Chapter 9
On Physiological Bases of States of Expanded Consciousness

Emil Jovanov

Abstract Altered states of consciousness provide valuable insights essential for a better understanding of the phenomenon of consciousness. Improved understanding of physiological correlates of states with expanded consciousness may allow possible use of biofeedback as a tool for achieving of those states at will. As a consequence, this approach may facilitate improvement of efficiency, creativity, and spiritual growth. This chapter presents a survey of relevant physiological correlates and present examples of two specific techniques: slow yogic breathing and chanting. We hypothesize that stabilization of physiological rhythms, such as breathing, heart rate variability, or blood pressure variability, creates favorable conditions in which states of expanded consciousness may arise.

9.1 Introduction

Consciousness remains the ultimate secret of human existence and contemporary science. Scientists even disagree about the possibility of correlating any of the physiological signals with subjective experience. Chalmers calls this the "hard problem":

> CONSCIOUSNESS, the subjective experience of an inner self, poses one of the greatest challenges to neuroscience. Even a detailed knowledge of the brain's workings and the neural correlates of consciousness may fail to explain how or why human beings have self-aware minds (Chalmers 2002).

Altered states of consciousness are essential for a better understanding of the phenomenon of consciousness (Tart 1972). Taking the system to extreme modes of operation or suspending elements of the functionality (e.g. sensor inhibition or overload, drug induced changes, etc., Vaitl et al. 2005) may improve our understanding of the states of expanded consciousness and provide valuable insights into

E. Jovanov (✉)
Department of Electrical and Computer Engineering, University of Alabama, Huntsville, AL, USA
e-mail: emil.jovanov@uah.edu

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possible mechanisms for improved efficiency, creativity, and spiritual growth. Csíkszentmihályi (1990) emphasizes that people are most happy when they are in a state of flow – a state of concentration or complete absorption with the activity at hand and the situation. The flow is a temporary state of heightened concentration that enables peak performance, while the “zone” usually refers to a similar state in athletes.

The idea of flow is identical to the feeling of being in the zone or in the groove. The flow state is an optimal state of intrinsic motivation, where the person is fully immersed in what he or she is doing, characterized by a feeling of great absorption, engagement, fulfillment, and skill – and during which temporal concerns (time, food, ego-self, etc.) are typically ignored. Children at play often exhibit a similar state of full immersion. Csíkszentmihályi described flow as:

> being completely involved in an activity for its own sake. The ego falls away. Time flies. Every action, movement, and thought follows inevitably from the previous one, like playing jazz. Your whole being is involved, and you’re using your skills to the utmost (Csíkszentmihályi 1990).

It has been shown that the mindfulness, meditation, yoga, and martial arts seem to improve a person’s capacity for focused attention, characteristic for the flow state (Vaitl et al. 2005). All of these activities provide the opportunity for prolonged improvement of attention and concentration.

There are two principal approaches to the investigation of consciousness. Connectionists describe the conscious processing of each stimulus and subjective experience as specific responses in the brain, activation of individual neurons, their hierarchical processing, and associations with other brain regions (Chalmers 2002; Crick 1994). For example, recognizing somebody’s face includes hierarchical processing of signals coming from eyes, the emergence of face features through hierarchical processing, and collection of meaning through associative response in other parts of the cortical network. The second approach is based on fields and assumes a synergistic effect of cerebral electromagnetic fields in addition to the neural connections. It is hypothesized that the field serves as a global integrating medium of neural activity (Cosic et al. 2006; Rakovic 1991; Penrose 1994).

We hypothesize that the states of expanded consciousness (sometimes called “higher consciousness”) allow access to individual and collective unconsciousness as a mechanism of insights and creativity. We assume collective consciousness as a physical mechanism described by Carl Gustav Jung as:

> a second psychic system of a collective, universal, and impersonal nature which is identical in all individuals. This collective unconscious does not develop individually but is inherited. It consists of pre-existent forms, the archetypes, which can only become conscious secondarily and which give definite form to certain psychic contents (Jung 1991).

The connectionist approach would attribute collective unconscious and archetypes to genetically inherited organization of our nervous system and the seamlessly infinite knowledge database of our genetic information. However, this approach can hardly explain complex psychological phenomena, which are still hard to document, such as synchronicity (Jung 1991). The field based approach may provide possible explanations for those phenomena through interaction with the "field of consciousness" (Penrose 1994; Rakovic 1991, 1995).

Our body functions through a hierarchy of interrelated rhythms. We believe that every thought or action creates "ripples" throughout the hierarchy of our rhythms. Science may or may not be able to explain the ultimate mechanisms of consciousness (the hard problem) and the physiological correlates of conscious processes. However, by monitoring physiological correlates as ripples in our stream of consciousness and providing results with minimum latency, we might facilitate personalized insights into physiological correlates of various altered states of consciousness. For example, alerting the user about detected anxiety (increased heart rate and decreased heart rate variability) may allow user to gain new insight into the particular content in their stream of thoughts. If the person was thinking about swimming, for example, an indication of emotional stress and anxiety might indicate traumatic childhood experience hidden deeply in the personal unconsciousness. The user might further explore the experience in one or more sessions. Ultimately, the user can resolve the issue by safely exploring the unconscious mind and hidden experiences. As another example, it has been shown that major discoveries often appear during a relaxed, but alert, state. We call it the *eureka* effect, in reference to the Archimedes, who proclaimed "Eureka!" when he stepped into a bath and suddenly realized that the volume of water displaced must be equal to the volume of the submerged parts of his body. By providing feedback about individual physiological correlates of conscious processes, we might a person to re-create the physiological basis of a particular state of consciousness at will and explore it in the quest for insights that would allow expanding of their consciousness.

