



Final Project Report

Project title: Does meditation practice modulate the dynamics of attentional neural networks? An EEG study

Bursary No: 30/08

Project Leader: Dr Peter Malinowski, Liverpool John Moores University

Start of project: 01 September 2009

End of project: 30 November 2010

Introduction

The research project investigated the question how regular meditation practice influences different aspects of attentional functions and in particular what the psychophysiological mechanisms are that underpin those changes. Research into the effects of meditation practice has been recognised as an important area of study as it promises to deliver a detailed understanding of the beneficial effects meditation is assumed to have and to provide insight into the neuronal mechanisms of practice-related changes in general.

So far, the majority of studies in this area have employed cross-sectional paradigms, usually comparing meditators with meditation-naive control participants or meditation beginners. While useful as an initial starting point, such studies are not able to reveal strictly causal relationships, and thus cannot tell whether the differences observed between meditators and non-meditators do actually result from meditation practice. The current study thus aimed to overcome this major shortcoming of prior research by employing a longitudinal and experimental approach, combined with advanced procedures for analysing electrophysiological data. Furthermore, it was important for us to focus on participants who integrated meditation practice into their ordinary, daily life, thus making the findings relevant and applicable to a large population and not only to specialist meditators who may spend a lot of their time in seclusion and/or entertaining an uncommon lifestyle.

As the refinement of attentional abilities is considered to be a core component in the practice of meditation, we focused our investigation on attentional functions aiming to draw conclusions about the modulation of neuronal networks that are understood to subserve attentional processes.

General Project Overview:

After the successful recruitment of the research assistant the project commenced in September 2009. As planned, the first months of the project were dedicated to the induction and training of the research assistant as well as for advertising the study and for the recruitment of participants. The completion of the new, purpose built research facilities at Liverpool John Moores University suffered a further delay, so that it was decided not to start with the actual data acquisition before January 2010. The time before that was used for informing and screening potential participants who came forward and for the pilot-testing of planned paradigms. A pilot study revealed that the envisaged attentional blink paradigm is not suited for the data analysis strategy we were aiming to implement. We thus redesigned the task and developed a relatively similar paradigm for the measurement of continuous/sustained allocation of attentional resources based on the steady-state evoked potential method, which the project leader has been using for many years successfully for answering various questions related concerning the deployment of selective visual attention.

After completion of the new lab facilities, which now includes an electrically shielded chamber for recording EEG data, the actual testing period started in January 2010. During the preparatory and planning phase, the PI carried out a research visit to the collaborating research group at the Neurophysiology Department of the University Hospital in Hamburg/Germany (Dr Supp). The purpose of this visit was to discuss, prepare and finalise details concerning the experimental details. This visit took place from 30 Sept – 03 Oct 2009. Furthermore, in early September the opportunity arose for the Research Assistant to attend the conference “*Health, Mental Health and Exceptional Human Experiences*” which was organised by Christine Simmonds-Moore a colleague from Liverpool Hope University, whose work is also funded by a BIAL bursary. Attendance of this conference was part of the initial training of Adam Moore and allowed him to gain insight into other scientific projects and approaches in this area of research and to liaise and network with colleagues working on similar questions. Subsequent meetings with the collaborators at the University of Hamburg and the University of Osnabrück (both Germany) were financed by other means. Furthermore, details regarding the data analysis procedures that did not require physical meetings were discussed via online video conferencing and e-mail exchange.

In Autumn 2010 the research assistant (Adam Moore) moved on to a PhD position in our lab, where he can put to use many of the skills acquired while working on this project. For the remaining two months of the project another research assistant (Bethan Mead) took his place and completed one more study which we were able to carry out due to the agreed extension of the project. Ms Mead had been working in our group for a while already and was thus familiar with many aspects of the project, which made it easy for her to get fully involved immediately. The extension of the project made it possible to carry out a further electrophysiological study where, building on the main longitudinal study, we investigated the link between mindfulness practice and meta-cognition, one aspect of attentional control that so far has not been investigated in much detail. Due to the growing international

reputation of our research group, it was possible to carry out this project in collaboration with Professor C. Rueda from the Cognitive Neuroscience Research Group at the University of Granada, in Spain. A part of the related data analysis is currently being carried out in the group of Prof. Rueda at Granada University.

