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(Research Article)

Continuous autonomic nervous system assessment using heart rate variability methodology during near-death and mystical experiences

Calixto Machado [1,*], Andrew Newberg [2], Yanin Machado [1], Mauricio Chinchilla [1], Deb Klesel [4] and Robert Hesse [3,4,*]

[1] *Institute of Neurology and Neurosurgery, Havana, Cuba.*
[2] *Thomas Jefferson University, Villanova, Pennsylvania, United States of America.*
[3] *University of St. Thomas, Houston, Texas, United States of America.*
[4] *Contemplative Network, Houston, Texas, United States of America.*

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Abstract

Introduction: We have recently recorded, processed, and published preliminary research (Part I) on brain activity by quantitative electroencephalography (EEG) tomography (QEEGt), comparing separate subjects remembering their near-death experiences (NDEs) and mystical experiences (SCE). Several reports have affirmed that NDE and SCE are related to important functional changes in the autonomic nervous system (ANS). The autonomic nervous system and the hypothalamus regulate pulse, blood pressure, breathing, and arousal in response to emotional cues. When activated, the sympathetic nervous system prepares the body for emergency actions by controlling the glands of the endocrine system. Heart rate variability (HRV) refers to how much an individual's heart rate (HR) varies, and it is a powerful method to assess the ANS. Several reports have affirmed that NDE and SCE are related to important functional changes in the ANS. We used the continuous EEG monitoring (CEEG) system to compare the memories of two groups with a NDE and a SCE. CEEG permits continuous electrocardiogram monitoring, allowing calculation of HR and HRV during SCE and NDE remembering. Hence, using HRV methodology, it is possible to assess the emotional effect of remembering NDE and SCE.

Conclusion: We demonstrated the usefulness of using the CEEG methodology, which allows us to continuously assess the ANS through the HRV methodology, showing important significant functional changes in the autonomic nervous system (ANS), and comparing SCE and NDE.

Keywords: Heart rate variability; Quantitative electroencephalography; Continuous EEG monitoring autonomic nervous system; Near-death experience; Mystical experiences (SCE)

1. Introduction

Over the centuries, the wisdom literature in most faith traditions has reported SCEs and NDEs with both altered states of consciousness having similar attributes. These traditions are at the cusp of theories about transcendence to the next life, which neuroscience has never studied comparatively in this way.[1-22]

We have recently recorded, processed, and published preliminary research (Part I) on brain activity by quantitative electroencephalography (EEG) tomography (QEEGt), comparing separate subjects remembering their near-death experiences (NDEs) and mystical experiences (SCE).[23]

* Corresponding author: Robert Hesse
University of St. Thomas, Houston, Texas, United States of America.

Several reports have affirmed that NDE and SCE are related to important functional changes in the autonomic nervous system (ANS). The autonomic nervous system and the hypothalamus regulate pulse, blood pressure, breathing, and arousal in response to emotional cues. When activated, the sympathetic nervous system prepares the body for emergency actions by controlling the glands of the endocrine system.[24-29]

Several reports have affirmed that NDE and SCE are related to important functional changes in the autonomic nervous system (ANS) during these two ASC.[30-36]

The autonomic nervous system (ANS) and the hypothalamus regulate pulse, blood pressure, breathing, and arousal in response to emotional cues. When activated, the sympathetic nervous system prepares the body for emergency actions by controlling the glands of the endocrine system. The ANS and the hypothalamus regulate pulse, blood pressure, breathing, and arousal in response to emotional cues. When activated, the sympathetic nervous system prepares the body for emergency actions by controlling the glands of the endocrine system [24, 37-41]

The ANS comprises two major neurobiological subsystems that function independently and in concert: the parasympathetic and sympathetic nervous systems. These two systems often elicit opposing actions, so the other system inhibits it when one system enhances or activates a physiological response. The sympathetic nervous system is often called the "fight or flight" system, which accelerates the heart rate, constricts blood vessels, and raises blood pressure to enable a quick and mobilizing response, often as a reaction to an immediate threat. On the other hand, the parasympathetic system is often called the "rest and digest" system, which slows down the heart rate, lowers blood pressure, increases intestinal and gland activity, and relaxes sphincter muscles. As mentioned, the increased capacity to respond to stimuli generated by the sympathetic system has been termed phasic alertness. Therefore, phasic alertness requires the activation of the sympathetic system and cannot co-occur with a physiological state of parasympathetic dominance, which is the relaxation response. On the other hand, although tonic alertness is inconsistent with drowsiness and sleep, it can nevertheless occur concurrently with a moderate level of parasympathetic activation and, as described below, can also occur during relaxed states.[37-47]

Heart rate variability (HRV) refers to how much an individual's heart rate speed varies. It is clear that when we run or exercise in some way, then our heart rate will increase compared to when we are at rest, but the time in between each beat can also vary. Due to the intricate involvement of our heart with our emotions (not just metaphorically), this variation reflects our physiological state and the level of emotional arousal we are experiencing.[48-55]

The emerging technology of CEEG in intensive care units gives practitioners the ability to identify changes in the ANS by recording an electrocardiogram (ECG) leads and calculating heart rate (HR) and heart rate variability (HRV).

The study of HRV offers a unique view, a window into the complex mind-body connection that exists behind regulating life processes, such as blood circulation and breathing. However, the intrinsic properties of the complex autonomic regulation of cardiovascular function are difficult to measure since, even at rest, it may be affected by emotions and mental loading. HRV is a promising tool for assessing cardiovascular health and the degree of severity of cardiovascular diseases. It is a non-invasive and valuable method to assess the autonomic functioning of the heart from a simple ECG recording. The variability manifests HRV in R-R intervals of successive heartbeats, which reflects the sympathetic and parasympathetic activity of the autonomic ANS innervating the heart. ANS activity regulates the cardiac cycle of contraction in response to various changes and demands of the body. In the presence of cardiovascular disorders or one of their risk factors such as stress, the sympathetic nervous system predominates in the heart over the parasympathetic one, leading to increased heart rate (HR) and thus a decrease in the beat-to beat variability.[24, 25, 37, 39, 42, 48, 50, 56]