This process may work not only in the short term but also have lasting effects. It is known that the brain has the ability to rewire itself in the presence of the appropriate sensory input, even in later life after maturation of the nervous system. Recent evidence includes long term changes in brain electrical activity in meditators (Tei et al. 2009) and following integrative body-mind training (Tang et al. 2009).

Recent studies indicate the possible use of biofeedback for voluntary control of physiological processes, allowing researchers to observe perceived changes in the state of consciousness as correlates of physiological states (Benson 1984; Cade and Coxhead 1979; Schwartz and Andrasik 2003; Vaitl et al. 2005). Various methods have been proven effective in control over physiological processes, such as temperature, heart rate, blood pressure, vasomotor responses and muscular tension. Recent scientific studies indicate that elevation of theta over alpha activity could enhance music performance (including ratings of interpretative imagination) (Egner and Gruzelier 2003). Also, improvements in attention and semantic working memory in medical students have been reported. Moreover, if EEG/MEG represents correlates of the state of consciousness, inducing changes of brain activity might lead to voluntary changes in consciousness.

Comparative analyses of traditional spiritual techniques for stimulation of altered states of consciousness indicate similar changes in basic physiological signals. We hypothesize that stabilization of physiological rhythms, such as breathing, heart rate variability, blood pressure variability, etc., creates favorable conditions in which states of expanded consciousness may arise. In this chapter we present changes in autonomous nervous system during meditation, slow yogic breathing exercises, and chanting as commonly used mechanisms to facilitate changes in the state of consciousness.

9.2 Physiological Correlates of Consciousness

The study of consciousness has entered an intense experimental phase (Tononi and Koch 2008). The most frequently monitored parameter is brain electrical activity (electroencephalography, EEG) for analysis of activation of neurons and groups of neurons and functional magnetic resonance (fMRI) for monitoring of activation (metabolism) of brain regions. Experiments involving monitoring of individual neurons and small regions require insertion of electrodes in the brain, and therefore can be used only for animal experiments. However, the assessment of higher cognitive functions, such as object recognition, is limited and requires a very specific experimental setup. Therefore, subjective experience during altered states of consciousness is a valuable tool for understanding the nature of consciousness (Rakovic et al. 1999; Tart 1972).

One of the safest methods of generating altered state of consciousness is meditation (Banquet 1973; Hirai 1960; Saraswati 2004). The traditional yogic path to experiences of expanded consciousness includes a combination of breathing exercises (pranayama, Saraswati 2004; Swara Yoga 1983) and meditation techniques:

> Through those practices (pranayama and meditative practices), the prana can be controlled. In this manner one is freed from sorrow, filled with divine ecstasy and becomes enraptured with the supreme experience (Saraswati 2004, p. 432).

Rhythmic drumming has been used for centuries alone or in combination with dance and/or song as a method of achieving an altered state of consciousness and is a frequently cited technique for the shamanic journey (Eliade 1964; Harner 1990; Maxfield 1990). Although drumming is widely used, the exact physiological mechanism behind the changes it achieves is still unknown. We present a brief review of the main physiological changes induced by rhythmic music and some fundamental technical issues in the analysis of physiological signals during entrainment.

Music is traditionally used as a medium for brain stimulation. However, the frequency range of many physiological rhythms (e.g. 3, 4, and 10 Hz cycles) is not in the audible range. Therefore, two basic approaches are applied:

- *Rhythmic entrainment*, such as drumming or repetition of high frequency tones at lower frequencies.
- *Binaural beats*, which arise from the difference in pitch between two audible sounds of higher frequencies (Oster 1973). Although individual sounds can have higher frequency (pitch), their difference is in the range of target physiological

frequencies and there is evidence that this generates brain entrainment at the difference of pitch frequencies (Lane et al. 1998; Stevens et al. 2003).

In addition to auditory driving, stimulation techniques frequently use multiple stimulation modalities. The most frequently used are optical and vibration stimulation (Thompson 2006; Vibroacoustic, http://vibroacoustic.org/). Optical stimulation can be implemented by providing light modulated by the sound. Changes in sound intensity may produce changes in light intensity or light frequency (color). As a result, the vision processing cortical areas in the brain start receiving direct electrical stimulation from optical nerves. Vibration stimulation can be achieved by exposing the body to sonic vibration. For example, low-frequency bass speakers might be embedded in a special chair or bed to deliver vibration directly to tactile sensors in our body. As a result, the music can be perceived not only through hearing, but also through the visual and tactile senses. This effect might be amplified by body movements. Multi-sensory stimulation very often produces synergetic effect where the overall effect is more than the sum of individual effects.

