Autonomic regulation - What is it teaching us about living at peace in the world?

Dr Niikee Schoendorfer PhD MHSc BHSc ND Dip Ed

Postdoctoral Research Fellow, Institute of Intuitive Intelligence

Academic – Health Science, Torrens University

Abbreviation key –

PVT – polyvagal theory

ANS – autonomic nervous system

SNS – sympathetic nervous system

PSNS – parasympathetic nervous system

DVS – dorsal vagal system

VVS – ventral vagal system

RSA – respiratory sinus arrhythmia

SES – social engagement system

Introduction to Polyvagal Theory

Much of the way we act and react in our lives is dependent on several physiologic mechanisms throughout the body. One of the most popular theories to date is polyvagal theory (PVT), which was elucidated in its current form by Stephen Porges in 1995 (1). This theory extends on previous research, which heralded overall autonomic nervous system (ANS) regulation as simply a matter of balancing the sympathetic nervous system (SNS) stress response with the parasympathetic nervous system (PSNS) relaxation response. The overall ANS in the body governs several involuntary body processes such as metabolism, breath, and heart rate, even our capacity to think clearly. It also regulates much other physiology, which will be discussed in further detail throughout this paper.

Whilst the previous theory has not been totally discredited, continued research and the development of more precise diagnostic techniques, adds further depth and precision to the old model. PVT suggests that the 10th cranial vagus nerve, which was previously attributed

to PSNS function, in fact, has two components: the ventral vagal (VVS) and dorsal vagal (DVS), which works in concert with and not in direct opposition to the SNS.

These autonomic subsystems are behaviourally linked to social communication like facial expression, vocalisation, and listening with the VVS; mobilisation like fight-flight behaviours with the SNS; and immobilisation such as behavioural shutdown or freeze with the DVS. These three systems, the VVS, DVS, and SNS are dynamic and provide adaptive responses to safe, dangerous, or life-threatening contexts, respectively (1).

When the SNS is activated in response to real or assumed danger, or as a hallmark of chronic ANS dysregulation, substantial physiologic changes occur within the body, including increased muscle tone, heart and respiratory rate, blood shunted from the extremities, inhibited gastrointestinal function, dilation of the bronchi and the release of stress hormones from the adrenal glands.

In contrast, DVC activation in a defence state is a passive freeze response to immense danger or terror. It is associated with decreased muscle tone and reduced cardiac output, as well as altered bowel and bladder function to reduce metabolic demands. Behaviourally, there may be collapse or loss of consciousness when this system is activated.

When an environment is perceived as safe, the body is regulated to promote growth and restoration. This is mediated through the VVS effects on slowing heart rate, putting the 'brake' on the SNS, reducing the release of stress hormones such as cortisol, and reduces inflammation by modulating immune reactions.

Another exciting aspect of the VVS is that it is believed to have evolved later than the other autonomic systems within the human species. Through this process of evolution, the VVS became integrated with the nuclei in the brain that regulate the muscles of the face and head, lending to its capacity to elicit social engagement behaviours such as facial gestures (2).

Noteworthy is that the VVS can be in a blended state with the SNS, as in during fun and play or with the DVS during intimacy. In these instances, the VVS is functional and, in its withdrawal, promotes further access to the SNS defence system. The SNS inhibits access to

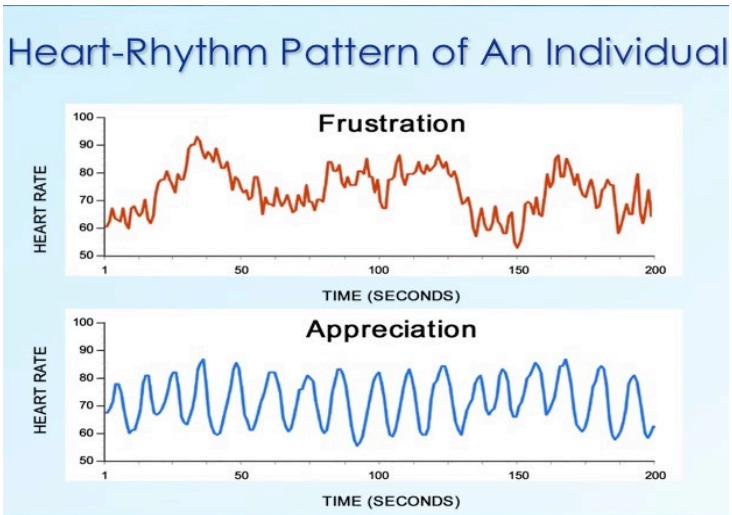
the DVS shutdown response; therefore, it is not possible for all these systems to be activated simultaneously.

