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Abstract We predicted that students in a sociology course that included contemplative practices (i.e., mindfulness meditation) would show an increase in performance on higher level cognitive abilities (executive functions) over the semester compared to a control group of students. Change in executive functions performance was not significantly different between the two groups. However, when looking within the meditation group, the time spent meditating predicted the amount of executive function improvement, suggesting that the amount of time spent meditating is strongly related to the level of improvement. This finding provides preliminary support for benefits of meditation for students' higher level cognitive abilities.

Keywords Meditation · Executive Functions · Education

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Over the past thirty years scientific research on meditation has grown significantly. Findings from many studies reveal beneficial results in brain functioning, immune response, and overall well being (e.g., Davidson et al., 2003; Hutcherson et al. 2008; Lazar et al., 2005) attributable to meditation. Other areas of research and application of meditative practices include work in organizational management (Duerr, 2004), athletic performance (Gardner & Moore 2004), social justice (Duerr et al. 2003), and a variety of other fields. Overall, research on meditation, argued Newberg and Iversen (2003), represents a critical, new area of inquiry for contemporary science.

Over a hundred years ago, James et al. (1890/1950) clearly articulated the importance and challenge of developing a type of mindful education in his book titled *The Principles of Psychology*, stating specifically in the chapter on attention that "the faculty of voluntarily bringing back a wandering attention over and over again, is the very root of judgment, character, and will. An education which should improve this faculty would be the education par excellence" (p. 424). A growing number of researchers and instructors have taken up James' call and have started investigating meditation techniques within the context of higher education (e.g., Hall, 1999; Shapiro et al. 2011; Solloway & Fisher 2007). This work is based on the assumption that teaching students' meditation techniques will enhance their ability to direct their attention in a conscious and controlled manner. Evidence from this work suggests an overall positive influence on student's academic performance and on achieving traditional academic goals such as critical thinking. In addition, such practices may help in the reduction of academic stress and an overall cultivation of the "whole person" (see Shapiro et al., 2011).

Although preliminary research has examined the effects of meditation on multiple cognitive abilities, the precise changes in cognitive functioning remain poorly understood. In this study we examined the effects of meditation on cognitive functioning within the college classroom, specifically the higher-level cognitive skills known as executive functions, which are explained below. The question, therefore, is *whether meditation in the classroom could benefit not only students' overall educational experience but also help to improve their cognitive functions.*

Meditation and Executive Functions

Meditation

Although there are many ways to define the practice of meditation, researchers have started to define meditation for empirical investigation. For example, Lutz et al. (2008) defined it as "a family of complex emotional and attentional regulatory training regimes developed for various ends" (p. 163). They went on to separate types of meditation into two general categories based on the theorized cognitive processes involved in each—focused attention and open monitoring. In focused attention meditation an individual tries to decrease mental states that interfere with concentration on a single object or mental goal whereas in open monitoring meditation the individual does not focus on objects or engage in a specific thought related to that object.

Rather than thinking of these as distinct practices, it is analytically more useful and accurate to conceptualize these styles on a continuum. Many meditation techniques fall somewhere in the middle of the continuum, incorporating both focused attention and open monitoring. The key component, as noted by Davidson & Goleman (1977), is the conscious attempt to control and direct attention or awareness. This intentional effort at control is

theorized to alter the underlying neural networks associated with attention and thus may affect higher level cognitive abilities. Recent studies have in fact found cortical changes in the brain after meditation (see Lazar et al., 2005; Pagnoni & Cekic, 2007).

Executive Functions

Executive functions is the term for the complex, cognitive abilities necessary for planning, self-monitoring, goal setting, and strategic behavior. These functions are thought to be mediated by the dorsolateral prefrontal cortex (Miyake et al., 2000; Welsh & Pennington, 1988). While there is no consistency in the literature as to what cognitive skills comprise executive functions, Welsh (2002) has suggested that some commonalities are "planning, inhibition, monitoring, and flexibility to recruit a range of basic cognitive processes such as attention, perception, language and memory" (p.143). Executive functions are critical for effectively navigating one's everyday environment. The ability to exert conscious control in order to solve problems and plan in novel situations, effectively monitor performance, inhibit automatic irrelevant responses, and adapt to changes to achieve one's goals is critical. For example, successful students must be able to switch their attention from one topic to another—or from their notes to the voice of the lecturer, they must inhibit irrelevant information while attending to their goal, and they must monitor their performance overall while being flexible to strategy change when they are not achieving their goal. Overall executive functions are important to successful classroom performance and it seems logical and safe to assume that improvements in executive function performance could be beneficial to students.