Shamanic drumming mostly consists of a steady, monotonous beat of 3–4.5 beats/s. It is used to facilitate entry into an altered state of consciousness and travel to other realms and realities, and to interact with the spirit world for the benefit of their community. It is interesting to note that those frequencies correlate with the delta frequency band of brain electrical activity. In electrophysiology this state is an indicator of the first phase of deep sleep and coma. Maxfield found more theta activity while subjects were listening to rhythmic monotonous and patterned drum beats than when they were listening to unstructured beat sequences (Maxfield 1990).

During the shaman's journey, he or she may travel to the "upper world" or the "lower world." Images that are traditionally associated with an entry to the upper world include climbing a mountain, tree, cliff, rainbow or ladder, ascending into the sky on smoke; flying on an animal, carpet or broom, and meeting a teacher or guide. The upper world journey may be particularly ecstatic. In the lower world journey, the shaman may experience images of entering into the earth through a cave, hollow tree stump, water hole, tunnel, or tube. Powerful animals or animal allies (guardian spirits) or other figures representing the spirit realm may be encountered. The lower world is traditionally a place of psychological or emotional tests and challenges (Eliade 1964; Harner 1990). Similar images and metaphors are also common features in mainstream Western psychological guided imagery and hypnotic induction.

To accomplish the shamanic journey, the shaman enters into a specific type of altered state of consciousness that requires that he or she remain alert and aware. In this state, the shaman can move at will between ordinary and non-ordinary reality. Michael Harner designates this pro-active state as a Shamanic State of Consciousness (SSC). There are various techniques for entering into the SSC, including sensory deprivation, fasting, fatigue, hyperventilation, dancing, singing, chanting, exposure to extremes of temperature, the use of hallucinogenic substances, the set and setting dictated by the beliefs and ritualized ceremonies of the culture, and, most relevant to this study, the rapid and sustained use of percussive sound (Ludwig 1968; Tart 1972; Vaitl et al. 2005).

With the present state of technology, investigation of these types of practices can be undertaken in a much more precise and dynamic way than ever before. Modern technology can help provide a precise experimental setup including sound generation and real-time feedback with significant improvements in monitoring systems.

9.2.1 What We Measure

Activation of certain functions might be monitored directly or indirectly. Direct monitoring allows monitoring of physical correlates of physiological functions, such as electrical activity of neurons. The most frequently used direct parameters represent brain electrical activity with an electroencephalogram (EEG) or magnetoencephalogram (MEG), heart electrical activity with an electrocardiogram (ECG), muscle electrical activity with an electromyogram (EMG), and electrical activity of eyes with an electrooculogram (EOG).

Indirect monitoring is frequently used to assess the increased metabolism of the affected region. For example, activation of certain brain regions might be monitored as increased amplitude of brain electrical activity or the increase of blood flow to the region of interest. However, the parts of the brain that control emotional response are buried deeply inside the brain and hard to monitor. Therefore, indirect monitoring may be employed. The most frequently used indirect parameters include body temperature, galvanic skin resistance (GSR), pulse pressure (photoplethysmogram, PPG), blood pressure (BP), functional near infrared brain imaging (fNIR), positron emission tomography (PET), functional magnetic resonance imaging (fMRI), and others.

Electrical signals are amplified and converted to digital format for archiving and processing. Each signal is characterized by intensity (amplitude of the signal in volts), characteristic patterns in time, and spectral content. For example, Fig. 9.1 presents electrical activity of the heart as an ECG, with characteristic patterns that represent individual heart beats. Each signal can be decomposed to a set of components at different frequencies. The frequency of each component specifies how many times a single wave occurs over a period of 1 s and is cited as the number of cycles per second or hertz (Hz). The most frequently used transformation from time to frequency domain is called a Fourier transform. It is used to transform or decompose a time signal into frequency components. Each component is represented by amplitude and phase, and collectively they represent the *spectrum* of the signal.

9.2.2 Brain Activity

Investigation of the brain's electrical activity (EEG) began with the publications of Hans Berger in 1924. Berger described the basic rhythms of the brain's electrical

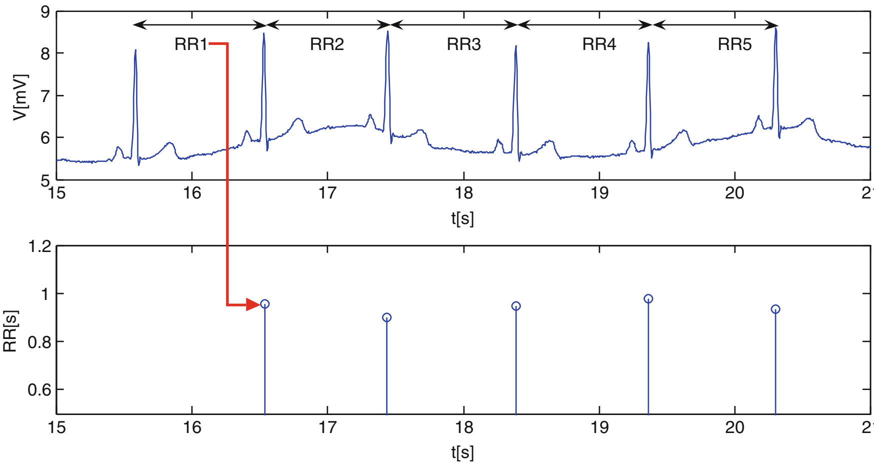

Fig. 9.1 ECG waveform (*upper plot*) and interbeat intervals (R–R intervals in *lower plot*)

