Chapter 5

Perception

5.1 Introduction

Many contemplative traditions, such as Theravadin and Zen Buddhism, maintain that sensory, perceptual and cognitive abilities can be altered and enhanced by the systematic training in meditative practices (Austin 1998; Rahula 1959). An elegant illustration of these abilities comes from literature on sensory processing and perception which report differences between varieties of yoga and Zen Buddhism (§2.2.1). The majority of yoga practices involve deep concentration, referred to as *samadhi* or an "absorption into inner experience...[ignoring] stimuli from the world of the senses" (Buzsáki 2006). Zen meditation on the other hand employs a combination of single-pointed sustained attention and a mindfulness-like meta-awareness of bare experience (Austin 1998). These two phenomenologically distinct states have provided researchers with opportunities to examine changes in the neurophysiology and perceptual awareness of meditators exposed to assorted stimuli. Past experiments range from presenting subjects with auditory clicks or tones during meditation (Becker & Shapiro 1981; Kasamatsu & Hirai 1966; Murata et al. 2004) to the more obscure and extreme examples, such as placing a subject's hand in cold (4°C) water (Anand et al. 1961) or the self-piercing of a meditator's tongue (Peper et al. 2006). The prevailing consensus is that alpha EEG oscillations are largely unaffected by external stimulation during yogic states of absorption (Anand et al. 1961; Das & Gastaut 1957), while continued blocking of alpha EEG rhythms without habituation occurs during Zen meditation (Kasamatsu & Hirai 1966). These findings are intriguing considering the similarities in the amplitude, frequency and distribution of alpha activity between the two styles (for review, see Cahn & Polich 2006). Discussion of these phenomena with regard to specific meditation styles is given in more detail in §1.2.

Perceptual changes depend, in part, on the allocation of brain resources with regard to attention and sensory processing (Davidson et al. 1976). In attempts to better understand the neural counterparts of perception, studies have included other cortical measures such as early sensory evoked potentials (EPs) and event-related potentials (ERPs). Changes in auditory brainstem responses (Liu et al. 1990; McEvoy et al. 1980) and middle latency responses (Liu et al. 1990; Panjwani et al. 2000; Telles et al. 1999), as well as specific components during auditory and visual evoked potentials (Barwood et al. 1978; Zhang et al. 1993), suggest meditation may influence initial cortical sensory processing. Recently, meditators were found to exhibit smaller attentional blinks and concomitant changes in P3b event-related potentials, demonstrating that mental training can result in increased control over the distribution of limited brain resources (Slagter et al. 2008).

Other studies on awareness and perceptual sensitivity have examined how meditation affects conscious awareness of external stimuli. Brown et al. (1984b) examined visual sensitivity during mindfulness meditation and found that after a three month mindfulness training retreat, meditators could detect shorter single-light flashes and required a shorter interval to differentiate between successive flashes correctly, compared to non-retreat meditators. A follow-up study using similar assessment methods indicated that meditation training can have long-term effects on perception (Brown et al. 1984a). The results support statements found in Buddhist texts concerning changes in perception during the practice of mindfulness meditation.

Successive phenomenally distinct states of concentrative meditation have so far remained unexamined in scientific literature. Collaboration with the Lifeflow Meditation Centre therefore provided an ideal opportunity to investigate the perception of external stimuli in more depth. Unless explicitly indicated, further discussion of meditation will refer to practices at the Lifeflow Meditation Centre as outlined in §1.3.

5.1.1 Perceptual acuity

Perceptual acuity describes the sharpness or keenness of hearing, vision and feeling to external stimuli which is reported by practitioners to change according to the depth of meditation (§1.3.5). Comparable to Zen, the concentrative meditation technique studied here employs the faculty of meta-awareness which is primarily used to monitor the efficacy of focus on the intended object but is also used in monitoring hyper-arousal and drowsiness. Although meta-awareness is relatively low in light states of meditation (first and second absorptions) compared to deeper states, it is still sufficiently strong enough to detect external and internal perturbations more effectively than during states of general relaxation or mind-wandering (§1.3.4). Meta-awareness may be much higher in deeper states of meditation, however, it is only effective for internal stimuli and mental processes. Awareness of external stimuli is significantly diminished in the third absorption and entirely absent in the fourth absorption. By virtue of the meditative process, meditators experience immobility during deep states of meditation (third, fourth and formless absorptions) and are unable to provide behavioural responses. Without the possibility of subject feedback, perceptual acuity is therefore only measurable during the first and second absorptions.

This experiment aimed to determine if perceptual acuity (viz. awareness of external stimuli) improved during light states of meditation. To achieve this, subjects were presented with tones, flashes of light and electrical sensations during control conditions and meditative states and asked to respond each time a stimulus was noticed.

