willis, C., Eaglen, R., & Lamont, E. (2005). Working memory and phonological awareness as predictors of progress towards early learning goals at school entry. *British Journal of Developmental Psychology, 23*(3), 417–426.

[2] Aron, A. R., Robbins, T. W., & Poldrack, R. A. (2014). Inhibition and the right inferior frontal cortex. *Trends in Cognitive Sciences, 18*(4), 170–177.

[3] Baddeley, A. D. (2013). Working memory and emotion: Ruminations on a theory of depression. *Review of General Psychology, 17*(1), 20-27.

[4] Biegel, G. M., Brown, K. W., Shapiro, S. L., & Schubert, C. M. (2009). Mindfulness-based stress reduction for the treatment of adolescent psychiatric outpatients: A randomized clinical trial. *Journal of Consulting & Clinical Psychology, 77*(5), 855–866.

[5] Bishop, S. R., Lau, M., Shapiro, S., Carlson, L., Anderson, N. D., Carmody, J., & Devins, G.M. (2004). Mindfulness: A proposed operational definition. *Clinical Psychology: Science and Practice, 11*(3), 230–

[6] Black, D. S. (2015). Mindfulness training for children and adolescents: A state-of-the-science review. In K. Brown, D. Creswell, & R. Ryan (Eds.), *Handbook of mindfulness: Theory, research, and practice* (pp. 283–310). New York: Guilford Press.

[7] Black, D. S., Milam, J., Sussman, S., & Johnson, C. A. (2012). Testing the indirect effect of trait mindfulness on adolescent cigarette smoking through negative affect and perceived stress mediators. *Journal of Substance Use, 17*(5–6), 417–429.

[8] Borders, A., Earleywine, M., & Jajodia, A. (2010). Could mindfulness decrease anger, hostility, and aggression by decreasing rumination? *Aggressive Behavior, 36*(1), 28–44.

[9] Breckenridge, K. (2007). *The structure and function of attention in typical and atypical development* (Unpublished PhD thesis). University of London.

[10] Breckenridge, K., Braddick, O., & Atkinson, J. (2013). The organization of attention in typical development: A new preschool attention test battery. *British Journal of Developmental Psychology, 31*(3), 271–288.

[11] Brooker, J. E., Webber, L., Julian, J., Shawyer, F., Graham, A. L., Chan, J., & Meadows, G. (2014). Mindfulness-based Training Shows Promise in Assisting Staff to Reduce Their Use of Restrictive Interventions in Residential Services. *Mindfulness, 5*(5), 598–603.

[12] Brown, K. W., & Ryan, R. M. (2003). The Benefits of Being Present: Mindfulness and Its Role in Psychological Well-Being. *Journal of Personality Social Psychology, 84*(4), 822–848.

[13] Brown, R. P., & Pinel, E. C. (2003). Stigma on my mind: Individual differences in the experience of stereotype threat. *Journal of Experimental Social Psychology, 39*(6), 626–633.

[14] Cameron, C. E., Brock, L. L., Hatfield, B. E., Cottone, E. A., Rubinstein, E., Locasalecrouch, J., & Grissmer, D. W. (2015). Visuomotor integration and inhibitory control compensate for each other in school readiness. *Developmental Psychology, 51*(11), 1529–1543.

[15] Davidson, M. C., Amso, D., Anderson, L. C., & Diamond, A. (2006). Development of cognitive control and executive functions from 4 to 13 years: Evidence from manipulations of memory, inhibition, and task switching. *Neuropsychologia,44*(11), 2037–2078.

[16] Deikman, A. (2000). A functional approach to mysticism. *Journal of Consciousness Studies, 7*(11–12), 75–92.

[17] Deikman, A. J. (1963). Experimental meditation. *Journal of Nervous & Mental Disease. 136*(4), 329–343.

[18] Deloache, J. S., Eisenberg, N., & Siegler, R. S. (2010). *How Children Development.* New York, NY: Worth Publishers.

[19] Eldar, S., Ricon, T., & Barhaim, Y. (2008). Plasticity in attention: implications for stress response in children. *Behaviour Research & Therapy, 46*(4), 450–461.

[20] Flook, L., Goldberg, S. B., Pinger, L., & Davidson, R. J. (2015). Promoting prosocial behavior and self-regulatory skills in preschool children through a mindfulness-based kindness curriculum. *Developmental Psychology, 51*(1), 44–51.

[21] Friese, M., Ostafin, B., & Loschelder, D. (2017). Mindfulness as an intervention to improve self-control. *Handbook of self-control in health and well-being*(pp.431–445).New York, NY: Routledge.

