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The Effects of Brief Mindfulness Meditation Training on Experimentally Induced Pain

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Abstract: This study investigated the effects of brief mindfulness meditation training on ratings of painful electrical stimulation. In Experiment 1, we used a 3-day (20 min/d) mindfulness meditation intervention and measured pain ratings before and after the intervention. Participants' numerical ratings of pain to "low" and "high" electrical stimulation significantly decreased after meditation training. Pain sensitivity, measured by change in stimulus intensity thresholds, also decreased after training. We investigated, in Experiment 2, how well relaxation and a math distraction task attenuated experimental pain. Math distraction but not relaxation reduced high pain ratings. There was no reduction in pain sensitivity in these participants. In Experiment 3, we directly compared the effects of meditation with math distraction and relaxation conditions. Our findings indicated significant effects of both meditation and math distraction. Consistent with what was observed in Experiment 1, these participants also demonstrated a decrease in pain sensitivity after meditation training. Changes in the mindfulness and anxiety assessments suggest that meditation's analgesic effects are related to reduced anxiety and the enhanced ability to focus on the present moment.
***Perspective:* Our findings indicate that a brief 3-day mindfulness meditation intervention was effective at reducing pain ratings and anxiety scores when compared with baseline testing and other cognitive manipulations. The brief meditation training was also effective at increasing mindfulness skills.**

Key words: *Brief meditation, mindfulness, pain perception, attention.*

The recent resurgence of meditation research has been important in the promotion of positive health outcomes and well-being.[15,32,35,38] For example, meditation interventions have been found to attenuate pain symptoms in both experimental and clinical settings.[15-17,20,31,33,40] Mindfulness-based stress reduction (MBSR) programs are currently the most widely implemented meditation interventions examining pain outcomes.[15] MBSR programs are usually 8 weeks long, include daily homework assignments, require a trained professional, and include a day of silent retreat.[15,19,22] Although there are variations in mindfulness meditation training, most interventions teach participants how to maintain focus on a dynamic and automatic stimulus while allowing thoughts or feelings to be acknowledged but not judged. Researchers have found that persistent meditation practice over time is associated with better health outcomes.[1,42] However, individuals such as chronic pain patients may not have the time or ability to fully participate in MBSR programs. Furthermore, it may be difficult to disseminate the beneficial effects of meditation to the general population if it is perceived that meditation's palliative effect requires an extensive time commitment.[35] This study sought to determine whether the beneficial effects of mindfulness meditation can be realized with brief training in an experimental setting.

Although a few researchers have examined the effectiveness of brief meditation interventions, none have implemented a training as brief as the one described here. For example, Kingston et al[23] used a 6-session, 3-week meditation intervention and found increases in pain tolerance with a cold pressor task. Lane et al[26] reported that a 1-month mindfulness meditation intervention increased positive mood and reduced distress. Similarly,

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Jain et al[18] implemented a 1-month meditation program and found a reduction in negative mood states and rumination in meditators when compared with control subjects. Together, these studies suggest that relatively brief meditation training can influence pain as well as affect and cognition.

Notably, pain perception can also be attenuated by cognitive and affective factors.[8,10,12-14,24,29,34,43] For example, reduction in anxiety after both meditation and relaxation training was correlated with decreased pain perception.[23] It is possible, therefore, that meditation's analgesic effects are experienced through both the cognitive ability of maintaining focus[16] and attenuating affective appraisal of stimuli.[44] To examine the analgesic effect of brief meditation, we measured pain ratings to electrical stimulation before and after meditation training. For the purpose of comparison, the effects of relaxation and math distraction were studied in a second experiment with another group of participants who were also measured in 2 sessions. In Experiment 3, all 3 effects (relaxation, math distraction, and meditation) were directly compared. The math distraction task was used because distraction has been shown to be effective at redirecting attention away from the painful stimuli.[10,11] Similarly, relaxation, a component of meditation,[27] has been found to reduce the perception of pain.[20]

Experiment 1

Materials and Methods

Participants

All procedures were approved by the University of North Carolina, Charlotte, Institutional Review Board and held in accordance with the Declaration of Helsinki and its most recent amendments. Participants provided written informed consent and received course credit for their participation. All participants were screened and excluded from participation for factors that are known to alter perception of experimental pain. These factors include previous meditation experience, psychological disorders, using pain medication, and/or acute or chronic pain conditions. Participants with experience of yoga were not excluded because commercial yoga practice does not encompass the same concentrative techniques of mindfulness meditation.[1,7] Twenty-eight students were recruited from the Psychology subject pool at the University of North Carolina, Charlotte. Five students dropped out after learning about the nature of the experiment, and 1 was excluded because that individual was using pain medication. Twenty-two students (15 males) completed all experimental sessions. The recruitment protocol explained that participants needed to be interested in learning meditation. The participants' median age was 19 years (range, 18 to 36). Eighteen of the participants were white, 2 were "other," 1 was African-American, and 1 was Latino.

