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Effects of a short mindful-breathing intervention on the psychophysiological stress reactions of German elementary school children

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Abstract
This research investigates whether a short mindfulness exercise can reduce children's psychophysiological stress reactions in the face of a performance task. To answer the question, a randomized controlled trial with 106 elementary school children, aged between 5 and 11 years, was conducted. An intervention group completed a two-minute breathing exercise, whilst a comparison group watched a short video, before both groups performed a stress-evoking Stroop test. The stress levels of both groups were measured via galvanic skin response and compared. It was hypothesized that the comparison group would show a higher stress reaction during the stress-evoking task than the intervention group. Contrary to the hypothesis, results show that the intervention group had a higher psychophysiological stress reaction during the task than the comparison group. However, the stress reaction to the announced difficulty of the task was smaller in the mindfulness group than in the comparison group. Results are discussed based on different theoretical mechanisms of mindfulness. Directions for future research include the use of different techniques and durations of mindfulness

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interventions, different control group activities and stress-test operationalizations, as well as the distinction between age groups.

Keywords
mindfulness, psychophysiology, stress response, elementary school children, mindful breathing, mindfulness intervention

Introduction

Elementary schools are not just places to acquire academic skills, but also to foster students' resilience to stress, connections with peers, and future aspirations (OECD, 2017). However, school is where children's performance is rated—a potential stress burden. Thus, it is important to create a supportive learning environment and empower children to cope with achievement stress (OECD, 2017). Mindfulness-based interventions offer a promising approach for addressing children's stress and anxiety (Napoli, Krech, & Holley, 2005; Van de Weijer-Bergsma, Langenberg, Brandsma, Oort, & Bögels, 2014). But until now, mindfulness programs are not widespread in Germany or many other countries. The federal government of North-Rhine-Westfalia (a federal state of Germany) started an evaluation study by giving mindfulness lessons at all elementary schools in one town (Stoldt, 2016). However, there is no nation-wide mindfulness program or evaluation of such.

Mindfulness interventions for children in school settings

Mindfulness is a process or state of mind of openly attending to and being aware of one's experience in the present moment (Creswell, 2017). This can take many forms, including focusing on one's body sensations (e.g. breath), emotional reactions, mental images, mental talk, and perceptual experiences (e.g. sounds). Furthermore, an attitude of openness or acceptance toward one's experiences is critical, i.e. mindfulness involves nonjudgmental attention to present-moment experiences (Brown, Ryan, & Creswell, 2007; Kabat-Zinn, 2009).

Some studies have investigated the effects of mindful breathing in school settings (Table 1 gives an overview; for a more extensive review, see Zenner, Herrnleben-Kurz, & Walach, 2014), although they used various mindfulness methods—not only breath focus (Dhungel, Malhotra, Sarkar, & Prajapati, 2008; Idler, 2015; Pramanik, Pudasaini, & Prajapati, 2010), but also yoga (Butzer et al., 2014; Hagins, Haden, & Daly, 2013; Mendelson et al., 2010), body scan (Napoli et al., 2005; Van de Weijer-Bergsma et al., 2014), or a mixture of different mindfulness techniques. Results show that mindfulness reduces rumination and emotional arousal due to stressors (Mendelson et al., 2010), children are less anxious before tests and have an increased ability to pay attention (Beauchemin, Hutchins, & Patterson, 2008; Napoli et al., 2005), and mindfulness interventions can reduce

Table 1. Overview of studies on mindfulness breathing interventions in children.

References	Age	*k*	Intervention components	Intervention plan (min per session/ no. of sessions)	Design	Outcomes
Mendelson et al. (2010)	4th–5th grade	51	Yoga-based physical activity, breathing techniques, guided mindfulness practices	45/48 (12 weeks)	rct	Less rumination, intrusive thoughts, emotional arousal than in control group
Napoli et al. (2005)	5–8 years	225	Breathwork, body scan, sensorimotor awareness activities	45/12 (24 weeks)	rct pre-post	Decreased test anxiety and ADHD behaviors, increased ability to pay attention
Beauchemin et al. (2008)	13–18 years	34	Meditation (focus on breath, thoughts, feelings)	5–10/25 (5 weeks)	Pre-post	Decreased state and trait anxiety, improved social skills and academic performance
Van de Weijer-Bergsma et al. (2014)	8–12 years	208	Non-judging awareness of sounds, bodily sensations, breath, thoughts	30/12 (6 weeks)	Pre-post-follow-up	Prevention effects on stress and well-being
Bazzano et al. (2018)	3rd grade	52	Breathing, guided relaxation, yoga	40/10 (8 weeks)	rct	Improved quality of life
Butzer et al. (2014)	2nd–3rd grade	36	Yoga, meditation, relaxation	30/10 (10 weeks)		Decreased baseline cortisol in second, but not third grade; decreased cortisol after the attention task in second and third grade, indicating increased anxiety