[22] Good, D. J., Lyddy, C. J., & Glomb, T. M. (2015). Contemplating mindfulness at work: : An integrative review. *Journal of Management, 42*(1), 877–880.

[23] Huang, Y., Li, X,D., Wang, Y.(2002). A follow-up study of sensory integrative dysfunction in children. *China Journal of Pediatrics,40*(5), 260–262. [Huang Yueqin, Li Xudong, Wang Yufeng. (2002). A follow-up study of sensory integrative dysfunction in children. *Chinese Journal of Pediatrics*, 40(5), 260–262.]

[24] Ivanovski, B., & Malhi, G. S. (2007). The psychological and neurophysiological concomitants of mindfulness forms of meditation. *Acta Neuropsychiatrica, 19*(2), 76–91.

[25] Josefsson, T., Lindwall, M., & Broberg, A. G. (2014). The Effects of a Short-term Mindfulness Based Intervention on Self-reported Mindfulness, Decentering, Executive Attention, Psychological Health, and Coping Style: Examining Unique Mindfulness Effects and Mediators. *Mindfulness, 5*(1), 18–35.

[26] KabatZinn, J. (1994). Wherever you go there you are. *Hyperion New York, 94*(2), 146–148.

[27] KabatZinn, J. (2003). Mindfulness-based interventions in context: Past, present, and future. *Clinical Psychology–science and Practice, 10*(2), 144–156.

[28] Kabatzinn, J. (2005). Bringing mindfulness to medicine: an interview with Jon Kabat-Zinn, PhD. Interview by Karolyn Gazella. *Advances in mind-body medicine, 21*(2):22–7.

[29] Kim, J. S., Sun, I., Jung, I. S., & Ko, Y. J. (2005). Bringing mindfulness to medicine: an interview with Jon KabatZinn, PhD. Interview by Karolyn Gazella. *Advances in mind-body medicine, 21*(2), 22.

[30] Klingberg, T., Fernell, E., Olesen, P. J., Johnson, M., Gustafsson, P., Dahlstrom, K., Westerberg, H. (2005). Computerized Training of Working Memory in Children with ADHD-A Randomized, Controlled Trial. *Journal of the American Academy of Child and Adolescent Psychiatry, 44*(2), 177–186.

[31] Lee, J. K., & Orsillo, S. M. (2014). Investigating cognitive flexibility as a potential mechanism of mindfulness in Generalized Anxiety Disorder. *Journal of Behavior Therapy & Experimental Psychiatry, 45*(1), 208–

[32] Lenroot, R. K., & Giedd, J. N. (2006). Brain development in children

and adolescents: Insights from anatomical magnetic resonance imaging. *Neuroscience & Biobehavioral Reviews, 30*(6), 718–729.

[33] Lenroot, R. K., Schmitt, J. E., Ordaz, S. J., Wallace, G. L., Neale, M. C., Lerch, J. P., Giedd, J. N. (2009). Differences in genetic and environmental influences on the human cerebral cortex associated with development during childhood and adolescence. *Human Brain Mapping, 30*(1), 163–174.

[34] Lutz, A., Slagter, H. A., Dunne, J. D., & Davidson, R. J. (2008). Attention regulation and monitoring in meditation. *Trends in Cognitive Sciences, 12*(4), 163–169.

[35] Modesto-Lowe, V., Farahmand, P., Chaplin, M., & Sarro, L. (2015). Does mindfulness meditation improve attention in attention deficit hyperactivity disorder?. *World Journal of Psychiatry, 5*(4), 397–403.

[36] Moore, A., & Malinowski, P. (2009). Meditation, mindfulness and cognitive flexibility. *Consciousness & Cognition, 18*(1), 176–186.

[37] Moore, B. A. (2013). Propensity for experiencing flow: The roles of cognitive flexibility and mindfulness. *Humanistic Psychologist, 41*(4), 319–332.

[38] Mrazek, M. D., Franklin, M. S., Phillips, D. T., Baird, B., & Schooler, J. W. (2013). Mindfulness training improves working memory capacity and GRE performance while reducing mind wandering. *Psychological Science, 24*(5), 776–781.

[39] Mrazek, M. D., Smallwood, J., & Schooler, J. W. (2012). Mindfulness and mind-wandering: Finding convergence through opposing constructs. *Emotion, 12*(3), 442–448.

[40] Ma,C.(2013).Comparative study of the executive function training and mindfulness training on the promotion of children's attention (Master's thesis). Neimeng Normal University. [Ma Chao. (2013). Comparative study of executive function training and mindfulness training on promoting children's attention (Master's thesis). Inner Mongolia Normal University.]

