Meditation, Brain Waves & Altered States of Consciousness

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Abbreviations

FA – focused attention

OP – open presence

MBST – mindfulness-based stress reduction

TM – transcendental meditation

LK – loving kindness

ACC - anterior cingulate cortex

PFC - prefrontal cortex

EEG - neuroelectric electroencephalographic

Abstract

Meditation has been practiced in varied styles and traditions for thousands of years. Practitioners have always been aware of the benefits of regular participation, as written through the ages. Today, much scientific research exists aiming to understand the physiological mechanisms and make tangible the outcomes of such practices.

Aside from the well-documented psychological base and other more tangible health benefits, research has also focused on the modifications in brain function reported in those who meditate. This review attempts to consolidate the current literature to elucidate underlying neuronal mechanisms and brainwave states, as well as better understand the scope of different lineages of practice through the ages.

Introduction

Meditation as a construct is broad in that it incorporates a wide range of philosophical underpinnings and techniques, over many traditions. This heterogeneity of practices and their potential to engage different neural pathways, coupled with the varying levels of expertise of practitioners within different studies (1), makes it difficult to accurately

synthesise the research literature and come to any overall conclusions, from an analytical research science perspective.

Other confounding factors which make it difficult to come to fixed overall conclusions are the variations in the measurement of endpoints attempted to be achieved as a result of practice.

For example, in Buddhism the state of open presence reflects the basis of all reality and that with practice becomes the cultivation of Nirvana, being the realisation of that state (2). With mystical experience, is that which transcends thought and common perception, from a neuroscience perspective these principles may not be readily described or analysed.

There are, however, similarities in overall concepts such as the regulation of attention and endpoint relationships to wider states of awareness, such as longer-term benefits of the practice. These have been categorised as the verifiable aspects of this traditional knowledge and continue to be the centre of research investigation. Some of these overarching concepts include the assumption that each practice induces its own distinctive state which is hallmarked by specified observable features.

Once the specific observable features have been established for a particular style of meditation, with repeated practice, these can be used as markers of benefit should they increase the specific desired effects. A successful practice might also have the capacity to enhance these effects, with improvement over time (3). These are seen as characteristic of beneficial meditation practices.

Post-meditative effects are also considered to be a potential measurable marker of the benefits of a particular style of practice. These might include state changes like a dreamlike quality in one's perceptions for some time after practice (4).

There are inherent difficulties in finding tangible and comparable outcomes, as well as a level of consistency in the diversity of meditation practices. This paper outlines various traditional views of states of being which could be used as defined measures to research the benefits of practice. It then discusses what has been demonstrated thus far in neuroscience research using neuroelectric and imaging measures, as well as relatable subjective state and trait measures.

Meditation Traditions and Defined States of Being

Overall, much of the research literature today focuses on 3 main Buddhist traditions; Vipassana or Insight Meditation, the Zen tradition of Japan and the Tibetan tradition; Yogic forms of practice, Transcendental meditation (TM), or the Western adaptation of mindfulness-based stress reduction (MBSR) (5). Again, despite their many variances, some of the basic principles apply such as inward focus, reduction of mental content, the importance of breath and the relevance of body awareness.

The majority of the main practices across traditions, for ease, may be classified as mindfulness/ insight at one end of the spectrum or concentrative/ focus at the other, with most somewhere on the continuum between these poles (6).

Concentrative styles incorporate focused attention (FA) or Samatha meaning quiescence. This technique encompasses one-pointed concentration on a specific object, mental or sensory activity, such as a candle flame, a repeated sound or body sensations such as the breath. This state of focused attention (FA) which is cultivated by Samatha, improves concentration and the susceptibility to distraction. It is thought to improve both stability and intensity of focus, as well as mental and physical wellbeing (7).

Mindfulness practices on the other hand, generally involve allowing thoughts, feelings or sensations to arise in one's field of awareness, to attentively witness these without judgement or analysis, as a non-attached observer. Also known as open presence (OP), these are often found in contemplative traditions such as Zen or Vipassana meaning insight. Although Samatha is believed to be necessary for most contemplative traditions, it is often alongside another style of practice, such as open presence (OP) to assist with longer-term trait changes in the practitioner (8).

Vipassana or Insight Meditation, despite being a modern movement, has its roots in older contemplative traditions of Theravada Buddhism in Myanmar, Thailand and Sri Lanka. In the early stages of this practice, the focus remains on the breath without distraction. As one recognises when the mind starts to wander and then return to the breath, meta-awareness becomes engaged. This awareness refers to contemplating the mind at a meta-level, from an open perspective as the observer. Then refraining from allowing this meta-awareness to become a new source of distraction such as becoming frustrated with the wandering mind (9).