5.2 Hypotheses

During lighter states of meditation (first and second absorptions), meditators often report awareness of stimuli from the surrounding environment. Awareness of external stimuli is attributable to the faculty of meta-awareness, which is employed during meditation to monitor the efficacy of focus and states of arousal. Additionally, practitioners describe their mental milieu as more quiescent due to diminished thought activity.

Accordingly, MEDITATORS are hypothesised to demonstrate increased levels of perceptual acuity during the first and second absorptions, in comparison to baseline and mind-wandering control states. Increased perceptual acuity will be demonstrated by an ability to detect quieter tones, dimmer flashes and weaker electrical sensations. Improvements in perceptual acuity are also hypothesised to positively correlate to the depth of meditation, that is, acuity will increase in the first absorption (compared to control states) and increase further in the second absorption. *Controls* are not expected to demonstrate any changes in perceptual acuity.

5.3 Methods

5.3.1 Subjects

Out of the twenty-six subjects recruited for this study, one MEDITATOR'S data was contaminated by electrical interference and was excluded from the perception experiment. The *control* paired to this subject also had to be excluded to ensure that only pair-matched subjects were included in analyses. Therefore, twelve MEDITATORS (♀ 7, ♂ 5, age range 30–62 years, $\bar{x}$=47.75 years) with 4–30 years meditation experience ($\bar{x}$=17.6 years) from the Lifeflow Meditation Centre in Adelaide, South Australia participated in the perception experiment (Table 3.1) and all MEDITATORS were pair-matched with non-meditator *controls* for age (± 6 years), gender, handedness and education level (§2.7.2.2). A number of scores from nine subjects and two stimulus modalities were not included in analysis for a number of reasons (§5.3.2.3). The pair-matched group numbers for the auditory, visual and somatosensory conditions (outlined in §5.3.2.3) were twelve, eight and five, respectively.

5.3.2 Experimental protocol

As visual acuity depends upon previous light stimulation and hearing acuity possibly depends upon previous sound stimulation (Gescheider 1997), subjects underwent a 5 minute period of darkness and silence in order to allow the retina to become adapted to the dark and the auditory system to become adapted to the silence. In addition, a stimulus-free baseline measure was included before stimuli were presented (Figure 5.1). During two control states (baseline and mind-wandering) and the first and second absorptions, tones, flashes of light and electrical sensations were repeatedly administered , referred to hereafter as *stimulus runs*. These three stimuli represented the three modalities of auditory, visual and somatosensory respectively.

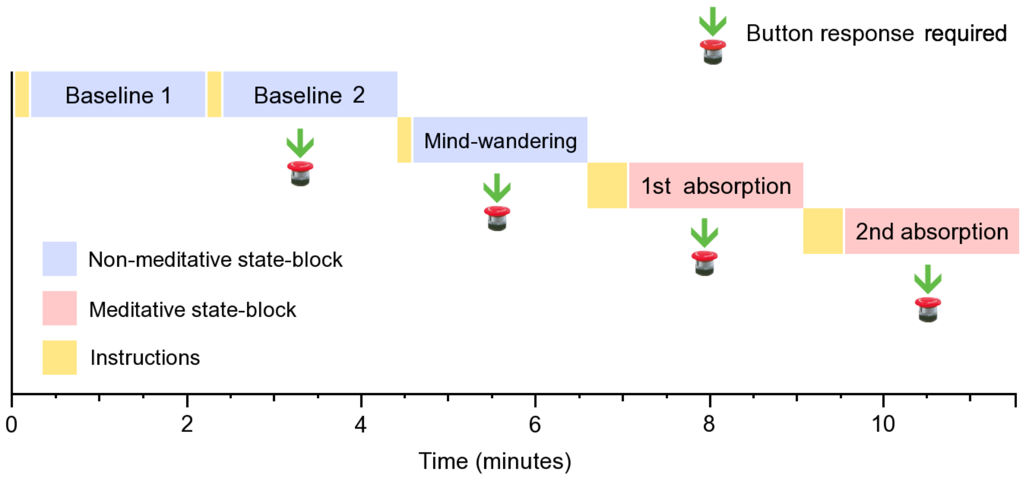

Figure 5.1: **Perceptual acuity experiment protocol.** A stimulus-free baseline preceded the second baseline and mind-wandering conditions and the first and second absorptions. Auditory, visual and somatosensory stimuli were presented during these four states and required responses from subjects when stimuli were detected.