[41] Mao, B, B.(2009). The investigation and training on 4~6 years old children's sensory integration ability (Master's thesis). Shanxi Normal University. [Mao Binbin. (2009). Investigation and training on 4-6 year-old children's sensory integration ability (Master's thesis). Shanxi Normal University.]

[42] Oh, S., & Lewis, C. (2008). Korean Preschoolers' Advanced Inhibitory Control and Its Relation to Other Executive Skills and Mental State Understanding. *Child Development, 79*(1), 80–99.

[43] Pascual-Leone, A., Amedi, A., Fregni, F., & Merabet, L. B. (2005). The plastic human brain cortex. *Annual Review of Neuroscience, 28*(28), 377–401.

[44] Pan, X, X., Ma, H, W. (2009). The application of continuous performance task in diagnosis and treatment of ADHD. *International Journal of Pediatrics,*

36(1), 100-102. [Pan Xuexia, Ma Hongwei. (2009). The application of continuous performance task in diagnosis and treatment of ADHD. *International Journal of Pediatrics*, 36(1), 100–102.]

[45] Purser, R. E., & Milillo, J. (2015). Mindfulness Revisited: A Buddhist-Based Conceptualization. *Journal of Management Inquiry, 24*(1), 3–24.

[46] Razza, R. A., Bergen-Cico, D., & Raymond, K. (2015). Enhancing Preschoolers' Self-Regulation Via Mindful Yoga. *Journal of Child & Family Studies, 24*(2), 372–385.

[47] Reznick, J. S., Morrow, J. D., Goldman, B. D., & Snyder, J. (2004). The onset of working memory in infants. *Infancy, 6*(1), 145–154.

[48] Robins, C. J., Keng, S. L., Ekblad, A. G., & Brantley, J. G. (2012). Effects of mindfulness-based stress reduction on emotional experience and expression: a randomized controlled trial. *Journal of Clinical Psychology, 68*(1), 117–131.

[49] Riggs, N. R., Black, D. S., & Ritt-Olson, A. (2015). Associations Between Dispositional Mindfulness and Executive Function in Early Adolescence. *Journal of Child & Family Studies, 24*(9), 2745–2751.

[50] Rueda, M. R., Checa, P., & Cómbita, L. M. (2012). Enhanced efficiency of the executive attention network after training in preschool children: Immediate changes and effects after two months. *Developmental Cognitive Neuroscience, 2* (4), S192–S204.

[51] Ruff, H. A., Capozzoli, M., & Weissberg, R. (1998). Age, individuality, and context as factors in sustained visual attention during the preschool years. *Developmental Psychology, 34*(3), 454-464.

[52] Rothbart, M. K., Mccandliss, B. D., Saccomanno, L., & Posner, M. I. (2005). Training, Maturation, and Genetic Influences on the Development of Executive Attention. *Proceedings of the National Academy of Sciences of the United States of America, 102*(41), 14931–14936.

[53] Roth, RM., Randolph, JJ., Koven, NS., Isquith, PK. (2006). Neural substrates of executive functions: Insights from functional neuroimaging(pp.1–36). NY: Nova Science Publishers.

[54] Salamé, P., & Baddeley, A. D. (1982). Disruption of short-term memory by unattended speech: implications for the structure of working memory. *Journal of Verbal Learning & Verbal Behavior, 21*(2), 150–164.

[55] Semple, R. J., Lee, J., Rosa, D., & Miller, L. F. (2010). A randomized trial of mindfulness-based cognitive therapy for children: Promoting mindful attention to enhance social-emotional resiliency in children. *Journal of Child & Family Studies, 19*(2), 218–229.

[56] Shapiro, S. L., Carlson, L. E., Astin, J. A., & Freedman, B. (2010). Mechanisms of mindfulness. *Journal of Clinical Psychology, 62*(3), 373–386.

[57] Smallwood, J., & Schooler, J. W. (2015). The Science of Mind Wandering: Empirically Navigating the Stream of Consciousness. *Annual Review of Psychology, 66*(1), 487–518.

[58] Tang, Y. Y., Tang, Y., Tang, R., & Lewispeacock, J. A. (2017). Brief mental training reorganizes large-scale brain networks. *Frontiers in Systems Neuroscience,11:6.doc:10.3389/fnsys.2017.00006.

[59] Tang, Y. Y., Yang, L., Leve, L. D., & Harold, G. T. (2012). Improving Executive Function and its Neurobiological Mechanisms through a Mindfulness-Based Intervention: Advances within the Field of Developmental Neuroscience. *Child Development Perspectives, 6*(4), 361–366.