Open presence (OP), which comes from insight practice, is one of the main traits that practitioners attempt to cultivate over time and between practices, regardless of tradition or style of practice. This state, by its very nature, recognises any perceived flaws constructed by the mind to be misconceptions. These faulty beliefs might then be corrected by the wisdom and understanding cultivated by insight practices. In its advanced form, OP is objectless and there is no attempt to either suppress or create any specific mental content (10).

Tibetan traditions maintain the importance of the balance of both Samatha (focus), being the stability of the meditative state and vipassana (insight), relating to the clarity or subjective intensity, in each practice (2).

Transcendental Meditation (TM) is another example of a practice that contains both focus and insight, where despite the subject being centred on mantra repetition, the emphasis is on the absence of concentrative effort leading the practitioner into a state of transcendental awareness (11).

Another way to describe the 2 polarity constructs of FA and OP/insight, is through the concepts of dullness and excitement, respectively, which can create an imbalance in each other.

During FA meditation, the focus becomes on dullness. However, as this dullness increases, the clarity of the focus becomes hindered, and drowsiness might overtake the practice. Similarly, at the other end of the scale when excitement occurs during OP/insight style of practice. With this, as clarity progresses, the potential for distractions can also more easily arise and focus lost on the original object (9).

When beginning to practice meditation, it is often encouraged to delve more into clarity as avoiding dullness rather than excitement, can be more pertinent in the early stages of practice (12). In essence, it is thought that the ideal meditative state is that in which exists a symmetry between the stability of focus and the clarity of insight.

Loving-kindness (LK) meditation which cultivates the third most common state known as non-referential compassion, is another style of practice that has received attention. This cultivation of great compassion aims to create a sense of love and compassion toward all living things, through a wide range of techniques. Unlike FA or OP, this state produces a specific and intense emotional state of loving-kindness (3).

The practice known as non-referential compassion is like OP in that it ultimately holds objectless awareness. It does differ, however, during the early stages of the practice, in that it has a focus on the emotion of compassion that forms the context of the practice, later to be released and maintained in the space of OP. Practitioners of this tradition find benefit in their overall sense of wellbeing, whilst long-term meditators are said to also influence others around them, imparting a greater sense of wellbeing and happiness (12).

The final popular style to develop in India, which warrants a brief mention, is known as Tantric Wind meditation. These types of practices aim to shift various forms of energy referred to as wind or Vayu, that flow through channels throughout the body, analogous to nerve impulses. For example, this might be achieved through visualisations of syllables or breath practices directed into certain parts of the body to elicit changes in energy flow (3).

Subjective State and Trait Changes as Outcome Measures

In research, the term ‘state’ refers to the various conditions cultivated in the moment, during a meditation practice such as changes in sensory, cognitive, or self-referential awareness. The term ‘trait’ on the other hand, refers to the longer-term and lasting changes produced beyond the practice.

Some of the most frequently reported state changes to include cessation or slowing of internal dialogue, a deep sense of peace and calmness, experiences of perceptual clarity during OP/insight practice and conscious merging with an object of focus during FA meditation practice (13).

Trait changes because of long-term meditation include an increased sense of comfort and calmness, as well as heightened sensory awareness, and altered perceptions around the relatedness of thought, feelings and the experience of the self.

With successful practice, over time, there becomes an awareness around the concept of separation between all things and self-identity, as creating limitations within the lived experience. Recognition of impersonal beingness arises, as the realisation of oneness and the interconnectedness of all things becomes realised (11).

The main long-term traits documented to arise from OP practices include the maintenance of particular states between meditation sessions and the capacity to regulate one's emotions to be less easily disturbed by fluctuations. The mind is also said to be more sensitive and flexible, by supporting the cultivation of other positive states and traits (12).

Other longer-term trait changes have also been researched, such as inhibition of anger between meditation sessions, as found with regular love and compassion-focused practices (4).

Brain Patterns, Changes and Neuroplasticity

One of the foundational principles of meditation practice is that its experience is not rigid, but rather flexible and transformable. It supposes that whilst introspection, attention, and emotions are ongoing and labile, they can be trained like other skills. Such practices are based on the mind being malleable which aligns with the well-documented theory of experience changing the brain as in neuroplasticity (14).

Much research has previously delineated changes in brain structure and function based on different scenarios such as during conditions of chronic stress and abuse (15), as well as in depression (16).

More recently, research has been investigating the potential for meditation practices that cultivate positive qualities such as equanimity and loving-kindness to also produce alterations in brain function and structure. This would presumably be magnified in long-term practitioners, however, even short-term training such as 30mins of emotional regulation has been shown to produce reliable changes in brain function (17). Beneficial changes in patterns of prefrontal brain activity have also been documented after a 2-month course in Mindfulness-Based Stress Reduction (MBSR) (18).

