



Feasibility of a school-based mindfulness program for improving inhibitory skills in children with autism spectrum disorder



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ABSTRACT

Background: Executive dysfunction is prevalent in children with autism spectrum disorder (ASD), including prominent difficulties in the two facets of inhibition, as well as with selective attention. School-based mindfulness has been used in typically-developing children to improve executive functioning, though this has not been investigated in children with ASD. Therefore, the purpose of this study was to examine the efficacy of a school-based mindfulness program for improving inhibition (prepotent response inhibition and interference control) and selective attention in children with ASD.

Method: Using a quasi-experimental, pre-post design, an eight week school-based mindfulness program (*Mindful Schools*; <https://www.mindfulschools.org/>), was administered to students with ASD (n = 27) at a private, not-for-profit school for children with special needs. The Walk/Don't Walk test and the Color-Word Interference test were used to evaluate prepotent response inhibition and interference control, respectively. Selective attention was measured using a cancellation test.

Results: Significant improvements followed the intervention for prepotent response inhibition and interference control (medium effect sizes), as well as for overall selective attention (large effect size).

Conclusions: The study's findings demonstrate that school-based mindfulness holds promise for increasing specific executive functioning abilities in children with ASD.

1. Introduction

Currently, 1 in 68 children carry an autism spectrum disorder (ASD) diagnosis (Christensen et al., 2016). This has particular importance because healthcare utilization and additional educational services that are required for ASD have been estimated to be over \$17,000 per child annually (Lavelle et al., 2014). Over one's lifetime, the costs associated with an ASD diagnosis have been estimated to be as high as \$2.4 million for individuals who had comorbid intellectual disability and \$1.4 million for individuals without that comorbidity (Buescher, Cidav, Knapp, & Mandell, 2014). With nearly one third (31 %) of individuals who have ASD

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utilizing some form of therapy (Lavelle et al., 2014), establishing effective treatment methods that are both efficient and cost-effective are crucial.

There are well-established, evidence-based interventions for children who are diagnosed with ASD, with several other promising interventions gaining support (Will et al., 2018). In order to improve functional independence, these treatments frequently focus on reducing the symptom severity of the core features of ASD, including deficits in social communication, as well as restrictive and repetitive behaviors (RRBs; American Psychiatric Association, 2013). These later symptoms can manifest motorically (i.e. stereotyped hand or body movements) or cognitively (i.e. "Insistence on Sameness"), and frequently co-occur (Szatmari, 2011). There is a wealth of evidence supporting the effectiveness of behavioral interventions, such as Early Intensive Behavioral Intervention (Reichow, Hume, Barton, & Boyd, 2018) and Applied Behavioral Analysis (Virués-Ortega, 2010), for improving social functioning and functional independence in children who are diagnosed with ASD (Peters-Scheffer, Didden, Korzilius, & Sturmey, 2011). While much of the published literature focuses on treating the behavioral manifestations of ASD, interventions focusing on the cognitive difficulties that accompany ASD, such as executive dysfunction, are beginning to emerge (Kenworthy et al., 2014).

Executive functions are effortful, cognitive processes that allow us to function in society and to be successful in endeavors that we pursue (Anderson, 2002). Though executive functions are implicated in numerous processes (for example, controlling our emotions), three are primary: Inhibition (self-control), working memory (active manipulation of mental information), and cognitive flexibility (changing one's perspectives) (Diamond, 2013). While impairments in executive abilities are not included as diagnostic criteria for ASD, significant difficulties in inhibition (Geurts, van den Bergh, & Ruzzano, 2014), working memory (Kercood, Grskovic, Banda, & Begecke, 2014), and cognitive flexibility (Leung & Zakzanis, 2014) commonly occur in ASD populations (Sanders, Johnson, Garavan, Gill, & Gallagher, 2008).

Executive functioning difficulties have been shown to be prevalent in child (White et al., 2017), adolescent (Sachse et al., 2013), young adult (Brady et al., 2017; White et al., 2017), and older adult (Geurts & Vissers, 2012) ASD populations, as well as in individuals who fall at the higher functioning end of the spectrum (South, Ozonoff, & McMahon, 2007). Deficits in executive functioning are associated with a reduced quality of life (de Vries & Geurts, 2015) and fewer developed adaptive behaviors as the child with ASD ages (Pugliese et al., 2016). Thus, examining the efficacy of interventions focused on improving executive ability in ASD is warranted.

Although executive functioning appears to be generally problematic for children with ASD, research findings on inhibitory abilities in particular are mixed. For example, some studies have shown no differences in inhibitory performance when comparing individuals who are diagnosed with ASD to other groups (Ozonoff & Jensen, 1999; Sinzig, Morsch, Bruning, Schmidt, & Lehmkuhl, 2008), while other studies have indicated impairment in specific types of inhibition and not others (Christ, Holt, White, & Green, 2007; Sanderson & Allen, 2013). Studies that specifically focus on the different facets of inhibition in ASD populations are needed to help reconcile the mixed findings.

