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Research Article

The Effectiveness of Short Meditation on Attentional Performance: A Quick Classroom Activity

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Abstract

Undergraduate students suffer from stress and attention problems throughout their academic career. This is a great time for students to learn a new skill; meditation practices have been shown to improve mental and physical health and our activity can introduce them to this beneficial practice. Utilizing the learning-cycle approach, we had students first engage with a problem, explore interpretations, conduct a meditation experiment, and then interpret and explain results. This short activity investigates the impact of focused-breathing meditation on the attention of students using the psychomotor vigilance test (PVT). The within subjects' design showed that a majority of students see reaction time improvements with just 5-minutes of meditation or 5-minutes of being sedentary. This has been repeated over many years and in both an introductory biology course and as well in a 300-level neuroscience techniques course. We also investigated if the amount of sleep the previous night would impact performance changes, but this was found to have no effect. Our 5-minute meditation activity taught with the learning-cycle approach can be quickly added to any neuroscience, biology, behavior, or psychology course. Further discussion focuses on the stress response, the neurophysiology of meditation, brain electrical activity, brain regions, and impact of behaviors on physiology.

Keywords: Meditation; Attention; PVT; Pedagogy; College education; Stress reduction

Introduction

Undergraduate students, especially first year [1] and minority students including ethnic minorities [2,3], transgender students [4,5] and first-generation students [6,7], experience a large amount of anxiety and stress when transitioning to college. College is a new social and geographical environment that is often accompanied by large amounts of stress, more than that experienced by non-college attending peers [8]. Stress is pervasive and highly detrimental to class performance [8-10], something all academics know too well. The stress response also increases aging [11,12], disease [13,14], and prevalence of psychological disorders [15,16]. Meditation has been shown in various contexts to decrease stress [17-22]. Teaching meditation to students can take place in multiple ways, but this study focuses on a brief introduction to meditation and the neurophysiological changes it can elicit, even in first time meditators.

As a time of intense stress, being in college also provides an opportunity to learn new life skills and stress reduction techniques. On average, college students are generally more open to meditation, since they use complementary and alternative medicine at a higher rate than the overall American population. Meditation is not new to college classrooms, but most uses of meditation have interventions that span weeks or a whole semester. These

long-term interventions have successfully helped these students decrease their stress response and improve in multiple areas of life, including increased healthy habits [23], better psychological wellbeing and increased compassion [24]. Meditation has also been used to improve classroom performance as a method of self-reflection and led to better retention of classroom material [25]. Study group interventions that practice 10-minutes of meditation at the start and end of their study time had significantly higher semester and cumulative GPAs compared to a studying only control group [26]. For further reading, meditation in the collegiate context has been thoroughly reviewed by Shapiro S, et al. [27].

We believe that meditation, when used in the classroom can not only teach students a new technique but can be a good introduction to neurophysiology and brain neuronal dynamics. Meditation has been successfully integrated into a semester long course, Neuroscience of Meditation [28]. This course included many types of meditation, brain dissections, performance measures, EEG, and psychological questionnaires. These students experienced a reduced barrier to meditation and had an improvement of attitudes toward science in general, through the study of meditation [28]. This course showed promising results but requires an entire semester of work. For many neuroscience, psychology, or physiology courses, this may not be possible. Our exercise aims to expose students to meditation in a single class session and show the short-term impact meditation can have on their physiology.

The University of Kentucky's STEMCats program is a living learning program for first year students in STEM fields that are planning to pursue professional STEM careers, such as medicine, dentistry, pharmacy, engineering, and research. This program provides social, academic, and professional development opportunities for success in these programs. One special course for those in the STEMCats program is the fall Biology 101 in which students explore opportunities, research, and career paths in a variety of STEM fields. During these sessions, faculty and professionals are guest speakers about their particular field to provide information and activities. We took this opportunity to develop our meditation activity and to teach the neurophysiology of meditation to these students.