Given the numerous essential functions under the control of the VVS, maintaining and enabling this system is beneficial for optimal health. In much of today's modern world, the culture of being busy and constantly overloaded is commonplace. As these patterns continue to stimulate the SNS stress response, alterations in function on multiple levels and organ systems in the body become highly destructive.

Heart Rate Variability

Heart rate variability (HRV) is referred to as the change in time intervals between heartbeats, where larger variations are indicative of positive health outcomes and smaller variations of negative health outcomes. Figure 1 below demonstrates these patterns related to emotional input. Much research indicates that the pattern and stability of the rhythm of the heart are more important than heart rate on the global effects of brain function, influencing the activity of the frontal and motor cortex areas. These areas directly affect psychological factors such as attention level, motivation, perceptual sensitivity, and emotional processing (3). This suggests that a larger HRV is essential to think and feel effectually within the world and with clarity.

Figure 1. HRV patterns, Heart Math Institute 2019.



Respiratory sinus arrhythmia (RSA) is a measure of HRV associated with the breath cycle and refers to the natural alternate increase in heart rate during inspiration and decrease during expiration where the heartbeat is synchronised with breath rhythm. This concept was postulated to be associated with the vagus nerve as early as 1910 by Hering, who wrote, '*it is known with breathing that a demonstratable lowering of heart rate is indicative of the function of the vagi*' (4). Research has since clearly established the capacity to regulate heart rate through regulating the breath.

The ANS is postulated to play a major role in coordinating HRV and RSA (5). Research shows that larger differences in heart rate between in-breaths and out-breaths (RSA) are indicative of good health, whilst smaller differences are found in reactive conditions of stress, autism spectrum, and substance use disorders (6).

RSA is used as a marker of cardiac-linked vagal tone, as well as an index for emotion regulation and as a useful indicator of self-regulatory capacity. This suggests that the ANS, in fact, controls emotional and cognitive processing, i.e., how we think and feel (7).

PVT suggests that the VVS is involved with emotional regulation and facilitates social engagement, allowing humans to inhibit the more primitive neural structures that control the fight, flight, or freeze behaviours (2). The theory also introduces the concept of a social engagement system (SES), defined as the links between vagal regulation of the heart and the muscles of the face, head, and neck. In light of this, facial expressions provide important precognitive information to our nervous system as to whether we are safe or otherwise in the presence of a person or group of people.

Several studies on cardiac vagal tone and SES highlight that people with higher baseline vagal tone, experience higher levels of positive emotions. Vagal tone refers to an ability to enable VVN relaxation responses readily in the face of challenge. People with higher vagal tone also exhibit patterns of interactions between positive emotions, social engagement, and cardiac vagal tone (8), suggesting the capacity to move back into balance more effectively in any given situation.

Other studies have shown that people exposed to interventions that support vagal regulation, such as loving-kindness meditation training, experience higher levels of positive emotions and social interactions (9). The authors hypothesised an ‘upward spiral dynamic,

mediated by people's perceptions of their positive social connections', meaning that there was a greater capacity to regulate a stress response in those that were more positive about others.

A meta-analysis of 14 different studies measuring HRV in adolescents and adults interestingly documented a decrease in HRV with negative social interactions involving social stressor tasks, whilst positive and neutral speaking interactions did not change HRV from baseline (10). This directly demonstrates a change in HRV mediated through perceived stressful social situations and more positive social interactions. The authors of this review concluded that vagal tone established over time, as we see with continued positively affirming practices, may facilitate the positive patterns found in social interactions and that these occur from the VVS influence on the heart.

Neuroception & Interoception

To shift efficiently from social engagement to defensive mechanisms when necessary, the mammalian nervous system needs to assess risk and, if perceived safe, inhibit the more primitive structures that control flight, fight or freeze behaviours.

Two of the main systems governing the awareness of safety or danger signals are neuroception and interoception, being the capacity to sense different signals within ones external or internal environment, respectively.

The term neuroception refers to the subconscious evaluation of risk in the environment. This mechanism is thought to involve voice, face, and hand movements, which contribute to an individual being intrinsically perceived as safe or trustworthy. In the absence of threat, the SNS and DVS are inhibited, allowing proximity, physical contact, and other social behaviours.