activity. It is interesting to note his claim that "we have to assume that the central nervous system is always, and not only during wakefulness, in a state of considerable activity." This concept is similar to the recent concept of the default mode network (DMN) or the brain's dark energy (Raichle 2010). Brain states can be considered as separate global functional states over time that show extended periods of quasi-stability separated by rapid and major changes of state (Lehmann et al. 2009). Microstate analysis of EEG data indicates that the human brain's electrical state is quasi-stable for a fraction of a second, then rapidly reorganizes into another state. Different classes of thoughts in a daydreaming condition were found to belong to different classes of microstates of about 120 ms duration that may represent psychophysiological building blocks or "atoms of thought" (Lehmann et al. 2009).

Changes of electrical potential on our scalp are generated by the synchronized firing of large populations of neurons as a response to sensory stimulation or as a result of mental processing (Basar 1980, 1988; Mormann and Koch 2007; Nunez and Srinivasan 2006). Unfortunately, the skull attenuates the signals. As a result we measure signals with amplitudes of tens of microvolts. In addition, the signal is contaminated with power line interference and modulated by changes of conductivity of the scalp caused by changes in the blood vessels that form a somewhat independent process. In spite of all the issues described above, the EEG has been routinely used as a diagnostic tool for more than half a century.

The brain's electrical activity in various frequency bands is often understood as a correlate of certain states or a correlate of specific processing. Both the intensity and phase of waves at different brain locations indicate possible correlates of conscious processing. The conscious perception of a stimulus triggers widespread cortical interactions that indicate the binding of remote cell groups to form cell assemblies (Nunez and Srinivasan 2006).

The most frequent spectral components in EEG/MEG are (Guyton and Hall 2006):

- *Gamma* rhythm (30–100 Hz) is widely accepted to represent the binding of different populations of neurons to perform a certain function.
- *Beta* rhythm (12–30 Hz) is associated with active attention and focus on the exterior world. Beta is also present during states of tension, anxiety, fear and alarm.
- *Alpha* rhythm (8–12 Hz) is the basic rhythm amplified by closing the eyes and by relaxation. Consciousness is alert but unfocused, or focused on the interior world.
- *Theta* rhythm (4–8 Hz) are usually associated with drowsy, near-unconscious states, such as the threshold period just before waking or sleeping. They have also been connected to states of reverie and hypnagogic or dream-like imagery. Often these images are startling or surprising. For many people, it is difficult to maintain consciousness during periods with increased theta activity without some sort of training, such as meditation. Awake theta is associated with reports of relaxed, meditative, and creative states. Long-term meditation is characterized by increased theta EEG activity over the frontal region. The intensity of the blissful experience correlates with increases in theta power in anterior–frontal and frontal–midline regions.
- *Delta* rhythm is associated with deep sleep or unconsciousness.
- *Slow cortical potentials* (SCP) represents activation of a group of neurons approximately every 10 s. Note that traditional EEG amplifiers discard all rhythms slower than 0.5 or 1.5 Hz.

9.2.3 Limbic System Activity

Variation of periods between consecutive heartbeats provides unique insights into the state of autonomous nervous system. This parameter is very attractive since it is very easy to monitor, even in ambulatory settings. For example, Fig. 9.1 shows the ECG of heart activity recorded at the chest. In the upper plot, six heartbeats are clearly visible, denoted by sharp R-peaks (Guyton and Hall 2006). Interbeat intervals are represented as time differences between consecutive heartbeats. The lower plot represents five interbeat intervals from the upper plot. For convenience, we represent the value of interbeat intervals at the moment of the current heartbeat, although we could represent it in the middle of the interbeat interval. The value of the interbeat interval can be represented as instantaneous heart rate. For example, the first R–R interval is RR1 = 0.956 s, which is equivalent to a heart rate of 60/0.956 = 62.76 beats/min. The mean value of five intervals in Fig. 9.1 is 0.94 s, which is equivalent to a heart rate of 60/0.94 = 63.6 beats/min. Therefore, interbeat variability, R–R variability, and heart rate variability (HRV) can be used interchangeably to describe the same phenomenon.

The diagnostic value of HRV has been known for more than 40 years. HRV provides insights into the operation of the autonomic nervous system (ANS) with huge potential for early diagnosis and analysis of trends. In 1965, Hon and Lee demonstrated that changes in interbeat interval precede changes of heart rate in the case of fetal distress. Several studies in the last 20 years have demonstrated a correlation between post-infarction mortality and reduced HRV (1996) and mortality of emergency room patients (Cook et al. 2006).