[60] Ying, H. K., & Wang, C. K. J. (2012). Relationships between mindfulness, flow dispositions and mental skills adoption: A cluster analytic approach. *Psychology of Sport & Exercise, 9*(4), 393–411.

[61] Thurman, S. K., & Torsney, B. M. (2014). Meditation, mindfulness and executive functions in children and adolescents. In N. N. Singh (Ed.), *Psychology of meditation* (pp. 187–207). New York, NY: Nova Science Publishers.

[62] Wang, Y., Xin, T., Liu, X, H. et al. (2012).Mindfulness Can Reduce Automatic Responding: Evidences from Stroop Task and Prospective Memory Task. *Acta Psychologica Sinica, 44*(9),1180–1188 [Wang Yan, Xin Tingting, Liu Xinghua, Zhang Yun, Lu Huanhua, Zhai Yanbin. (2012). Mindfulness training can reduce automatic responding: Evidence from Stroop and prospective memory tasks. *Acta Psychologica Sinica*, 44(9), 1180–1188.]

[63] Wechsler, D. (2003). *Wechsler intelligence scale for children–Fourth Edition (WISC-IV)*. San Antonio, TX: The Psychological Corporation.

[64] Weijer-Bergsma, E. V. D., Formsma, A. R., Bruin, E. I. D., & Bögels, S. M. (2012). The Effectiveness of Mindfulness Training on Behavioral Problems and Attentional Functioning in Adolescents with ADHD. *Journal of Child & Family Studies, 21*(5), 775–787.

[65] Westbrook, C., Creswell, J. D., Tabibnia, G., Julson, E., Kober, H., & Tindle, H. A. (2013). Mindful attention reduces neural and self-reported cue-induced craving in smokers. *Social Cognitive & Affective Neuroscience, 8*(1), 73–84.

[66] Wood, AG., Smith, E. (2008). Executive functions and the frontal lobes: A lifespan perspective(pp. 203–216). Philadelphia, PA: Taylor & Francis.

[67] Wu, J, J., Zheng, R, C.(2008). The review of mental awareness intervention. *Chinese Mental Health Journal, 22*(2),148–151. [Wu Jiujun, Zheng Richang. (2008). A review of mental awareness intervention. *Chinese Mental Health Journal*, 22(2), 148–151.]

[68] Yang, L, Z., Song, H. (2003). Development on preschool children's self-control ability. *Studies of Psychology and Behavior, 4*(1),51–56. [Yang Lizhu,

Song Hui. (2003). Development of preschool children's self-control ability. *Studies of Psychology and Behavior*, 4(1), 51–56.]

[69] Zeidan, F., Gordon, N. S., Merchant, J., & Goolkasian, P. (2010). The Effects of Brief Mindfulness Meditation Training on Experimentally Induced Pain. *Journal of Pain, 11*(3), 199–209.

[70] Zeidan, F., Johnson, S. K., Diamond, B. J., David, Z., & Goolkasian, P. (2010). Mindfulness meditation improves cognition: Evidence of brief mental training . *Consciousness & Cognition, 19*(2), 597–605.

[71] Zelazo, P. D. (2006). The Dimensional Change Card Sort (DCCS): a method of assessing executive function in children. *Nature Protocol, 1*(1), 297–301.

[72] Zelazo, P. D., Anderson, J. E., Richler, J., Wallnerallen, K., Beaumont, J. L., & Weintraub, S. (2013). II. NIH Toolbox Cognition Battery (CB): measuring executive function and attention. *Monographs of the Society for Research in Child Development, 78*(4), 16–33.

[73] Zelazo, P. D., & Lyons, K. E. (2012). The Potential Benefits of Mindfulness Training in Early Childhood: A Developmental Social Cognitive Neuroscience Perspective. *Child Development Perspectives, 6*(2), 154–

[74] Zelazo, P. D., Müller, U., Frye, D., Marcovitch, S., Argitis, G., Boseovski, J., Sutherland, A. (2003). The development of executive function in early childhood. *Monographs of the Society for Research in Child Development, 68*(3), 48–64.

[75] Zoogman, S., Goldberg, S. B., Hoyt, W. T., & Miller, L. (2015). Mindfulness Interventions with Youth: A Meta-Analysis. *Mindfulness, 6*(2), 290–302.

[76] Zheng, X, X., Li, Y, Q. (1991). *The manual of children's sensory development checklist implementation.* Taipei: The special education center of Taipei city normal college. [Zheng Xinxiong, Li Yueqing. (1991). *Manual for the implementation of children's sensory development checklist.* Taipei: The Special Education Center of Taipei Municipal Teachers College.]

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Note: Figure translations are in progress. See original paper for figures.