Inhibition involves two primary components: Prepotent response inhibition and interference control. It should be noted that, although executive functioning involves distinct constructs, neuropsychological measures may end up measuring aspects of both prepotent response inhibition and interference control, as each relies on the other in order to perform certain tasks successfully (Diamond, 2013). Prepotent response inhibition is the ability to override a given propensity to respond in a certain way in order to achieve a behavioral goal (Miyake et al., 2000). Optimal performance on tasks of prepotent response inhibition requires an individual to cancel, or stop, a response that has already been set in motion (Eagle, Bari, & Robbins, 2008). An example of such a task is the Walk/Don't Walk (W/DW) subtest from the Test of Everyday Attention for Children (TEA-Ch; Henry & Bettenay, 2010). Using the W/DW, findings from several studies have shown that children with ASD have borderline impaired (i.e. scaled score of 6 or below) prepotent response inhibition (Yerys et al., 2009; Zandt, Prior, & Kyrios, 2009). Geurts et al. (2014) completed a meta-analysis on inhibitory processes in ASD and found a moderate effect size for youth with ASD having difficulties with inhibiting a prepotent response, as well as difficulties pertaining to interference control (Geurts et al., 2014).

Interference control is the ability to persist in a task without letting distractions impede one's performance. The Stroop task (Stroop, 1935) exemplifies interference control (Pires, Leitão, Guerrini, & Simões, 2017), as an individual must ignore certain aspects of the stimuli in order to perform well on the task (i.e. ignoring the text "blue" and stating the conflicting ink color that the text is printed in, for example "red"). A portion of children with ASD exhibit greater difficulty in accurately inhibiting their responses on Stroop-like tasks (Robinson, Goddard, Dritschel, Wisley, & Howlin, 2009). The Stroop task and the W/DW test have previously been used to detect changes in inhibitory skills following intervention, including mindfulness-based interventions (Napoli, Krech, & Holley, 2005; Wenk-Sormaz, 2005). Cancellation tasks serve as a measure of selective visual attention (Casco, Tressoldi, & Dellantonio, 1998). In order to perform well on these tasks, an individual must quickly search for and mark a target object while suppressing this action for distractor or background stimuli (Pradhan & Nagendra, 2008). Given the intentional focus on a specific stimulus, while actively ignoring distractor stimuli, cancellation tasks also measure aspects of interference control (Lezak, Howieson, Loring, & Fischer, 2004). Unlike Stroop-like tasks, most cancellation tasks involve a time limit in which individuals must identify as many target stimuli as they can; therefore, there are additional cognitive demands for this type of task (i.e. self- and task- monitoring; Flehmig, Steinborn, Langner, Scholz, & Westhoff, 2007). Cancellation tasks have been effectively used to detect changes in cognitive abilities in children who are diagnosed with ASD following intervention (Aman et al., 2008) and to differentiate clinical populations from controls (Wu et al., 2017).

Mindfulness is an intervention that holds promise for increasing executive functioning. Mindfulness is the purposeful shifting of attention to be in one's immediate purview (Kabat-Zinn & Hanh, 1990). A primary aim of mindfulness is to reduce the automaticity of attention, resulting in increased awareness and acceptance of one's present-moment reality (Kabat-Zinn, 1994). This is accomplished through training an individual to be in control of their attentional resources (Hassed & Chambers, 2014). Thus, mindfulness has

potential to improve executive functioning in children with ASD, as it has been shown to do in clinical (Huguet, Ruiz, Haro, & Alda, 2017) and non-clinical child populations (Napoli et al., 2005).

Implementing mindfulness-based programming into K-12 schools is garnering attention from academic and educator communities (Meiklejohn et al., 2012). To date, the available research on the efficacy of such programming on improving cognitive and psychological functioning is scarce (Semple, Droutman, & Reid, 2017). In fact, many manualized programs of school-based mindfulness interventions have not yet been published in peer-reviewed journals (Semple et al., 2017). Much of the published work on school-based mindfulness programming focuses on the experiential aspects of various school-based mindfulness interventions (i.e. “*did the child enjoy it?*”, “*was it popular among teachers and administration?*”; Burke, 2010). While experiential evidence and levels of satisfaction are important, it may not provide sufficient evidence for school administrators to invest in such programming as K-12 schools continue to face financial limitations (Leachman, Albares, Masterson, & Wallace, 2016). Therefore, it is important to scientifically examine the potential cognitive and psychological benefits of engaging in school-based mindfulness programming.