There have been many research publications investigating an 8-week MBSR program which was originally developed to create long-term changes in the set patterns of chronic illness in a hospital setting and has since been used successfully in a wide variety of populations (19). Based primarily on Buddhist practices, the program is effective for chronic pain, anxiety disorders, general psychological wellbeing, psoriasis, and recurrent depression.

The underlying premise of mindfulness training is to separate the felt experience from the emotional cognitive processes that are created as a reaction to the felt experience. In doing so it highlights the unstable nature of feelings and sensations relative to their aversion. This

creates a heightened ability to counteract the likelihood of a reaction resulting from physical or psychological pain (20).

Neuroimaging and Meditation Studies

Neuroimaging research has been used to gain more precise insight into the mechanisms of meditation on brain function. Research shows that the posterior of the brain is important for gathering tangible information within and around us, whilst the anterior function relates more to ongoing processing between feelings, emotions, cognition and reflective mental activity. As these processes day-to-day are continuous at varying levels of activity around these regions, even at rest, they display constant seemingly random activation patterns.

These arbitrary patterns can become another confounder, influencing the lack of clarity sometimes found when assessing comparisons in meditation research studies (21).

Studies using functional MRI have shown meditation to activate various regions of the brain including the prefrontal cortex (PFC), insula and anterior cingulate cortex (ACC), with different forms of practice shown to activate different areas.

Focused attention (FA) increases activity in the ACC more so than with Open Presence (OP), which is implicated in several functions such as empathy, impulse control, emotion and decision making. In FA, increased activation in the right dorsolateral PFC which is involved in a variety of cognitive tasks such as decision making, conflict management, mood regulation and timing, has been found. Greater connectivity to the right insula which is engaged in homeostatic regulation functions such as thirst, pain and fatigue, has also been found in FA with no such increases with OP (22).

Both FA and OP increase signaling in the posterior insula during interoceptive tasks which are indicative of the capacity to interpret one's somatic reactions to stimuli. This suggests improvements in self-awareness and insight. Both practices also increase connectivity in the dorsal attentional network (23), which assists in the interpretation of sensory-motor information such as reaching and grasping, to support knowing how to use objects.

Most meditation practices deactivate the default mode network (DMN) (24) which is generally activated during rumination and mind wandering. This demonstrates the ability of meditation to improve focus and reduce the potential for trauma patterns to be unwillingly and continuously recycled.

This research shows that meditation activates specific brain regions responsible for executive functioning and the regulation of moods, as demonstrated by volumes of MRI studies. Different frequency patterns in brain waves have also been the focus of much attention in the scientific literature, which is considered next.

Brain Waves and Neuroelectric Research

Neuroelectric electroencephalographic (EEG) studies investigating meditative states date back 60 years, with no definitive and clear consensus being reached regarding specific neurophysiological mechanisms. There have however been some repeatable EEG frequency effects for theta and alpha activity, as well as measured brain responses to event changes and subsequent EEG coherence documented in meditative practices (25).

Generally speaking, communication between neuronal networks is elicited by the oscillation of electrical pulses which then form waves of varying frequency. These become altered depending on activities where slower brainwaves generally typify feelings of tiredness, and higher frequencies predominate when there are feelings of hyperactivity.

The slowest known brain waves originating from the thalamus or cortex are Delta waves (0.5-3Hz) which generate during deep meditation and dreamless sleep. Healing and regeneration are also thought to occur in this state, as external awareness becomes dissociated.

Theta waves (3-8Hz) are a pattern found in the cortical and subcortical structures which are thought to be the hallmark of the dream state. Theta activity has also been described during learning tasks including memory and virtual spatial navigation, whilst decreased theta activity has been associated with poor episodic memory (26).

Theta brainwave increases during meditation have been widely documented in the scientific literature, with reports of increases in frontal midline theta. Studies have found similar activation patterns in non-meditation during sustained attention (27) suggesting the concentrative aspects of the meditative practice to be enhancing theta power.

This frontal midline area of the brain is important for voluntary movement, expressive language and higher-level executive functions such as the capacity to plan, organise, initiate and self-monitor to achieve goals.

Increases in frontal midline theta, as generated by either the ACC or PFC have also been documented during hypnotic states (28) and autonomic nervous system self-regulation, which might be induced by various breathing practices (29).

Individuals that demonstrate greater theta activity generally report lower state and trait anxiety scores. It is believed that this might be related to the feelings of bliss and peace with lower thought content observed with theta bursts (26).

Studies in both Zen and yogic meditative practices have demonstrated that the increase in theta activation is correlated to the competence of the practitioner in the technique (30). Interestingly, simple OM mantra meditation in nonmeditators also facilitated increased theta waves across all brain regions in the same group when compared to their pre-practice levels (31).

The next elevation in frequency bands is that of alpha (8-12Hz) which is associated with wakeful relaxation.