(continued)

Table 1. Continued.

References	Age	*k*	Intervention components	Intervention plan (min per session/ no. of sessions)	Design	Outcomes
						before the test; no decrease from before to after a yoga class
Idler (2015)	4th grade	4	Breathing	3/12 (6 weeks)	Alternating treatment	No differences between control and training condition in reading fluency and ability to pay attention
Crescentini, Capurso, Furlan, and Fabbro (2016)	7–8 years	31	Meditation focusing breath, body parts, and thoughts vs. reading and commenting a book	9–30/24 (8 weeks)	rct pre-post	Less ADHD symptoms and anxiety after the training; no decrease in depressive symptoms
Semple, Lee, Rosa, and Miller (2010)	9–13 years	25	Sensory exercises (e.g. breath, body scan, visualization practices)	90/12 (12 weeks)	rct pre-post-follow-up	Reduced attention and anxiety problems
Pramanik et al. (2010)	25–30 years	50	Breathing	5/1	Pre-post	Decreased systolic and diastolic blood pressure, heart rate
Dhungel et al. (2008)	24.67 (mean)	36	Breathing	15/38 (4 weeks)	Pre-post	Decreased pulse rate, respiratory rate, diastolic blood pressure

k: sample size; rct: randomized controlled trial; ADHD: attention deficit hyperactivity disorder.

stress and improve well-being (Bazzano, Anderson, Hylton, & Gustat, 2018; Van de Weijer-Bergsma et al., 2014).

Only a few studies have investigated the physiological effects of mindfulness interventions with children. Butzer et al. (2014) examined cortisol concentrations after a classroom-based yoga intervention. No acute effect of yoga on stress levels (as measured by cortisol concentrations) occurred, but a longitudinal decrease in overall cortisol concentrations was found. After behavioral stressor tasks, Hagins et al. (2013) found no differences in blood pressure and heart rate between a yoga group compared to a physical education group. These two studies show how inconclusive the evidence for the physiological effects of mindfulness interventions on stress is.

Evidence for the effectiveness of very short mindfulness interventions is inconclusive, too. Using fourth-graders as participants, Idler (2015) found no differences between training and control groups regarding the effects of a brief mindful breathing exercise on reading fluency, ability to pay attention, and feelings of stress. Carsley and Heath (2018) investigated the effects of a brief mindfulness coloring activity (coloring mandalas) compared to a free drawing activity on test anxiety in elementary school children. Test anxiety decreased and state mindfulness increased following both interventions.

It is also unclear exactly which component(s) of mindfulness influence the outcomes. Most mindfulness techniques share a common goal of focusing attention on something (e.g. breath or a sound) and increasing awareness of one's thoughts (Greenberg & Harris, 2012). A key element is breath focus because of autonomic nervous system regulation (Napoli et al., 2005). *Prāṇāyāma* (which is originated in the yoga tradition and represents slow and deep breathing) relieves stress and stabilizes the autonomic body function (Bhimani, Kulkarni, Kowale, & Salvi, 2011). After five minutes of pranayama, systolic and diastolic blood pressure decrease with a slight fall in heart rate, indicating a parasympathetic dominance (Pramanik et al., 2010). Performing breathing exercises 15 minutes a day for four weeks increased the parasympathetic activity, thus suggesting long-term influence: pulse rate, respiratory rate, and diastolic blood pressure decreased (Dhungel et al., 2008). A meta-analysis confirms pranayama's beneficial effects on stress level (Nivethitha, Mooventhan, & Manjunath, 2016). Although slow breathing is proposedly easy to learn, practice, and follow in daily life, there are differences in the feasibility between ages (Bhimani et al., 2011). Adults may be able to attend their breath for 45 minutes, whereas five year olds may only manage three minutes (Burke, 2010). A successful mindfulness intervention with children should use simple instructions and teachers should serve as models (Zelazo & Lyons, 2012).