Apparatus

Neurometer

Our method for delivering phasic pain used a transcutaneous alternating current sine wave delivered by a portable device (Neurometer CPT; Neurotron Inc, Balitmore, MD). The stimuli were brief electrical pulses (3 seconds on and 2 seconds off) delivered at 5 Hz.[4]

Stimulus Values

We used the method of limits to establish a stimulus-response curve for each participant. To make sure that the same degree of sensory experience occurred for all of the participants, a threshold procedure was used to determine the stimulus intensities associated with cutaneous threshold (CT), low pain, and high pain. The intensity at which the participant first detected a sensation was defined as the CT. To obtain the pain thresholds, stimulus values were progressively increased in increments between 5 and 10 milliamperes (mA). Participants rated each stimulation by using the following numerical rating scale (NRS; 0 = "no sensation"; 1 = "mildly unpleasant"; 2 = "moderately unpleasant"; 3 = "mildly painful"; 4 = "moderately painful"; 5 = "severely painful"; 6 = "intolerable"). The NRS was visible at all times during testing and participants responded verbally by assigning a value between 0 and 6. Once participants rated the stimulation above 5.5, the intensities were systematically decreased to the cutaneous threshold value observed on the first trial. Using this range, the experimenter then randomly delivered intensities that received a rating between 2 and 3 (low pain) and between 4 and 5 (high pain) to ensure consistency for each participant's pain ratings. Stimuli consistently given a rating of 2 and 4 at least 5 times were designated as low and high pain, respectively. All stimuli were randomly delivered during testing. Table 1 presents the average stimulus intensities measured in milliamperes for high and low pain that were used in the current experiments.

Table 1. Mean (SD) Stimulus Intensity (mA) Values for High and Low Pain for Each Experiment

	Session 1		Session 2	
	High Pain	Low Pain	High Pain	Low Pain
Experiment 1	279.0 (154.9)	167.5 (100.7)	353.4 (219.3)	240.0 (168.2)
Experiment 2	252.0 (130.6)	149.8 (73.0)	278.1 (94.3)	176.2 (74.31)
Experiment 3	354.0 (232.06)	215.8 (151.42)	409.7 (220.8)	260 (232.06)

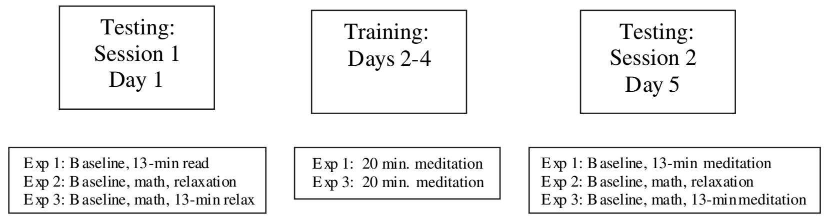

Figure 1. An outline of the experimental sessions and conditions used in each of the experiments.

Subjective Assessments

The State Anxiety Inventory (SAI)[37] is a 20-item scale designed to measure state anxiety. The SAI has been reported to exhibit high internal consistency with Cronbach α of 0.73.[37] Statements such as "I feel worried," are rated on a 4-point scale from 1 (not at all) to 4 (very much so). Scores ranged from 20 to 80, with higher scores indicating more anxiety. We administered the SAI to examine if 20 minutes of meditation would reduce state anxiety. Previous research has found that meditation practice decreases state anxiety.[19,27]

The Freiburg Mindfulness Inventory (FMI)[2] is a 30-item assessment that measures the experience of mindfulness. The FMI is a psychometrically sound instrument with high internal consistency (Cronbach α = 0.93).[41] Statements such as "I am open to the experience of the present moment" are rated on a 5-point scale from 1 (rarely) to 5 (always). Scores ranged from 30 to 150, with higher scores indicating more skill with the mindfulness technique. The FMI served as a manipulation check on participants' ability to engage in a "mindful" state.

Procedure

Participants were tested in 2 separate experimental sessions scheduled before and after a 3-day training session. Fig 1 provides a day-to-day outline of how the experiment was conducted. Each of the experimental sessions consisted of 2 conditions separated by a 13-minute period in which participants either "relaxed" while reading a magazine or meditated. Participants completed the FMI to measure degree of "mindfulness" at the beginning of session 1 and the end of session 2. They completed the SAI before and after each experimental session and on each day of mental training to measure changes in state anxiety.

Meditation Training

Meditation training was held on 3 consecutive days after the first day of testing (experimental session 1). Instruction was conducted by a facilitator who had trained for more than 10 years in mindfulness meditation techniques. The instruction was focused on teaching naïve participants how to practice the cognitive act of mindfulness meditation without any spiritual or religious emphasis. Each training session was held with groups of 3 to 8 participants and lasted approximately 20 minutes.

The instructor taught different meditation skills on each of the 3 days. On the first day, participants were told to focus on the flow of their breath, with their eyes closed, and to nonjudgementally become aware of their thoughts, senses, and feelings, while maintaing focus on the breath in the nostrils.[1,42] On the second day of the intervention, participants meditated to a standard 20-minute mindfulness meditation tape by Jon Kabat-Zinn emphasizing how moment to moment awareness can alter the manner one experiences external/internal events. The focal point of the meditation practice was the "whole breath," including the inhalation sensation of the nostrils, the rise and fall of the abdomen, and the dynamic sensations of exhalation. On the third day of the meditation intervention, participants were given more instruction and details about mindful practices. For example, it was emphasized that participants could try to quiet the mind by sustaining focus on their breath and to pay attention to the dynamic sensations of other parts of the whole body while nonjudgmentally allowing discursive thoughts to simply pass.[42] Before and after each meditation session, participants were encouraged to ask questions about difficulties while meditating.

