Electroencephalographic, Cognitive and Autonomic Correlates of States of Concentrative Meditation

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Abstract

Meditation is generally characterised as "a family of complex emotional and attentional regulatory strategies developed for various ends, including the cultivation of well-being and emotional balance" (Lutz et al. 2008). Although specific methods vary, most meditative techniques strive for and report states of mental alertness and focus, as well as simultaneous states of physical and emotional relaxation. This project investigated distinct states or absorptions of Buddhist concentrative meditation as transliterated from traditional texts into clear and comprehensible descriptions and explanations which are amenable to science.

The way meditative states and traits are classified and characterised in the scientific literature is appraised, including a discussion on the definitions and technical terms associated with meditation. In addition, an explication of the concentrative meditation technique investigated in this project discusses the cognitive and psychological processes in meditation, descriptions of meditative states and how meditators enter and maintain each state. The history and philosophy of Buddhism is also briefly discussed. After relevant background information is supplied with regard to electroencephalography (EEG), the evidence for the effects of meditation is reviewed.

This project involved four experiments which were run in a counterbalanced order during a single day, however each subject came in on a different day. Thirteen meditators and thirteen non-meditator controls were recruited, however due to subject and equipment complications, the number of subjects used in analysis varies between experiments. These details are given in each chapter.

Experiment 1. To assess whether concentrative meditation influences early sensory processing and attentional resource allocation, event-related potentials (ERPs) and behavioural responses were recorded from ten meditators and ten pair-matched non-meditator controls during an audiovisual continuous performance task, performed before and after a meditation condition. This task required subjects to respond to audio and/or visual target stimuli interspersed among distractor and non-target stimuli by pressing a button. An improvement

in response speed and accuracy in both groups after meditation was interpreted as the ability of both groups to enter a light state of meditation between attention tasks. Consistently larger P2 mean amplitudes were found in meditators, compared to controls, suggesting that extended practice of meditation can influence the long-term capacity to selectively attend. In addition, larger P3 mean amplitudes in occipital electrodes were found in meditators. This result is likely to represent a long-term enhancement of target detection, precipitated by the practice of meditation.

Experiment 2. Additionally, five different meditative states were examined using measures of EEG and autonomic activity in twelve meditators and twelve pair-matched non-meditator controls. During the experiment, meditators were found to demonstrate significant changes in theta and gamma EEG activity which intimate enhanced focus and mental quiescence during meditative states. In addition, changes in autonomic activity were indicative of decreased sympathetic tone, in other words physical, mental and emotional relaxation.

Experiments 3. The perception of external stimuli during meditation was examined in twelve meditators and twelve pair-matched non-meditator controls. Subjects responded with a button-press when they became aware of an auditory, visual or tactile stimulus. No changes in any group or condition were found that could be interpreted as a significant effect from meditation.

Experiment 4. Cortical steady-state responses were recorded from eight meditators and eight pair-matched non-meditator controls during meditation. No changes in any group or condition were found that could be interpreted as a significant effect from meditation.

In summary, contributions have been made to the scientific understanding of meditation by providing evidence for the efficacy of meditation to induce states of physical relaxation, mental and emotional calm, enhanced concentration and diminished thought activity.

Each of us literally chooses by way of his attending to things what sort of universe he shall appear to himself to inhabit.[1]

William James (1842 – 1910 AD)

All that we are is the result of what we have thought: it is founded on our thoughts, it is made up of our thoughts.[2]

Siddhattha Gotama (the Buddha) (563 – 483 BC)

[1] Principles of Psychology (1890)
[2] The Dhammapada

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Declaration

I certify that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

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List of Abbreviations

ACC	Anterior cingulate cortex
AM	Amplitude-modulated
ASSR	Auditory steady state response
ANS	Autonomic nervous system
BP	Blood pressure
CO_2	Carbon dioxide
DCx	(Non-linear) dimensional complexity
ECG	Electrocardiography
EDL	Electrodermal level
EDR	Electrodermal response
EEG	Electroencephalography
EMG	Electromyography
EOG	Electro-oculograhy
EP	Evoked potential
ERP	Event-related potential
Fm	Frontal midline
fMRI	Functional magnetic resonance imaging
GSR	Galvanic skin response
HRV	Heart rate variability/variation
ISI	Inter-stimulus interval
LORETA	Low resolution brain electromagnetic tomography

mPFC	Medial prefrontal cortex
O_2	Oxygen
OBAMA	Object-based attentional meditation approach
NOBAMA	Non-object-based awareness meditation approach
PET	Positron emission tomography
PFC	Prefrontal cortex
PhC	Phenomenological clusters
SAM	Sinusoidally amplitude-modulated
SCR	Skin conductance response
SPECT	Single positron emission computed tomography
SSEP	Steady state evoked potential
SSSR	Somatosensory steady state response
SpO_2	Peripheral blood oxygen saturation
SSR	Steady state response
SSVER	Steady state visual-evoked response
TM	Transcendental Meditation
VSSR	Visual steady state response

Executive Summary

This project comprises of four experiments which examine 1) the influence of meditation on attentional performance as measured by event-related potentials (ERPs) and behavioural responses during a continuous performance task, 2) the effects of meditative states on electroencephalographic (EEG) and autonomic activity, 3) perception of external auditory, visual and somatosensory stimuli during states of meditation and 4) the sensory processing of continuous auditory, visual and somatosensory stimuli during different focus conditions. All four experiments were carried out on meditating and non-meditating control subjects.

Chapter 1 begins with an appraisal of the way meditative states and traits are classified and characterised in the scientific literature. This first chapter will include a discussion on the definitions and technical terms associated with meditation methods. This chapter also includes an explication of the concentrative meditation technique investigated in this project, as explained and practiced by our colleagues at the Lifeflow Meditation Centre. The explication will discuss the cognitive and psychological processes involved in meditation, descriptions of meditative states and how meditators use the adopted object of meditation (viz. the breath) to enter and maintain each state. A brief section on the history and philosophy of Buddhism is also included to provide information about the motivations and concepts behind the practice of meditation. Chapter 2 begins by outlining aspects of electroencephalography relevant to this research project, including event-related potentials and steady state responses. The evidence for the effects of meditation is then reviewed, concentrating on research involving neuroelectric, neuroimaging and autonomic measures, as well as studies on aspects of cognition and psychology. Chapters 3, 4, 5 and 6 concern the four experiments and are classically structured with sections of Introduction, Hypotheses, Methods, Results and Discussion. The first experiment, covered in Chapter 3, investigated if meditation methods employing focused attention could alter early sensory processing and attentional resource allocation in ways which were detectable using ERPs and behavioural measures. Continuous performance attention tasks using

auditory and visual stimuli were undertaken in which subjects were asked to respond to targets among non-targets and distractors. This task was followed by a condition in which subjects were asked to meditate, and then the attention tasks were repeated. Chapter 4 regards the second experiment in which 120-channel EEG, in addition to autonomic measures of heart rate, respiration, electrodermal activity, skin temperature, blood oxygen saturation and blood pressure, were recorded during five phenomenologically distinct states of Buddhist concentrative meditation. The chapter 5 experiment on perception involved presenting auditory, visual and somatosensory stimuli at varying intensities to subjects while meditating in order to determine if meditation alters perception of external stimuli. The last experiment on sensory processing (Chapter 6) examined if changes in attentional focus affect steady-state responses in the brain, by presenting continuous stimuli during different conditions in which subjects focused on either their thoughts, their breath or the stimulus. The last chapter summarises the contributions of this thesis and suggests future research directions.