From a clinical perspective, maladaptive neuroception might contribute to an inability to inhibit defence systems in safe environments. This appears to be key in anxiety-related disorders or defensive behaviours associated with psychiatric conditions with social limitations such as autism, obsessive-compulsive or social anxieties, and various phobias (2).

Interoception on the other hand, are nervous system signals derived from the sensing, interpretation, and integration of the physical condition of the entire body. It performs a key role in modulating the stress response via the recognition of various arousal states ranging from calm to agitated, pleasant to unpleasant, and a sense of the self as emotionally aware (11).

Major interoceptive inputs include cardiovascular, respiratory, immune, metabolic, thirst, and microbiomal, with pain signals and fascia tension having perhaps the largest input (12). What this alludes to is that any manner of physical dis-ease, particularly common conditions such as musculoskeletal tightness, is having a direct effect on the capacity for the VVS to become operational and allow the body to ultimately relax. The implication of this is significant given that socialisation and the capacity for the body to heal and regenerate is largely dependent on VVS safety signaling.

The common predisposition of an ability to activate a stress response through thought alone adds to the subconscious signals being received through both neuroceptive and interoceptive mechanisms. These can create chronic stress syndromes associated with reduced behavioural self-regulation, along with multi-scale physical, emotional and cognitive changes seen in states of illness and aging (13).

Our body is receiving informational input continuously through the subconscious, whether the signals be derived from external stimulus, internal physiological messages, or altered thought perceptions running through the mind. All these largely determine the state of our ANS and its capacity to remain in a balanced state. The downstream effects, which have been scientifically elucidated and discussed, have widespread ramifications connected to every system of the body therefore, should be a major focus in all health and wellness modalities, as well as mainstream medical approaches to health care.

Building Resilience & What can be done

Self-regulation is the conscious ability to maintain system stability through the ANS, in the face of threat or adversity. Resilience or tone is the ability to 'bounce back' and adapt in response to stressful circumstances in a timely way. High resilience has been correlated with

quicker cardiovascular recovery following subjective emotional experiences, less perceived stress, greater recovery from illness or trauma, and better management of dementia and chronic pain. Compromised resilience results from ANS and VVS imbalances, as measured in the scientific literature by RSA (14).

There are many modern-day mind-body practices that assist in building more effective self-regulation via methods that coregulate stress responses and embodied cognition (15). Techniques that enhance one's interoceptive awareness and facilitate resilience to stressors include intentional noticing, sensing, and being aware of how ones' own body is feeling, often through movement and breathing. These types of methods view physiology as inseparable from affective and cognitive aspects of a person, whereas modern science has largely been based on the Cartesian dualism of the body and mind (16). By bringing these important aspects together, it is possible to be able to coregulate one through the other. For example, using the breath to calm the mind in the moment and using creative visualisation or positive emotion practices to restore longer-term balance in various physiologic processes governed by the ANS.

According to the research conducted by Greccucci (2015), affective-focused practices include the use of imagery, emotional memory, or intentional compassion, whilst attitudinal modifications through body listening, trusting, emotional awareness, not worrying, and curiosity have also been the focus of research studies. Results have consistently found improvements where conscious self-regulation resulted in improved mood and social behaviours (17). The increased awareness of social interconnectedness mediates positive emotions, in turn producing increases in vagal tone (9) which benefits overall capacity to maintain ANS balance over the long term.

Breath Practices

Respiratory activity modulates activation of the VVS and SNS, with the most obvious being effect being the change in RSA, as described previously. This activity is termed 'respiratory gating' and has a finite capacity that can be overridden at high levels of stimulation.

Despite the ability of varied breathing to modulate autonomic reactivity, it does not appear to influence the overall tone of the ANS in maintaining balance (18). This alludes to the fact that whilst the breath can be used to increase or decrease an autonomic response at any given time; it may not have an overall effect on long-term autonomic responsiveness and the capacity to remain relatively equanimous. This suggests that altering breathing patterns has the capacity to regulate the ANS in the moment; however, in the long term, it doesn't seem to confer benefit beyond breath regulation being a continued requirement. In short, one needs to consistently be aware of the breath to consciously find nervous system balance over time.

