

Subject: Final Progress Report, 17th June 2024

Research Project: Title: Attending Mindfully: A Psychophysiology Study of Sensory Processing in Meditators (92/18)

Project Background and Aims

Meditation, a form of mental training using a range of practices and techniques, has been gaining popularity across countries and cultures to promote a heightened state of awareness, efficient emotion regulation and psychological well-being (reviews, Álvarez-Pérez et al., 2022; Goyal et al., 2014; Gu et al. 2015; Keng et al. 2011). There are numerous confirmations of a positive association between different meditation practices (e.g., mantra meditation, mindfulness) and psychological health, including increased self-awareness, emotion regulation, and improved mood (reviews, Álvarez-Pérez et al., 2022; Behan, 2020; Dunning et al., 2019; Goyal et al., 2014; Gu et al., 2015; Keng et al., 2011). The exact mechanisms underlying these effects or associations (both across and within different meditation practices) remain to be fully established and may vary according to particular style/s (Lutz et al., 2015) and duration or intensity of practice (Antonova et al., 2015). Further research using precise markers of early information processing can help to further advance this field.

The present study aimed to further characterise sensory information processing profiles of regularly meditating individuals, relative to meditation-naïve individuals, as assessed by habituation, prepulse inhibition, and affective modulation of the acoustic startle response. Startle modulation paradigms have been utilised to index brain's automatic and early sensory information processing mechanisms in a wide variety of contexts (reviews, Santos-Carrasco & De la Casa, 2023). Habituation occurs following repeated presentation of the same startling stimulus (Geyer & Braff, 1982), reflecting its redundancy in absence of any behavioural consequences. PPI refers to a reliable reduction in startle response amplitude to a strong sensory stimulus, the pulse (e.g., a loud noise), if this is preceded by 30-150 ms by a weak near-threshold stimulus, the prepulse (e.g., weak noise) (Graham, 1975). PPI is considered to provide an operational index of sensorimotor gating. Affective startle modulation refers to startle inhibition by pleasant foreground stimuli and startle potentiation by unpleasant stimuli as compared to response amplitude in a relatively neutral context. In addition, we examined trait mindfulness, alexithymia (reflecting difficulties in recognising, expressing and describing one's emotions) and difficulties in emotion regulation in meditators, compared to non-meditators, and explored possible associations of habituation, PPI and affective startle modulation measures across and within the meditator and non-meditator groups.

Methods

Two independent samples comprising regularly meditating adults and non-meditating adults (final sample with usable psychophysiology and self-report data, UK = 68; India = 56) were assessed, on a single occasion, on habituation and PPI of the acoustic startle response, along with established measures of emotion regulation. Participants in both meditator samples included individuals who meditate regularly using secular mindfulness or other practices (e.g., secular mindfulness, Vipassana, Tibetan Vajrayana, Mahayana, Theravada, Transcendental Meditation, Raj Yoga Meditation, Zen) with likely effects ranging from 'simple relaxation' to a 'higher sense of well-being' (Dahl et al., 2015; Lutz et al., 2015).

For assessing startle habituation, we developed a new paradigm for this project (Kumari et al., 2023). For PPI, we created a variation of the PPI paradigm where a pulse is preceded by one or two prepulses in close proximity (Kumari et al., 2003). For affective modulation we used a paradigm based on Shukla et al. (2020). Although different equipment and software were used for psychophysiological recording of the eye-blink startle responses in the UK (at Brunel University London) and India (Banaras Hindu University) labs, the startle stimuli and all experimental parameters matched as closely as possible. Detailed meditation history, including the length and style of practice, was obtained for all meditators using a self-report questionnaire used in our previous studies (Antonova et al., 2015; Kumari et al., 2017). Trait or dispositional mindfulness was assessed using the 39-item Five Facet Mindfulness Questionnaire (FFMQ, Baer et al., 2006). Alexithymia was assessed using the 20-item Toronto Alexithymia Scale (TAS-20, Bagby et al., 1994). Emotion regulation was assessed using the 36-item Difficulties in Emotion Regulation Scale (DERS, Gratz & Roemer, 2004).

Main Findings and Interpretation

In the UK sample, there was no significant difference between meditators and non-meditators in habituation or PPI. However, within the meditator group, there also was a negative association between alexithymia and PPI. More importantly, there was significantly greater PPI in meditators who self-reported being able to enter and sustain non-dual awareness during their meditation practice relative to those who could not. This finding suggests that subjective differences in meditation experience may be associated with differential sensory processing characteristics in meditators. However, with the current design, we can not rule out the possibility that the subgroup of meditators who showed the strongest PPI had good PPI or sensorimotor gating (which is typically correlated with lower distractibility) prior to starting meditation practice, which facilitated their ability to reach and sustain non-dual awareness (i.e., good PPI was the cause, rather than an effect, of non-dual awareness being experienced) during meditation practice. Future studies adopting longitudinal design should investigate the cause-effect relationship of stronger PPI/sensorimotor gating with the ability to enter and sustain non-dual awareness during meditation practice. Finally, it would be valuable to directly compare the predictors and outcomes of meditative practices (e.g., Dzogchen, Mahāmudrā) that focus on eliciting and sustaining non-dual awareness (Dahl et al., 2015; Meling, 2022) with other types of meditation practices in sufficiently powered studies.