To date, two studies have investigated the effects of a specific school-based mindfulness program, *Mindful Schools*, both of which have focused on children’s mental health/behavioral functioning. Liehr and Diaz (2010) recruited children from ethnically diverse backgrounds who experienced anxiety and depressive symptomatology. Children were randomly assigned to the *Mindful Schools* intervention group or a comparison group that consisted of psychoeducation. Their findings included a significant reduction of depressive symptomatology in the mindfulness intervention group, but not for the comparison group. Black and Fernando (2014) examined the effects of *Mindful Schools* on teacher perceptions of classroom behavior in a public elementary school. Results showed significant improvement in teacher perceptions of their students’ ability to pay attention, participate in activities, show care and respect for others, and to exhibit self-control following the intervention. Their findings indicated sustained improvements in these areas for at least seven weeks following the intervention.

At present, there has been no published work that has evaluated the use of mindfulness for improving executive functioning abilities in children who are diagnosed with ASD; therefore, the current study sought to address this significant gap in the literature. In the current study, we investigated the effectiveness of a school-based mindfulness program for improving both attentional and inhibitory abilities in children who are diagnosed with ASD. Following the *Mindful Schools* intervention, we hypothesized that performances in selective visual attention, prepotent response inhibition, and interference control (speed and accuracy) would improve for the study’s sample.

2. Material and methods

2.1. Compliance with ethical standards

The authors’ institutional review board approved the current study and all study-related procedures were conducted in accordance with the code of ethics of the World Medical Association (Declaration of Helsinki). The educational system delivered the *Mindful Schools* intervention to their middle and high school students. Parental permission was solicited from all middle and high school students to participate in the research procedures (pre/post-testing). Assent to participate in the study was sought from students whose parents had given their permission for their child to participate in research.

2.2. Participants

Consenting and assenting procedures resulted in 37 students being enrolled into a larger study, 29 of whom met inclusionary criteria for the current study. All students in the current study attended a private, not-for-profit school that specifically focuses on educating children with special needs. The school enrolls children in kindergarten through 12th grade who have various diagnoses and developmental disabilities, including ASD. The inclusion criteria for the current study included being between the ages of 10 through 17 years, being verbal, and having English fluency in reading, writing, and spoken language, as well as an ASD diagnosis (verified via educational records). All children who were involved in the study were higher functioning (i.e. could read, write, and were verbal) within the autism spectrum.

As the mindfulness intervention was given system-wide, accommodations for any type of control group was not feasible in the current study. Two students declined to complete post-testing, resulting in the final sample of 27 students who completed the intervention and both pre/post-testing sessions. Of these 27 students, four had missed one intervention session and one had missed three interventions sessions. All remaining students in the sample completed every intervention session.

The sample’s demographics are shown in Table 1. The majority of the participants were male (77.8 %, 21/27), which is consistent with the greater ASD population (Christensen et al., 2016). All 27 participants in the study had a primary diagnosis of ASD. Of these 27 participants, 11 had one comorbid mental health diagnosis (40.7 %) and 10 had at least two comorbid mental health diagnoses (37.0 %). Comorbid diagnoses included ADHD (n = 18), Anxiety Disorder (n = 11), Sensory Processing Disorder (n = 3), and Speech or other Language Disorder (n = 1). The mean age of the participants was 13.60 (± 1.66) years. Educators participated in the mindfulness intervention alongside the students.

2.3. Outcome measures

The measures in the current study were administered by trained research staff and were given according to the standard administration procedures outlined in each measure’s respective administration manual. All test protocols were double-scored to ensure

Table 1
Demographics of the sample.

Variables	n	Percent	Mean (SD)	Range
Age (years)			13.60 ± 1.66	11.00–16.00
Years at Specialized School			2.11 ± 1.76	0.00–6.00
Gender				
Male	21	77.80		
Female	6	22.20		
Race				
Caucasian/White	24	88.90		
African American/Black	1	3.70		
Hispanic/White	2	7.40		
Primary Diagnosis				
Autism Spectrum Disorder	27	100.00		
Comorbid Diagnoses				
Attention Deficit Hyperactivity Disorder	18	54.55		
Anxiety Disorder	11	33.33		
Sensory Processing Disorder	3	9.09		
Speech or other Language Disorder	1	3.03		

Note. SD = standard deviation.

accuracy; once by the examiner and once again by a different member of the research staff. All data derived from the test protocols were double-entered into a spreadsheet in a similar manner to ensure the integrity of the data prior to conducting statistical analyses.

Three neuropsychological measures were administered to participants before and after the *Mindful Schools* intervention. These measures included the Color-Word Interference Test (CWIT), which is a subtest from the Delis-Kaplan's Executive Function System (D-KEFS; [Delis, Kaplan, & Kramer, 2001](#)), the W/DW subtest from the TEA-Ch ([Manly, Robertson, Anderson, & N.-S. I., 1999](#)), and the cancellation subtest (CN) from the Wechsler Scale of Intelligence for Children, Fourth Version (WISC-IV; [Wechsler, 2003](#)). The CWIT, W/DW, and CN tests were selected in order to evaluate the effectiveness of the school-based mindfulness intervention for improving interference control, prepotent response inhibition, and selective attention, respectively. These or similar measures have been used in previous intervention studies to assess inhibition in children and/or adolescents ([Aman et al., 2008](#); [Napoli et al., 2005](#); [Wenk-Sormaz, 2005](#)).