Research on the impact of mindfulness interventions on stress and anxiety in schools often has methodological limitations, most notably small participant numbers or lack of control groups (although there are exceptions, of course, e.g. Crescentini et al., 2016). Typically, research on mindfulness interventions occurs in small group settings over several weeks, but research on young children is still limited. The appropriate dosage and method for younger children also remains unclear (Davidson & Dahl, 2018). The studies reviewed above mostly measured perceived stress during school in general, and few studies investigated the immediate impact of a mindfulness exercise on performance stress. The present study will attempt to address these gaps within literature and investigate the effects of a short mindfulness breathing exercise on the physiological stress reaction of elementary school children in the face of an immediate performance stressor.

Theoretical approaches to stress reduction by mindfulness activities

As mentioned in the beginning, mindfulness is about being aware of and accepting the present moment experiences (Creswell, 2017). Bishop et al. (2004) proposed a two-component model of mindfulness, consisting of self-regulation of attention and orientation to experience (including the acceptance of whatever experience might occur).

Mechanisms of mindfulness

Few theoretical accounts describe the psychological mechanisms of mindfulness. The concept by Hölzel et al. (2011) assumes that mindfulness involves a combination of four underlying mechanisms:

Attention regulation. Attention as an important part of early mindfulness practice is supposed to rest on a single object during meditation. Maintaining the focus of attention on one object, while disregarding distractions, is referred to as executive attention. This is mainly associated with the anterior cingulate cortex (ACC) (Hölzel et al., 2007) and it is part of many meditation and mindfulness techniques (e.g. focusing on one's breath, body parts, or a mantra). Thus, attention regulation is a very basic part of mindfulness.

Body awareness. The focus of attention is usually an object of internal experience, thus body awareness is also a very basic part of many mindfulness techniques (an exception being focus on the environment). The insula (the brain are associated with sensory experiences, Liu et al., 2017) as well as the secondary somatosensory area, are more active after a mindfulness-based stress reduction course focusing on participants' momentary experience (Farb et al., 2007). The enhanced sensory processing has been suggested to represent increased bottom-up processing (Hölzel et al., 2011).

Emotion regulation. During the modification of emotional responses, prefrontal control systems modulate emotion-generative systems, such as the amygdala which detects affectively arousing stimuli (Hölzel et al., 2011). Attention to breathing down-regulates amygdala activation and increases amygdala-prefrontal integration

(Doll et al., 2016). Thus, mindfulness improves prefrontal cortex (PFC) control over amygdala responses, promoting the ability to regulate emotions.

Change in perspective on the self. A change in perspective on the self happens due to structural and functional changes in structures that support self-referential processing (Hölzel et al., 2011). Self-referential processing activates cortical midline structures, which support memory for self-traits and the autobiographical integration (Northoff & Bermpohl, 2004; Northoff et al., 2006; Van der Aar, Peters, Van der Cruijsen, & Crone, 2019). These structures evaluate stimuli's importance to the self, thus, mindfulness assumably leads to decreased self-referential processing (Ott, Walter, Gebhardt, Stark, & Vaitl, 2010). However, here it is hard to draw a link to specific mindfulness techniques.

Overall, the interaction and sequence of these processes remains unclear. At a beginner's level, emotion regulation might be most prominent (Doll et al., 2016). Therefore, a mindfulness exercise might reduce the stress reaction to an immediate stressor, due to the down-regulation of the amygdala by the PFC, and a decrease in self-referential processing is prominent at a beginners level (Ott et al., 2010), meaning the participants may not evaluate the stimulus in reference to their self-concept or abilities. They may, therefore, upkeep a reduced stress reaction.