In fact, specific breathing practices have been shown to reduce symptoms of stress and anxiety, insomnia, post-trauma stress, obsessive compulsion, depression, attention deficit, and schizophrenia, as they are being practiced. Various yogic methods that voluntarily change the rate, pattern, and quality of the breath can reduce imbalances in the ANS, as well as improve emotional regulation, stress, and associated hormonal responses (19). Examples of these types of practices can be found in Appendix A at the end of this paper.

Slow breathing at 4 to 6 breaths per minute, with equal length, inhale and exhale, has been shown to optimally balance ANS stress responses as demonstrated via increase HRV in most adults. Four breaths per minute conferring the largest beneficial increase in HRV, whilst three breaths per minute created a decreased efficacy (20), highlighting that over restriction of breath cycles may negate any benefits and create higher levels of stress.

Interestingly research demonstrates that chanting OM, involving slow breathing, airway resistance, and vibrational effects, which increase vagal tone and physiologic relaxation, was shown to significantly deactivate the limbic system, which is responsible for activating the SNS (21).

Changes in breathing patterns alter interoceptive messages from the body through the vagus nerves to the brain's regulation centres. The millions of sensors throughout the respiratory system signal the brain to respond in kind with changes in attention, perception, emotional regulation, subjective experience, and behaviour (19).

Overall slow, gentle breath practices are safe in all psychiatric populations, and most asthmatics can benefit if they are not having acute symptoms. It should be noted, however,

that risks exist in utilising stimulating practices in vulnerable individuals. Rapid and forceful breath practices can trigger anxiety and panic attacks, mania in bipolar, flashbacks in PTSD, and altered states or psychotic episodes in conditions such as schizophrenia and borderline personality disorders. Rapid breathing practices are also contraindicated in pregnancy, cardiovascular disease, hypertension, lung disease, asthma, seizures, hernia, recent surgery, or myocardial infarction (22).

Yoga and Other Mind-Body Traditions

Many stress-related and other mental health disorders are associated with low levels of inhibitory neurotransmitter GABA which is responsible for mitigating the hormonal stress response. These types of disorders are also documented to exist with concurrent low HRV indicative of poor vagal tone, underactive prefrontal cortex, and subsequent overactive amygdala, all of which contribute to the myriad of symptoms in these conditions.

The prefrontal cortex contributes to a wide variety of executive functions like impulse control and managing emotional reactions, along with predicting consequences of actions and events in the environment. When its function is reduced, it fails to keep the amygdala's responses in check leading to emotional dysregulation and increases in the reactivity of SNS and DVS (21). These self-propagating cycles create an inability to self-regulate, which continues to create the same patterns of imbalance throughout the ANS.

Many traditional-based practices which utilise combinations of movement, breath, and meditation enhance VVS pathways, which in turn reduce SNS and DVS reactivity to various stimuli. These methods of practice increase the action of the GABA system in brain pathways and structures that mediate threat perception, emotional regulation, and stress reactivity (22).

Yogic practices themselves are associated with lower levels of stress markers like cortisol (24) whilst are correlated to both improved psychological resilience and VVS regulation (14). Evidence suggests that VVS increases the release of prosocial hormones, oxytocin, vasopressin, and prolactin which enhance feelings of love, bonding, empathy, and meaning reported by many yoga practitioners (25).

Other considerations are the mounting research evidence for the benefits of technology-assisted therapeutic breathing tools, such as those that send reminders to consciously breathe or facilitate the rate of breath by following a predetermined sequence. Numerous mobile and computer applications and devices benefit in the way that they open the practice of conscious breathing to those that might not otherwise utilise traditional guided practices (26).

Non-invasive electroacupuncture stimulation of the tragus of the ear, through which vagal afferent nerves run, has also been documented. Researchers found that specific stimulation parameters, just below the level at which the subjects could feel, elicited an increase in VVS activity measured via HRV ratios (27).

Another point of interest is the research literature on the beneficial effect of soft tissue mobilisation via Rolfing 'pelvic tilt' methods on the potential improvement of PSNS tone and resultant ANS regulation (28).

Other Systems Under Autonomic Control

Cardiovascular health is determined by changes in autonomic activity related to blood pressure, cardiac function, and response to exercise. According to research, during aging VVS signals to the heart decrease, whilst SNS tone increases. HRV and changes in RSA as indicators of vagal tone show there is a decline in PSNS control of the heart with an increase in SNS activity. Research also shows that the larger the HRV with advancing age, the lower the risk of developing cardiovascular disease (29). In fact, there is such a close correlation between HRV and mortality that it is used as a predictor of survival post-heart attack (26).