The CWIT is comprised of four conditions, the first three of which are analogous to the Stroop Task. The first condition involves naming patches of color, whereas the second condition entails the participant reading words. Condition 3 requires the participant to tell the examiner the ink color in which the words are printed in (interference control) and Condition 4 requires the participant to alternate between naming an ink color or reading the word, depending on how the word is presented (i.e. as it was in Condition 3 or if the word is printed in a box). The primary score derived from their performance is based on how quickly participants can complete the respective condition. Each condition yields an age-corrected scaled score for their completion time. Frequencies for the types of errors made were analyzed to determine whether or not accuracy was sacrificed for speed in their performance of each condition. The types of errors included self-corrected errors (where the child provides an inaccurate response and then corrects themselves) and uncorrected errors (where the child does not correct the error that they made), as well as the total number of errors made.

The W/DW subtest requires the participant to listen to an audio recording consisting of two different sounds; one sound indicates that it is "safe to walk" (target), while the other sound indicates that it is not safe to walk (non-target). For the W/DW subtest, the participant marks a step on a path (target) as they follow along to the pace of the audio tape, continuing to mark their steps until the non-target sound is played. The W/DW subtest is comprised of 20 trials. The subtest becomes more difficult as the test progresses given that the duration of interstimulus-intervals between the tones becomes shorter and shorter. The number of steps taken before the non-target sound is played varies among the trials. The W/DW subtest is essentially a child-friendly version of a Go/No Go task and it is a measure of prepotent response inhibition. The available alternate version of this measure was used during post-testing to address potential practice effects. Performance on the W/DW is measured by the child's ability to stop marking their steps upon hearing the non-target sound within the 20 trials. The sum of the successful trials (ranging from 0 to 20) is used to calculate the child's age-corrected scaled score.

The CN consists of two trials, each lasting a maximum of 45 s, where the participant must cross out (i.e. cancel) as many target stimuli before the time runs out. The type of stimuli remain the same between the two trials, but the ways in which the stimuli are presented vary. For the first trial, the child must cross out as many of the target stimuli (i.e. animals, such as a bear or frog) while ignoring the distractor stimuli (i.e. objects, such as a violin or umbrella) from a series of color images that are scattered across the page (CN: Random). The second trial neatly lines up the stimuli in columns and rows (CN: Structured). There are 64 targets (20 % of stimuli) per trial. Individuals are penalized for commission errors (i.e. crossing out distractor stimuli). The number of targets that were crossed out within the time limit of each trial, as well as the sum of their performance on both trials (CN: Combined), are used to calculate the child's age-corrected scaled scores. Completion times (in seconds) for CN: Random and CN: Structured were also analyzed to assess the child's accuracy for each condition in relation to the speed of their performance.

2.4. Intervention

The mindfulness intervention was carried out using the *Mindful Schools* curriculum (<https://www.mindfulschools.org/>). This specific school-based mindfulness program was determined by the school system prior to the study's inception. The intervention sessions occurred twice per week for eight consecutive weeks and included a mindfulness educator joining a classroom of 9–12 students for 30 min per session. Depending on the needs of the students, each session also included two to five educators who also participated in the *Mindful Schools* curriculum.

Every session progressed in a similar manner. First, a transition period of approximately 5–10 min occurred. Next, a mindful tone was played by a gong to further help the participants shift their focus onto the present moment. Following that, participants (including students and educators) engaged in mindful breathing for approximately 1–2 min. Following the mindful breathing exercise, participants were able to check-in and discuss their experiences with mindful practices that occurred during the time between sessions. The remainder of each session focused on a single domain from the *Mindful Schools* curriculum, of which lasted approximately 12–15 min. This equated to a total duration of eight hours (480 min) for the mindfulness intervention over the course of the eight weeks.

Mindful Schools consists of 16 sessions. Each session focused on a different aspect of mindfulness, such as mindful breathing, bodies, listening, thoughts, and emotions, as well as learning and practicing a corresponding skill. At the beginning of the intervention, students were introduced to the basic tenets of mindfulness. Following this introductory session, sessions became skill-driven. First, students were trained in maintaining a “mindful posture” (Mindful Bodies). This includes maintaining a still and quiet body while their eyes are closed or gazing downward. Students were instructed to notice how allowing their body to be still helps to quiet the mind. Second, students were taught how to pay close attention to the sounds in their environment, including the mindful tone that started each session (Mindful Listening). This session also involved a discussion around specific sounds that they heard during the session and how learning to focus one's attention on sound can be helpful. Third, students were guided in how to use their breath as an anchor for focus and attention (Mindfulness of Breath). This included each student selecting an anchor spot, such as the tip of their nose, the rise and fall of their abdomen, or using internal anchor words (i.e. “breathing in, breathing out”) while learning how to “stay at [their] base”. Other sessions covered strategies such as focusing attention on different areas of the body (i.e. noticing any sensations that arise in a non-judgmental way and discussing benefits for being mindful of one's body; Body Awareness) and noticing when one's mind is thinking about the past, present, or future, as well as learning how to use one's breath to bring their thoughts back to the present moment (Mindful Thoughts).