Students are more interested in a topic if they have first person experience with it. A learning-cycle approach is a widely used teaching method to increase student engagement and retention of material [29,30] and has been specifically applied to neuroscience courses [31]. We used this teaching method to first engage with a problem, explore interpretations, conduct the meditation experiment, and explain the results. For the learning-cycle approach to work to link meditation and neurophysiology, we needed an experiment that included a measure that is impacted by a single session of meditation. A previous study completed by our lab showed that a longer 40-minute meditation had an acute impact on psychomotor vigilance [32]. The psychomotor vigilance task (PVT) measures reaction time and sustained attention in response to a visual stimulus [33]. Kaul and colleagues also showed that the performance boost due to meditation may also be related to previous nights' sleep duration, so sleep data was gathered from students [32]. PVT performance is known to be susceptible to sleep loss [34] and may be impacted by long meditation experience [32].

The goal of this study is to show the effectiveness of a short meditation activity in the classroom. We wanted to determine if performance boosts are measurable from a short 5-minute meditation period, using a computer-based PVT program that is readily accessible for a wide variety of courses and teaching activities.

Materials & Methods

Our session was a 50-minute activity that included a 15-20-minute lecture, discussion on experimental design, meditation exercise, data collection, and discussion of data. All research protocols were reviewed and approved by the University of Kentucky's Institutional Review Board.

Subjects

All subjects (n=419) were students enrolled in the STEMCats class, BIO 199, which gives undergraduates a chance to be exposed to a diversity of STEM fields and research through lectures and activities with multiple faculty and researchers at the University of Kentucky.

Lecture Design

Using the learning-cycle approach we designed an experiential activity and lecture for first-year undergraduates. We first introduce the topic of meditation, explaining the history of meditation traditions, types of meditation, and end with an open-ended question on the claimed benefits of meditation (including anti-aging, anti-hypertensive, relaxation, decreased depression, helps insomnia). This introduction leads to a class-wide discussion about how meditation affects performance and how this can be tested in a classroom setting. Our learning objectives were for students to: recognize the extraordinary claims about meditation, demonstrate within subject experimental design, interpret human reaction time data, and describe the impact of sleep loss and meditation on reaction time.

Next the class had a brief discussion about the potential benefits of meditation and what the students already know about meditation. This led the entire class to think about what meditation can do and how we can measure changes in some variable. During this time, the discussion was led to get students to talk about the

materials that we have at our disposal including a group of novice meditators and a performance measure (the PVT). At this time an overview of the experiment was given students will complete a PVT, do the meditation activity, and take a post-meditation PVT.

PVT was completed using an online 2-minute Psychomotor Vigilance Test from the Sleep Disorders Center Florida http://www.sleepdisordersflorida.com/ pvt1.html). This is available for all internet enabled devices. For the purposes of this class, PVT was completed in a computer lab with desktop computers that each had a dedicated corded "mouse" to click. Steps were taken to ensure that PVTs are taken using the same device within subjects to reduce inter-test variability. Students were then asked to record their average response time, which is automatically calculated via the website (false starts are automatically removed, as are response times less than 100 msec - which is faster than humans can respond to a real visual stimulus). Data was recorded using a slip of paper that includes: Sleep Duration Last Night (hours), Before Meditation average response time (msec) and number of false starts, After Meditation average response time (msec) and number of false starts.

After the pre-meditation PVT data was recorded, students were instructed how to do the 5-minute focused breathing meditation. During meditation, subjects are asked to close their eyes, then focus on their breathing, and if their minds wander to bring focus back to their breath. Each trial was completed with the same meditation instruction:

"We will now begin the focused breathing meditation. Everyone sit up straight in your chair with your feet flat on the ground. Place your hands in your lap or in a comfortable position. During this meditation, focus only on your breathing. Close your eyes and I will tell you when 5 minutes is over. Begin."