The mechanism by which meditation training may affect executive functions is that both may share neural pathways. Tang et al. (2009) examined attention and self-regulation after only five days of integrative body-mind meditation training. Undergraduates were randomly assigned to either a meditation or control group. The authors hypothesized that meditation training would result in increased efficiency of executive functions. It was found that participants did not differ on the cognitive tests before assignment. After the five days, participants in the meditation group showed improvement on an executive function measure. This study indicates that even short-term exposure to meditation can enhance executive function. In a follow-up study (Tang et al. 2009) investigated the physiological and neural changes associated with meditation. They found that the meditation group had stronger activity associated with the anterior cingulate cortex, which seemed to produce an overall decrease in the autonomic nervous system. This finding is important because it associates an increase in performance on executive function tests with a decrease in overall arousal. Other studies investigating the neural correlates of meditation using functional Magnetic Resonance Imaging have also found increased activation in regions of the brain associated with cognitive function in expert meditators versus non-meditators while showing decreased activation in regions involved in the executive function of inhibition (Brefczynski-Lewis et al., 2007). These differences in the hemodynamic response after meditation experience could be indicative of a decrease in the amount of effort needed to maintain focus. Collectively this research indicates that some types of meditation may alter the efficiency with which cognition can be directed.

Overall, only a handful of studies have examined whether or not meditation enhances executive functions in specific. The few studies conducted have yielded promising but nevertheless inconsistent results with some showing an increase in executive function while others show an increase in some, but not all, measures (e.g., Chambers et al. 2008; Chan & Woollacott 2007). For example, Chan and Woollacott (2007) investigated the role of

meditation, specifically the level of meditation experience, on executive functions using the Stroop test (see Golden, 1978). They found that meditators had reduced interference on the Stroop test—indicating increased inhibitory control. Interestingly, they did find that the length of time spent meditating per day was correlated with interference scores. As time spent meditating increased, interference scores decreased. On the whole, they concluded that meditation may enhance the efficiency of executive functions. Chambers et al. (2008) found that meditators had an increase in attention and executive function scores after a 10-day intensive training session when compared to the control subjects. Heeren et al. (2009) examined executive functions and meditation using several tests, and they found that the meditators showed more improvement on inhibition and cognitive flexibility measures than non-meditators. These studies provide support for the possibility that meditation enhances performance on some executive function tests. Nevertheless, more research is needed to identify whether some, or all, executive functions are modified by meditation.

Meditation, Education, and the Purpose of the Study

There has not been much research examining the effects of meditation on cognition in an educational setting. As stated above, previous research does provide evidence for an improvement in executive functions after meditation training. Therefore, it is important to identify whether or not we can see this improvement in executive functions when meditation is taught in the classroom setting. One study, conducted within the context of education, examined the potential influence of meditation on college students' academic performance (Hall, 1999). Students in a psychology class were assigned to either a meditation group or a non-meditation group. Both groups were required to engage in 1-hour study sessions once a week throughout a college semester, and the meditation group was asked to meditate before and after study sessions as well as when studying outside of the sessions. Prior to the class, the groups did not differ in overall grade-point-average; however, after the semester ended there was a significant difference between the two groups with the meditation group having a higher GPA. The results of this study point to the possibility that meditation can improve cognitive function in the educational context. However, the exact reason for this change in GPA is unknown. It may be that the students in the meditation group had actually improved their cognitive abilities. As interest in meditation and other mindfulness training increases, it is important to conduct studies that assess how it may change or improve the way students approach their educational tasks and activities.

If meditation training in the classroom can positively influence a student's performance, it would be useful to identify the reasons why this happens. Our study sought to determine if teaching meditation as part of a course can actually further benefit students by enhancing their executive functions—those cognitive skills that are conducive to studying and performing well in academia. We predicted that students in a course that includes contemplative practices (i.e., mindfulness meditation) would show an increase in performance from the beginning to the end of the semester on executive function tests compared to other students.

Method

Participants

This study was conducted using students enrolled in either an upper level sociology or a psychology course. Students in both classes were given extra credit for their participation in

the study, and students choosing not to participate in the study were offered an alternative assignment to complete for extra credit. Institutional Review Board approval had been obtained prior to testing. The meditation group consisted of 18 participants (8 male, 10 female; mean age=20.37 (*SD*=1.34) enrolled in the sociology course at Purchase College in which they would undergo training in meditation. The control group consisted of 13 participants (3 male, 10 female; mean age=21.67 (*SD*=2.87) recruited from an upper level cognitive psychology class. None of the students reported having received prior training in meditation. Four students (two from the meditation group and two from the control group) who completed pre-testing but did not complete the post-testing were dropped from the analysis.