2.5. Statistical analyses

All statistical analyses were conducted using IBM's Statistical Package for Social Sciences, Version 21 (SPSS, 2012). Statistics were performed on age-based transformed scores for the CWIT, W/DW, and CN (i.e. scaled scores) and all statistical assumptions were met for those that were conducted in the current study. The primary statistic used to assess changes in prepotent response inhibition, interference control, and selective attention following the administration of the intervention was the paired sample *t*-test. All *p*-values were produced through use of two-tailed tests. When statistical significance was detected for changes that occurred between pre- and post-intervention scores, Cohen's *d* was calculated. Cohen's *d* effect size descriptors proposed by Sawilowsky (2009) were used, which include: $0.2 \geq$ small effect size, $0.5 \geq$ medium effect size, $0.8 \geq$ large effect size, and $1.2 \geq$ very large effect size.

Types of errors made (i.e. self-corrected, uncorrected, and total errors) within each condition of the CWIT were evaluated using the raw scores. While no outliers were present in the data that needed to be excluded from analyses, differences in degrees of freedom between the CWIT, CN, and W/DW occurred as two students had declined to complete the cancellation subtest at post-testing. Further, four students had turned 16 years of age prior to completing post-testing and therefore scaled score conversions were unable to be used in analyses for these individuals as normative data for the W/DW concludes at age 15 years and 11 months.

Given the high frequency of participants in the sample who had a comorbid ADHD diagnosis, separate univariate analyses of variance (ANOVA) were modeled to test the extent to which having a comorbid ADHD diagnosis could have impacted any observed improvements in the sample following the school-based mindfulness intervention. This was performed by assigning each participant to a group of either being diagnosed with ADHD and ASD or only being diagnosed with ASD. Group differences were evaluated for the pre-test dependent variables and changes between pre- and post-test scores, as well as group \times pre-test interaction effects.

3. Results

Following the school-based mindfulness-training program, significant improvements were observed in performance on the CWIT-3: Inhibition ($t(26) = -3.42, p = 0.002, d = 0.66$) and CWIT-4: Switching ($t(25) = -3.35, p = 0.003, d = 0.66$) conditions, which are the primary conditions that measure interference control (see Table 2 and Fig. 1). As expected, participants did not improve on CWIT-1: Word Reading or CWIT-2: Color Naming of the DKEFS as these conditions do not reflect inhibitory processes. With regard to prepotent response inhibition, significant improvement was found on the W/DW subtest ($t(22) = -2.85, p = 0.009, d = 0.59$), following the intervention. Medium effect sizes were produced by the improvements in interference control and prepotent response inhibition.

Additional analyses were completed for the CWIT to determine if similar improvements were observed in performance accuracy as the scaled score produced is solely based on completion time. Significant reductions were observed in the total errors made for the CWIT-3: Inhibition ($t(26) = 2.75, p = 0.011, d = 0.53$) and CWIT-4: Switching ($t(25) = 3.27, p = 0.003, d = 0.64$) conditions.

Table 2
Mean scores before and after the mindfulness intervention.

Measure	Mean 1 (SEM)	Mean 2 (SEM)	t (df)	p-value	d
CWIT 1: Color Naming	ss = 8.07 (0.70)	ss = 8.41 (0.86)	-0.53 (26)	ns	
Self-Corrected Errors	1.00 (0.26)	0.74 (0.22)	0.79 (26)	ns	
Uncorrected Errors	0.11 (0.08)	0.15 (0.12)	-0.25 (26)	ns	
Total Errors	1.11 (0.26)	0.89 (0.25)	0.63 (26)	ns	
CWIT 2: Word Reading	ss = 8.07 (0.75)	ss = 7.85 (0.81)	0.42 (26)	ns	
Self-Corrected Errors	0.74 (0.20)	0.33 (0.11)	1.89 (26)	ns	
Uncorrected Errors	0.04 (0.04)	0.22 (0.13)	-1.55 (26)	ns	
Total Errors	0.78 (0.23)	0.56 (0.19)	1.14 (26)	ns	
CWIT 3: Inhibition	ss = 8.07 (0.71)	ss = 9.59 (0.57)	-3.42 (26)	0.002***	0.66 ⁺⁺
Self-Corrected Errors	2.44 (0.44)	1.59 (0.33)	2.10 (26)	0.045*	0.40 ⁺
Uncorrected Errors	1.07 (0.42)	0.52 (0.16)	1.47 (26)	ns	
Total Errors	3.52 (0.63)	2.11 (0.41)	2.75 (26)	0.011*	0.53 ⁺⁺
CWIT 4: Switching	ss = 7.46 (0.59)	ss = 9.19 (0.67)	-3.35 (25)	0.003***	0.66 ⁺⁺
Self-Corrected Errors	3.23 (0.43)	2.08 (0.37)	2.36 (25)	0.026*	0.46 ⁺
Uncorrected Errors	1.96 (0.49)	0.92 (0.28)	2.43 (25)	0.023*	0.48 ⁺
Total Errors	5.19 (0.59)	3.00 (0.46)	3.27 (25)	0.003***	0.64 ⁺⁺
CN: Random	ss = 7.64 (0.70)	ss = 8.52 (0.79)	-2.32 (24)	0.029*	0.46 ⁺
Completion Time (sec)	45.00 (0.00)	44.88 (0.12)	1.00 (24)	ns	
CN: Structured	ss = 7.56 (0.86)	ss = 8.36 (0.76)	-2.07 (24)	0.050*	0.41 ⁺
Completion Time (sec)	44.96 (0.04)	44.84 (0.16)	0.72 (24)	ns	
CN: Combined	ss = 7.32 (0.83)	ss = 8.56 (0.84)	-4.36 (24)	< 0.001****	0.87 ⁺⁺⁺
W/DW	ss = 4.83 (0.76)	ss = 7.13 (0.86)	-2.85 (22)	0.009**	0.59 ⁺⁺