Verifying whether or not experimental participants are "truly" meditating is difficult[2,3,17]; however, manipulation confirmations were assessed through changes in FMI and SAI measures taken before and after training. We expected brief meditation practice would decrease state anxiety ratings and an increase in FMI scores as the participants acquired mindfulness skills.[21,41]

Experimental Testing Sessions

Participants were tested individually for approximately 60 minutes in each session. On arrival, informed consent was obtained, and the ventral surface of the nondominant arm was prepared for stimulation. Four sites were marked along the arm, 1 inch from each other, with the first at least 1 inch distal from the elbow. A different site was used for each experimental condition (eg, baseline, meditation) to minimize habituation or sensitization. The order of these sites was counterbalanced across participants.

Each experimental session began with a baseline condition, in which participants were instructed to rate stimuli with the NRS (described above). For each condition, phasic electrical pulses were delivered in 8 15-second trials consisting of a random ordering of the 3 stimulus values (CT; low; high) established by the threshold procedure. A trial consisted of 3 stimulus periods during which the stimulation was on for 3 seconds and off for 2 seconds. Three of these trials used the stimulus values associated with low pain, 3 were associated with high pain, and 2 used the value associated with CT. Participants verbally responded to each trial with a numerical value between 0 and 6 on the NRS that was visible during testing.

During test session 1, the baseline condition was followed by a 13-minute period in which the participants were told to "sit comfortably, relax, and read a magazine." All participants read the same magazine (a car sales brochure). No stimuli were delivered during this 13-minute period, which primarily served as a procedural control for the 13 minutes of meditation practice that occurred in session 2. After the 13-minute period, participants were tested a second time with 8 15-second trials consisting of a random ordering of the 3 stimulus values.

In test session 2, after thresholds were obtained, baseline testing was followed by a 13-minute meditation period. Participants were simply instructed to "begin meditating," without any guidance. After 13 minutes of meditation, participants were stimulated for 8 15-second electrical stimulation trials while they continued to meditate.

Analyses

Mean numerical ratings were computed by averaging across the trials for each participant's stimulus intensity ratings (cutaneous threshold, low, and high pain). A repeated-measures analysis of variance (ANOVA) was used to test for the effects of session (1 vs 2), condition (baseline vs reading/meditation), and stimulus intensity (low and high pain). To test for the hypothesized effect of meditation and relaxation, data for each session are analyzed separately with a condition by stimulus intensity ANOVA. The *F* tests that are reported include the Greenhouse-Geisser correction when necessary to protect against possible violation of the sphericity assumption. Numerical ratings in response to CT stimulation were less than 0.5 in all conditions and are not included in the analyses since they primarily served to check for false positives. Analysis of the CT ratings did not show any significant variations across conditions or sessions (*F*s <1).

Results

Pain Ratings

Fig 2 presents the mean numerical ratings with 95% confidence intervals for sessions 1 and 2. As expected by the threshold procedure, numerical ratings were higher to high (3.73) in comparison to low pain stimulation (2.07) [$F(1,21) = 247.64$, $P < .01$, $\eta^2 = 0.92$]; however, numerical ratings did not interact significantly with any of the other variables. There was an effect of session [$F(1,21) = 8.76$, $P < .01$, $\eta^2 = 0.29$] that resulted from a significant decline in both high and low pain ratings after meditation training; and session interacted with condition [$F(1,21) = 10.55$, $P < .01$, $\eta^2 = 0.33$], because meditation was more effective than reading in reducing high and low pain ratings. However, within-subject contrasts (at the $P < .05$ level of significance) showed that baseline numerical ratings for high (M = 4.47, SD = 0.68) and low

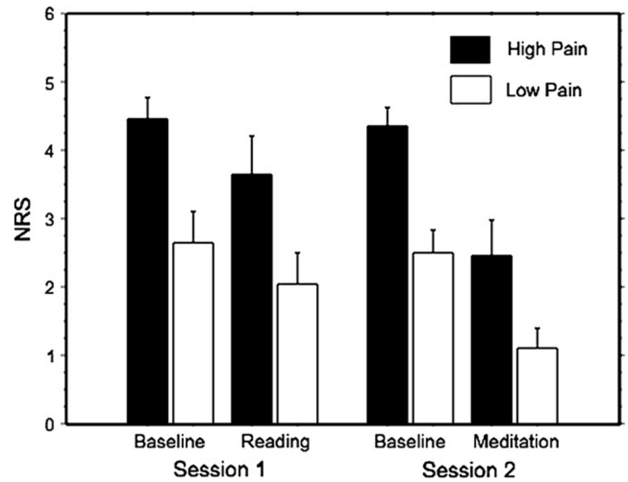

Figure 2. Mean numerical ratings (NRS) with 95% confidence intervals for experimental conditions in Experiment 1.

pain (M = 2.64, SD = 1.03) during session 1 were not significantly different from baseline numerical ratings during session 2; high pain (M = 4.35, SD = 0.61), low pain (M = 2.51, SD = 0.75).

The analysis on session 2 data showed a strong effect of meditation (baseline vs meditation) [$F(1,21) = 94.69$, $P = .01$, $\eta^2 = 0.82$]. Numerical ratings dropped from 4.4 in response to high pain in the baseline condition to 2.4 after meditation and from 2.51 in the baseline condition to 1.09 in response to low pain stimulation. The absence of an interaction of condition by stimulus intensity [$F(1,21) = 2.96$, $P = .10$] indicates that the decline in pain ratings with meditation was similar for both high and low stimulus values.