Another major role of the vagus nerve is in the gastrointestinal (GI) tract. As well as its role in regulating GI function and digestion, it also maintains the protective GI barrier and regulation of the immune response in the digestive tract, suggesting that its lack of tone may play a role in food intolerance, inflammatory processes, and other maldigestion and absorption syndromes (30).

Other studies have demonstrated the role of electrical stimulation of the vagus nerve fibres running through the neck in the treatment of certain diseases such as epilepsy, depression,

and inflammatory disorders such as rheumatoid arthritis (31). Further research is being conducted in Alzheimer's, schizophrenia and migraine (32), obesity, and episodic cluster headaches (33).

Conclusion

The ANS plays such a widespread and vital role in overall health, wellness, and longevity, as has been described in detail above. Given the relative ease of tonifying and augmentation of an active nervous system dysregulation pattern, it seems prudent that the various practices outlined in this paper become part of daily life. This would ensure a lowering of physical predictors of both morbidity and mortality at a population level. Efficient regulation of the ANS helps to ensure that well-rounded socialisation and positivity as a typical state of being in daily life.

Much of the work of the intuitive intelligence trainer (IITs) graduates from the Institute of Intuitive Intelligence is to empower clients through breath regulation practices. At the beginning of sessions, it is a vital component to support the client to become relaxed and present, so they can more easily connect with their feelings. As described in this scientific paper, stimulation of the VNS with the breath allows the brain to function optimally through the prefrontal cortex. As such, conscious full breaths enable the capacity to think and feel with clarity.

Other practices employed by IITs such as mantra and chanting have also been shown to stimulate the VVS and deactivate the limbic system responsible for the stress response. These practices are demonstrated to work very effectively in acute situations and in the moment to regulate the ANS during stressful events and create the environment required to function without reactivity and find peace in daily life.

Certain tools shared during IIT sessions enhance resilience and vagal tone while at the same time limiting reactivity in the long term. These tools include creative visualisations, intentional compassion, and positive emotional practices, which, over time, begin to entrain the ANS into a state of balance as a new set-point for daily living.

Advanced IITs incorporate additional mind-body practices that assist in building more effective stress regulation patterns which coregulate stress responses and embodied cognition. Techniques include intentional noticing, sensing, and being aware of how ones' own body is feeling, often through movement and breathing. By bringing these important aspects together, it is possible to coregulate one through the other.

IITs entrain their clients to consciously self-regulate nervous system responses, resulting in improved mood and awareness of social interconnectedness. In turn, this produces positive emotional experiences and increases vagal tone, which benefits stress resilience over the long term.

As outlined in this paper, the myriad of physical health benefits is also enhanced using these types of practices in daily life. As a collective, learning to live from a regulated nervous system would alleviate much of the distress of day-to-day living so a balance in mind, body, and spirit might prevail.

References

1. Porges SW. 1995. Orienting in a defensive world: Mammalian modifications of our evolutionary heritage: a Polyvagal Theory. Psychophysiology 32; 301-18
2. Porges SW. 2007. The polyvagal perspective. Biol Psychol 74; 116-43
3. Shaffer R, McCraty R & Zerr CL. 2014. A healthy heart is not a metronome: an interative review of the heart's anatomy and heart rate variability. Front Psyc 5; 1040
4. Hering HE. 1910. A functional test of heart vagi in man. Mens Munch Med Woch 57; 931-3
5. Yasuma F & Hayano J. 2004. Respiratory sinus arrhythmia: why does the heartbeat synchronise with respiratory rhythm? Chest 125; 5:683-90
6. Simoyi MF. 2019. Significance of Respiratory Sinus Arrythmia in human health and disease. J Sci Tech Res 17; 1:12450-2