After completing the full experimental protocol, students are presented with some data that was gathered previously to discuss data analysis. Students were asked to form a conclusion on said data. During this time, discussion was led to determine how performance variables could be assessed, explaining the basics - such as a lower number indicates a faster reaction time, within vs. between group differences, and how meditation might potentially improve their reaction time. This then leads into a further short lecture/presentation on what meditation is doing to your brain, basics of electroencephalography (EEG), brain regions, and the other impacts of meditation. Meditation practices have been extensively shown to cause changes in the EEG, general physiology, anatomy, and cognitive performance.

Analysis

Since this lesson gathered sleep and reaction time data, this allowed for us to investigate this group of novice meditators' responses from a 5-minute meditation period on subsequent PVT performance. To determine performance changes due to the 5-minute meditation, the difference between pre-meditation reaction time (RT) and post-meditation RT was calculated for all subjects. A paired t-test was used to determine significant changes in reaction time (α=0.05). Group differences between the meditation and control groups was determined using a two-sample unequal variance t-test. A bivariate fit of hours of sleep the night before testing and the change in reaction time was used to determine if the previous night sleep correlated with the change reaction time. All statistical analysis was completed using GraphPad Prism.

Results

From the entire data set (n=417), two subjects were outliers with change in RT > 1000 msec were removed for a final sample size of n=415. There was a significant improvement in RT ($t(416) = 6.73$, $p<0.0001$) with subjects showing a mean of 26.03 ± 79.02 msec improvement in reaction time after meditation. 65.8% of people in this study had improved reaction times after the 5-minute meditation session (Figure 1). Sleep time before meditating, in this sample, did not correlate with change in reaction time in the control group (p=0.93) or the meditating group (p=0.21).

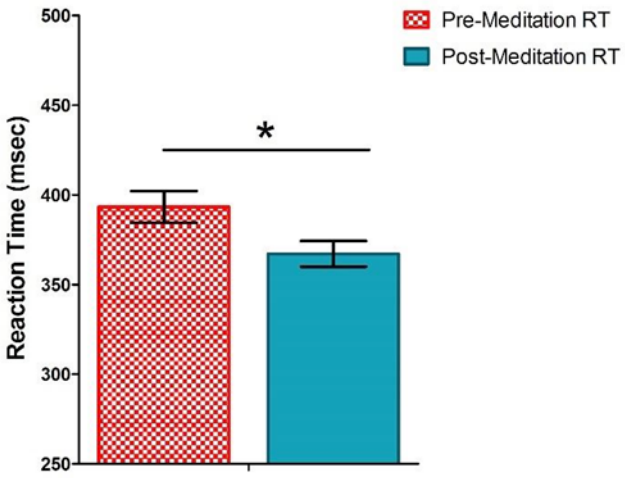

Figure 1: Performance improved, on average, following the 5-minute meditation session when all subjects were analyzed together. Reaction time decreased an average of 26 milliseconds from pre-meditation to post-meditation (n=417). Error bars denote SEM. *p<0.001 using paired t-test.

Cohort 1

The first data was collected during the 2015-16 STEMCats Seminar Courses. This group consisted of 186 students. Analysis was completed to determine if students got a boost in performance from the 5-minute meditation. These reaction times (RT) were measured using a 2-minute PVT and analysis was completed for the reaction time data. A one-tailed paired t-test showed a significant difference between pre and post meditation RT($t(185)=4.227$, $p<0.001$) (Figure 2). RT decreased an average of 13.2 msec from premeditation (335 ± 71.8 msec) to post meditation (321 ± 61.9 msec). This shows that there was a significant and consistent decrease in reaction time after students underwent five minutes of meditation. From premeditation to post meditation, 122 out of 186 people improved their reaction times.

Cohort 2

The next set of data was collected in 2016-2017 and consisted of 102 students. These students also showed an improvement in RT pre versus post meditation ($t(101) = 4.882$, $p<0.0001$) (Figure 2). Reaction time decreased an average of 59.57 msec from premeditation (555 ± 281.9 msec) to post meditation (495 ± 227.9 msec). From premeditation to post meditation, 71 out of 102 people improved their RTs.