HRV is affected by various factors, including mental activity and changes in emotion and mood, such as practicing meditation and physical exercises. This represents some adaptation of the heart to external stimulators and their response. Furthermore, other lifestyle factors, such as smoking and caffeine intake, may affect HRV when studying the heart response to a certain stressor stimulant. Therefore, people with a worrying trait who consume more caffeine or smoke regularly show higher HR and lower variability in their heartbeat pattern.[57-61]

Increased sympathetic nervous system (SNS) or diminished parasympathetic nervous system (PNS) activity results in cardio acceleration, whereas decreased SNS or increased PNS activity causes cardio-deceleration. The SNS mainly acts on the ventricular muscles and increases their contractility. Moreover, the SNS increases the excitation frequency, excitation conduction velocity, and excitability of the sinoatrial (SA) node. When the SNS is maximally stimulated, the magnitude of the HR and contractility can triple and double, respectively. To reduce HR, the PNS primarily acts on the SA and atrioventricular (AV) nodes. Vagal and sympathetic activity constantly interacts. As the SA node is rich in acetylcholinesterase, the effect of the vagal impulse is brief, owing to the rapid hydrolysis of acetylcholine. Under resting conditions, vagal tone prevails over sympathetic activity, and variations in the heart period are largely dependent on vagal modulation. When the SNS and PNS are removed, the HR rises above steady-state rates. Vagal dominance occurs when the vagus nerve, a parasympathetic nerve in a stable state, is more active than the sympathetic nerves.[39, 50, 62-65]

In 1996, the Task Force of the European Society of Cardiology (ESC) and the North American Society of Pacing and Electrophysiology (NASPE) defined and established standards for the measurement, physiological interpretation, and clinical use of HRV. Time-domain and frequency-domain indices and geometric measures are standard clinical parameters. Time-domain analysis measures variation in HR over time or the intervals between successive normal cardiac cycles. Time-domain analysis of recording data involves simple calculations of mean normal-to-normal (NN) intervals and the variance between NN intervals. One of the simplest time-domain analysis variables is the standard deviation of the NN interval (SDNN; i.e., the standard deviation of NN).[66-69]

We used the continuous EEG monitoring (CEEG) system to compare the memories of two groups, with a NDE, and a SCE. CEEG allows continuous electrocardiogram monitoring, allowing calculation of HR and HRV during SCE and NDE remembering.

Objective

Compare the continuous ANS changes of subjects in the process of remembering a prior SCE and NDE using the CEEG system.

2. Material and methods

2.1. Protocol

We used the CEEG system to compare the memories of two groups with a NDE and a SCE.. CEEG allows continuous electrocardiogram monitoring, allowing calculation of heart rate (HR) and heart rate variability (HRV) during SCE and NDE remembering.

2.2. Sample Groups

Two groups were studied, each having five subjects from 19 to 65 years of age, both male and female, paired in age and gender. The NDE group was selected from cases who had suffered a cardiac arrest (C-AR) inside the ICU. The SCE group was selected from subjects who described having a SCE during their practice of Centering Prayer (CP), an interdenominational Christian form of prayer. [23]

All subjects, SCE and NDE, had neurological examinations, and the Grayson Scale (GS) was applied[45]. The Grayson Scale (GS) was used as an objective measure of a valid NDE and SCE. The subjects who did not describe a NDE or SCE using the GS were excluded from the study.

2.3. Experimental Design

Every subject was studied with HRV variability monitoring during remembering NDE and SCE. CEEG was assessed during 7 minutes of basal recording, and 7 minutes of remembering their NDE and SCE. The CEEG monitoring system (Neuronic, SA) was used.

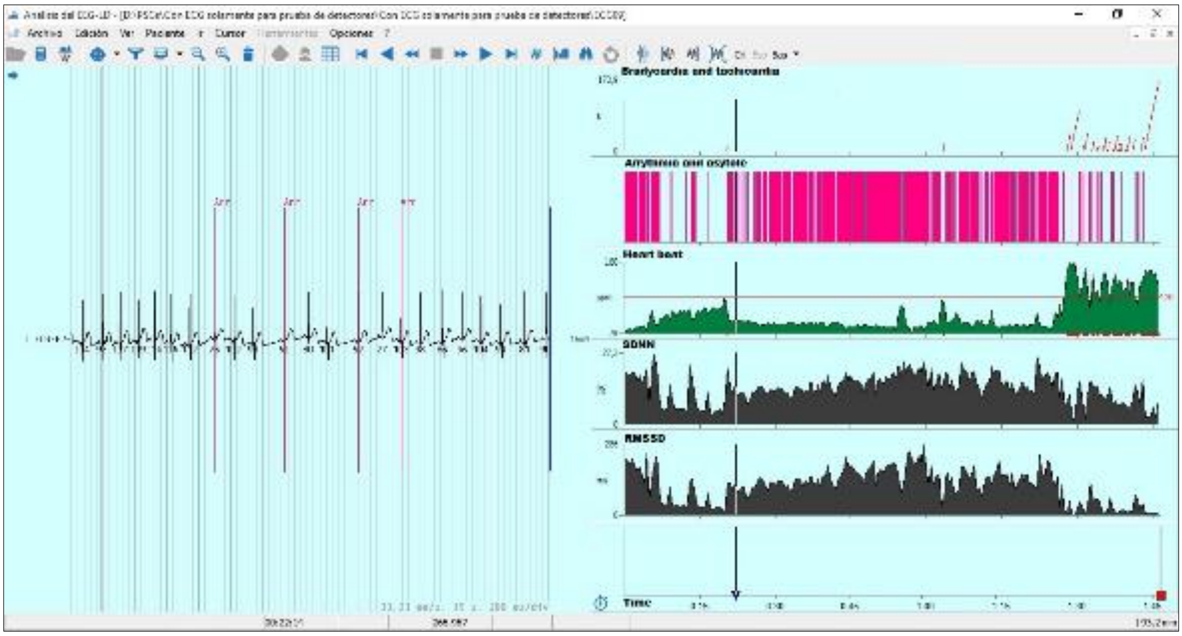

Figure 1 CEEG allows continuous electrocardiogram record. The system automatically detects bradycardia, tachycardia, arrhythmia, and asystole. It also calculates heart ratre (HR) and two HRV variables: SDNN and RMSSD

2.4. CEEG Assessment [70-76]

A bipolar chest electrocardiogram (ECG) lead was recorded with 0.5 to 30 Hz EEG filters for monitoring purposes. The system allows continuously calculate HR in beats/minute and HRV from the time dominion:

2.4.1. SDNN

The related standard deviation of successive RR interval differences (SDSD) only represents short-term variability. SNS and PNS activity contribute to SDNN and are highly correlated with ULF, VLF, and LF band power and total power. This relationship depends on the measurement conditions. When these bands have greater power than the HF band, they contribute more to SDNN.

