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Meditation experience predicts less negative appraisal of pain: Electrophysiological evidence for the involvement of anticipatory neural responses

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ABSTRACT

The aim of mindfulness meditation is to develop present-focused, non-judgmental, attention. Therefore, experience in meditation should be associated with less anticipation and negative appraisal of pain. In this study we compared a group of individuals with meditation experience to a control group to test whether any differences in the affective appraisal of pain could be explained by lower anticipatory neural processing. Anticipatory and pain-evoked ERPs and reported pain unpleasantness were recorded in response to laser stimuli of matched subjective intensity between the two groups. ERP data were analysed after source estimation with LORETA. No group effects were found on the laser energies used to induce pain. More experienced meditators perceived the pain as less unpleasant relative to controls, with meditation experience correlating inversely with unpleasantness ratings. ERP source data for anticipation showed that in meditators, lower activity in midcingulate cortex relative to controls was related to the lower unpleasantness ratings, and was predicted by lifetime meditation experience. Meditators also reversed the normal positive correlation between medial prefrontal cortical activity and pain unpleasantness during anticipation. Meditation was also associated with lower activity in S2 and insula during the pain-evoked response, although the experiment could not disambiguate this activity from the preceding anticipation response. Our data is consistent with the hypothesis that meditation reduces the anticipation and negative appraisal of pain, but effects on pain-evoked activity are less clear and may originate from preceding anticipatory activity. Further work is required to directly test the causal relationship between meditation, pain anticipation, and pain experience.

1. Introduction

The use of alternative medicine is common for self-managing chronic and stress-related conditions that do not respond well to conventional medicine [15]. Despite this there is debate about whether alternative therapies have anything to offer beyond the placebo effect [24]. A major problem facing research into alternative therapies is the lack of clear hypotheses regarding their therapeutic mechanisms.

One of the few alternative therapies that has been adopted by conventional psychological medicine is mindfulness meditation [22,39,43]. The therapeutic mechanisms of meditation have been discussed in terms of attentional functioning [5,27]. Such mechanisms may be clinically relevant to a wide range of psychological, psychosomatic and stress-related diseases [1,22]. Although there is a broad range of meditation techniques, those related to mindfulness meditation involve training in cognitive control, specifically the ability to voluntarily direct attention to a chosen sensory or cognitive event whilst minimizing distraction by other sensory or cognitive phenomena [27]. Mindfulness methods include focusing on the internal feeling of breathing and other body sensations at objects of concentration.

It has been noted that one aspect of training in meditation is to learn how to re-focus attention away from either past or anticipated future experience and onto present-moment experience [5,10]. Meditation should therefore reduce the emotional appraisal of pain or other stressful events by withdrawing attention away from anticipating their unpleasantness. This would be expected to be associated with reductions in brain processes related to anticipating the unpleasantness of pain, without necessarily reducing those brain processes related to the pain itself.

Research using fMRI suggests that regions of the pain matrix showing differential responses to pain in meditators include the thalamus, primary and secondary somatosensory cortices, insula, prefrontal cortex, and the anterior cingulate cortex [23,34]. However, the effects of meditation may occur at multiple time points in the sequence of anticipating and experiencing pain. Limitations in the design of fMRI investigations have meant that it is not clear whether meditation primarily affects anticipatory or pain-evoked responses. We aimed to resolve this problem using high-density

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electrophysiology to measure affective processing during the anticipation and response to pain.

We recruited participants with a broad range of experience of meditation to compare with a non-meditating control group and to determine the effects of lifetime meditation experience. We hypothesized that meditation experience would be related to anticipatory activity in brain regions such as cingulate, prefrontal and parietal cortices. We used a methodology previously reported [7–9,11] for defining the sources of brain activity during different time periods of anticipation and pain experience. We and others have previously suggested that early anticipatory processes are likely to involve establishing an expectation [8] and confidence in that expectation [9]. However, late anticipatory processes more likely relate to preparatory (e.g. attentional and motor) and motivational processes, as well as establishing top-down influences on pain [8]. It is during late anticipation that we would expect differences in cognitive control to influence the affective appraisal of pain and top-down affective influences on pain perception.

2. Methods

2.1. Participants

The research study was approved by Tameside and Glossop Local Research Ethics Committee. The recruitment of subjects for the study was advertised as open to volunteers both with and without experience of practicing meditation. Our intention was to be as inclusive as possible regarding recruitment of subjects with different types of meditation practice, as long as they declared that "sustained focused attention" was the predominant aspect of their practice, as a way of standardizing their meditation experience.