A smaller but still significant drop in pain ratings relative to baseline was also obtained in the pretraining data (session 1) for the second condition "relax while reading a magazine" [$F(1,21) = 7.64$, $P = .01$, $\eta^2 = 0.27$]. As in the previous analysis, condition was not found to interact with stimulus values [$F(1,21) = 1.26$, $P = .27$].

Subjective Assessments

The meditation intervention was effective in reducing reports of anxiety. Changes in state anxiety, reported in Table 2, were tested with a session by pre/post-testing repeated-measures ANOVA. Reduction in scores on the SAI produced a significant session by pre/postinteraction [$F(4,68) = 6.70$, $P < .01$, $\eta^2 = 0.28$] and main effects for test session [$F(4,68) = 6.8$, $P < .01$, $\eta^2 = 0.29$] and pre/post-testing [$F(1,68) = 74.3$, $P < .01$, $\eta^2 = 0.81$]. The interaction can be explained by the decrease in mean SAI scores during post-testing for every session except the first, which was run before meditation training.

A comparison of FMI ratings before (M = 55.19, SD = 8.49) and after (M = 61.00, SD = 9.73) training revealed a significant increase in "mindfulness" [$F(1, 21) = 21.72$, $P < .01$, $\eta^2 = 0.52$]. As expected, the 3-day intervention was effective in increasing mindfulness as measured by the FMI.

Additionally, correlations were calculated to investigate whether the change in pain ratings during

Table 2. **Mean (SD) State Anxiety Inventory Scores (SAI) at Each of the Experimental and Training Sessions**

Session	Before Testing	After Testing
Experiment 1		
Session 1	37.8 (7.0)	37.0 (6.9)
Training day 1	34.7 (5.7)	25.53 (5.0)
Training day 2	36.3 (8.9)	27.1 (7.3)
Training day 3	36.3 (8.5)	26.9 (6.5)
Session 2	36.3 (8.6)	28.3 (7.2)
Experiment 2		
Session 1	37.4 (6.9)	37.3 (8.5)
Session 2	33.0 (7.9)	30.9 (6.4)
Experiment 3		
Session 1	36.8 (10.2)	37.7 (8.9)
Training day 1	37.9 (7.2)	22.7 (5.9)
Training day 2	39.5 (10.2)	29.4 (7)
Training day 3	38.7 (8)	29.4 (6.6)
Session 2	34.5 (6.4)	27.7 (5.2)

meditation in session 2 were associated with the other self-reported measures. The change in pain ratings to the high stimulus intensity were significantly associated with FMI scores measured during session 2 [$r(20) = .44$, $P < .05$], suggesting that participants who were more "mindful" perceived less pain during stimulation. Reductions in pain were not associated with SAI scores measured during session 2 [$r(20) = 0.13$, $P = .57$]; however, FMI and SAI scores were found to be inversely related [$r(20) = -0.46$, $P = .04$]. Those who are mindful tended to be less anxious.

Stimulus Intensities

Stimulus intensity values obtained as high and low thresholds were analyzed with a session by stimulus intensity ANOVA. As can be seen in Table 1, there was an unexpected increase from session 1 to session 2 [$F(1,21) = 5.80$, $P < .05$, $\eta^2 = 0.22$] and an effect of stimulus intensity [$F(1,21) = 68.90$, $P < .01$, $\eta^2 = 0.77$]. There was no interaction [$F < 1$].

Discussion

The results show that mindful states promoted by a brief (3 day) mindfulness meditation intervention were effective in reducing pain ratings to experimentally induced pain. Participants reported less pain to both "low" and "high" intensities when meditating compared with baseline testing. In addition, there were significant reductions in state anxiety after each meditation session. The 3-day meditation intervention also increased mindfulness skills as measured by the FMI. Additionally, participants who scored higher on the FMI reported the greatest reductions in pain ratings. These data suggest that a decrease in anxiety and the ability to sustain focus on the present moment can attenuate the feeling of pain. There were 2 unanticipated findings of note. One was the significant increase in stimulus intensity values, determined by the threshold procedures, after meditation training. This is noteworthy because it may indicate that 3 consecutive days of meditation practice is sufficient to increase mindfulness skills such that there is a lasting effect on the conscious experience of pain.[42] The other finding that has no ready explanation was the pain reduction obtained in session 1 after the 13 minutes of reading. It is possible this effect was due to simply relaxing or having a pause in the testing session. Experiment 2 was conducted to provide some context for how much pain reduction could be experienced by other manipulations.

Experiment 2

To examine whether the same degree of change in pain ratings can be achieved with other cognitive manipulations, a second experiment was conducted with math distraction and relaxation conditions. Distraction and relaxation conditions were chosen in an attempt to address other possible mechanisms[33] for the analgesic effect seen in Experiment 1. This experiment uses a comparison group who is tested for 2 sessions under the same testing procedure as Experiment 1.

Participants

Twenty-seven students, without any meditation experience, were recruited from the same subject pool as Experiment 1. For 14 of the students, the call for participation differed from the one in Experiment 1; it did not specifically select from those interested in meditation. Four students dropped out after learning about the nature of the experiment, and 2 were excluded because they were using pain medication. Twenty students met the same inclusion/exclusion criteria as Experiment 1 and completed all experimental sessions. The participants provided written informed consent and received course credit. All procedures were approved by the University of North Carolina, Charlotte, Institutional Review Board. Median age of the participants was 19 years (range, 18 to 41). Thirteen were female and 7 were male. Ethnic membership for the sample is as follows: 13 were white, 5 were African-American, 1 was Hispanic, and 1 was "other."

