

# Chapter 7

## Conclusion

Experiments in this thesis availed themselves of distinct states or absorptions of Buddhist concentrative meditation as transliterated from traditional texts by Dr Graham Williams and Mr John Burston of the Lifeflow Meditation Centre (Adelaide, South Australia). Each state of meditation has a number of distinct phenomenological factors which distinguish them from one and another (§1.3.5). With competent guidance and sufficient training, one can learn to recognise these states and voluntarily sustain and move between them at will. All experiments involved non-meditator *controls* who were pair-matched to MEDITATORS for age, gender, hemispheric dominance and education level.

In addition, this thesis used the Buddhist model of the processes of consciousness (§1.1 and Table 1.1) in an attempt to guide hypotheses and interpretations of data. The model proposes five components or aggregates of individual experience: 1) the physical sense organs interacting with the external world; 2) the resulting experience from this interaction; 3) the basic registration of objects (for example, sounds and shapes); 4) thoughts, ideas, opinions, prejudices and decisions; and 5) subjective experience and awareness of mental objects.

Chapter 3 examined whether concentrative meditation influences early sensory processing and attentional resource allocation by measuring event-related potentials and behavioural responses during an audiovisual continuous performance task. To assess the long-term and acute effects of meditation, the attention tasks were performed before and after a meditation condition with instructions to

meditate in the second absorption. The Buddhist model of the processes of consciousness was used here to develop hypotheses and assist with the interpretation of findings.

The experiment in Chapter 4 investigated five states of meditation and two controls states using 120-channel EEG and autonomic measures of heart rate, respiration, electrodermal activity, skin temperature, blood oxygen saturation and blood pressure. Based on a reading of the scientific literature, a number of specific hypotheses were proposed for each control and meditative state as well as each frequency band (§4.2). The hypotheses regarded mental, physical and emotional arousal (for example drowsiness, tension, relaxation and sympathetic tone), mental activity (viz. thought suppression and conceptual processing) and concentration. Hypothesis generation and data interpretation were also guided by descriptions of meditative states (§1.3.5), the Buddhist model of the processes of consciousness and post-study reports of subjective experiences during the experiment (§4.4).

The Chapter 5 experiment investigated the effect of meditation on the perception of external stimuli by presenting auditory, visual and somatosensory stimuli at varying intensities during the baseline and mind-wandering control states and the first and second absorptions.

Given the training of attention during meditation, the last experiment in Chapter 6 examined if changes in attentional focus effect steady-state responses in the brain, by presenting continuous stimuli during conditions of mind-wandering, attending to the breath and attending to the stimulus.

## **7.1 General discussion**

This summary will consider the results from each experiment with regard to state and trait effects as well as discuss possible meanings and implications of the findings.

### 7.1.1 Attention

**State effects** While state effects are generally considered to occur during the practice of meditation, they are considered here as those changes which occurred during the post-meditation attention task, in other words acute trait effects, as it was hypothesised that subjects might perform the attention tasks whilst in light states of meditation.

Both groups showed significant improvements in response speed and accuracy after the meditation condition. This finding suggests either a practise effect or an effect of meditation. The latter interpretation is more likely due to 1) the high level of education in control subjects providing sufficient attention to meditate lightly, which is supported by 2) a non-significant increase in theta activity found in controls during the first absorption in the meditation experiment (§4.5). No differences in ERP potentials were found between pre-intervention and post-intervention, in other words, the meditation condition did not affect brain potentials.

**Trait effects** Pre-intervention and post-intervention changes in P1 and P2 mean amplitudes in electrodes over auditory regions during the auditory attention task may reflect the potential for meditation to influence the auditory modality more than the visual modality. Fronto-central increases in N1 amplitudes in the left hemisphere of MEDITATORS may be related to the ability of the left auditory cortex to process fast sounds, such that the practice of meditation may facilitate the processing of auditory stimuli in the left cortex.