The assessment of alpha brain wave activity via neuroelectric EEG signal was first documented by Hans Berger as far back as 1929. Since then, greater levels of alpha activity

have been repeatedly associated with lower levels of anxiety and increased feelings of calmness and positivity (1).

Alpha power increases have often been observed when comparing meditators during meditation with non-meditating controls (30). This alpha band is also shown to be stronger at rest in meditators versus non-meditators (12), suggesting that both state and trait alpha changes occur from regular meditation practice.

Both FA and OP meditation styles are associated with increases in PFC and left parietal activity during non-REM sleep. The increase is correlated with the amount of meditation training. This suggests the potential for regular meditators to have an increased level of awareness not only during waking activities, but also during sleep, compared with non-meditators (32).

The effect of alpha waves has also been documented in relaxation practices with no differences found in activity levels between relaxation, TM or yogic meditation (33, 34). Significantly greater increases however have been documented in both theta and alpha waves during nondirective meditation than during relaxation (35).

Many studies suggest that the meditation-specific state induces increases in both alpha and theta waves rather than increases in alpha alone (12, 35, 36).

In a regular waking state, Beta waves (12-38Hz) predominate, is typically associated with sensorimotor processing, and linked to attention, emotion and cognitive control (37).

Depending on the style of meditation, these waves have been shown to increase or decrease in specific brain areas. For example, OP demonstrates decreased beta wave patterns, in the angular gyrus, posterior cingulate and parietal cortices, as well as decreases in occipital oscillations during TM style practices. Conversely, evidence suggests increased beta band activation in the insula, inferior frontal gyrus and anterior temporal lobe, in mindfulness practices such as LK and yogic meditations (38).

The fastest-moving brain waves are known as Gamma (38-42Hz) which relate to the simultaneous processing of information from different brain areas and a state of expanded consciousness. These higher frequency oscillations have been evidenced in experienced practitioners in traditions such as FA, OP, LK and TM, with increases mainly in parieto-occipital gamma, which may account for the often-described enhanced perceptual clarity reported during various meditative practices. Whilst the role of gamma is yet to be clarified, is it suggested that it may play a role in neuroplasticity via repetition (39).

One study on yogic meditation documented intermediate practitioners with an average experience of 4 years, to have increased low-frequency oscillations of theta and alpha waves in the right superior frontal, right inferior frontal and right anterior temporal lobes. Interestingly, advanced practitioners with an average of 30 years of experience, showed increased high-frequency oscillations of beta and gamma in the same brain regions (40).

Several earlier studies with EEG on meditation report sleep-like stages with increased alpha and then theta power, which led to the theory that the meditative state was somewhere

between sleep and wakefulness (41). Meditators might remain in what is like sleep Stage 1, in which theta predominates, before sleep Stage 2 in non-meditators. The main documented difference in further research was found to be the subsequent increase in alpha alongside theta in meditators, whereas alpha power generally decreases during Stage 1 sleep to onset drowsiness (28).

Conclusion

There are a wide variety of meditation styles used to cultivate positive qualities in the mind, along with enhanced insight and awareness. Meditation also has a multitude of meanings in different contexts such as those used religiously or spiritually as devotional practices, through to practices aimed at self-regulating the mind.

Much of the scientific literature points to meditation as having beneficial effects on mood, consciousness and awareness. Alternative styles of practice display different areas of brain activation and frequency of oscillation waves, as do levels of meditation experience even within the same traditional style of practice. This diffuse patterning has proven to create some degree of difficulty in pinpointing the precise mechanisms thought to be eliciting altered states of consciousness.

The very fact that long-term more permanent trait changes occur can also confound research results, in that the distinction between times in and out of meditation becomes blurred with increased years of practice. This creates issues in the data when trying to distinguish if a specific practice has any changes in outcomes between pre and post-meditation.

Conversely, the lack of focus in non-meditators also makes assessment of the benefits of practice in this group challenging, due to the inability to accurately measure when they are in and out of the actual meditation during each practice.

As with all subjective experience, defining the somewhat sort after goals across traditions also defies standard definition. For example, concepts of enlightenment vary around constructs like kensho, stream of entry, and realising the nature of the mind at different stages of awakening, as described in Buddhist traditions. In Tibetan Lineages, enlightened awareness ‘sees all’ as truly beyond suffering, as an inseparable emptiness- bliss state, just as awareness itself. How to measure these outcomes remains to be elucidated.

Overall, meditation has however been shown to result in both structural and functional brain changes, with specific and measurable changes in cortical activity which increase with experience. Longer-term practitioners appear to show more consistent EEG changes and the capacity to hold the meditative traits between practice sessions.

Given the plethora of scientific research evidence relating to the myriad of measurable health benefits in meditation practitioners of all types, it seems prudent to incorporate any desired style of practice into everyday life.

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