Procedure

Each participant was tested individually in 2 60-minute sessions (see Fig 1) that were 3 days apart. After completing consent forms, participants were administered the same self-report assessments (ie, SAI and FMI) and followed the same threshold procedure as in Experiment 1. One difference between the experiments was the number of conditions in each of the experimental sessions. Three conditions were tested in Experiment 2 (baseline, math distraction, and relaxation). Baseline was always presented first followed by the others in counterbalanced order.

In the math distraction task, participants were asked to start with 1000, subtract 7, and report each difference aloud during electrical stimulation. Instructions emphasized the importance of both speed and accuracy and the answers were recorded. Participants rated the electrical stimulation at the end of each trial and resumed subtracting from the last reported answer (which the experimenter supplied).

In the relaxation condition participants were instructed to "close their eyes" and "relax" while being stimulated. They were given 5 minutes to relax and to "become comfortable in their chairs." The participants were not instructed to focus on the breath or to engage in any other type of cognitive act.

As in the previous experiment, each condition was tested with 8 15-second trials consisting of a random ordering of the 3 stimulus values. The relaxation and distraction conditions followed baseline and were counterbalanced across participants. As in the procedure for Experiment 1, participants completed the SAI for a second time at the end of testing. The second session followed the same procedure as the first and was conducted 3 days later.

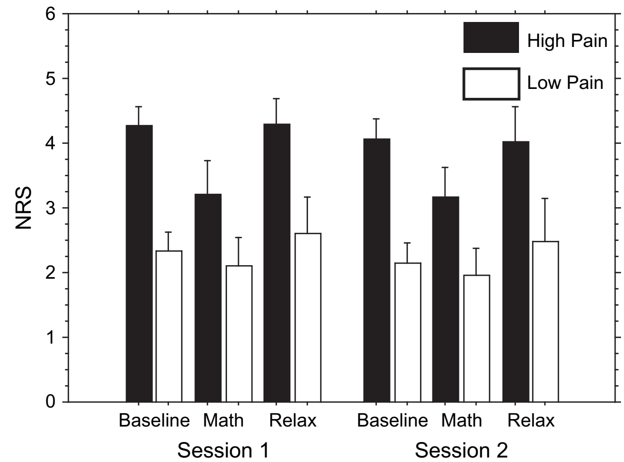

Figure 3. Mean numerical ratings (NRS) with 95% confidence intervals for experimental conditions in Experiment 2.

Results

Pain Ratings

As in Experiment 1, numerical ratings in response to CT stimulation were less than 0.5 in all conditions and are not included in the analyses. Fig 3 presents the pain ratings with 95% confidence intervals. A 2 × 3 × 2 repeated-measures ANOVA showed that repeating the testing on 2 separate days did not have an influence on numerical pain ratings. There was no main effect of test session and none of the interactions with test session were significant [*F*s < 1]. There was a significant effect for condition (baseline, math distraction, and relaxation) [$F(2,38) = 10.07$, $P < .01$, $\eta^2 = 0.35$] and a significant main effect of stimulation level [$F(1,19) = 467.06$, $P < .01$, $\eta^2 = 0.96$]. These 2 variables interacted [$F(2,38) = 12.95$, $P < .01$, $\eta^2 = 0.41$]. A simple effects test was conducted to examine the effect of condition at each stimulation level.

The analysis on the high pain ratings revealed a main effect for condition [$F(2,38) = 16.51$, $P < .01$, $\eta^2 = 0.47$]. Within-subject contrasts (at $P < .05$ level of significance) showed that the math distraction condition was effective in reducing high pain ratings when compared with baseline, but relaxation was not.

The analysis on the low pain ratings also showed an effect of condition [$F(2,38) = 3.81$, $P = .03$, $\eta^2 = 0.17$]. However, the condition effect can be explained by the relaxation condition exhibiting higher pain ratings when compared with the other conditions ($P < .05$). Math distraction was not effective in reducing low pain ratings when compared with baseline condition.

Subjective Assessments

Mean SAI scores are reported in Table 2. A repeated-measures ANOVA examined SAI ratings across the 2 sessions and within (pre/post-testing) a session. There was a significant drop in SAI scores across the sessions [$F(1,17) = 7.56$, $P = .02$, $\eta^2 = 0.17$]. However, there was no pre/post effect [$F(1,17) = 1.02$, $P = .33$] or interaction between pre/post and session [$F < 1$].

This group of participants also completed the FMI in session 1 (M = 54.79, SD = 7.71) and session 2 (M = 54.26, SD = 8.78); as expected, there were no significant differences in mindfulness [$F < 1$]. In contrast to the findings of the previous experiment, SAI scores were not related to FMI scores for session 2 [$r(18) = .02$, $P = .92$], and change in pain ratings in response to high stimuli were not related to either FMI score [$r(18) = 0.21$, $P = .38$] or SAI [$r(18) = 0.13$, $P = .59$].

Stimulus Intensities

Stimulus intensity values (Table 1), obtained in the thresholding procedure for high and low pain, were analyzed with a session by stimulus intensity ANOVA. Repeated-measures ANOVA revealed an effect on stimulus intensity [$F(1,19) = 110.29$, $P < .01$, $\eta^2 = 0.85$] but no effect of session ($F < 1$) and no interaction between session and stimulus intensity ($F < 1$). In contrast to the findings from Experiment 1, there was no significant change in pain sensitivity from session 1 to 2.