5.3.2.1 Stimulus threshold

The idea of a stimulus threshold was conceived in psychophysics in the 19th century to investigate the relationship between sensations in the psychological domain and stimuli in the physical domain. The stimulus or absolute threshold refers to the smallest amount of stimulus energy necessary for conscious detection (viz. to produce a sensation) (Gescheider 1997). Due to biological variability, sensitivity to external stimuli not only varies between individuals, but also from moment to moment. In order to address these issues, stimulus threshold was assessed for each subject before the experiment in a manner reminiscent of Gustav Theodor Fechner's method of limits described in his Elements of Psychophysics (Hirsh 1952). Each stimulus (viz. tone, flash or sensation) was presented continuously, beginning well below threshold (subliminal) and increasing to a maximal level of intensity comfortably tolerated by the subject (set prior to the experiment). Subjects were asked to press a response-button when they first detected the stimulus, thereby setting the stimulus *high point* for the stimulus runs (see below). Then after the stimulus had reached maximal intensity, it was decreased to sub-threshold levels and subjects responded when they no longer detected the stimulus, thereby setting the stimulus *low point* for the stimulus runs. Although this method was not identical to Fechner's method of limits, and a less accurate assessment of stimulus threshold than his method of constant stimuli (Gescheider 1997), it was much quicker to administer and was used here due to time constraints. As momentary sensitivity in subjects also fluctuates, the threshold detection test was performed twice and the two scores averaged for more accurate measurements.

5.3.2.2 Stimulus runs

Changes in perceptual acuity across experimental states were assessed by presenting two series of nine stimuli of increasing intensity during each state. This method was adapted from Fechner's above method of limits (viz. the ascending series of stimuli). By administering a series of nine stimuli representing a narrow range of sensitivity based around sensory threshold values, either increases or decreases in perception sensitivity could be ascertained. For increased accuracy, stimulus runs were administered twice within each state (excluding the stimulus-free baseline state) and subjects were required to press a button each time a stimulus was detected. The response to the detected stimulus provided an stimulus index, hereafter referred to as a *score*.

Stimuli began at subliminal levels, defined by taking 10% of the maximum stimulus intensity and subtracting this value from the aforementioned stimulus low point. The end of the stimulus run was defined as 10% of the maximum stimulus intensity above the stimulus high point. The nine stimuli were evenly allocated across this range and each stimulus was presented for a duration of 100 ms with uniformly distributed random inter-stimulus durations (1000–2000 ms). Both MEDITATORS and *controls* underwent the same experiment with identical instructions.

5.3.2.3 Analysis

For each subject, two scores were recorded for each of the four states (second baseline, mind-wandering, first absorption and second absorption) and for each of the stimulus modalities (auditory, visual and somatosensory). The two scores from each state were averaged, resulting in four mean scores for each stimulus modality. Subject data which revealed no change in perceptual acuity at either end of the intensity scale (that is, subjects detecting all stimuli in all states or only detecting the last stimulus of the run in all states) were excluded from analysis (three MEDITATORS and two *controls* for visual condition, five MEDITATORS and four *controls* for tactile condition). All stimuli detected from the first state onwards might indicate a ceiling effect in perceptual acuity, while only the last stimulus detected from the first state onwards might indicate a floor effect. As there is no way of knowing if a subject increased their awareness of the stimulus in the case of a ceiling effect or decreased their awareness in the case of a floor effect, the inclusion of these scores might bias the results if included in analyses.

Repeated measures ANOVAs were performed for each stimulus modality with group and state as factors. The analyses contrasted mean scores from each of last three states with the mean scores from the baseline state in order to test for acute effects of meditation. Descriptive statistics of contrasts, profile plots, and means and standard errors were exported from SPSS and stored (see Appendix G). As subjects set the stimuli intensities within each modality according to individual thresholds, any changes in sensitivity were only related to initial individually set levels. Consequently, a comparison on baseline states between groups would be irrelevant and was not conducted.

5.4 Results

Both MEDITATORS and *controls* demonstrated an increase in perceptual acuity in the auditory condition. In both the visual and somatosensory conditions, neither group, state, nor group-by-state contrasts revealed any significant effects.

5.4.1 Auditory

Group and group-by-state contrasts failed to reveal any significance, however, state contrasts revealed highly significant p-values (all below 0.001) for mind-wandering, first absorption and second absorption. On examination of the profile plot (Figure 5.2), both groups were found to have increased perceptual acuity in all states following the baseline.

5.5 Discussion

Both groups demonstrated improved perceptual acuity of auditory stimuli and no differences were found between groups.