Scientific Details

We employed a randomised control group design. The 40 participants that were recruited were randomly allocated to either the meditation group (N=20) or the age and gender matched waiting list control group (N=20). The participants in the meditation group received a two-hour meditation induction around the time of the first assessment (T1). Between the first and second assessment (T2) they received a further one-hour meditation training session.

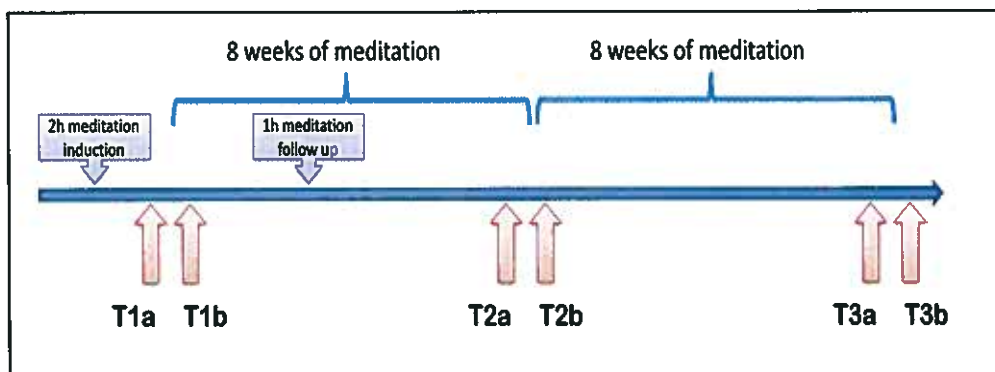


Figure 1: Overview of the study timeline (T1a to T3b denote the six time points of assessment)

The meditators engaged in 16 weeks of meditation training and were required to meditate for at least 10 minutes each day. Furthermore, they kept a meditation diary, recording the daily amount of meditation practice.

The general set up and timing of the study is depicted schematically in Figure 1. Due to the number of tests and assessments carried out, for each of the three assessment time points (T1, T2, T3) we invited the participants to come into the lab twice (labelled as a and b in Figure 1) within the period of a maximum of one week. In most cases the participants (meditators and controls) took part in the testing on successive days. All participants were subjected to a thorough electrophysiological assessment with 64-channel high-density EEG recordings of their brain activity at rest, during meditation and while completing two attentional tasks that tap the central attentional abilities of resource allocation over time and the susceptibility to interference. To acquire more information about meditation-specific attentional states, some of these tasks were also completed after participants induced a meditative state. Note that due to the number of participants that needed to be tested within a relatively short period of time, we used a staggered procedure, so that the meditators were

trained in three groups while participants of the control group entered the study sequentially to make sure that the timing of the testing sessions was not compromised. Thus overall the testing period lasted approximately 7 months.

From the 40 participants who participated in the study, 34 (85%) completed testing at T2 and 32 (80%) completed it until the end (T3). The main reasons for dropping out were time constraints. Because of changes in their personal situation participants did not find the time to meditate and/or to attend the testing session. One participant from the meditation group had to withdraw due to mental health reasons. The two participants from the control group that did not complete the study did not provide any explanation and did not respond to our attempts at contacting them.

Due to the complexity and the amount of data (we recorded approx 50 gigabyte of EEG raw data) more detailed, in depth data analysis is still ongoing. A particular challenge is to make sure that for each participant sufficient and equivalent amount of data are available for each assessment time point. Due to the nature of EEG recording and the likelihood of artefacts in the data, this is not easily achieved. We thus adapted a novel procedure of artefact detection and removal that is based on independent component analysis and several thresholding algorithms.

Available analysis results indicate that, as expected, the levels of mindfulness increased significantly in the group of meditators, while no significant change was visible in the control group (see Figure 2).