Default Mode Network and mindfulness

The Default Mode Network (DMN) is a network of separate brain structures (medial PFC, ACC, and posterior cingulate cortex) with synchronized activation patterns. It is active during rest and attenuated during goal-directed behaviors (Brewer et al., 2011; Raichle et al., 2001) and associated with mind-wandering, self-referential processing, rumination, attentional lapses, and anxiety (Brewer et al., 2011; Buckner, Andrews-Hanna, & Schacter, 2008).

Mindfulness deactivates the medial PFC and posterior cingulate cortex, in favor of the ACC (supporting attentional monitoring) and a sustained limbic network activation (involving the thalamus, insula, and primary sensory regions) (Brewer et al., 2011; Farb, Anderson, & Segal, 2012). The insula and other brain regions have direct and indirect influences on the DMN and its counterpart (the central-executive network) so they can switch between these networks (Sridharan, Levitin, & Menon, 2008). Breathing practices (sensory experiences, thus activating the insula) help in controlling the DMN.

Furthermore, mindfulness exercises direct attentional resources away from cognitive elaboration and evaluation of negative emotions, as induced by stressful situations. Automatic negative self-evaluation is reduced, and tolerance for negative affect is increased (Farb et al., 2012). Thus, mindfulness techniques train the attention away from self-reference and mind-wandering, and potentially away from default-mode processing, which is related to the experience of stress (Brewer et al., 2011).

Physiological equilibrium of the autonomous nervous system

The physiological explanation of the stress-reducing effects of mindfulness is based on the autonomous nervous system, more precisely the sympathetic (SNS) and the parasympathetic nervous systems (PSNS). SNS influences the inner organs in times of increased demands, such as physical strain or mental exertion. When the body is exposed to acute stress (i.e. short-term, energy-mobilizing demands), SNS increases heart rate, blood pressure, activates perspiratory glands, etc. Its counterpart, PSNS, leads to relaxation, tranquilization, and regeneration (Schandry, 2011).

Various processes contribute to balancing the SNS and PSNS. For example, the lungs contain slow adapting pulmonary stretch receptors which activate when the lungs expand during inhalation, causing SNS suppression. Thus, PSNS activity increases, downregulating stress reactions (Eckberg, 2003). Slow breathing influences stress-related physiological reactions, as shown by the Pranayama studies (Nivethitha et al., 2016; Pramanik et al., 2010).

Physiology of the stress response

Lazarus (1991) proposed a very prominent stress model: via ‘‘primary appraisal’’ (neuro-affective stimulus processing), stimuli are classified as dangerous—being a threat—or not. A threat evokes a stress reaction if resources to cope with the stimulus are perceived as insufficient. The stress response consists of psychological and physiological changes, like an increase in electrodermal activity and other autonomous nervous activity parameters. Mindfulness has been shown to influence the appraisal of stress-evoking events as well as the subsequent coping strategies (Weinstein, Brown, & Ryan, 2009).

The human stress response which arises after a stressor event and its cognitive appraisal is a multidimensional process in which many body systems interact: the neural axis, the neuroendocrine axis, and the endocrine axis. Most important for the purposes of this study is the neural axis which provokes the activation of the autonomous nervous system and neuromuscular nervous systems (Everly & Lating, 2019). SNS activation includes a sweat gland activation, thus the stress response can be measured via skin conductance (Kreibig, 2010). Research showed an impact of mindfulness interventions on psychophysiological parameters. Lush et al. (2009) demonstrated that mindfulness-based stress-reduction reduced skin conductance and SNS activity in fibromyalgia patients.

Hypothesis

As we have seen, different approaches explain the stress-reducing effects of mindfulness activities. This paper proposes that a short mindfulness-based breathing exercise reduces the stress reaction to a demanding task for four reasons: (a) mindfulness includes emotion regulation and improves attention (psychological approach; Hölzel et al., 2011); (b) mindfulness deactivates the DMN (neurological approach; Brewer et al., 2011), (c) the SNS gets deactivated by slow breathing (physiological approach; Eckberg, 2003), and (d) mindfulness impacts the cognitive appraisal of a threat (cognitive approach; Lazarus, 1991; Weinstein et al., 2009).

H1: A very short mindfulness-based breathing exercise reduces children's level of physiological stress in a testing situation.