It is not possible to determine from this experiment whether the increase in auditory perceptual acuity was due to meditation or not, however, a number of reasons suggest that *controls* were able to enter the first, and potentially the second, absorptions. As mentioned in §2.7.2, all non-meditator *controls* were

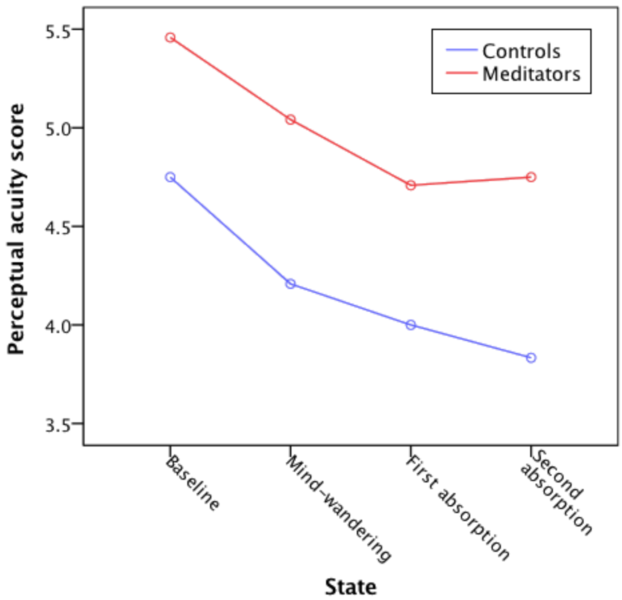

Figure 5.2: **Auditory perceptual acuity scores.** Perceptual acuity scores for MEDITATORS (green) and *controls* (blue) plotted across experimental states.

pair-matched to MEDITATORS for education-level. All subjects were tertiary educated which requires a degree of intensive concentration for sustained durations. Secondly, non-significant frontal/central theta power increase in *controls* during the first absorption is likely to reflect focused attention. Considering these two points, it is feasible that the positive trend found between enhanced auditory perceptual acuity and the depth of meditation may be due to both groups entering light meditative states. This said however, the lack of comparable perceptual acuity increases in visual and somatosensory conditions suggest either that the effect was due to other reasons (see below) or that meditation only affects auditory perception. Even though every effort was made to measure each modality as carefully as possible, the absence of change in visual and somatosensory modalities might be due to differences in the sensitivity of measurements.

5.5.1 Critique of experiment

A lack of change in the visual condition potentially resulted from the pre-experiment dark-adaptation period being too short. Sensitivity of the retinal rod pathway improves considerably after 5-10 minutes in the dark, however, about one hour is required for both cones and rods to completely recover their sensitivity (Gescheider 1997). The rate at which retinal cells adapt to the dark has been calculated and plotted as a dark-adaptation curve. Although an incomplete retinal adjustment to the dark might be expected to cause an increase in perceptual acuity across states (viz. over time), the dark-adaptation curve is bi-phasic and different intensities and duration of pre-adapting light affect this curve in different ways. Consequently, these influences on dark-adaptation may have contributed to the lack of change in perceptual acuity. The dark-adaptation period selected for the experiment was limited by the amount of time available. On a reading of the literature, no indication was found that such an adaptation period existed for the auditory and somatosensory modalities.

Discrepancies between results with other studies (Brown et al. 1984a, 1984b) might be because the duration of light was used to assess perceptual acuity in those studies, as opposed to the intensity of stimuli (for example, brightness of light flashes) administered here. Duration of stimuli, rather than intensity, was also used in the study on attentional blink (Slagter et al. 2008) which investigated the ability to detect targets using a rapid stream of events presented in close temporal proximity. The authors found that meditators exhibited smaller attentional blinks, that is, shorter durations required to detect targets. Stimulus intensity was chosen for two reasons: 1) the experimental protocol was limited by time (§3.3.1) and 2) past studies examining perception during meditation have not included stimulus intensity.

Due to experimental time constraints, the method of limits used to detect absolute stimulus thresholds was only repeated twice for each subject and stimulus runs were only repeated twice in each state. This limited validation of thresholds and acuity was a potential and likely cause of data variability as alternate ascending and descending series are often administered a total of ten times (Gescheider 1997). Repetition of the method of limits provides a more accurate assessment of stimulus threshold, especially with regard to moment to moment fluctuations in individual sensitivity. This said however, the advantage of a small number of series used in detecting thresholds helped to minimise two constant errors reported by psychophysics. These are 1) the error of expectation, where the subject may anticipate stimulus detection and make a premature judgment and 2) the error of habituation, where the subject may continue reporting perception of stimuli in an accustomed manner, even beyond the threshold.

Defining such a narrow range of sensitivity for stimulus runs also introduced an apparent complication. The range provided by the nine stimuli presented during the stimulus runs provided high resolution for detecting changes in perceptual acuity, however, this narrow range also limited the amount of change that could be detected. As was found, the limit of detection was reached by a number of subjects (ceiling or floor effect) which resulted in the exclusion of some data from analysis.

In a situation with more available time, the method of constant stimuli or staircase procedures (Gescheider 1997) would be a preferred test for determining initial thresholds and also for ascertaining any change in perception sensitivity during meditative states.

In conclusion, the meditation technique utilised in this study is understood to involve both focused attention and meta-awareness, yet results from our study did not support the idea that object-based concentrative meditation increases or decreases perceptual acuity, that is, the ability to detect external stimuli.