Cohort 3

A year after the last group, in 2018-2019, 41 students performed the test. This group also showed significant improvement in RT post mediation ($t(40) = 1.925$, $p=0.0308$) (Figure 2). RT decreased an average of 7.46 msec from premeditation (304 ± 33.8 msec) to post-meditation (297 ± 24.8 msec). From premeditation to post meditation, 21 of 41 people improved their reaction times.

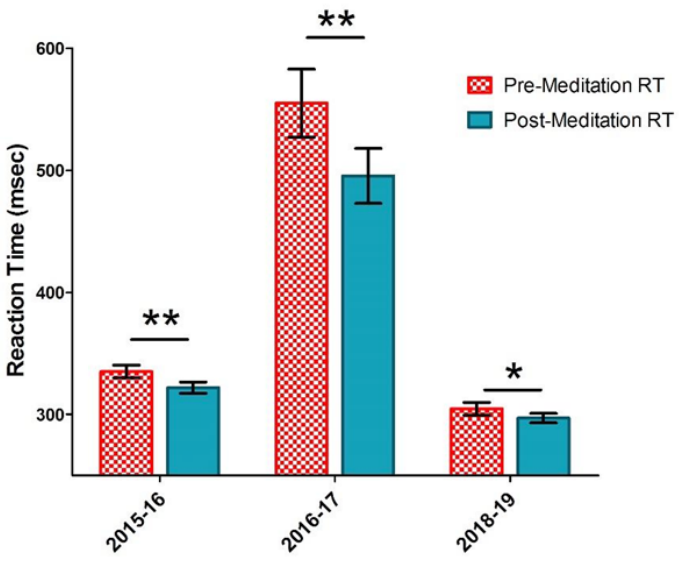

Figure 2: Each group of students show a significant improvement in RT after their short meditation. RT decreased in the Cohort 1 (2015-2016) group by 13.25 msec, in the 2016-2017 group by 59.57 msec, and in the Cohort 3 (2018-2019) group by 7.463 msecs. Error bars denote SEM. *$p<0.05$, **$p<0.0001$ using a paired t-test. **Note:** We do not know the cause of the slower reaction times in 2016-2017, but this website-based version may respond slower than the traditional PVT machines, or various PC based program that are equivalent, and may have had an especially slow connection in this one year. However, the delay appeared to be consistent throughout this year, and thus should not impact the pre vs. post comparisons.

Cohort 4 (with control sedentary activity)

To conclude the study, in 2019 a group completed a 5-minute control sedentary activity, followed by the 5-minute meditation protocol. To determine if reaction time differences significantly differed between meditation and the control sedentary activity, a (n=72) and all meditation subjects. Two-sample unequal variance t-test was performed on the difference between control. Despite the greater RT improvement with meditation vs. control activity (26msec vs. 15msec), there were no statistically significant differences between the control activity and meditation. Follow up analysis showed that the control sedentary activity also significantly improved RT ($t(71) = 3.41$, $p<0.0005$). RT decreased from the sedentary activity an average of 15 msec from pre-activity (363 □ 98.5 msec) to post control (347 ± 81.5 msec) (Figure 3).