New computer and sensor technology has made possible spectral analysis of the sequence of R–R intervals to reveal characteristic rhythms in heart rate variations. The main component of HRV is respiratory sinus arrhythmia (RSA), generated by a combination of respiration-induced biochemical changes, changes in intrathoracic pressure, and central vagal stimulation (Song and Lehrer 2003; Zhang et al. 1997). This change can be seen in Fig. 9.1, since the basic period of R–R interval changes is around 4 s, which is caused by breathing at 15 breaths/min. The main spectral components of HRV are:

- *High frequency band* (0.15–0.4 Hz) represents changes in the ANS, mostly caused by changes in breathing. The effect is called respiratory sinus arrhythmia (RSA).
- *Low frequency band* (0.04–0.15 Hz) represents changes caused by regulation of blood pressure and the sympathetic branch of the ANS.
- *Ultralow frequency band* represents changes mostly caused by the regulation of body temperature.

The frequency of the RSA component falls in the high frequency (HF) range for more than 9 breaths/min. Slower breathing generates peak power on the HRV in the low frequency (LF) range. The highest oscillation amplitudes are measured in the range 0.055–0.11 Hz and generate sinusoidal oscillations of R-R intervals by resonance among various oscillatory processes in the cardiovascular system (Vaschillo et al. 2002). Song and Lehrer found that a respiration rate of 4 breaths/min produced the highest amplitudes on the HRV, while even lower rates (3 breaths/min) generated smaller amplitude (Song and Lehrer 2003). Trained individuals (e.g., using yogic breathing techniques) can breathe at very slow rates, down to 1 breath/min or less (Jovanov 2005; Lehrer et al. 1999). Very slow breathing with frequency of less than 0.04 Hz (more than 25 s per breath) generates a dominant respiration component in the very low frequency (VLF) band (0.003–0.04 Hz) (Jovanov 2005). An example of spontaneous resonance caused by slow breathing is shown in Fig. 9.2.

Practitioners often report a state of calm, clear, and expended consciousness after practice. Therefore, it is frequently used as a preparation for longer meditation and to facilitate quieting of mind and detachment of everyday worries and non-essential mind processes.

Studies during bilateral and 15 min of unilateral nostril breathing indicate that in addition to cardiovascular changes (e.g., increased RSA), beta-2 EEG activity in the frontal leads shows lowered peak power during unilateral nostril breathing, indicating a relaxation-specific effect and a homolateral relationship between the nostril airflow and EEG theta activity. This is attributed to a lateralized modulation of the subcortical generators of EEG theta-band during unilateral nostril breathing. As a result, altered states of consciousness can be evoked by changes in the respiratory pattern and they share common basic mechanisms of respiratory, circulatory, and electrocortical interaction (Vaitl et al. 2005).