Note. Errors are given based on frequency of occurrence and completion times are given in seconds. All other scores are provided as scaled scores based on age-based transformations from the respective measure's normative sample. CWIT = Color Word Interference Test. CN = Cancellation Subtest. W/DW = Walk/Don't Walk. SEM = standard error of the mean. *df* = degrees of freedom. *d* = Cohen's *d*. ns = not significant. ss = scaled score. sec = seconds. * = *p*-value < 0.05. ** = *p*-value < 0.01. *** = *p*-value < 0.005. **** = *p*-value ≤ 0.001. + = small effect size (*d* = 0.20–0.49). ++ = medium effect size (*d* = 0.50–0.79). +++ = large effect size (*d* = 0.80–1.19).

Overall, medium effect sizes were produced from the reduction in total errors made for the CWIT-3: Inhibition and CWIT-4: Switching conditions following the intervention.

For CWIT-3: Inhibition, self-corrected errors significantly reduced ($t(26) = 2.10, p = 0.045, d = 0.40$), while uncorrected errors did not. There was a significant reduction in both self-corrected ($t(25) = 2.36, p = 0.026, d = 0.46$) and uncorrected ($t(25) = 2.43, p = 0.023, d = 0.48$) types of errors for the CWIT-4: Switching condition. All effect sizes approached medium magnitudes based on the observed reductions in errors by type and condition. As expected, there were no significant reductions in the total errors made for the CWIT-1: Word Reading or CWIT-2: Color Naming conditions.

As shown in Fig. 1, overall performance in selective attention also improved following the intervention (CN: Combined; $t(24) = -4.36, p < 0.001, d = 0.87$). This was the case regardless if the stimuli were presented in clear arrays (CN: Structured; $t(24) = -2.07, p = 0.050, d = 0.41$) or indiscriminately dispersed throughout the stimulus page (CN: Random; $t(24) = -2.32, p = 0.029, d = 0.46$). As previously mentioned, the derived CN scaled scores are based on the accuracy of one's performance, independent of speed. To ensure that the improved accuracy was not at the expense of a slower performance, completion times for CN: Structured and CN: Random were evaluated. Completion time did not significantly change for either condition following the intervention.

Additional analyses were completed to assess for the possible contributions that having a comorbid ADHD diagnosis could have had on the current findings. For this, the sample was subdivided into two groups who had both pre- and post-test data ($N = 25$). These two groups included those who were diagnosed with ASD ($n = 9$) and those who were diagnosed with both ASD and ADHD ($n = 16$). The results of the ANOVAs showed that there were no significant differences between these two groups on any of their pre-test scores, nor was there any significant interaction effects between having a comorbid diagnosis of ADHD and pre-test scores. There were no significant differences between these two groups on any of the measures following the school-based mindfulness intervention.

4. Discussion

The aim of the current pilot study was to investigate the use of a school-based mindfulness program for improving inhibition and attentional abilities in students diagnosed with ASD. Specifically, we anticipated that for children who are diagnosed with ASD, *Mindful Schools* would be effective at increasing prepotent response inhibition (W/DW), interference control (CWIT), and selective attention (CN) in our sample. These hypotheses were supported following the eight-week mindfulness intervention. The results of the current study are consistent with the work of Napoli et al. (2005), where executive functioning improvements occurred following the use of a school-based mindfulness program in their sample of typically-developing children. To the authors' knowledge, the current study appears to be the first published work that investigated the use of a school-based mindfulness program for improving executive functioning in children who are diagnosed with ASD.