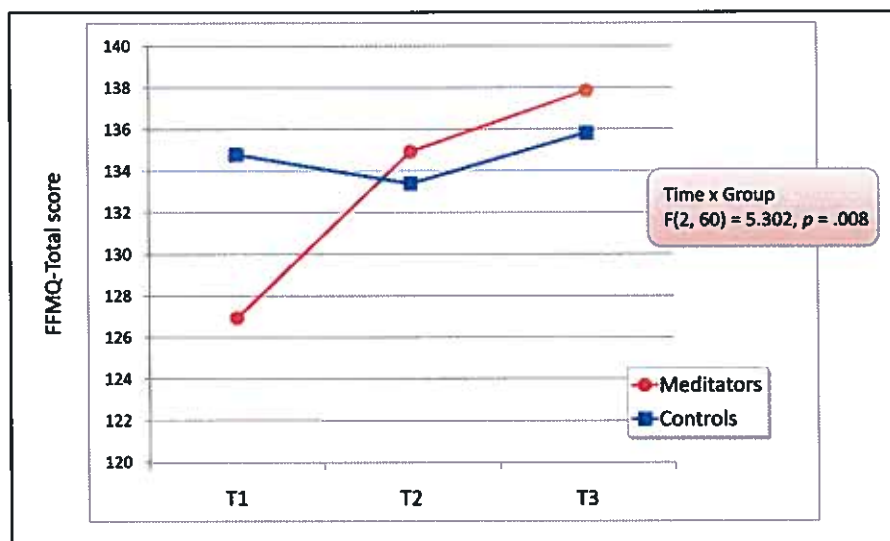


Figure 2: Total levels in self-reported mindfulness (FFMQ) at all three assessment time points (T1 – T3)

More evidence that the observed increases in mindfulness are actually related to the meditation practice participants engaged in comes from the fact that the increase in mindfulness throughout the study (T1 to T3) was highly correlated with the amount of time

(total minutes of meditation) participants in the meditation group actually engaged in formal meditation practice (see Figure 3).

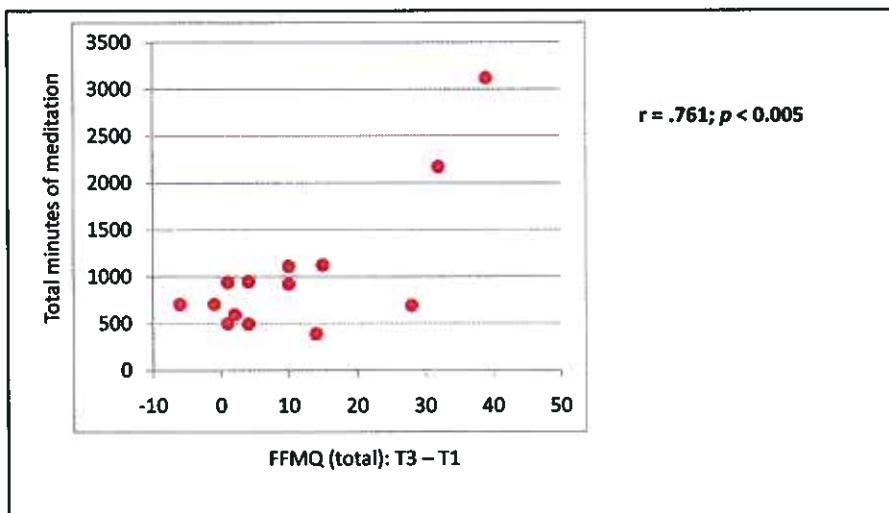


Figure 3: Scatter graph depicting the Pearson correlation between the increase in total mindfulness from T1 to T3 and the amount of time invested in formal meditation practice.

Regarding the performance in the attention tests that were carried out, the data revealed that the overall response time – as an indicator of general cognitive processing speed – decreased more sharply in meditators than in the control group (see Figure 4).

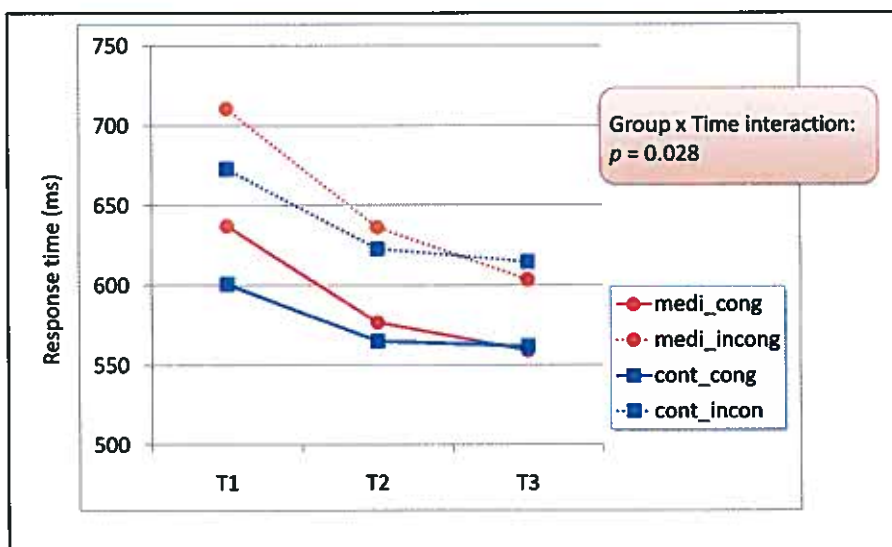


Figure 4: Decrease in overall response time in meditators and controls over the course of the study for congruent and incongruent experimental conditions