The goal of this study is to investigate the effects of a very short mindfulness intervention in order to contribute to the examination of the appropriate dosage of mindfulness intervention for children. Demonstrating the effectiveness of a very short mindful breathing intervention would have implications for practice, since schools may be more likely to adopt and implement simple and brief intervention strategies.

Methods

Sample

The study was carried out in a German elementary school. Every student's parents received an information letter, which asked for the child's voluntary participation. Of the 134 students attending the school, written consent was provided from parents of 113 students. Due to technical problems (e.g. the smartband unfastened, so that the skin–electrode contact was interrupted, or children who accidentally turned off their smartband), seven students had to be excluded from the analysis. Thus, the final sample consisted of 106 children. All participants were native German speakers from grades one to four. Specifically, 24% of the participants were in grade one, 26% in grade two, 30% in grade three, and 20% in grade four. This led to a sample which was between 5 and 11 years old ($M_{\text{age}} = 8.7$, $SD = 1.12$, 58% female). Table 2 shows the breakdown of demographic variables.

Design

The sample was split into the intervention group (with the breathing exercise) and the comparison group (without the breathing exercise). Each class was randomly divided into two to three groups, up to 10 children per group, which were randomly

Table 2. Demographic breakdown.

	Grade 1	Grade 2	Grade 3	Grade 4	Female (percent)	Mean age	Total
Intervention group	14	15	12	11	34 (65%)	8.8	52
Comparison group	11	13	20	10	27 (50%)	8.6	54
Total	25	28	32	21	61 (57%)	8.7	106

assigned to the conditions. It was not randomized on an individual level due to the substantial administrative effort.

The app used in the experiment was different in the two experimental groups: for the intervention group, it started immediately with the Stroop task. For the comparison group, it showed a drawing video before the Stroop task. The Stroop task, in this case, was a replacement for the breathing exercise and an alternative for the "no stimulus" white screen that is often used to bridge the interstimulus interval. Pre-surveys showed that this white screen is not at all a "no stimulus", but instead fosters mind-wandering, i.e. one starts to think of anything that comes to mind. The drawing video was an alternative for this white screen as it impedes mind-wandering by capturing the children's attention and not causing arousal at the same time. The dependent variable was the stress reaction, which was measured via the smartband.

Procedure

The study took place in a classroom at the children's elementary school. Multiple students' desks and chairs were ranged in rows. On each desk, two workplaces were separated through blinds. Each workplace consisted of a tablet PC, the smartband, and headphones. The children participated in the study procedures multiple at a time but separated by condition (comparison and intervention group). The comparison and intervention groups were separated due to slightly different procedures, as outlined below.

When the children had their workplace, they put on the smartband and were told they would play a computer game and would receive sweets as a reward if they solved the task. During the experiment, the teacher (who is one of the authors) was the only person present alongside the children. The teacher explained the Stroop task (see below) and made sure that everyone understood. Then, the children put on headphones. The control group started immediately after the instruction with the app on the tablet, which showed a drawing video (painting-by-numbers) before the Stroop task. The intervention group completed a breathing exercise beforehand. They were instructed to sit up straight, count their breath until 20 (the teacher counted aloud), and focus on their breath. After the exercise, the intervention group began with the Stroop task.

The Stroop task was conducted three times. Each trial was shorter than the one before with the same amount of words, making it more difficult in each trial. The increased difficulty was announced via the headphones.

Material

The Stroop task was used to induce stress. It consists of color words which are written in different colors (e.g. the word "blue" is written in red font color). One has to select the word of the color in which the word is written. The Stroop task produces mental overstimulation due to cognitive conflict and time pressure, and it induces stress on all levels which are required for a stress test (psychological and physiological effects, electromyographical activity, changes in adrenaline concentration; Tulen, Moleman, van Steenis, & Boomsma, 1989). In comparison to a school exam, the Stroop task may be more of a "learning game" than a cognitive performance exercise. However, the Stroop task has similarities to a school testing situation since it is a performance test: one has the ambition to give the correct answer and avoid false answers and there is time pressure. However, the time component might not be as intense in elementary school as in the experiment. However, these are the crucial components of a stress situation in school that were tried to be realized in the study.