Two complementary mechanisms have been proposed for how mindfulness affects attention, including intentionally focusing

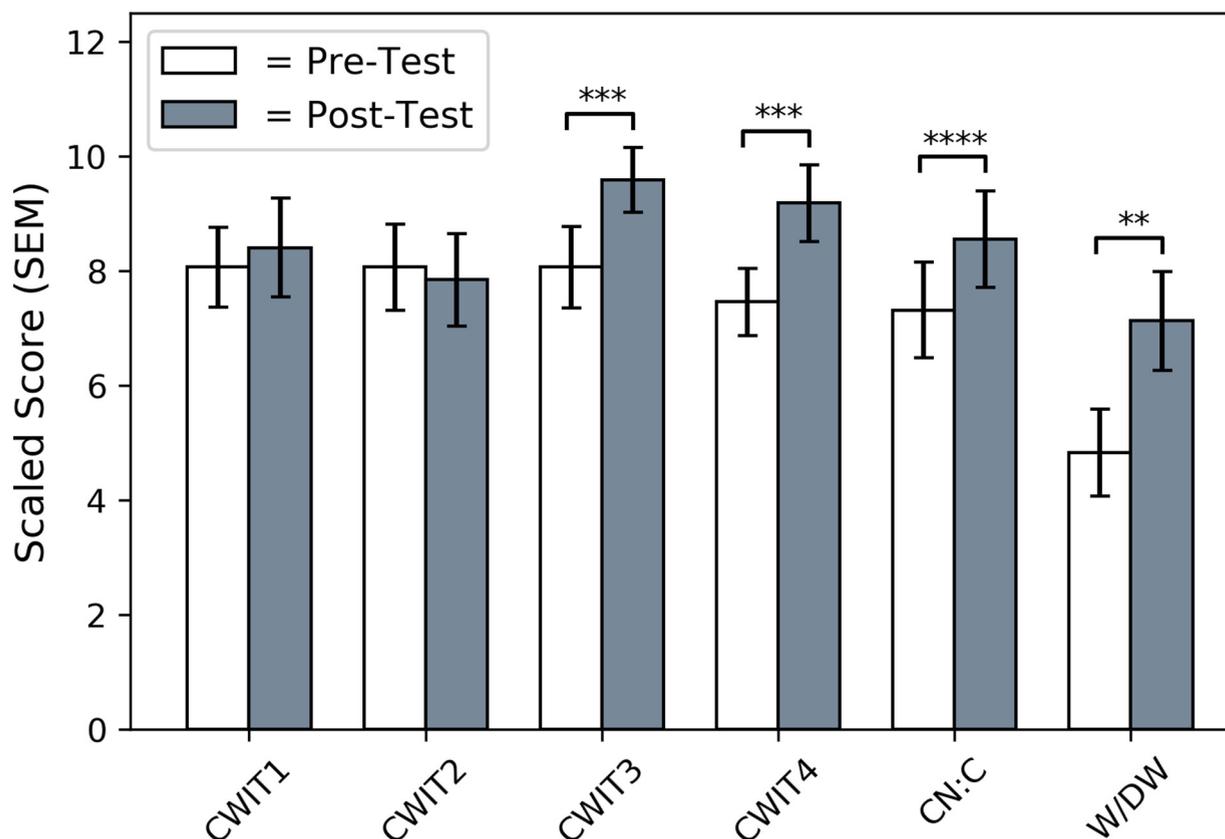


Fig. 1. Mean improvements on measures of executive functioning. Significant improvements in interference control, prepotent response inhibition, and selective attention were shown following the *Mindful Schools* program. CWIT = Color Word Interference Test. CWIT1 = Color Naming. CWIT2 = Word Reading. CWIT3 = Inhibition. CWIT4 = Inhibition/Switching. CN:C = Cancellation: Combined. W/DW = Walk/Don't Walk. SEM = standard error of the mean. ** $p < 0.01$. *** $p < 0.005$. **** $p < 0.001$.

one's attention on a specific activity and increasing one's awareness for unintentional shifts in attention (i.e. becoming distracted). Shapiro, Carlson, Astin, and Freedman (2006) postulated that mindfulness is the intentional act of paying attention. During the practice of mindfulness, an individual is instructed to focus their attention, in its entirety, on the task at hand (Lutz, Slagter, Dunne, & Davidson, 2008). As awareness increases, an individual will begin to recognize that they have become distracted. At this point, individuals are instructed to return their attention back to the task at hand (i.e. acting with awareness; Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006). These proposed mechanisms suggest that an individual can be trained to actively control their attentional processes in order to improve their inhibition performance. Given the proposed mechanisms of mindfulness practices, it was selected as an intervention for children who are diagnosed with ASD to increase their abilities in prepotent response inhibition (i.e. by focusing on the signal that indicates the termination of their activity), interference control (i.e. by shifting focus to the appropriate stimulus and "tuning out" irrelevant stimuli), and selective attention.