Discussion

Math distraction but not relaxation was found to diminish experimentally induced pain. However, math distraction was only effective at reducing ratings of high but not low pain across the 2 experimental sessions. One reason that relaxation did not significantly reduce pain perception may be because our relaxation protocol was not a standardized intervention. In contrast to Experiment 1, participants in Experiment 2 did not show the changes across session in either the pain sensitivity or in mindfulness. There was, however, a decrease in state anxiety between the 2 sessions.

We investigated distraction and relaxation because previous research suggested they may be associated with meditation.[33] Our findings provide mixed support for the literature. However, there are some differences between the participant samples used in the 2 experiments that make it difficult to compare the findings. There were gender differences between Experiment 1 (15 males; 7 females) and Experiment 2 (7 males, 13 females), and the groups may have differed in their willingness to engage in meditation training. Accordingly, Experiment 3 was conducted to directly compare the effectiveness of meditation and math distraction on pain perception with the same group of participants. We wanted to determine whether the effects of brief mindfulness training could be replicated and to also compare its effectiveness directly with math distraction as a technique for diminishing pain in response to electrical stimulation.

Experiment 3

To further examine the efficacy of 3 days of mindfulness meditation training in comparison to other methods of pain control, we implemented a within-group comparison of meditation, relaxation, and math distraction conditions. This allowed direct comparison of the effective cognitive manipulations in Experiment 2 to our brief mindfulness meditation training protocol. This experiment followed the same experimental protocol as the previous experiments. We were interested in the relative pain attenuation between meditation and math distraction.

Participants

Twenty-three students, without any meditation experience, were recruited from the same subject pool as the previous experiments. One student withdrew after learning about the nature of the study, and a second dropped out when he became ill. Twenty-one students met the same inclusion/exclusion criteria as Experiment 1 and completed all experimental sessions. The participants provided written informed consent and received course credit. All procedures were approved by the University of North Carolina, Charlotte, Institutional Review Board. Median age of the participants was 21 years (range, 18 to 26). Thirteen were female and 8 were male. Eleven of the participants were white, 4 were African-American, 3 were Hispanic, 1 was Asian, 1 was Native American, and 1 was "other."

Procedure

Experiment 3 followed the same procedure as Experiment 1 with 2 separate experimental sessions scheduled before and after a 3-day mindfulness meditation training intervention (see Fig 1). For each experimental session, we delivered painful stimulation during baseline, math distraction, and either relaxation or meditation conditions. Subjects experienced the same threshold procedure and experimental protocol as Experiments 1 and 2. In session 1, subjects completed the SAI and the FMI. Next, their pain ratings of 2 (low pain) and 4 (high pain) were calibrated to stimulus intensities. Each experimental trial consisted of 15-second stimulation, after which, participants gave their numerical responses based on the NRS. Baseline and math distraction conditions were counterbalanced across participants after the threshold procedure. After the first 2 conditions, participants were told to relax for 13 minutes. However, instead of reading a magazine for 13 minutes as in Experiment 1's protocol, they were instructed to relax and take deep breaths for 13 minutes. The relaxation condition was run after the math and baseline conditions to control for potential aftereffects associated with relaxation. Subjects were stimulated while continuing deep breathing and told to continue to relax. After the experimental trials ended, the subjects completed the SAI.

Subjects met for 3 consecutive days (20 minutes per session) for mindfulness meditation training. This intervention was the same as the intervention in Experiment 1. On the second experimental test session, subjects' high and low pain ratings were calibrated to stimulus intensity values. Again, baseline and math distraction conditions were counterbalanced within and between subjects. Participants were then told to "begin meditating"; there was no other guidance or instruction. Participants meditated for 13 minutes before stimulation began, and numerical responses were obtained after each 15-second trial ended. They were told to stop meditating after the experimental trials were complete. FMI and SAI assessments were completed after the end of the experimental block.

Results

Pain Ratings

As in Experiments 1 and 2, numerical ratings in response to CT stimulation were less than 0.5 in all conditions and are not included in the analyses. Fig 4 illustrates the mean numerical ratings with 95% confidence intervals for sessions 1 and 2. Numerical pain ratings were higher for high pain (3.96) when compared with low pain ratings (2.08) [$F(1,20) = 313.93$, $P < .01$, $\eta^2 = .94$]. There was a significant main effect for condition [$F(2,40) = 18.48$, $P < .01$, $\eta^2 = 0.48$] as well as session [$F(1,20) = 10.30$, $P < .01$, $\eta^2 = 0.34$]. Condition interacted with stimulus level [$F(2,40) = 13.56$, $P < .01$, $\eta^2 = 0.40$] and session [$F(2,40) = 11.05$, $P < .01$, $\eta^2 = 0.36$]. Stimulus levels did not interact with session [$F(1,20) = 1.02$, $P = .33$] or condition by session [$F(2, 40) = 2.89$, $P = .07$].

To understand the interactions and to test for the effectiveness of meditation in comparison to the other techniques, a follow-up simple effects analysis tested for the effect of condition and stimulus levels at each session. In the analysis on the data from session 1, there were significant differences between conditions [$F(2,40) = 8.11$, $P < .01$, $\eta^2 = 0.29$] and a significant interaction effect between condition and stimulus levels [$F(2,40) = 9.14$, $P < .01$, $\eta^2 = 0.31$]. Within-subject contrasts ($P < .01$ level of significance) indicated that in response to high and low pain stimulation, math distraction (high pain, M = 2.90, SD = 0.95; low pain, M = 1.68, SD = 0.71) reduced pain ratings relative to baseline (high pain, M = 4.06, SD = 0.74; low pain, M = 2.21, SD = 0.89) but relaxation(high pain, M.80, SD = 0.71; low pain, M = 1.80, SD = 0.94) did not.