Testing and Procedure

Meditation Training The upper division sociology course was titled "Personal Transformation and Social Change." The course was not just about meditation, but the overall theme lent itself to a variety of meditation practices. The class met twice a week, and the first ten minutes of every session were dedicated to a specific meditation practice. Students were given the option of not participating and could read, rest, or do anything else non-disruptive to others during this time period. However, none of the students opted out of the in-class meditation practice. The meditation sessions were led by the instructor who has over ten years of meditation training. In addition, students were responsible for continuing the practice throughout the week and keeping a journal, in which they kept track of the days and times they meditated, any difficulties they encountered, and their overall experience. The amount of time they meditated outside of class was left to individual discretion. It was suggested, however, that they meditate a minimum of five to ten-minutes for five days a week.

Along with receiving basic theoretical information about meditation, students were trained in three meditation techniques over the course of the semester: concentration, mindfulness, and visualization. The concentration practice entailed a single pointed focus on the sensations of the breath on the skin as it entered and exited the nostrils. Mindfulness practice involved a more expansive, moment to moment awareness of sensations of the body and sounds. For the visualization practice they were taught "Loving-Kindness" meditation in which they evoke a mental image of themselves and others along with feelings of care and loving concern. Although each technique is theoretically distinct, there is a great deal of overlap in actual practice. For instance, concentration practices demand a certain mindfulness to know when the object of concentration has been lost. Becoming mindful of the sensations of the body or evoking a visualization also demands a certain degree of concentration. It is also important to explain that students were engaged in simple relaxation techniques before the meditation activity, which provided a transition from their fairly hectic lives to the specific practice.

The Stroop Color and Word Test (Golden & Freshwater, 2002) This test was administered according to the protocol established in the manual by the test developers. Participants were given three sheets of paper with 100 words quasi-randomly presented (20 words per column) on each sheet and asked to read either the word or identify the color the word was written in for 45 seconds. The first sheet contained the color words *red*, *blue*, and *green* in black ink, and participants were asked to read these words (WORD condition). They were then given a sheet with X strings (XXXX) where the string was printed in either red, green or blue font, and participants were asked to identify the color of the X's (COLOR condition). The third

sheet had the words *red*, *blue*, and *green*; however, the word's font color did not match the word, and they were asked to name the color of the font and not the name of the word (COLOR-WORD SCORE). In other words, if *red* was written in blue font, the correct response was blue. The number of items read in 45 seconds in this condition was used as the participant's score.

Trail Making Test (Army Individual Test Battery, 1944) The Trail Making Test is composed of an A and B section. Trails A requires the subject to sequentially connect 25 numbers randomly arranged on a sheet of paper with a pencil as fast as they can. On section B, the subject must connect numbers (1 to 13) and letters (A to L) sequentially; however, they must alternate between the two (e.g. 1-A-2-B, etc.). This test requires cognitive flexibility because subjects must switch between letters and numbers, and it has been found to correlate with other executive function measures such as the Wisconsin Card Sorting Test (Kortte et al. 2002). The subjects' score is the time it takes to complete Trails B. Errors made do not directly count against the score; however, they are reflected in the extended time needed to take the test.

The first testing session was conducted during the first two weeks of the semester. All participants gave informed consent and filled out a form with demographic information and were then assessed using the Stroop test and the Trail-Making test in order to measure their baseline executive function performance. The order of tasks was counterbalanced evenly among all of the participants. The students in the sociology class then received meditation training as part of their course while the control group did not receive any training. The second testing session was conducted during the last two weeks of the semester. Participants who participated in the meditation training were asked to report the time they spent meditating outside of class, and all participants were assessed again on the Stroop and Trail-making tests and debriefed.

Results

Means and standard deviations for the executive function tests are presented in Table 1. The mean amount of minutes spent meditating per week in the meditation group was recorded at 84.71 (SD=87).

Table 1 Means and standard deviations on the executive function tests

Variable	Pre-test		Post-test	
	Mean	SD	Mean	SD
Stroop Color-Word				
Meditation	52.9	8.81	60.7	9.57
Control	45.3	9.10	51.9	9.57
Trails B				
Meditation	49.1	14.09	40.1	13.13
Control	50.2	17.48	41.5	9.77

The Stroop Color-Word test is from Trenerry, Crosson, DeBoe, & Leber (1989). The value presented represents the number of incongruent words read in 45 seconds. The Trails B test, from the Army Individual Test Battery (1944), represents the time to complete the test in seconds.