2.4.2. RMSSD

The root mean square of successive differences between normal heartbeats (RMSSD) is obtained by calculating each successive time difference between heartbeats in ms. The RMSSD reflects the beat-to-beat variance in HR and is the primary time-domain measure used to estimate the vagally mediated changes reflected in HRV.

2.5. Ethical Issues

Written informed consent was obtained from each subject with a form approved by the IRB committee of the Institute of Neurology and Neurosurgery, Havana, Cuba.

3. Results

The following Figures 1-5 show the continuous monitoring of the ANS assessment during memories of SCE.

The red arrows indicate the start and finish of remembering over seven minutes. When comparing basal vs. remembering records, there was a significant decrement of HF and an increment of HRV, measured by SDNN and RMSSD HRV variables. All SCR subjects referred to quietness and peace after finishing the record.

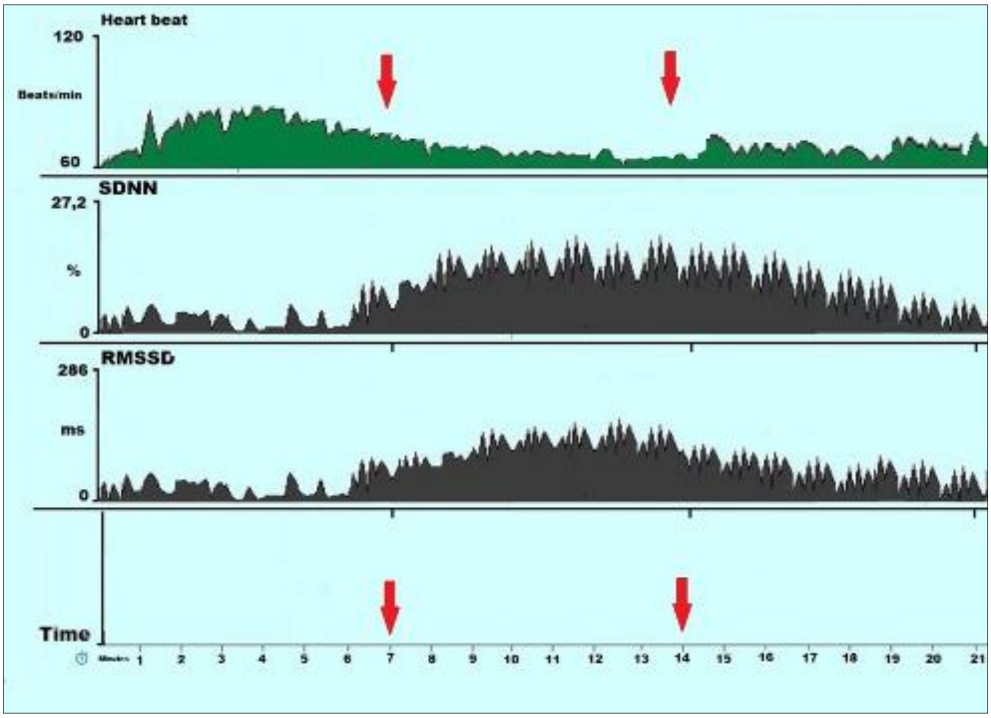

Figure 2 SCE – Case 1

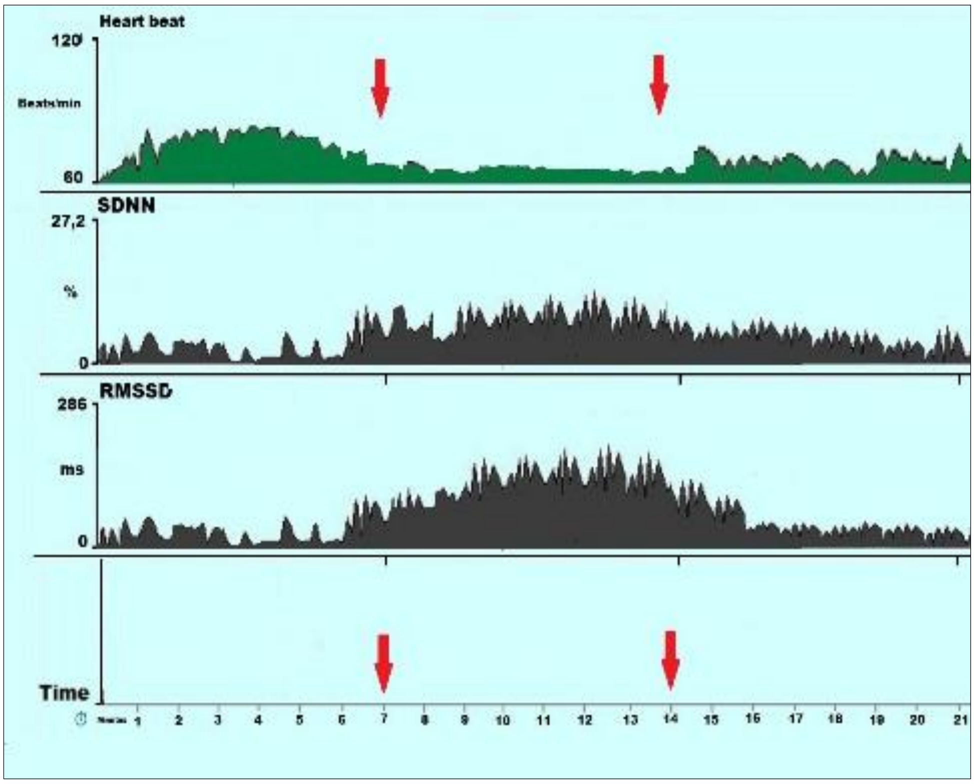

Figure 3 SCE – Case 2

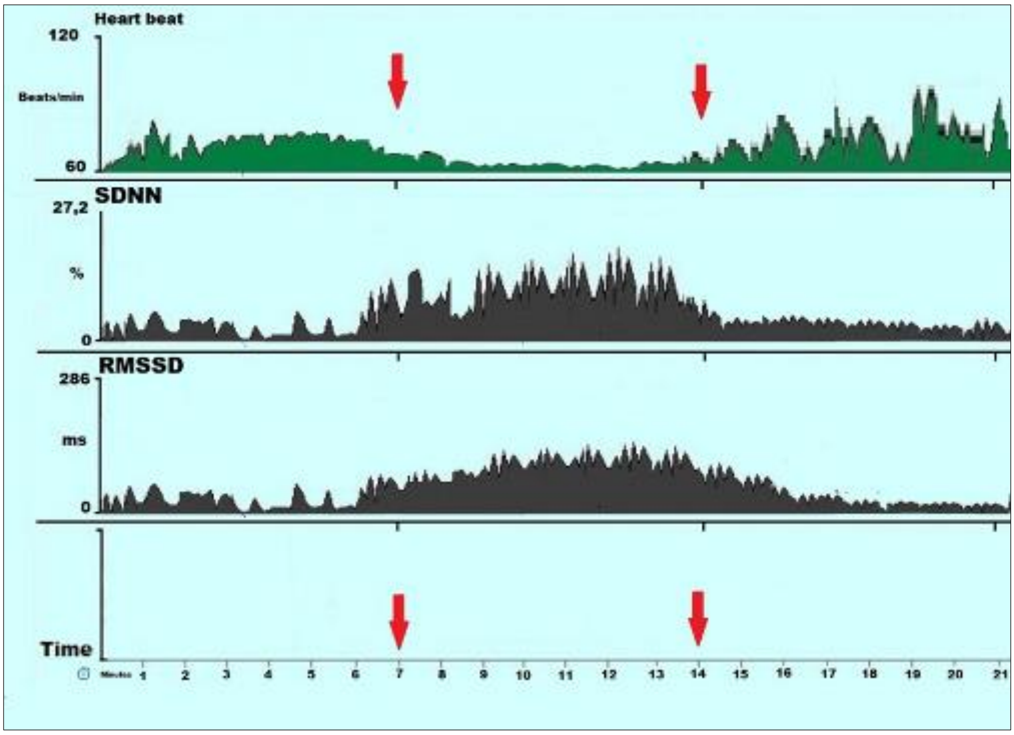

Figure 4 SCE – Case 3

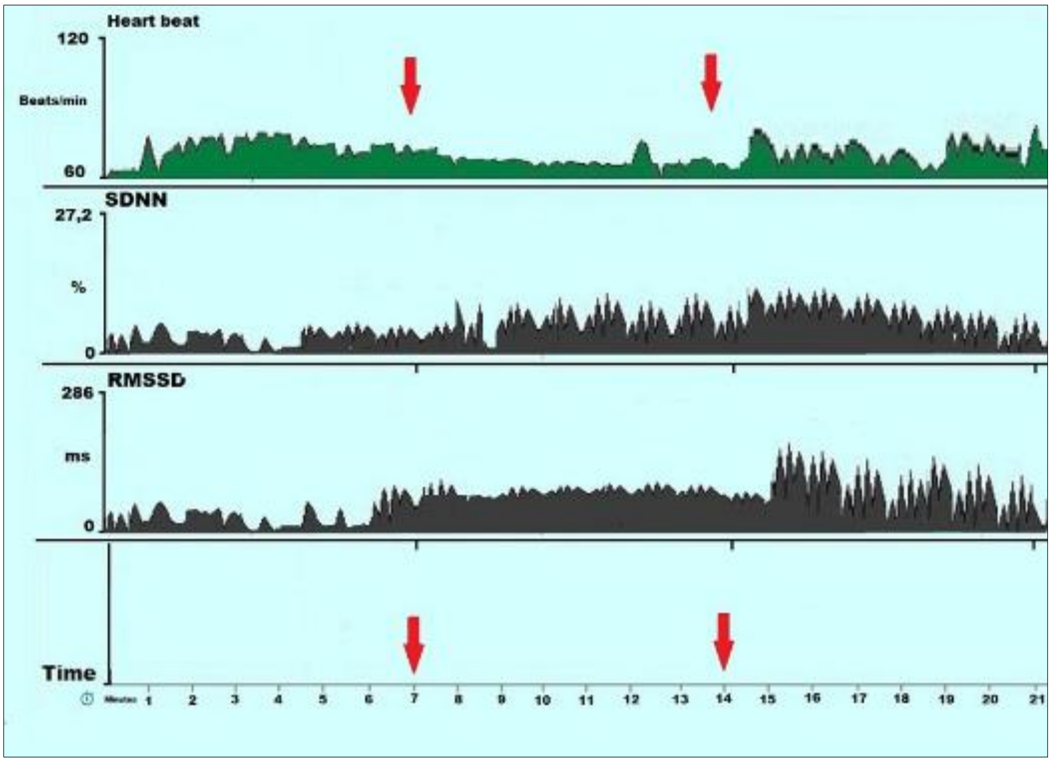

Figure 5 SCE – Case 5

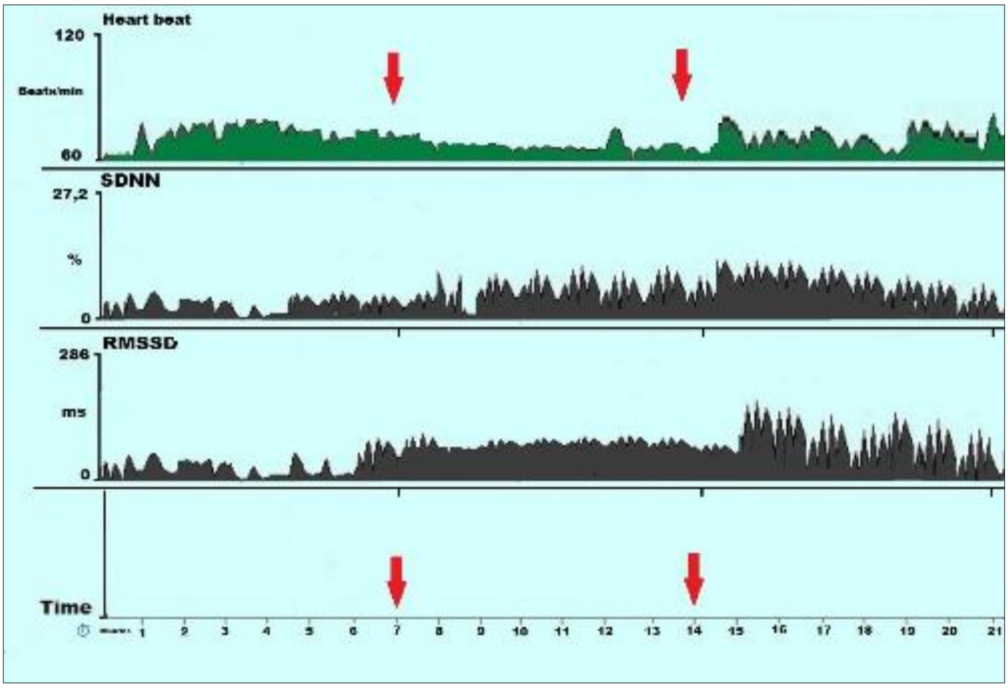

Figure 6 Case 5

Regarding NDE, in three cases (Figures 7-9), there was an increment of HF and a decrement in HRV. These subjects referred after finishing the record that when they remembered their NDE experience, they felt anxious and scared.