In total, 27 healthy, right-handed subjects participated in the study (13 female, 14 male; mean age 34 ± 14). All subjects gave informed written consent. Of these subjects, 12 declared having experience of meditation (6 female, 6 male; mean age 37 ± 13), whilst the remaining 15 subjects had no experience of meditation (8 female, 7 male; mean age 32 ± 14). These two groups are referred to as the meditation and control groups respectively. Independent-samples *t*-test statistics revealed no significant difference between the ages of the two groups.

2.2. Measurement of meditation experience

Subjects in the meditation group were questioned about the type of meditation practice they do in terms of (1) which precise method they follow, (2) how long they had been practicing over their whole lifetime, and (3) roughly how many hours per week they currently commit to a formal meditation practice. However, many subjects in the meditation group, in addition to reporting regular formal periods of meditation practice, also reported informal meditation practice during their daily activities, and stated that it was not possible for them to accurately estimate how much time they spend practicing informally each week. Furthermore, many subjects also reported that the number of hours they practice each week has changed since they first began, and could not accurately estimate past meditation experience. From the majority of participants, we therefore did not collect data on the number of hours each week they had practiced in the past.

From this data, we sought to calculate the level of experience of each practitioner to correlate with our experimental data. We regarded the number of hours spent formally practicing each week as an unreliable measure of past experience due to the difficulties in measurement stated above, and chose to calculate meditation experience as the total number of weeks practicing meditation over the whole lifetime of each individual. There were likely to be large differences between participants in the amount of time they have spent each week in formal meditation practice; however a measure based on total weeks of practice had the advantage that we were able to avoid making assumptions which are difficult to justify in the present study design. These assumptions are: (1) that formal meditation practice is the only opportunity that a participant has each day to cultivate mindfulness in their daily life, and (2) that formal meditation practice would be the greatest contributor to variation in the experimental data. In our subject sample it is likely that cumulative *in*formal meditation practice in relation to life experience outside of formal practice is a major contributor to the person's mindfulness skills. This becomes critically important when considering that participants in the present study received no instructions to engage in formal meditation practice during data collection. Hence our experimental results are likely to be more closely related to informal meditation practice, which is nearly impossible to quantify in hours.

Details of the meditation practices reported by the 12 subjects in the meditation group were as follows, and summarized in Table 1. Of the 12, five subjects practiced mindfulness meditation, and reported sustained focus on breathing as their central method. Two subjects practiced Samatha, a Buddhist form of meditation that also uses the breath as a focus. Two subjects practiced Tantra-Yoga (non-Buddhist) which involves visualization and repetition of a personal mantra in time with the breathing. Two subjects practiced Zen (Buddhist) meditation which involved some focus on breathing and body sensations as a whole. The remaining one subject practiced Sahaj Marg, which involves focusing on the perception of body sensations and a feeling of lightness and peacefulness in the heart. Therefore, although subjects in the meditation group practiced a variety of different methods, the majority involved a significant component of focus on the body and/or breathing and all involved sustained focused attention as a primary component.

2.3. Measuring emotional responses to pain

To induce painful sensations, we used laser stimuli that specifically activate nociceptors in the skin (Aδ- and C-fibre transmission) due to the absence of skin contact [31]. Using a CO_2 laser stimulator, heat stimuli of 150 ms duration and a beam diameter of 15 mm were applied to the dorsal surface of the subjects' right forearm. Subjects wore protective laser safety goggles during the experiment. Laser stimuli were randomly delivered to different positions on the arm over a skin area of 3 cm × 5 cm in order to avoid habituation, sensitization or skin damage.

An initial psychophysics procedure was performed using a 0–10 numerical scale of pain intensity, which was anchored such that a level 4 indicated just painful (pain threshold). A ramping procedure was repeated three times (up to 30 trials each time) in order to determine a moderately painful level of laser stimulus intensity (level 7 on the scale) for each subject. Participants were told to

Table 1
The main type of meditation practiced by participants in the meditation group, represented in order of their total lifetime meditation experience.

Subject	Main type of meditation	Meditation experience (weeks)
1	Zen	1820
2	Mindfulness of breathing	1612
3	Tantra-Yoga	1040
4	Samatha	884
5	Mindfulness of breathing	832
6	Zen	676
7	Mindfulness of breathing	416
8	Samatha	156
9	Sahaj Marg	156
10	Mindfulness of breathing	78
11	Mindfulness of breathing	52
12	Tantra-Yoga	39