Consistently larger P2 mean amplitudes in MEDITATORS, compared to *controls*, were found before and after meditation. Increased P2 amplitudes can be interpreted as a reflection of augmented attention to stimuli and reduced task interference from internal and external distraction. The findings of enhanced brain potentials support previous meditation research and suggest that extended practice of meditation can influence the long-term capacity to selectively attend.

Significantly larger P3 mean amplitudes in occipital electrodes were found

in *MEDITATORS* before and after the meditation condition. This increase, facilitated by reduced distraction and enhanced attention (indicated by larger P2 amplitudes), is likely to represent a long-term enhancement of target detection, precipitated by the practice of meditation.

### 7.1.2 Meditation

Although numerous forms of meditation exist, most techniques strive for and report states where one is mentally alert, still and focused, while simultaneously remaining physically and emotionally relaxed. During the experiment, *MEDITATORS* were found to demonstrate significant changes in theta and gamma EEG activity reflecting mental focus and thought quiescence during meditative states. In addition, changes in autonomic activity were indicative of decreased sympathetic tone, in other words, physical, mental and emotional relaxation.

#### EEG activity

**State effects** Small yet significant theta increases were found fronto-centrally in *MEDITATORS* during all meditative states except the first absorption. These increases suggest the involvement of the prefrontal cortex (PFC) and the anterior cingulate gyrus in initiating willful acts and sustaining attention. Although increases in theta were only very small, such changes have significant implications for mental behaviour. Increased frontal theta activity feasibly correlates with the suppression of evaluating and interpreting processes of prefrontal brain structures. Descriptions of idealised states correspond closely to the subjective reports obtained from *MEDITATORS* post-experiment (Table 4.1), which indicate an experience of single-pointed concentration and diminished thought activity during the second absorption.

Additionally, *MEDITATORS* consistently reported the experience of pleasant feelings and sensations during the second absorption, often referred to as “bliss”, which corresponded to increases in left fronto-central theta.

Lastly, the unique experience of spaciousness and expanding into space dur-

ing the formless absorption was associated with widespread posterior increases in theta power in *MEDITATORS*. This may support a relationship between the occipital and temporal cortices and spatial awareness.

*MEDITATORS* demonstrated a greater ability to relax, particularly in the first absorption, indicated by posterior decreases in beta2, gamma1 and gamma2 activity, likely to be muscle activation (EMG). Decreases in *MEDITATORS* across all meditative states contrasted with posterior high frequency increases in *controls* during all states following the baseline, indicating increasing tension.

The more interesting finding of high frequency activity occurs centrally in *MEDITATORS* during all meditative states, primarily as decreases in gamma1, which was interpreted as EEG due to electrode topography. Given the associations between gamma EEG activity and higher cognitive function, central decreases in high frequency activity (most notably between 25 and 48 Hz) may reflect the deactivation or unbinding of neuronal assemblies involved in higher brain functioning. This interpretation is supported by subjective reports across all meditative states of diminished thinking and mental quiescence (Table 4.1).

**Trait effects** Tests between groups at baseline did not reveal differences for any EEG frequency band at any scalp electrode. Although an absence of results fails to support the hypothesis that meditation has a long-term effect on resting EEG activity, it may be that within-group variation was greater than any effect (Appendix F). Further investigation of larger populations is required to determine if there exist differences in EEG activation during meditative states between meditators with varying degrees of experience.

### **Autonomic activity**

**State effects** Overall increased finger temperature and decreased blood oxygen saturation and electrodermal activity were found in *MEDITATORS* during meditative states, in comparison to *controls*. Although the changes were not correlated with distinct states of meditation, the overall differences, as well as the faster decreases in blood oxygen saturation and electrodermal activity in *MEDITATORS*,

compared to *controls*, indicate that meditation has a greater efficacy than a quiet mental state to reduce sympathetic tone. While respiratory rate did not differ significantly from *controls* during meditative states, MEDITATORS had an overall lower respiratory rate during the experiment in comparison to *controls*, also indicating a reduction of sympathetic tone during meditation. Given that increases in sympathetic tone, particularly in relation to peripheral skin temperature and electrodermal activity, are associated with arousal and stress, the findings of decreased sympathetic tone support claims by MEDITATORS that the practice of meditation induces a calm, restful state, both physically and emotionally.