In the India sample, again there was no significant difference, on average, between the meditator and non-meditator groups in habituation or PPI. However, in the meditator group, greater startle habituation strongly correlated ($r > 0.50$) with longer duration (total hours of practice, total number of years) of meditation practice which corresponds well with our findings in the UK showing stronger startle habituation in meditators with moderate intensity practice compared to non-meditators with a large effect size (Antonova et al., 2015) and a medium size association between stronger habituation and trait mindfulness in meditation-naïve adults (Kumari et al., 2023; arising from the current project). Affective modulation did not significantly differentiate the meditator and non-meditator groups, though startle modulation from pleasant to unpleasant stimuli was, as expected, correlated negatively with trait mindfulness and positively with difficulties in emotion regulations, depression and stress scores.

Both in the UK and India samples, as expected, meditators, compared to non-meditators, scored higher on trait mindfulness and lower on the measures of alexithymia and difficulties in emotion regulation. Trait mindfulness had a negative association with alexithymia and

difficulties in emotion regulation, and there was a positive association between alexithymia and difficulties in emotion regulation across the entire sample.

We have already published one full paper based on psychophysiological data that we had collected prior to the COVID-19 pandemic for this project (and acknowledging this grant) in the *International Journal of Psychophysiology* (Kumari et al., 2023), and recently resubmitted a manuscript after addressing comments from two reviewers (initial version submitted on 09/02/2024) for publication in *Consciousness and Cognition*. We plan to submit a further manuscript (Shukla et al.; currently being reviewed by the co-authors) in July/Aug 2024.

Additional Findings and Publications (acknowledging #92/18)

In addition to the research proposed in this project, we used our time (when no laboratory work was allowed due to the COVID-19 related restrictions) to analyse previously collected data for a related project and published our findings in a full paper (Pandey et al., 2023). Specifically, we report that the relationship between higher trait mindfulness and better mental health is best explained by reduced maladaptive emotion processing styles and associated lower negative affect, rather than by enhanced adaptive emotion processing and higher positive affect. We recommend further research to investigate whether the same mechanisms might explain psychological benefits of meditation practice.

Lastly, we wrote and published a highly cited review/opinion piece (Antonova et al., 2021) in *Frontiers in Psychiatry*.

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Final report

Table highlighting the differences between expected and achieved output indicators

Expected and achieved output indicators (number of actions)

Output indicators	Expected (according to application)	Achieved
Advanced training: PhD theses	0	0
Advanced training: Master theses	4	5
Organization of seminars and conferences	2	1 (see Note below)
Book	0	0
Book chapter	1	0
Conference presentation	4	5
Journal Article	4	5
Other	1	Training of 1 Placement Student (with a written report at the end) Poster presentation by 2 MSc students

Note: We ran a 1-day Seminar “*Neuroscience of Mindfulness: What We Know and What We Need to Know*” on 11.11.2023, using a hybrid format, where four members of the research team did oral presentations. We had initially planned to run one in-person event in the UK and one in-person event in India to disseminate our findings to academic and non-academic audience but this was not necessary since a hybrid format for our UK-based 1-day Seminar allowed local as well as national and international participants to join at no additional cost and also facilitated direct interaction between the UK and India research teams. In addition, we have presented our findings at the 2024 Conference of British Society for the Psychology of Individual Differences (19th April, 2024), and there were two poster presentations at King’s College London by MSc students who received training as part of this project.

List of Publications (acknowledging #92/18)

1. Antonova E, Schlosser M, Pandey R, Kumari V (2021). Coping with COVID-19: Mindfulness-based approaches for mitigating mental health crisis. *Frontiers in Psychiatry* 12: 563417. <https://pubmed.ncbi.nlm.nih.gov/33833695/>
2. Pandey R, Mandal S, Shukla M, Tripathi V, Antonova E, Kumari V (2023). Attenuated maladaptive emotion processing as a potential mediator of the relationship between dispositional mindfulness and mental health. *Heliyon*, 9 (11), e21934. [https://www.cell.com/heliyon/pdf/S2405-8440\(23\)09142-9.pdf](https://www.cell.com/heliyon/pdf/S2405-8440(23)09142-9.pdf)
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4. Kumari V, Tailor U, Saifullah A, Pandey R, Antonova E (2024). Non-dual awareness and sensory processing in meditators: insights from startle reflex modulation. *Consciousness and Cognition*. Resubmitted on 23/05/2024 (after addressing the reviewers' comments; initial submission on 09/02/2024).
5. Shukla M, Upadhyay, N, Tripathi VK, Kumari V, Pandey R. The role of regular meditation practice and trait mindfulness in startle modulation: a psychophysiology study. To be submitted in July/Aug 2024 to *Psychophysiology*