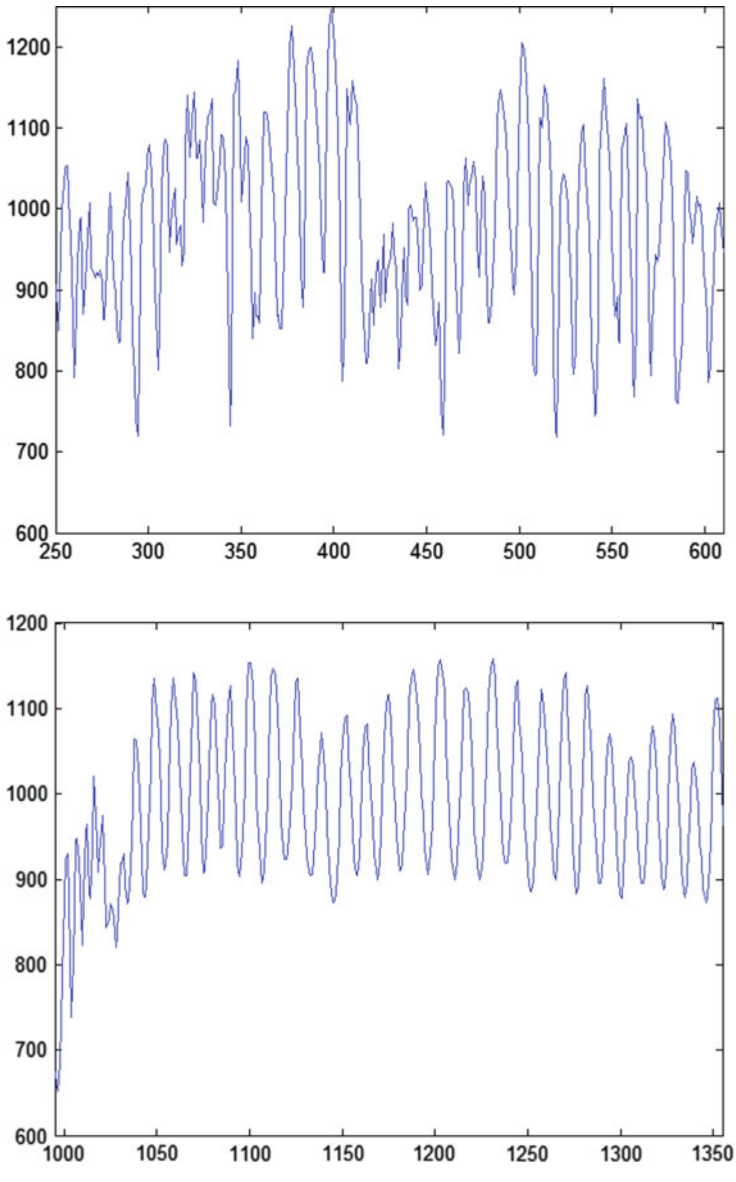

Fig. 9.2 The effect of very slow yogic breathing (1 breath/min): Inter-beat intervals before (*upper*) and after (*lower*) very slow breathing exercise (Jovanov 2005). Inter-beat intervals in milliseconds are represented as a function of time in seconds

Voluntary control of cardiac variability through biofeedback may have important effects on autonomic health and has been used in treatment of asthma patients (Vaschillo et al. 2006).

Reliable estimates of slow rhythms require very long sequences of R-R intervals, with typical durations of 5–10 min. However, this implies that every spectral estimate represents mostly the state in the middle of the processing window, which in turn implies a processing latency of about 5 min. This might be a problem for real-time analysis of cardiac variability, e.g., for emergency interventions where early detection of hemorrhaging is crucial for the survival of subjects (Jovanov et al. 2006). Minimal latency is also essential for biofeedback applications to allow users to evaluate the effectiveness of different techniques.

Changes in ANS activity are very well understood and documented (Heart Rate Variability 1996). Research has confirmed that such practices as yoga and meditation produce changes in the electrical activity of the brain, leading to a baseline increase in alpha and/or theta rhythms, and enhanced baseline theta and the maintenance of theta waves during meditation are found to be characteristic of long-term meditators. These meditators are able to keep their self-awareness intact and remain alert in this “twilight” state of consciousness.

In research on imaging, meditation, and relaxation techniques with inexperienced practitioners, it is a common observation that maximal or optimal physiological response occurs within the first 10–15 min of stimulation, and after 25 min a diminishing return sets in. Audio material for meditation and relaxation are often limited to 30 min in length for this reason (Cade and Coxhead 1979).

Low frequencies may facilitate communication with the personal unconsciousness and collective unconsciousness, as defined by Jung (1991). In Jungian terms, the role of rhythmic entrainment at lower frequencies (in the spiritual and religious cultures of the world) may be to facilitate spiritual experiences in which individual unconscious material is connected to the greater sphere of collective consciousness. In Western psychological terms, these experiences may facilitate the integration of incongruous or difficult psychological material into a person’s overall sense of self, producing a genuine state of lessened psychological stress and anxiety that can lead to feelings of deep connection with other individuals. The strengthened connections may remain as a lasting effect of these spiritual experiences, and as we suggested earlier, can have long-lasting and measurable psychophysical restorative properties.

9.3 Experimentation Techniques

Experiments involving physiological correlates of conscious experiences are relatively rare. Most of the published papers evaluate the overall physiological status of a certain state of consciousness, e.g., during meditation. Monitoring techniques mostly include EEG, fMRI, and heart rate. The main problem with human experiments is making exact correlations and mappings between physiological correlates and psychological states. Users can rarely associate a specific state with a particular moment when a specific correlate has been recorded. Every action performed to mark an event creates a disturbance in the flow of consciousness and disturbs the current state by initiating a physical action. The approach used by Lehman et al. (1995) was to interrupt the session immediately after a certain physiological correlate was recorded and annotate the event with the subject's description of the content of consciousness and emotional state. However, this approach interrupted the initial event and the flow.

This section describes physiological states of altered consciousness caused by meditation, rhythmic music, and chanting. The literature cited in this section presents the state of the art in our understanding of physiological correlates of altered states of consciousness.

9.3.1 Physiological Changes Caused by Meditation

Most of the research associated with changes in brain electrical activity in altered state of consciousness is related to meditation. Meditation exercises mostly aim at increased awareness of ongoing experiences through sustained attention and detachment as a conscious effort not to analyze or judge those experiences. Long-term meditation practice is believed to affect the ability to increase awareness and achieve greater detachment during non-meditative states, as evidenced by analysis of the sources of electrical activity in the brain (Tei et al. 2009). However, different types of mediation may produce different states and different physiological correlates.

The most important features of EEG changes related to meditation are:

- Establishing alpha activity even with open eyes (Hirai 1960)
- Increased amplitude of alpha activity (Banquet 1973; Hirai 1960; Wallace and Benson 1972)
- Slower frequency of alpha rhythm (Banquet 1973; Hirai 1960; Wallace and Benson 1972)
- Rhythmic theta waves (Banquet 1973; Hirai 1960; Wallace and Benson 1972)
- Increased synchronization (hypersynchronization) (Banquet 1973)
- Dissociation of perception from the external sense organs (Hirai 1960; Ray 1988)
- Transcendent signal (Ray 1988; Ray et al. 1999)
- Occasional fast wave activity during meditation (Banquet 1973; Cahn et al. 2010; Ott 2001; Ray 1988)

The first four changes are reported during one of the first studies of EEG changes related to Zen meditation (Hirai 1960). Kasamatsu and Hirai ranked the changes in this order and find out that the changes depend directly on mental state and experience in meditation. During *zazen* (Zen meditation), alpha was slowing to 7–8 Hz, and rhythmical theta waves at 6–7 Hz appeared in the last phase attained only by skilled monks with long meditation experience.