The teacher who performed the study with the children received training from the last author regarding the breathing exercise. The teacher was instructed how to count, as well as how fast to count, and practiced it various times before doing it in front of the children. The breathing exercise is a guided breathing meditation because this ensures that the breathing situation is as parallel as possible between different groups. Guided breathing meditation was also chosen because it might be difficult for young children without any meditation experience to focus on their breath for this period of time.

Thinking of the mindfulness mechanisms by Hölzel et al. (2011), the short breathing exercise fosters the attention regulation, due to sustained attention on the breath. It supports body awareness because the breath is somehow related to the body, and it fosters emotion regulation, since Doll et al. (2016) have shown that attention to breathing influences amygdala activation. However, it is not clear if such a short breathing exercise with, presumably, totally unexperienced meditators is already changing the perspective on the self. But since this study only uses one component of meditation techniques rather than a complete mindfulness program, it should not be surprising if this component does not elicit all the effects of mindfulness interventions. The drawing video, however, should not foster body awareness nor emotion regulation or change in perspective on the self. The only mechanism that could be influenced by this video is the attention regulation because the children have to focus on the video.

The smartband (Figure 1) used in this study was developed by Papastefanou (2018), as a tool to measure Galvanic skin response and skin temperature at a rate of 10 Hz with 10 Bit resolution. Additionally, skin contact quality and ambient temperature are measured to detect artifacts caused by changing contact quality of skin and transducers. The smartband validity has been confirmed by experimental and field research (Hogertz, 2010; Li et al., 2016; Steinitz, 2014).

The smartband's classification algorithm (Papastefanou, 2013) allocates physiological reactions to emotions. It is leaned on a framework of basic emotions (Ekman, 1992). Specific emotional states are correlated with specific physiological arousal reflected in peripheral parameters (skin conductivity, skin temperature, heart rate variability; Kreibig, 2010, 2014; Levenson, Carstensen, Friesen, & Ekman, 1991). An elementary valence (aversive vs.

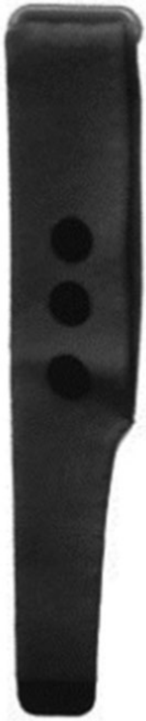

Figure 1. Sensor wrist band.

Table 3. Typology of aversive and appetitive EDA (electrodermal activity) emotions.

EDA-based emotion response type	"feelings" connotations
Appetitive arousal (orientation, surprise, expecting reward)	Joy, curiosity, surprise, newness
Aversive arousal (Flight–Fight Response, expecting loss)	Fear, anger, tension, stress, discomfort
Balance	Vigilance, well-being, hedonic pleasure
Retraction	Shut-off, dis-interested, mental withdrawal, tired, deeply relaxed

appetitive) of physiological emotion responding is identified, with stress being aversive arousal (Table 3).

The smartband also saves a time stamp and it measures all the parameters continuously. Thus, the high temporal resolution of the data allows us to determine the trigger of a certain emotional response (e.g. if this response was elicited by the announcement of the task's difficulty or by the Stroop task).

Statistical analysis

We operationalized the dependent variable by the binary occurrence of negative arousal peaks (stress reactions) during the Stroop task (negative arousal yes/no) for each measurement moment, while clustering the data by subject. We modeled the effects of the treatment (breathing exercise vs. no breathing exercise) on this binary dependent variable by estimating a logistic regression with the variance–covariance matrix of the estimators corrected for clustered data.

Results

The logistic regression estimation showed a significant difference between the comparison and the intervention group, $z = 2.89$, $p = .004$. However, contrary to the hypothesis, the stress reaction of the intervention group was stronger than of the comparison group during the Stroop task, *Odds Ratio* = 2.83 (95% CI: 1.4–5.73).

Explorative analyses

To understand the unexpected direction of the main effect, exploratory analyses were conducted. First, the stress level during the breathing exercise/drawing video were investigated, following the idea that the stress level during the exercise might be crucial for the treatment effects. Thus, the logistic regression model was extended by adding the number of occurrences of negative peaks during the comparison and treatment activity before the Stroop task, as the main effect of its own plus its interaction with the treatment variable. An interaction between groups and stress during the treatment activity, $z = 1.39$, $p = .16$, was found. This indicates that the stress level during the activity moderates the treatment effect on the stress responses during the Stroop task. However, the treatment main effect remains significant, $z = 2.01$, $p = .035$.