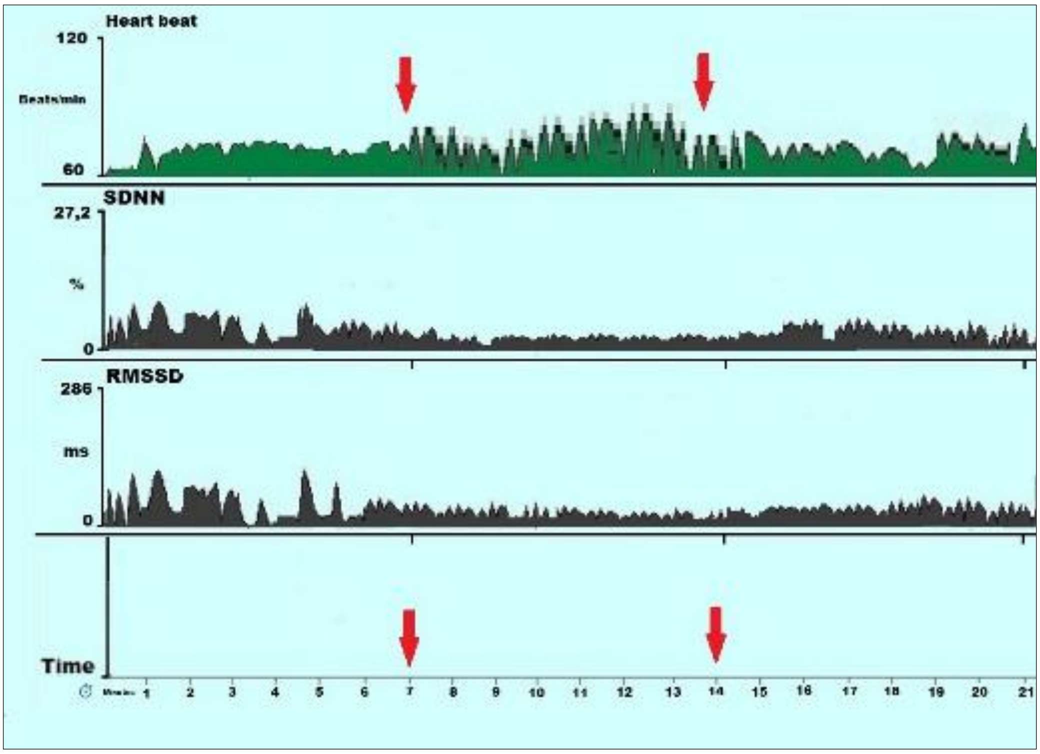

Figure 7 NDE - Case 1

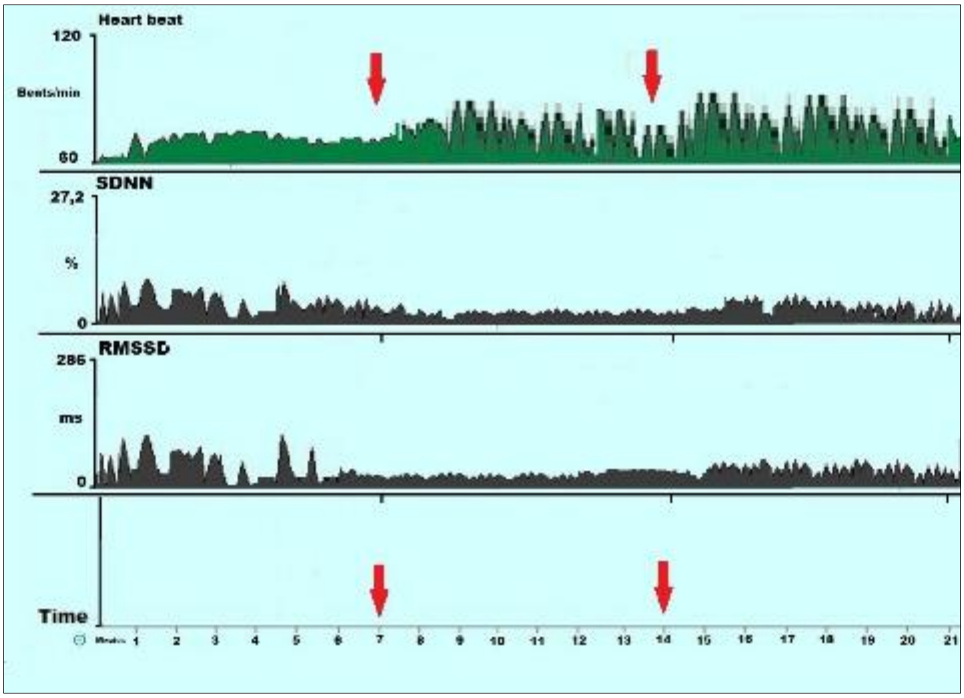

Figure 8 NDE – Case 2

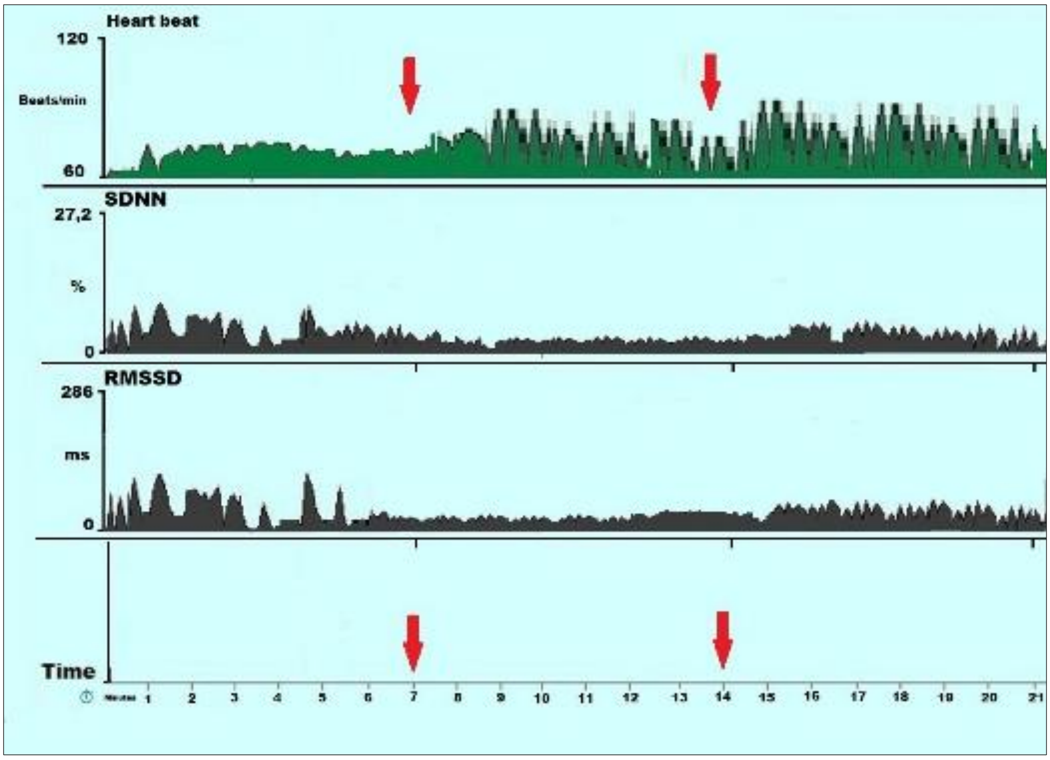

Figure 9 NDE - Case 3

The other 2 NDE subjects (Figures 5 and 6) presented similar changes in HF and HRV; i.e., comparing basal vs. remembering records, there was a significant decrement in HF and an increment in HRV. These subjects referred after finishing the record that when they remember their NDE, and felt quietness and peace.