Increased awareness is often evidenced as increased gamma activity. Ray calls this "focused arousal" at a frequency of 38 Hz during the *Dharana* stage of *Rajayoga* (Ray 1988). *Dharana* means holding the mind at a certain point.

Changed perception during meditation is frequently reported. Subjects usually define this as a relaxed awareness with stable reception. We defined this state as dissociation of perception from the external sense organs. Quantitative investigation is possible by analyzing evoked responses, such as brain electrical activity evoked by sound stimulation (e.g., clicks). It is normal to see a diminished response to frequent stimuli (habituation). This approach is commonly used in the operating room to estimate the depth of anesthesia. However, Hirai found alpha block dehabituation during meditation (Hirai 1960).

Fast wave activity was occasionally reported. Banquet identified synchronous beta waves from all brain regions of almost constant frequency and amplitude (Banquet 1973). This activity was found in four advanced meditators during their subjectively reported deepest meditation.

To the best of our knowledge, EEG changes related to the healing process are rarely investigated. Zhang reported the EEG alpha activity during the Qi Gong state that occurred predominantly in the anterior regions (Zhang et al. 1988). Qi Gong represents a system of physical and mental training for "energy cultivation" and the manipulation of intrinsic energy that can be used for healing. The peak frequency of EEG alpha rhythm was slower than the resting state, and the change of EEG during Qi Gong between anterior and posterior readings had negative correlation. It can be seen that reported changes are very similar to the previously described changes during the meditation (Jovanov 2005; Rakovic et al. 1999).

Prominent changes in ANS function have been frequently reported, mostly as an increase of cardiac variability (Peng et al. 1999; Ray et al. 1999). This change is mostly attributed to very slow breathing.

9.3.2 Physiological Changes Caused by Rhythmic Music

Music is frequently used as an effective means of achieving altered states of consciousness (Drury 1989; Eliade 1964; Harner 1990). As melody or rhythm, music has the power to move participants on subconscious level. After experiencing the shamanic journey Nevill Drury writes:

> One thing never ceases to amaze me – that within an hour or so of drumming, ordinary city folk are able to tap extraordinary mythic realities that they have never dreamed of (Drury 1989).

The literature reports that listening to or playing sustained, repetitive drumming, is associated with an ASC or a qualitative shift in mental functioning (Neher 1961, 1962). The phenomenology of the interactions between drumming and states of consciousness has been well documented, but much remains unexplained. Possible explanations include: (a) Rhythmic drumming might act as a focus for concentration, used in combination with sensory deprivation, fasting, fatigue, and mental imagery to achieve an ASC; (b) the rhythm or monotony of the drumming facilitates an ASC; (c) evoked responses in brain electrical activity create a resonance with the external stimulation and induce an ASC.

Music has been also used to create an emotional state that would facilitate an ASC (Kreutz et al. 2008; Rakovic et al. 1999; Ray 1988).

9.3.3 Physiological Changes Caused by Chanting

Rhythmic chanting can be seen as a devotional practice that synchronizes the hierarchy of a subject's bodily rhythms and strengthens the coupling between them. Therefore, during this practice we can expect to see an increased interaction of breathing and HRV, or larger amplitude of the RSA and larger variation of interbeat intervals.

We investigated changes of heart rate and HRV caused by prolonged chanting. Participants reported a quiet and peaceful state after prolonged collective chanting. We measured heart rate as interbeat intervals of two subjects before, during, and after the session. An example of changes in heart activity is shown in Fig. 9.3. The