Second, the extended model with the stress reaction during the second, more difficult Stroop task phase, was used as a dependent variable. The suggested interaction of the prior analysis is now significant, $z = 2.37$, $p = .02$, whilst the main effect of treatment becomes insignificant, $z = -0.36$, $p = .72$. That means the moderation effect becomes clearer with increased difficulty. This becomes even more apparent in the last and most difficult Stroop task interval: the interaction between treatment and stress level during the pre-activity is highly significant, $z = 3.92$, $p < .000$. The main effect of treatment remains insignificant, $z = -1.04$, $p = .3$.

Third, another analysis, focusing on the stress reaction to the test itself compared to the announcement of the test difficulty, was conducted. During the announcement interval, the intervention group shows a lower stress reaction than the comparison group, $z = -1.52$, $p = .13$, $OR = .41$. Inspired by the idea of moderation, another logistic model extended by the stress level during the activity as main effect and the interaction of stress level during the treatment activity and the treatment itself was conducted. No significant interaction, $z = -1.88$, $p > .06$, was found but the main effect of treatment becomes more clear, $z = -1.88$, $p = .06$, with the intervention group showing a smaller stress reaction to the mere expectancy of stress than the comparison group. This effect becomes even more apparent in the announcement before the last Stroop exercise, where the children are told that it will get even more difficult. The main effect of group is decreased, $z = -1.58$, $p = .11$, with the intervention group being less stressful than the comparison group, $OR = .25$. In the extended interaction model, the intervention group shows the least stress levels compared to the comparison group, $z = -2.29$, $p = .02$, $OR = 0.09$.

Discussion

Mindfulness may help elementary school children to cope with stress. The existing literature on mindfulness in school settings is still not totally clear about all the effects and needs more studies with physiological measures and very short mindfulness interventions. This study contributed to that literature by conducting a short mindfulness breathing study with elementary school children and psychophysiological stress measures.

Results show that, contrary to the proposed hypothesis, the stress reaction during the stress-evoking Stroop task was stronger for children in the intervention group than in the comparison group. Nevertheless, publishing mindfulness studies with unexpected results is important to better understand the concept and the relevance of its components (Davidson & Dahl, 2018). Interestingly, exploratory analyses indicate that the stress level during the breathing/comparison exercise moderates the treatment effect on the stress responses. The more stress a child has before the test, the more stress it has during the Stroop task. This moderation effect increases with the growing task difficulty. Thus, the stress reaction during the mindfulness (or comparison) intervention is crucial, too.

Furthermore, results show differences between the stress reactions to the Stroop task compared to the announcement of its difficulty. Concerning the difficulty announcement, it was found that the intervention group shows less stress than the comparison group. Thus, the breathing exercise did not reduce the stress response to the task itself but may have helped to cope with the expectation of difficulty. Perhaps this could be explained by the cognitive appraisal theory (Lazarus, 1991), in the sense that the mindfulness exercise may have enabled a reappraisal of the announcement, classifying it as a non-threat. However, during the actual task, coping resources could have been perceived as insufficient, therefore still eliciting a stress reaction. This finding might also be linked to the so-called "third wave of cognitive therapy" which is based on findings to mindfulness (Mindfulness-Based Cognitive Therapy; Segal, Teasdale, & Kabat-Zinn, 2018). Following this train of thought, mindfulness might help children to initiate tasks because they might have a reduced stress response before the task. They are not influenced by knowing that the task will be difficult. Like this, mindfulness could help to tap a child's full potential because it does not refuse to do a task due to the anxiety to show a bad performance, but instead they might just start with the task and do it as good as they can, because they are curious and accept the present-moment experiences (Farb et al., 2012).

One possible explanation for the lack of support for the original hypothesis is that watching a video of a painting task can serve as a mindfulness intervention too (Carsley & Heath, 2018). For children, it might even be a more mindful experience than counting breath because they are used to it, whereas breath-counting could be a stressful experience for them because they are not used to listening to body signals. Maybe breathing exercises are not age-appropriate for elementary school children. Future research has to examine this. However, the hypothesized direction of results in the stress reaction to the difficulty expectation was found. This cannot be explained by this idea of painting as a mindful activity. Additionally, the children did not paint in person in the current study, but they solely watched a video.