**Trait effects** Due to the way peripheral blood oxygen saturation, temperature and electrodermal activity were measured, differences between MEDITATORS and *controls* during the initial baseline state could not be determined. No differences between groups at baseline were found for blood pressure or heart rate. However, a significant difference was found in respiratory rate between groups during the first baseline, suggesting that meditation may have a long-term effect on reducing sympathetic tone.

### 7.1.3 Perception

**State effects** Both MEDITATORS and *controls* demonstrated an increase in perceptual acuity of auditory stimuli during the mind-wandering control state, the first absorption and the second absorption. Although it is possible that both groups were able to meditate, the fact that the perceptual acuity increased during the mind-wandering state suggests that the effect was due to natural changes in sensitivity occurring over time. No changes across states or between groups was found for the visual or somatosensory modalities. Therefore, the idea that meditation increases or decreases perceptual acuity was not supported.

**Trait effects** Due to biological variation, the intensities of the stimuli presented were individually determined at the beginning of the experiment. Therefore the assessment of trait effects was not feasible for this experiment.

### **7.1.4 Sensory processing**

No modulation of steady-state response (SSR) amplitudes in any group or condition (viz. mind-wandering, attend-to-breath and attend-to-stimulus) was found. These findings suggest that meditation does not enhance attentional focus enough to influence SSRs. Failure to confirm previous findings of the augmentation of SSRs by attention in either group suggests that specific attention to the stimuli presented may be required (viz. an amplitude-modulated discrimination task).

### **7.1.5 Summary of contributions of this thesis**

- ❖ Meditation is physically relaxing
- ❖ Meditation is emotionally calming
- ❖ Meditation shows heightened attention
- ❖ Meditation involves diminished thinking
- ❖ An example of respectfully and scientifically experimenting on meditation
- ❖ A novel classification of meditation comprising of 1) object-based attentional meditation approaches (OBAMAs) and 2) non-object-based awareness meditational approaches (NOBAMAs)

## **7.2 Future work**

### **7.2.1 Investigation of disparate meditation techniques**

The term “meditation” is used to describe a large number of disparate techniques involving different instructions and experiential states. Researchers are only now beginning to sufficiently elucidate the specific cognitive and psychological factors involved in various forms of meditation. In order to better understand the specific technique under investigation as well as the similarities and differences between it and other techniques, phenomenological data needs to be carefully gathered and utilised in the interpretation of neurophysiological data.

As discussed in §1.2.1, there exists a two-fold issue regarding investigation of the practice and experiential states of meditation. Firstly, meditation practices can be classified based on the presence or absence of object emphasis. A practice involving the single-pointed concentration of an object is referred to in this thesis as an object-based attentional meditation approach (OBAMA). Alternately, a practice which initially begins with an OBAMA but changes to primarily relying on open or diffuse non-judgemental awareness of the internal and external environment is defined as a non-object-based awareness meditation approach (NOBAMA). Secondly, an OBAMA can either involve a strong emphasis on developing and maintaining meta-awareness during deep meditation (Lifeflow meditation used here and Zen) or it does not (TM and most yoga practices). This has been aptly demonstrated in studies on alpha-blocking and habituation (§2.2.1). The variation in results from studies across techniques is likely to be a result of their inadequately defined instructions and descriptions of methods and experiences. An obvious example from reading the literature is TM which involves no prescribed method of concentration, physical postures or breathing exercises apart from repeating a word or sound (mantra).

Therefore, careful investigation of both OBAMAs and NOBAMAs is required regarding: 1) the implementation of attention during meditation and changes in brain activity associated with variations in the strength, direction and sustainment of attention; 2) the employment of meta-awareness during meditation; and 3) the effects caused by specific meditative techniques such as visualisation and verbalisation. Additionally, any investigation would be strengthened by the inclusion of phenomenological reports.