In session 2, a significant effect of condition [$F(2,40) = 31.16$, $P < .01$] and an interaction of condition by stimulus level [$F(2,40) = 8.58$, $P < .01$, $\eta^2 = .30$] was again found. Within-subject contrasts ($P < .05$) showed, in comparison to baseline, math distraction was effective at reducing pain ratings in response to high but not low stimulus intensities. However, the largest effects relative to baseline

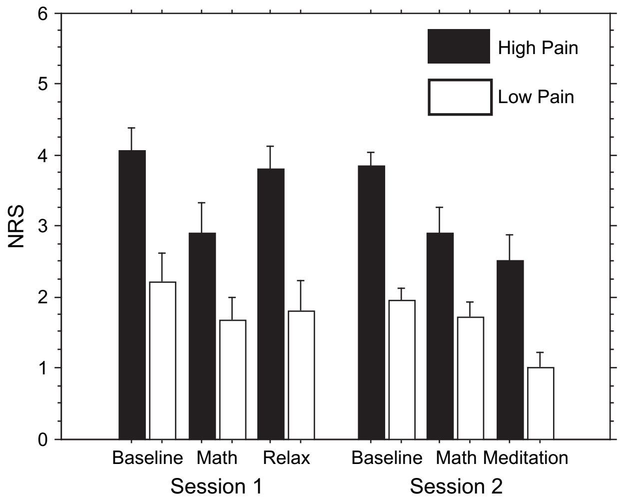

Figure 4. Mean numerical ratings (NRS) with 95% confidence intervals for experimental conditions in Experiment 3.

(M = 3.85, SD = 0.42) were found with meditation. Meditation (M = 2.53, SD = 0.76) was more effective than math distraction (M = 2.91, SD = 0.79) in attenuating high pain ratings. Meditation (M = 1.00, SD = 0.48) was also more effective at reducing low ratings of pain when compared with baseline (M = 1.95, SD = 0.41) and math distraction (M = 1.71, SD = 0.51).

Subjective Assessments

Mean SAI scores are reported in Table 2. A 5 $\times$ 2 repeated-measures ANOVA examined SAI ratings across the 5 sessions and within (pre/post-testing) each session. Similar to Experiment 1, there was a significant pre-post [$F(1,20) = 116.86$, $P < .01$, $\eta^2 = 0.85$], session, [$F(4,80) = 5.11$, $P < .01$, $\eta^2 = 0.20$], and pre-post by session interaction effect [$F(4,80) = 10.98$, $P < .01$, $\eta^2 = 0.35$]. Again, the interaction was found because, in session 1, there were no significant differences on state anxiety. However, in every session in which the participants meditated, there were significant reductions in state anxiety ratings from pre to post.

Consistent with the findings of Experiment 1, a comparison of FMI ratings before (M = 46.33, SD = 9.78) and after training (M = 54.33, SD = 9.61) showed a significant increase in "mindfulness" [$F(1, 20) = 23.33$, $P < .01$, $\eta^2 = .54$]. Again, our findings suggest that 1 hour total of mindfulness meditation training can effectively increase levels of mindfulness as measured by changes on the FMI.

A correlational analysis examined relationships among the subjective assessments with the change in pain ratings. Changes in pain perception were not significantly related to assessments of mindfulness [$r(21) = 0.18$, $P = .22$] or state anxiety [$r(19) = -0.37.18$, $P = .10$]. However, FMI scores were related to SAI measures taken during session 2 [$r(21) = -0.47$, $P \leq .01$], a replication of Experiment 1.

Stimulus Intensities

Stimulus intensity values obtained during the thresholding for high and low pain values were analyzed with a session by stimulus intensity ANOVA. As can be seen in Table 1, there was a significant increase in stimulus values from session 1 to session 2 [$F(1,20) = 6.89$, $P = .02$, $\eta^2 = 0.26$] and an effect of stimulus intensity [$F(1,21) = 63.55$, $P < .01$, $\eta^2 = 0.76$]. There was no interaction ($F < 1$). These data replicate Experiment 1's findings, which suggest that 3 days of mindfulness meditation training may decrease pain sensitivity when compared with before mental training.

General Discussion

Previous findings of meditation's analgesic effect have been largely explored in highly experienced meditators and/or with long-term meditation interventions.[16,20] Experiments 1 and 3 demonstrated that a brief, 3-day (1 hour total) mindfulness meditation intervention significantly reduced subjective pain ratings, pain sensitivity, and state anxiety, while increasing levels of mindfulness. The meditation groups reported lower ratings to high and low pain intensities, relative to baseline, math distraction, and relaxation conditions. The findings are important for a number of reasons. First, they show that even brief meditation training can be effective at dampening the pain response. These findings suggest that the analgesic effect of mindful states may be realized after only a small investment of time learning mindfulness meditation. Second, our results provide some additional information about the relative benefit of cognitive techniques for controlling pain. Although it is well established that pain has sensory, cognitive, and affective components, most approaches for alleviating pain involve application of drugs rather than the use of cognitive manipulations. The present findings are consistent with others[10,29] that show pain dampening in reaction to cognitive techniques. Yet, meditation was more effective in reducing pain perception than these other techniques.