Another explanation is that children are more relaxed after the breathing exercise and therefore, they react more sensitively to external sensory stimuli (i.e. the Stroop task). Nevertheless, the relaxation helps them regulate the expectancy stress because this is caused by inner states (although it is triggered by external information in this case). This fits the assumptions of DMN: the Stroop task itself elicits stress because it is demanding (external stressor). The difficulty announcement does not elicit stress after the mindfulness exercise because self-referential processes are reduced and therefore the difficulty is not referred to oneself—the announcement does not cause the expectation to perform worse than before.

Due to ambiguous results and study design limitations, drawing clear conclusions from the current study is hard and more evidence is needed before one can conclude if it is reasonable to implement such mindful breathing exercises in class.

Limitations

There are several important limitations to this study that must be considered when interpreting the results and implications. One limitation is the lack of longitudinal measurement. There was no repetition of the intervention over several weeks as in other studies. However, it was the goal to investigate the effects of a very brief breathing exercise, without having mindfulness experience. The results show that this already has effects, although not precisely as hypothesized. Investigating regular repetition would nevertheless be insightful.

The sample has a very large age range (from 5 to 11 years), due to examining the whole primary school (grades 1–4). However, it is likely that children's emotion awareness and attention regulation skill evolve over these years (Simonds, Kieras, Rueda, & Rothbart, 2007), thus making the results more difficult to interpret. Future research should take this into account by reducing the age range in the sample, age matching participants, or controlling for age in the analysis. Further related to the sample, although the study aimed to examine a whole elementary school, the sample size is still smaller than it should be, especially since the breathing exercise was conducted only once.

Another limitation is the question of whether the drawing video is an appropriate control activity for the comparison group or if watching the video has a mindful effect itself. Since drawing has already been used as a mindfulness intervention (Carsley & Heath, 2018), it is possible that watching a video of it can have similar effects. Thus, future studies should use different activities for the control group.

Additionally, the Stroop task does not perfectly represent a testing situation at school since it has more of a game character and was presented at a tablet computer. Thus, the Stroop task might have been less stressful for the children because they knew that it was not a normal testing situation or even more stressful because it was a new and unfamiliar situation to them. This might be a problem when interpreting the results.

Another limitation is that the breathing exercise could be very hard for young children because they have to follow the rhythm of the teacher's counting. Although it can be assumed that it would not be better to let them breathe as fast or slow as they want while counting their breath because this would probably lead to strong mind-wandering, another design of the breathing exercise might be more appropriate for this age.

Due to the design of the study, it is not possible to distinguish if the non-effect of the breathing exercise on the stress response during the Stroop task is due to the shortness of the breathing exercise or the young age of the participants or some other factor. It is possible that such a short breathing exercise of approximately two minutes is too short to elicit mindfulness, in particular when this breathing exercise is only done once (although Idler, 2015, did not find effects of a very short breathing exercise after six weeks of intervention). However, it is also possible that it is more difficult for young children to attend to their breath or to reach the state of mindfulness due to their different attention regulation and cognitive control (Simonds et al., 2007).

Future research

Future research should try to close the gaps that have been depicted. This study was one step, but more research is needed to determine relevant components and dosage of mindfulness interventions (Davidson & Dahl, 2018), especially in young children. Further investigations need to examine whether a short breathing exercise can elicit mindfulness in school children, or if there are more effective ways to achieve this, e.g. with props like a stuffed animal that "instructs" the child to count its breaths (Zelazo & Lyons, 2012).

However, breathing is not the only part of classic meditation and mindfulness interventions. Thus, future research should also investigate different components and techniques of meditation, such as body scan or awareness of others. It would be insightful to know if these are more appropriate for young children or if they affect different parts of mindfulness (regarding the mindfulness mechanisms by Hölzel et al., 2011). Additionally, a longitudinal investigation of the single components of mindfulness interventions would also be insightful. Maybe such a short exercise as the current one does not affect stress level directly, but only after several times of practice.

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