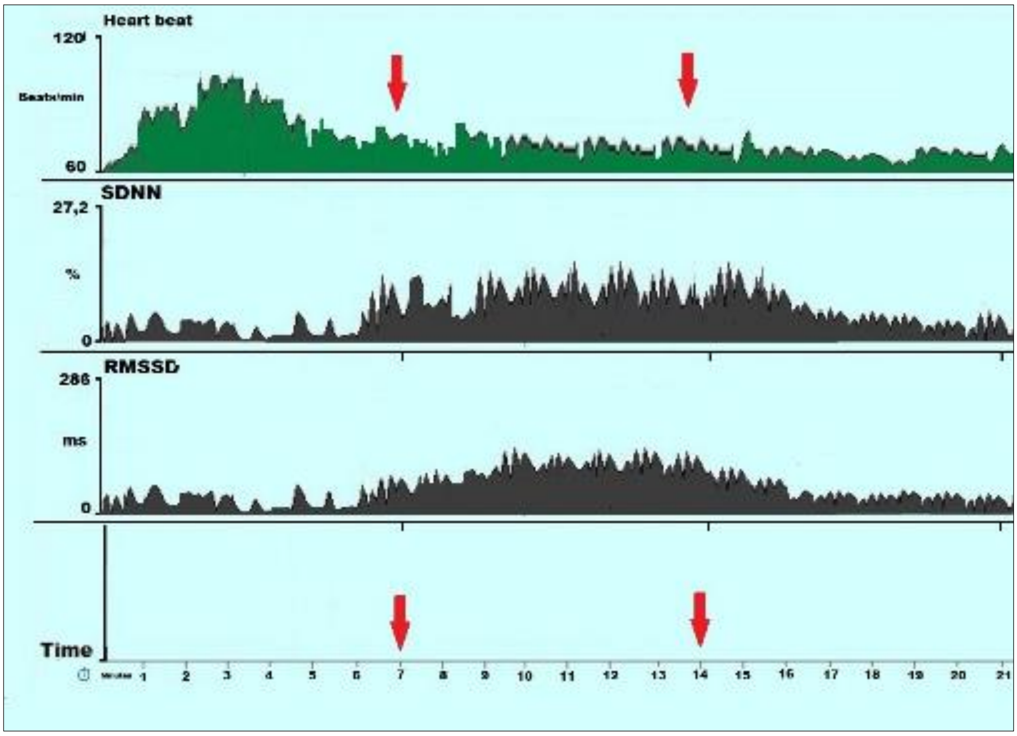

Figure 10 NDE – Case 4

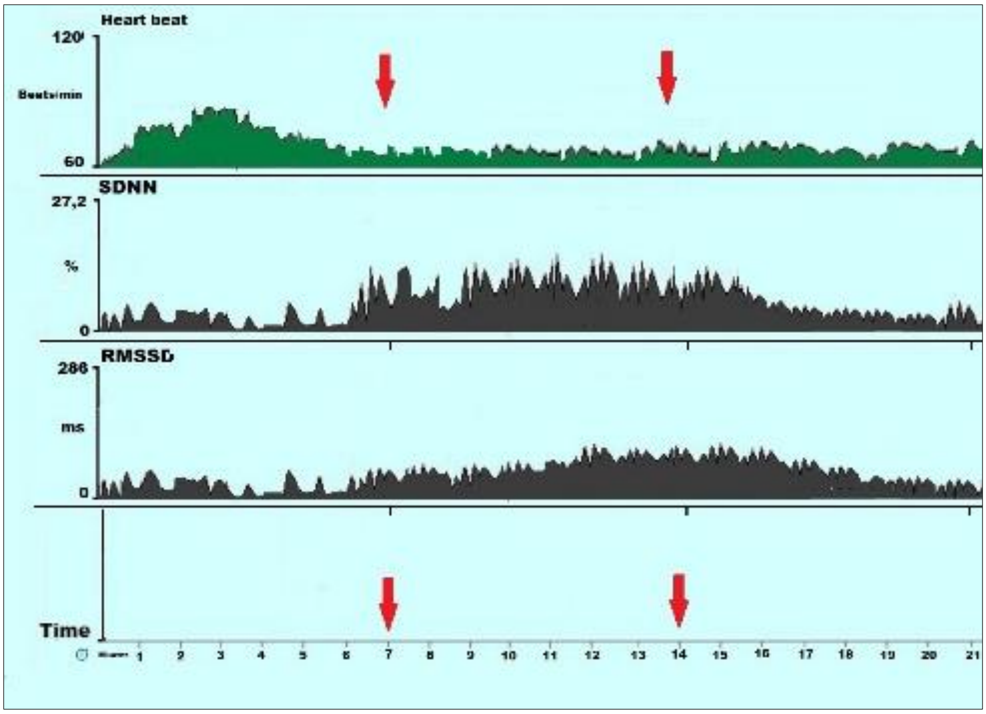

Figure 11 NDE - Case 5

4. Discussion

Neuronic CEEG-UCI has the necessary options for the detailed and specific analysis of neurological monitoring studies. Regarding the continuous assessment of the ANS, the system allows

- Automatic detection of artifacts according to different established criteria.
- Automatic detection of bradycardia, tachycardia, arrhythmia, asystole,
- Continuous calculation of HR.
- Continuous calculations of HRV variables. In this case, we selected two variables of the time dominium: SDNN and RMSS

4.1. HRV assessment for SCE and NDE

We found very interesting ANS changes during SCE and NDE remembering. In general, comparing basal vs. remembering records, there was a significant decrement of HF and an increment of HRV, measured by SDNN and RMSSD HRV variables. All SCR subjects referred to quietness and peace after finishing the record.

Regarding NDE, there was an increment in HR in three cases and a decrement in HRV. These subjects referred after finishing the record that when they remembered their NDE experience, they felt anxious and scared. The other two NDE subjects presented similar changes in HF and HRV; i.e., comparing basal vs. remembering records, there was a significant decrement in HF and an increment in HRV. After finishing the record, these subjects referred to when they remembered their NDE experiences and felt quietness and peace.

Some people who survived a life-threatening crisis reported an extraordinary and vivid NDE. Because of improved survival rates from modern resuscitation techniques, NDEs are reported more frequently. The content of NDEs and their effects on patients seem similar worldwide, across all cultures and times. The subjective nature and absence of a frame of reference for NDEs lead to individual, cultural and religious factors, which determine the vocabulary used to describe and interpret the experiences. NDEs are described in many circumstances: cardiac arrest in myocardial infarction, shock, electrocution; coma resulting from traumatic brain damage; intracerebral hemorrhage or cerebral infarction; near-drowning or asphyxia; and apnea.[77-82] Although these results cannot simply be correlated with human experiment, it suggests the brain's remaining activity may explain the NDE.[77-79]

As mentioned earlier from anecdotal observations, we occasionally found that when teaching CP to students, they relived their previous NDE experience during their CP. It became clear that the four attributes ascribed by Moody to NDEs also applied to SCEs: *paranormal* out-of-body, *cognitive* timelessness; *affective* peacefulness; *transcendent* divine. This was the case even when CP practitioners never had a previous NDE. Our neural correlate research seems to confirm this anecdotal observation.[8, 36, 83, 84]