The mechanisms associated with meditation's analgesic effects have yet to be fully explored.[33] However, it is believed that meditation's palliative effects may be associated with the cognitive focus on the dynamic changes of the breath,[28] a relaxed state of mind,[27] and the ability to regulate the affective reaction to pain.[22,30] Mindfulness meditation is premised on nonjudgmentally reappraising sensory events as momentary and fleeting.[19] Thus, this technique may attenuate pain through the sensory and affective dimensions by helping individuals calmly reappraise noxious stimuli as momentary and "not worthy" of emotional reaction.[7,9,28,39] Accordingly, reductions in state anxiety and increases in mindfulness provide behavioral evidence that 3 days of mental training can promote a mindful state, which, in turn, may attenuate the subjective experience of pain.[16]

Previous research has hypothesized that relaxation and distraction techniques are 2 active mechanisms in meditation's analgesic effect.[33] The comparison of meditation to the distraction condition in Experiments 2 and 3 demonstrated more effective pain reduction with meditation. These findings suggest possible differences in affective and attentional modulation of pain between the 2 techniques. Indeed, Holzel et al[15] found areas involved in emotional regulation were activated more during meditation than during a math distraction task. One difference is that a mindful state may regulate affective appraisal systems,[9] whereas distraction may not.[16,36,44] In a recent study, Villemure and Bushnell[44] found that mood and attention activate separate pain modulating neural pathways. Although we did not directly test for this, it may be that a mindful state promotes both attention-oriented and affective pain modulation during pain stimulation.[44] Math distraction may only affect the attentional modulation.[10,11] In fact, Kenntner-Mabiala et al[36] found that attention modulates sensory but not affective ratings of pain. Another way meditation may differ from distraction is that meditation can be associated with the cognitive act of "monitoring," which also reduces the anticipation of a noxious stimulus.[6,25] Therefore, focusing on the present moment may reduce expectations of an upcoming negative stimulus, which may reduce the perception of pain. Nevertheless, math distraction was effective in reducing ratings to high pain when compared with baseline but not low pain ratings. Math distraction's inability to reduce low pain ratings may be, in part, due to differences in the distribution of attentional resources to the 2 levels of stimulation.[10] For example, high pain stimulation probably requires more attentional resources and therefore lends itself to cognitive modulation more readily than the low pain stimulation. In comparison, mindfulness meditation is associated with enhanced top-down control and executive functioning.[5,7] This suggests that meditation's palliative effect on high and low pain intensities, in our study, may be due to the ability to modulate the sensory, affective, and attentional experience more broadly.[42]

In an unexpected finding, subjects demonstrated decreased pain sensitivity after brief mental training (Table 1). Participants in Experiments 1 and 3 required higher levels of stimulus intensity to attain ratings of low and high pain when compared with premeditation intervention pain ratings. This finding was surprising because the meditation groups were not meditating during pain threshold calibration. Indeed, Grant and Rainville[16] also found reductions in pain sensitivity in highly trained Zen practitioners, when compared with control subjects. In contrast, subjects in Experiment 2 did not show a significant decrease in pain sensitivity from session 1 to 2. This comparison is tempered a bit by the fact that a majority of the subjects in Experiment 2 were not expressly interested in meditation and may have differed in other ways. Still, brief mindful training appears to promote decreases in pain sensitivity when compared with control subjects.

The small but significant effect of reduced pain found after reading a magazine for 13 minutes in session 1 was puzzling. This effect could be due to the extended time period subjects had before receiving the pain stimulation; however, it is unlikely because the 13-minute relaxation condition, in Experiment 3, did not replicate this effect. Conversely, the relaxation condition in Experiment 2 resulted in higher levels of reported pain during instructions "to relax and sit comfortably in a chair." Unfortunately, we did not use a standardized relaxation technique and did not monitor how relaxed subjects were. Therefore, we cannot make any firm conclusions about relaxation relative to distraction and meditation, though it appears that any effect that might exist is likely small.

There are some limitations to our study that may qualify the findings. The data can only be generalized to healthy, college-aged adults who are interested in meditation. Procedurally, participants spent more time with the experimenters in Experiments 1 and 3 compared with Experiment 2. However, Experiment 3's findings robustly replicate both previous experiments' pain reductions, suggesting that 3 days of mindfulness meditation training can promote a state of mindfulness, which was found to effectively reduce ratings of low and high pain.

The goal of these experiments was to use an abbreviated meditation training period to demonstrate the effectiveness of meditation on experimental pain. There is no doubt, however, that the effectiveness of this technique may have been greater had we extended the training.[16,42] Therefore, the findings do not show the maximum benefit of this technique. Instead, this work provides a necessary first step in evaluating cognitive factors for pain relief and suggests that meditation training, however brief, may have some possible benefits with pain control and relief. Future work will be needed with chronic pain patients to assess the tradeoff between time spent in mindfulness meditation training and pain relief.

The present study's results suggest that the modulation of the subjective experience of pain can be experienced after a very brief meditation intervention. Although effective in reducing high pain ratings, math distraction was not as effective in reducing a more comprehensive feeling of pain. The FMI and SAI results suggest that decreased anxiety and mindfulness skills contributed to the decreased perception of pain for the meditation condition. Ongoing studies are examining the electrophysiological and neural activities associated with brief meditation training's effects on pain perception.

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