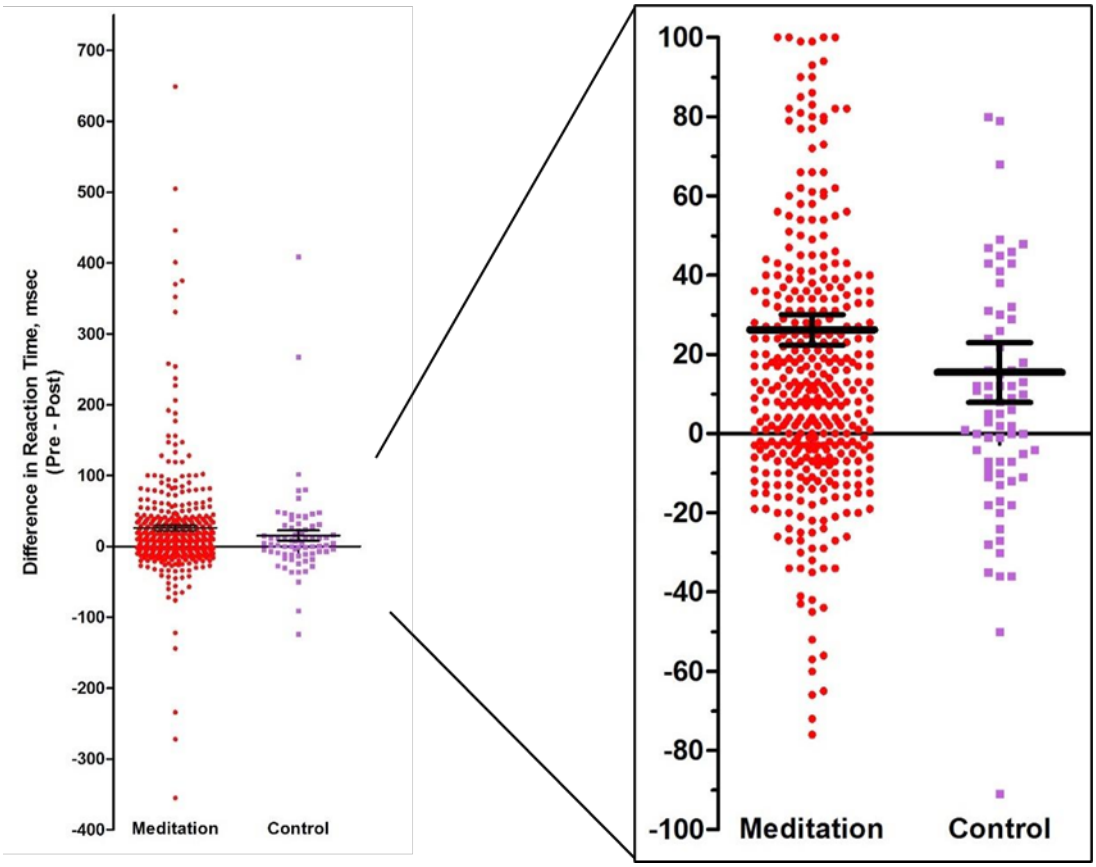

Figure 3: Both the control sedentary activity and meditation showed a decrease in RT. Meditation practice did show a 26 ± 79.2 msec reduction/ boost in reaction time from premeditation to post meditation for all subjects. The control activity is not dissimilar from some meditation practices and also showed a 15 ± 7.57 msec reduction of reaction time from pre activity to post control ($p<0.005$). Error bars denote SEM.

Conclusions

Problem

Our data show the effectiveness of a 5-minute introductory meditation exercise and its impact on reaction time as measured by a simple PVT. This activity requires little equipment and can be broadly used as an experiment to get students interested in their control over their own brain. Previous studies of meditation in the classroom have relied on long meditation training and semester long laboratory classes. These require much effort, laboratory materials, and student input. For wider, classroom applications we show the effectiveness of only a 5-minute meditation on basic attentional performance. The online PVT is easy for students to take using any device and can be completed at home if needed. Our activity can be used in introduction biology courses, neuroscience courses, seminars,

behavioral classes, and psychology courses. This activity is quick with consistently positive responses from students. This student response was not quantified, but in early years of these studies, students were able to choose different activities, and this activity had the highest attendance and highest interest (out of 12).

Contributions

Previous research has shown that longer training of meditation improves performance. This is the first paper that shows that 5 minutes of focused breathing meditation is effective in reducing reaction time in a large classroom study. Although data is limited to RT, this is still encouraging for future meditation research. Using the same type of meditation, a previous study completed in our lab showed that a 40-minute meditation also significantly improved RT [32]. These data showed that participants' RT decreased by 16.5 msec, which was a slightly larger boost than that seen in this study [32], and essentially all subjects had at least a small improvement when averaged over two trials each. Thus, a longer duration of meditation appears to provide a more consistent boost in performance, however, the short 5-minute meditation often provided a similar (but slightly lower) improvement, and likely a similar physiological response.