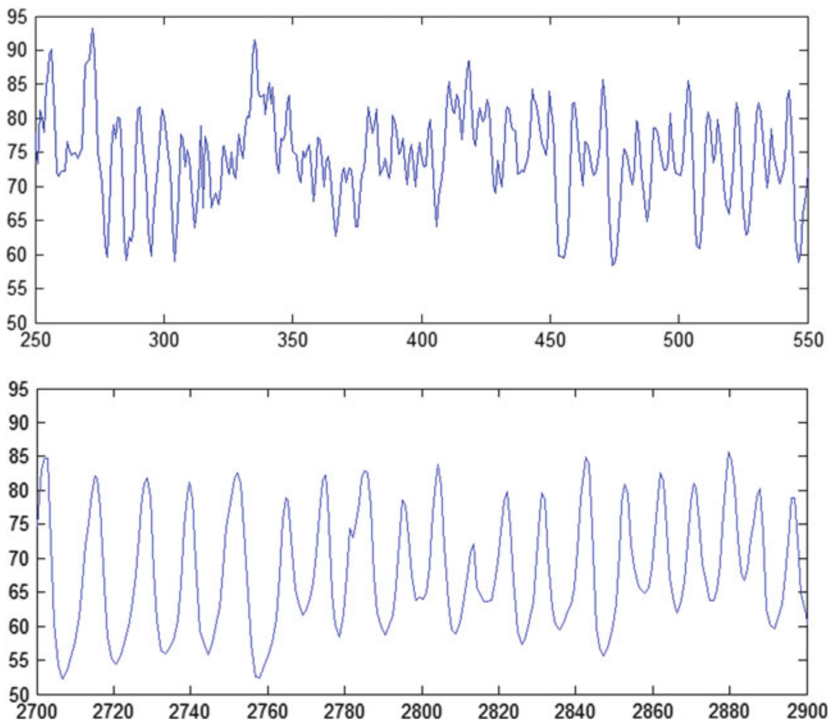

Fig. 9.3 The effect of rhythmic chanting: heart rate in beats/min as a function of time in seconds, initially (*upper plot*) and 45 min later (*lower plot*)

time resolution of measurements of interbeat intervals was 1 ms, as required for analysis of HRV. The subject was a 26-year-old healthy female with several years of experience of chanting. The upper plot represents interbeat variability at the beginning of chanting, while the lower plot represents the variability of the same subject after 45 min of chanting. A rhythmic, regular pattern of interbeat variability can be clearly seen on the lower plot. The pattern indicates slow, regular breathing, and strong coupling between breathing and heart rate. Precise quantification of the RSA would require precise measurement of lung volume that was not available at the time of experiment. Future work should include measurement of other physiological parameters, such as lung volume, blood pressure, and cardiac output.

9.4 Discussion and Conclusion

Increased coupling of bodily rhythms and conscious decoupling of the limbic system from the current content of consciousness may facilitate conscious exploration of the unconscious mind. We believe that the stabilization of basic physiological rhythms may serve as a foundation for altered states of consciousness that would facilitate insights and expansion of consciousness (Jovanov 1995, 2005; Rakovic et al. 1999).

The role of the limbic system is crucial for survival, since it allows activation of the high-priority body functions necessary during life-threatening events. During a journey into unconsciousness, the limbic system provides important indication about the emotional value of the experiences. However, during exploration the activation of the limbic system also influences mental content in our flow of thoughts. This results not only in a change in the stream of consciousness, but in the processing of conscious material. As we cannot consciously and directly control the functions of our limbic system, we cannot directly control our stream of consciousness. In a Buddhist philosophical context, this could account for the times when we are unable to stabilize the focus of our "wandering minds" on a particular issue. So, the critical question is that of how we can take advantage of the "message" of the emotional mind (limbic system) without significant modification of the stream of consciousness.

Undisturbed flow of consciousness might be attained by reflecting on the first of Patañjali's sutras (*yogah cittavrtti nirodhah*), on the cessation of movement in consciousness (Iyengar 1993). The sutra states that Yoga, or union of the individual and divine spirit, starts with the cessation of movements in consciousness.

We hypothesize that externally stabilized physiological rhythms can result in periods of uninterrupted conscious experience via the indirect stabilization of the limbic system. This stabilization can allow deep insights and a variety of integrating experiences to emerge. To paraphrase a frequently used metaphor, one can hardly see the bottom of the lake because of the constant chaotic ripples on the surface, whereas stable and regular waves allow one to see much deeper into the lake.

We also hypothesize that the entrainment techniques described here, including rhythmic drumming, slow breathing, and chanting, can stabilize and regulate basic body rhythms, which has therapeutic value in itself, and allow transcendent experiences to emerge. We hypothesize that these entrainment techniques provide extended control of the limbic system, offering one the chance to reduce “emotional noise” and settle the mind. We believe that externally stabilized physiological rhythms modulate control feedback between mental processes and the limbic system, producing periods of uninterrupted conscious experience and reflection, which allows deeper insights and facilitates spiritual growth. It would be interesting to simultaneously monitor subjects and drummer(s) to observe common patterns and synchronicity of changes. However, it is very important to understand the fundamental limitations of typical signal processing techniques used to analyze the changes of autonomic and central nervous system activity (Jovanov 2008). This is particularly important in the case of biofeedback techniques where processed physiological parameters are used in the entrainment process.

Future basic research in neurophysiology will greatly benefit from optical control of cells in animal experiments. This is a very promising approach used in molecular biology that will allow genetic modification of highly targeted cell assemblies and their control using optical stimulation at different wavelengths (Tononi and Koch 2008). This approach will allow researchers to “disconnect” at will very specific assemblies and test overall neural function in animal experiments.

Experimental research with human subjects is likely to include the development of experiments that will facilitate personalized selection of the monitored parameters and presentation modalities. Computerized monitoring and database acquisition of sessions correlated with personal experiences may facilitate mapping of uncharted territory of physiological correlates of states of consciousness; such a map would serve as a starting point for personal journeys to the realm of individual and collective consciousness.

Nunez and Shrinivasan conclude thus: “Maybe consciousness is a resonance phenomenon and only properly tuned brains can orchestrate beautiful music of sentience” (Nunez and Srinivasan 2006, p. 525). We believe that the current technology may facilitate proper “tuning” and self-exploration of the expanded realms of consciousness.

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