### **7.2.2 Alpha-blocking and habituation in distinct meditative states**

The interesting findings of differences in alpha-blocking and habituation between OBAMAs with varying degrees of meta-awareness suggest that this faculty has a strong influence on how the brain processes sensory stimuli. The distinct states of



meditation investigated here offer an unexploited opportunity to examine whether these states alter stimulus processing. Each state of meditation involves varying degrees of concentration and meta-awareness efficacy, which are related to conceptual processing, levels of arousal and quality of meditation (§1.3.5). Using repeated clicks or tones, it may be possible to correlate the level of meta-awareness during each meditative absorption and the time it takes to stop habituating to stimuli. As all states of meditation involve meta-awareness, alpha-blocking would not be expected to occur. This technique may also be used in determining if meditators and controls successfully meditate.

### **7.2.3 Correlating changes in autonomic function and meditative states**

The findings of overall increased finger temperature and decreased blood oxygen saturation and electrodermal activity in meditators compared to controls during meditation indicates a decrease in sympathetic tone. Although these autonomic changes were not able to be correlated to distinct states of meditation (§4.5), they support the claims of meditation's efficacy to relax the mind and body. As it was unclear from the experiment whether these changes were time-dependent or state-dependent, it would be worthwhile examining finger temperature, blood oxygen saturation and electrodermal activity in an extended duration study. For example, to assess whether finger temperature plateaus (or decreases) after increasing regardless of meditation absorption, or increases and then stabilises similarly in each subsequent descending absorption, meditators would need to spend much longer in each absorption (20 minutes for example). A possible design would be to stagger the absorptions out of order, for example, the third absorption followed by the first absorption, then the fourth absorption, then the second absorption, etc. If temperature changes were associated with distinct absorptions, one should observe comparably staggered changes in temperature, in other words, each absorption showing a correlation to a particular temperature.

#### **7.2.4 Sensory processing during meditation**

The experiment investigating the effects of meditation on steady-state responses (SSRs) did not reveal any changes or differences between groups. The findings of increased fronto-central theta EEG activity associated with attentional networks have been previously reported suggesting that attention can be strengthened through mental training (*viz.* meditation). Given the evidence for the ability of attention to modulate steady-state responses (SSRs), further investigation into the effects of meditation on SSRs is warranted. However, careful consideration is required in the way SSRs are attended to during meditation because our experiment did not reveal any changes. It appears that the modulation of SSRs requires a high degree of attention, for example, as shown to be involved during an amplitude-modulated (AM) discrimination task. As previously stated, a meditation technique has its own prescribed method of concentration, often involving a predetermined object, making the engagement in a discrimination task during meditation highly problematic, if not impossible. One approach would be to assess evoked SSRs in meditators during an AM discrimination task, compared to non-meditators, and then repeat the discrimination tasks after a meditation condition involving both groups. This experimental design would address both long-term and acute effects of meditation on attentional strength.

#### **7.2.5 Refined temporal studies of meditative states**

Changing between meditative absorptions occurs subjectively quickly. As the EEG changes reported here were averaged from two minute meditation periods, interrupted by instructions, it is not possible to determine the rate at which EEG changes occur. It would be of interest to continuously record EEG during predetermined changes between meditative states. In other words, a meditator would be instructed to meditate for one minute in the first absorption, followed by one minute in each of the subsequent descending absorptions. This method would avoid disruptions to meditation caused by instructions for subsequent states. Data examined using a spectrogram, which shows changes in frequency ampli-

tudes over time, would reveal the rate at which EEG activity changes between meditative states. Although one would not be able to accurately determine when the meditator was moving between states, modulations of the spectrogram may be distinct enough to interpret state changes objectively. This method may help to elucidate the interaction between frequencies across distinct states of meditation and how these changes relate to cognitive and psychological processes involved in each state.