Several studies have demonstrated that Mindfulness meditation can elicit a relaxation response using self-reports that are correlated with relaxation. Clinical stress reduction programs implementing mindfulness meditation have been shown to reduce stress and increase relaxation even after 4 to 5 weeks of training. [36, 83]

Transcendent meditation and Mindfulness meditation resulted in physiological changes indicative of a heightened activation of the parasympathetic nervous system and lowered sympathetic activity, such as decreased oxygen consumption and carbon dioxide elimination, lowered heart and respiratory rates, and marked relaxation. While finding effective methods of reducing stress and the risk of cardiovascular disease without drugs is promising, these studies have been relatively small. Larger studies with a more diverse population are necessary to confirm whether transcendental meditation is as powerful as these studies suggest.[39, 85-88]

4.2. Inward attention meditation

Some authors have emphasized that relaxing music provokes a decrease in HR and an increment of HRV based on parasympathetic activation. These authors emphasized that inward meditation appears to push the ANS balance to a parasympathetic predominance.[89, 90]

On the contrary, sometimes stress can seem more like a way of life. Chronic stress is ongoing stress that seems endless, such as a demanding job, difficult family life, or experiencing ongoing hardship. This type of stress is the most damaging to our health. With acute stress, the parasympathetic nervous system takes over once the perceived threat has passed, allowing us to relax and recover from the stressful event. However, during chronic stress, the body is continually exposed to the hormones that regulate stress. The system's natural feedback loop is interrupted. The relaxation response is not activated, and the pathway that regulates cortisol is shut down, rendering it unable to stop the stress's effects. The constant activation of the stress response leads to the negative health outcomes seen with chronic stress.[38, 91-94]

HRV increases during relaxing and recovering activities and decreases during stress. Accordingly, HRV is typically higher when the heart beats slowly and decreases as the heart beats more quickly. In other words, heart rate and HRV have a generally inverse relationship.[38, 93, 95-98]

This fact explains why during remembering SCE, HR decreased HRV meanwhile augmented in SCE. Two NDE cases showed similar findings. On the contrary, three NDE cases presented increased HR and decreased HRV. When these two cases remembered their NDE experiences, they felt scared and anxious.