Thus, the overall pattern of data confirms that the regular meditation practice influences attentional functions. Although not completed, our analysis of EEG data so far confirms this observation but we still need to identify more specifically the details of these effects.

In a second study that we carried out we were investigating the link between dispositional mindfulness (general levels of mindfulness, not developed through meditation practice) and mechanisms of attentional control as the ability to flexibly control and deploy ones cognitive resources are considered important aspects of efficient cognitive functioning. A large number of neuroscientific studies have confirmed that several attentional functions and related brain networks are involved in these processes and that the ability to flexibly control ones responses (executive attention) plays a crucial role in many processes. This study constitutes a first step towards a more profound, longitudinal investigation of the link between (trained) mindfulness and attentional control functions. We investigated whether the control mechanisms of process monitoring, conflict resolution and inhibitory control are linked to dispositional, naturally occurring mindfulness. If such a link can be established, longitudinal studies that aim at modifying these control mechanisms would be warranted.

40 participants (age 18+) from a varied background participated in the study. To widen the range of mindfulness levels this also included participants who already engaged in mindfulness practice (some of them were participants from the previous study reported above). Participants completed a mindfulness questionnaire (FFMQ) and took part in an adaptive flanker task, which adjusted its difficulty individually, to arrive at about 20% of errors. This was important as we were interested in investigating the *error related negativity* [ERN] and error positivity [Pe], electrophysiological indicators of the ability to successfully monitor ones responses. In a second, associated task, we measured the response impulsivity of participants by means of the well established go-nogo task. As in the previous study, we used a 64-channel high density EEG montage. We expect to find that dispositional mindfulness as measured by the self-report questionnaire will be related the monitoring ability and impulsivity as measured by the two tasks just described. The data are currently being analysed at the collaborating group at the University of Granada. It is planned that during a research visit towards the end of February the full results can be discussed and first steps towards a publication can be made.

Dissemination

In all dissemination related to the project the contribution of the BIAL Foundation is clearly acknowledged. When published journal articles become available they will be forwarded to the BIAL Foundation.

Conference presentations

- First results of this study were presented at the recent congress “Meditation und Wissenschaft” (Meditation and Science), 26th/27th November in Berlin. Peter Malinowski presented an invited talk entitled “Meditation and Mindfulness: A path towards well-being.”

- Furthermore it is planned to present results of this project at the following conferences:
 - “Mindfulness Conference - Centre for Mindfulness Research and Practice, Bangor University”, 09-11 April 2011, in Bangor, Wales.
 - “Mind & Life Summer Research Institute”, Garrison Institute, 12-18 June 2011, Garrison, New York.
 - “Second World Congress on Positive Psychology”, 23-26 July, 2011, in Philadelphia, US
 - Presentations at further conferences, e.g. the XIth International Conference on Cognitive Neuroscience (ICON, Palma Mallorca Sept. 2011)
- Finally, Peter Malinowski will present some of the results as invited speaker at the high profile conference “Mindfulness – a Buddhist Contribution to Modern Society” (18th – 21st August, 2011, Hamburg) in a talk entitled: “How does Mindfulness Practice Promote Positive Psychological Change?”, with attendance of the Dalai Lama.

Journal articles

A first article related to this project has meanwhile been published. It relates to the theoretical background of the work, clarifying the various aspects of mindfulness based approaches that are currently used.

- Chiesa, A. & Malinowski, P. (2011). Mindfulness based approaches: are they all the same? *Journal of Clinical Psychology*, 67(4), 1-21. (a reprint of this article has been forwarded to the BIAL Foundation)

Further manuscripts presenting different aspects of the results are currently in preparation and will be submitted to high-ranking international neuroscientific journals in the near future.