Interestingly, the 5-minute "control" activity was also shown to have a performance boost. The act of meditation consisted of closing eyes in a controlled position. Meditation is also a time of sitting quietly, being removed from stress of academic activities, and not focusing on learning or other activities. These same things took place during the control activity, and we would even argue that this time of relaxation and sitting quietly is similar to meditation in several aspects, and perhaps allows the brain to "reset" to better perform in subsequent tasks (perhaps also similar to so-called 'power naps' of 5-10 minutes duration, that may or may not involve any actual sleep).

When discussing these data and your findings with your students, this can lead to discussions of the mechanism of action of meditation, which we and many others believe is increasing the neuronal coordination and inducing slower firing of the neurons [35-37]. This in turn leads to the performance enhancing effect (reviewed in [38]. Studies of longer durations of meditation with subsequent EEG recordings show that meditation can reduce attentional blink and allows for more effective brain resource allocations [39]. Other EEG studies have also shown that after meditation practice, meditation can have an immediate effect on attentional measures [40].

Limitations

This study only analyzes the effect of 5 minutes of meditation on a single performance measure, psychomotor vigilance. Other performance measures have been found to benefit from longer meditation, but it's unknown if 5 minutes of meditation would change performance on these other measures. Longer-term meditation has been shown to improve information processing, memory, and other measures of attention (reviewed in [38,27] and these require follow up studies.

Our data show no impact of self-reported sleep duration on reaction time. Due to the exploratory nature of our data, this was not unexpected. Normal sleep may show no effect due to meditation. A previous study completed by our lab [32] showed that after a full night of sleep deprivation there was a larger boost in reaction time performance by meditation, due to the slower reaction time pre-intervention for these sleep deprived subjects. Another study of attention and meditation after one night of sleep loss showed that those subjects that meditated had better attentional performance than those who rested [34]. Both studies show the impact of an entire night sleep loss on attention that is then improved by meditation. This finding may be limited to severe sleep deprivation and was unable to be seen in the sleep amounts reported by students, which cover a more modest level of sleep debt. Our 2-minute PVT may also not be sensitive enough to capture sleep loss induced attentional deficits, as both previous studies used the more widely accepted and validated 10-minute PVT [32,34]. This topic of sleep and meditation should undergo further study because undergraduate students in general suffer from poor sleep which can interact with missing classes, receiving lower grades, and poor mental wellness [41]. Lastly, as noted in the Figure 3.2 legend, the 2-minute website version used in this study appears to have a delay relative to the commonly used PVT-192 device that has been sold for decades, or equivalent PC versions [42], which typically use 10-minute test periods. However, the delay appears to be consistent within each subject and testing period, and thus our pre vs. post RT averages, and the subtraction of these values to assess increased or decreased speed should be accurate.

Implications

We showed that 5 minutes of meditation significantly decreased RT in the context of an introductory seminar-based class for biology majors. Beyond exposure to neuroscience through meditation, the exposure to meditation is valuable to students. As stated earlier, there is a myriad of psychological and physiological benefits from meditation practice itself.

Students can change a physiological measure, psychomotor vigilance and attention, by a very simple and short meditation. We have previously described the impact of meditation on performance [38] and this material is a good starting point for additional lecture and lab material. The authors also had success using this activity in a Bio 300 level course for Neuroscience majors: Introduction to Neuroscience Techniques (mostly sophomores and juniors). The meditation activity was used as a preface to an EEG-based

exploratory lab. This lab included this same meditation activity (data not collected for research purposes) and followed with a brief lecture on the neurobiology of meditation and the different frequency brain waves typically demarcated in EEG studies (delta, theta, alpha, beta, and gamma). Lab groups then used an EEG to visualize the immediate eyes closed occipital alpha power increase (unpublished data). They then increased alpha power while repeating the focused breathing meditation and/or relaxation. Multiple students have stated that this lab was one of their favorites in the course due to the personal and hands on nature of the activity.

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