7. Tonhajzerova I, et al. 2016. Respiratory sinus arrythmia as a non-invasive index of 'brain-heart' interaction in stress. Indian J Med Res 144; 6:815-22
8. Kok BE & Fredrickson BL. 2010. Upward spirals of the heart: autonomic flexibility, as indexed by vagal tone, reciprocally and prospectively predicts positive emotions and social connectedness. Biol Psychol 85;432-6
9. Kok BE et al. 2013. How positive emotions build physical health: perceived positive social connections account for the upward spiral between positive emotions and vagal tone. Psychol Sci 24; 1123-32
10. Shahrestani S et al. 2015. Heart rate variability during adolscents and adult social interactions: a meta-analysis. Biol Psychol 105; 43-50
11. Craig AD. 2002. How do you feel? Interoception: the sense of the physiological condition of the body. Nat Rev Neurosci 3; 8:655-66
12. Khalsa SA et al. 2018. Interoception and mental health: A roadmap. Biol Psyc: Cog Neuro Neuroimaging 3; 6:495-572
13. Hodes RJ et al. 2016. Disease drivers of aging. Ann N Y Acad Sci 1386; 1117-46
14. Sullivan MB et al. 2018. Yoga therapy and polyvagal theory: The convergence of traditional wisdom and contemporary neuroscience for self-regulation and resilience. Front Hum Neurosci 12; 67
15. Bennett SH et al. 2018. Rewiring the connectome: Evidence and effects. Neurosci Biobehav Rev 88; 51-62
16. Payne P & Crane-Godreau MA. 2015. The preparatory set: a novel approach to understanding stress, trauma, and the bodymind therapies.Front Hum Neurosci 9; 178:1-22
17. Grecucci A et al. 2015. Baseline and strategic effects behind mindful emotion regulation: behavioral and physiological investigation. PLOS one 10; 1:e0116541
18. Eckberg DL. 2003. The human respiratory gate. J Physiol 548; 2:339-52
19. Brown RP & Gerbarg PL. 2009. Yoga breathing, meditation and longevity. Ann N Y Acad Sci 1172; 54-62
20. Song HS & Lehrer PM. 2003. The effects of specific respiratory rates on heart rate and heart rate variability. Appl Psychophysiol Biofeedback 28; 1:13-23
21. Kalyani BG et al. 2011. Neurohemodynamic correlates of 'OM' chanting: a pilot functional magnetic resonance imaging study. Int J Yoga 4; 1:3-6

22. Brown RP et al. 2013. Breathing practices for treatment of psychiatric and stress-related medical conditions. Psychiatr Clin N Am 36; 121-40
23. Streeter CC et al. 2012. Effects of yoga on autonomic nervous system, GABA and allostasis in epilepsy, depression and PTSD. Med Hypothesis 78; 5:571-9
24. Michalsen A et al. 2005. Rapid stress reduction and anxiolysis among distressed woman as a consequence of a three-month intensive yoga program. Med Sci Monit 11; 12:CR555-61
25. Gerbarg PL. 2008. Yoga and neuro-psychoanalysis. In: Bodies in treatment: the unspoken dimension. Anderson ed. The Analytic Press Inc; 127-50
26. Alkhalidi HR et al. 2011. Insights on the robust variance estimator under recurrent events model. Biometrics 67; 4:1564-72
27. Deuchars SA et al. 2017. Mechanisms underpinning sympathetic nervous activity and its modulation using transcutaneous vagus nerve stimulation. Esp Physiol 103; 3:326-31
28. Cottingham JT et al. 1988. Effects of soft tissue mobilisation on parasympathetic tone in two age groups. Phys Ther 68; 352-56
29. Abhishekh HA et al. 2013. Influence of age and gender on autonomic regulation of heart. J Clin Monit Comput 27; 259-64
30. Bove C & Travagli RA. 2020. The vagus nerve. Encyclopedia of Gastroenterology. 676-82
31. Verlinden TJM et al. 2016. Morphology of the human cervical vagus nerve: implications for vagus nerve stimulation treatment. Acta Neurol Scand 133; 173-82
32. Broncel A et al. 2018. Medial septal cholinergic meditation of hippocampal theta rhythm induced by vagal nerve stimulation. Plos One 13; 11:e0206532
33. Garamendi-Ruiz I & Gomez-Esteban JC. 2019. Cardiovascular autonomic effects of vagus nerve stimulation. Clin Auton Res 29; 183-94

Appendix A (22)

- Paced breathing – controlling the respiratory rate and length of 4 phases of the breath cycle.
- Coherent or resonance breathing – the length of inhale and exhale are equal with a pause between. Various counts may be utilised.
- Resistance breathing – partial obstruction to airflow using laryngeal contracture, vocal cords, pursed lips or other means, which produces sounds and vibrations.
- Unilateral or alternate nostril breathing - involves closing one nostril such that all air flows through the other.
- Moving the breath - engages the imagination to move one's breath through different parts of the body.
- Breathing with movement – coordinates paced breathing with physical movements.