School-based mindfulness was selected as the intervention for this study as it has potential benefits that exceed those of other available treatments for children who are diagnosed with ASD. First, the mindfulness intervention was delivered during the school day, which increases access to treatment for families who would otherwise be limited (Bringewatt & Gershoff, 2010; Owens et al., 2002). Second, school-based mindfulness is not a pharmacological intervention, which is preferred by some parents or children who have concerns about the possible risks involved in pharmacotherapy (DuPaul & Carlson, 2005). Third, educators are also involved in the intervention and therefore they might also experience the same benefits as the child participants did in the current study (Meiklejohn et al., 2012). Finally, the mindfulness intervention occurred within the school in which the children attended, serving as a naturalistic environment. In contrast to interventions delivered in laboratory settings, the delivery method in the current study increases the generalizability of the results as it occurred in the environment under which such an intervention would be delivered.

Regarding the specific school-based mindfulness program used in the current study, *Mindful Schools* has several practical benefits that are superior to other school-based mindfulness programs. Other programs require higher intensity (Mendelson et al., 2010), higher frequency (Parker, Kupersmidt, Mathis, Scull, & Sims, 2014), and longer durations (Bakosh, Snow, Tobias, Houlihan, & Barbosa-Leiker, 2016). *Mindful Schools* is a low intensity (30 min per session), low frequency (two sessions per week), and brief (two months) school-based mindfulness intervention, which allows for it to be easily incorporated into the school day without significantly impacting student or educator schedules. The current study also examined the implications of having a comorbid ADHD diagnosis,

which supported that any observed improvements in executive functioning for this sample of children with ASD were not attributable to the intervention being more beneficial to children with or without a comorbid diagnosis of ADHD. Considering the prevalence of executive functioning deficits in children who are diagnosed with ASD (Demetriou et al., 2018), specific deficits in prepotent response inhibition and interference control (Geurts et al., 2014), and the current findings of improved inhibition abilities, *Mindful Schools* holds great promise as an effective and efficient intervention that schools can provide for their students who are diagnosed with ASD who have difficulties with executive functioning.

Although the current study has addressed an important gap in the available literature by investigating the use of school-based mindfulness for improving inhibition in children with ASD, there are limitations to note. First, the current study was unable to include a control or comparison group due to the intervention being delivered during the school day across all students. Due to this, one cannot rule out the possibility of practice effects explaining the observed improvements in executive functioning. To help control for practice effects, alternate forms were used where possible. Despite this, future studies seeking to replicate or expand upon these results would benefit from including a waitlist control/intention-to-treat group or a placebo intervention comparison/sham therapy group. In addition, including a non-ASD comparison group would allow researchers to examine whether or not other clinical diagnoses (i.e. ADHD) or even neurotypical children benefit in similar ways and to the same extent as an ASD sample. Applying randomization techniques to group assignment would also enhance any of the aforementioned group design options for future studies. For further recommendations on designing and evaluating intervention studies involving ASD populations, please see (Reichow, Volkmar, & Cicchetti, 2008; Smith et al., 2007). Without a proper control group, our findings must be viewed as preliminary while awaiting replication with a control group.

Another limiting factor is that the children in the study's sample were primarily Caucasian (88.9 %) and higher functioning (i.e. without an intellectual disability), which is not representative of the population's demographics. Though not feasible in the current study, future studies would benefit from having measures that specifically assess their sample's intellectual functioning and the severity of ASD symptomatology as these variables could moderate and/or mediate the results of the intervention.

Given our promising findings, this study provides the basis for further investigation into the use of school-based mindfulness programs for children who have ASD. First, as the W/DW, CN, and CWIT are laboratory measures, it is imperative to determine if the current results of improved inhibition and selective visual attention generalize to other aspects of the child's life (i.e. parental impressions, academic performance, and social functioning). Second, it will be important to determine the longevity in which these improvements are seen. Finally, the use of school-based mindfulness for increasing social functioning, emotional well-being, and academic performance in children who are diagnosed with ASD should be explored as other studies involving general education samples have shown improvements in these domains (Joyce, Ety-Leal, Zazryn, Hamilton, & Hassed, 2010; van de Weijer-Bergsma, Langenberg, Brandsma, Oort, & Bögels, 2014; For a full review, see Felver, Celis-de Hoyos, Tezanos, & Singh, 2016). These future directions will be essential for establishing the clinical significance of school-based mindfulness and its impact on children who are diagnosed with ASD.

5. Conclusions

Given the significant improvements that followed the intervention for prepotent response inhibition and interference control (medium effect sizes), as well as for overall selective attention (large effect size), school-based mindfulness holds promise for increasing specific executive functioning abilities in children with ASD. Future directions include examination of other effects of mindfulness and replication of our study using a well-designed randomized controlled design.

Author contributions

HG was responsible for the study concept and design. AJ contributed to the acquisition of subject data. All authors assisted with data analysis and interpretation of findings. AJ and HG drafted the manuscript. All authors critically reviewed content and approved final version for publication.

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Declaration of Competing Interest

The authors declare that they have no conflict of interest.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.ridd.2020.103641>.

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