Comparing the pre- and post-testing on both tests using two (meditation vs. control) x 2 (pre- vs. post-testing) mixed model ANOVAs found significant improvement in both groups on both tests (Stroop: $F(1,29)=17.56$, $p<.01$; Trails B: $F(1,29)=9.54$, $p<.01$). However, there was not a significant interaction between group and testing time for either the Stroop test, $F(1,29)=0.23$ or the Trails B test, $F(1,29)=1.61$.

Within the meditation group, the time spent meditating per week was significantly correlated with the change in executive function performance from pre- to post-testing, $r(16)=.82$, $p<.01$. A series of linear regression analyses identified the amount of variance in executive function test performance (change in performance from pre- to post-testing) explained by time spent meditating (mins/week). Time spent meditating explained 31% of the Trails B variance [$R^2=.31$, SE=9.19; $F(1,16)=6.58$, $p<.05$] and 60% of the Stroop Color-Word variance [$R^2=.60$, SE=5.14; $F(1,16)=22.82$, $p<.01$]. Using both the Stroop and Trails B as outcome variables, the amount of time spent meditating predicted 68% of the variance of the executive function scores [$R^2=.68$, SE=.48; $F(1, 16)=31.22$, $p<.01$)].

Discussion

In the classroom experience, the goal was for students to learn about meditation and other mindfulness practices. This study sought to identify whether or not students' cognitive functioning would improve as a result of engaging in meditation techniques. Based on previous research examining the relationship between meditation and executive function performance, we had hypothesized that students using meditation techniques would show improvement in performance on executive function tests when compared to a control group of students. Interestingly, both groups showed improvement on the executive function tests from the first testing session to the second. The positive change in both groups is most likely due to familiarity with the tests during the second session. Contrary to the hypothesis, the improvement in the meditation group was not significantly greater than the improvement in the control group. However, when examining test performance by group on the tests, one sees that the meditation group registers a larger increase from pre- to post-testing. The lack of significance in this finding may be due in part to the lack of power in the analysis because of the small sample size.

It is important to note that the amount of time the students in the meditation group spent meditating outside of class varied widely. The class instructor had asked that students meditate for a minimum of five to ten minutes for five days outside of class. Some students engaged in meditation for the minimum amount while others far surpassed this minimum requirement. The lack of control over this aspect is problematic; and, if possible, future studies should try to achieve greater consistency in the overall time spent meditating. Given the finding that the time spent meditating was predictive of the change in executive function performance, it may be that students need to meditate for a certain amount of time before any real changes in cognition can be experienced.

Previous research has been inconsistent regarding the effects of meditation on executive functions. While Zylowska et al. (2007) found that meditation did lead to improved cognitive flexibility (Trail Making Test), Chambers et al. (2008) found that flexibility was unaffected by a meditation intervention. There are also inconsistencies in the research regarding the role of meditation on enhancing inhibition. Zylowska et al. (2007), Jha et al. (2007), and Chan and Woollacott (2007) found that inhibition was enhanced by a meditation intervention while Josefsson and Broberg (2010) found that meditation had no effect on

inhibition. There may be multiple explanations for these inconsistencies—ranging from the type of meditation practiced, the time spent meditating, and even the age of the meditators.

Future research examining meditation and executive functioning in students should attempt to control for the amount of time students spend meditating outside of the classroom and examine academic performance as well as executive function abilities to determine the applicability of meditation-based cognitive improvements. In our study we did not collect data on other student behaviors that might have contributed to their performance on executive function tests such as diet or exercise. Future studies could collect such data in order to have a better idea of whether or not the differences are attributable to mediation or other factors. The participants in our study were primarily juniors and seniors; and, in order to increase the generalizability of these findings, it is important to investigate whether or not similar findings would occur at the freshman and sophomore levels and also in nontraditional student populations.

Another limitation of the study is that we used only two executive function measures; however, it is possible and plausible that they do in fact measure different types of executive functions. Future studies should use executive function tests that tap into different components of executive functions (e.g., Miyake et al., 2000) so as to allow for a systematic investigation of whether meditation affects some executive functions more than others. Understanding the relationship between the practice of meditation and executive functions is very important. Future studies should also continue to explore the relationship between meditation and cognition in general as well as executive functions specifically. In addition, students may also benefit from possible reductions in stress and improved immune function. Finally, in more general terms, the implications for the potential ability for meditation training to strengthen neural pathways are intriguing.

Conclusion

We believe that the results of our study show a potential positive impact of using meditation to promote learning. In the context of the classroom, students' experience may be enhanced by learning about meditation techniques as part of their overall education experience. Today's students are constantly inundated with information, and the ability to focus on relevant information is becoming more and more important in order to be a successful student. Meditation training could help students by strengthening the cognitive skills needed to focus their thoughts. These improvements could translate into real world successes in students' educational attainment and everyday life.

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