Most near-death experiences (NDEs) reported publicly over the past four decades have been described as pleasant, even glorious. Almost unnoticed in the euphoria about them has been the sobering fact that not all NDEs are so affirming. However, some are deeply disturbing. Distressing NDEs occur under the same circumstances and feature the same elements as pleasant NDEs. What differs is the emotional tone, which ranges from fear through terror to, in some cases, guilt or despair. The reports typically lack two elements common in pleasant NDEs: a positive emotional tone and loss of the fear of death. Like the better-publicized pleasurable NDEs, distressing near-death experiences are both fascinating and frustrating as altered states of consciousness. Because of the deeply rooted beleifs of hell in Western culture and its Christian association with eternal physical torment, they pose serious challenges to the individuals who must shape their lives around such a profoundly durable event and to their families, friends, and physicians. In the absence of clear-cut clinical data and universal cultural views, physicians are advised that neutrality of opinion and careful listening are likely to constitute the best professional practice for addressing these difficult near-death experiences.[20, 99, 100]

Distressing NDEs might explain the finding in three NDE subjects who showed an increment of HR and a decrement of HRV.

Limitations

This study has some limitations, foremost the relatively small number of subjects. The subjective memorization of NDEs and SCEs may not adequately reflect past experience. The base case of not being asked to remember anything may not be as valid as being asked to remember something uneventful, such as peeling a banana. We plan to run future protocols to address these limitations.

5. Conclusion

We demonstrated the usefulness of using the CEEG methodology, which allows us to continuously assess the ANS through the HRV methodology, showing significant important functional changes in the autonomic nervous system (ANS), when comparing SCE and NDE.

Compliance with ethical standards

Acknowledgments

The Authors thank Fr. Gilberto Walker, who provided access to the hard-to identify subjects who had a SCE.

Disclosure of conflict of interest

The Authors report no conflicts of interest.

Statement of ethical approval

Written informed consent was obatained from each subject using a form approved by the IRB of the Institute of Neurology and Neurosurgery, Havana, cuba

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

References

[1] Sleutjes A, Moreira-Almeida A, Greyson B. Almost 40 years investigating near-death experiences: an overview of mainstream scientific journals. J Nerv Ment Dis 2014;202:833-836.

[2] Parnia S, Spearpoint K, de Vos G, et al. AWARE-AWAreness during REsuscitation-a prospective study. Resuscitation 2014;85:1799-1805.

[3] Palmieri A, Calvo V, Kleinbub JR, et al. "Reality" of near-death-experience memories: evidence from a psychodynamic and electrophysiological integrated study. Front Hum Neurosci 2014;8:429.

[4] Moore LE, Greyson B. Characteristics of memories for near-death experiences. Conscious Cogn 2017;51:116-124.

[5] Marty AT, Hilton FL, Spear RK, Greyson B. Postcesarean pulmonary embolism, sustained cardiopulmonary resuscitation, embolectomy, and near-death experience. Obstet Gynecol 2005;106:1153-1155.

[6] Martial C, Charland-Verville V, Dehon H, Laureys S. False memory susceptibility in coma survivors with and without a near-death experience. Psychol Res 2018;82:806-818.

[7] Martial C, Charland-Verville V, Cassol H, Didone V, Van Der Linden M, Laureys S. Intensity and memory characteristics of near-death experiences. Conscious Cogn 2017;56:120-127.

[8] Martial C, Cassol H, Charland-Verville V, et al. Neurochemical models of near-death experiences: A large-scale study based on the semantic similarity of written reports. Conscious Cogn 2019;69:52-69.

[9] Martial C, Cassol H, Charland-Verville V, Merckelbach H, Laureys S. Fantasy Proneness Correlates With the Intensity of Near-Death Experience. Front Psychiatry 2018;9:190.

[10] Martial C, Cassol H, Antonopoulos G, et al. Temporality of Features in Near-Death Experience Narratives. Front Hum Neurosci 2017;11:311.

[11] Lange R, Greyson B, Houran J. A Rasch scaling validation of a 'core' near-death experience. Br J Psychol 2004;95:161-177.

[12] Lai CF, Kao TW, Wu MS, et al. Impact of near-death experiences on dialysis patients: a multicenter collaborative study. Am J Kidney Dis 2007;50:124-132, 132 e121-122.

[13] Kondziella D, Olsen MH, Lemale CL, Dreier JP. Migraine aura, a predictor of near-death experiences in a crowdsourced study. PeerJ 2019;7:e8202.

[14] Kondziella D, Dreier JP, Olsen MH. Prevalence of near-death experiences in people with and without REM sleep intrusion. PeerJ 2019;7:e7585.

[15] Khanna S, Moore LE, Greyson B. Full Neurological Recovery From Escherichia coli Meningitis Associated With Near-Death Experience. J Nerv Ment Dis 2018;206:744-747.

[16] Khanna S, Greyson B. Near-Death Experiences and Posttraumatic Growth. J Nerv Ment Dis 2015;203:749-755.

[17] Khanna S, Greyson B. Near-death experiences and spiritual well-being. J Relig Health 2014;53:1605-1615.

[18] Greyson B, Long JP. Does the arousal system contribute to near death experience? Neurology 2006;67:2265; author reply 2265.

[19] Greyson B, Fountain NB, Derr LL, Broshek DK. Out-of-body experiences associated with seizures. Front Hum Neurosci 2014;8:65.

[20] Greyson B, Bush NE. Distressing near-death experiences. Psychiatry 1992;55:95-110.

[21] Greyson B. The near-death experience. Altern Ther Health Med 2008;14:14; author reply 14-15.

[22] Greyson B. Consistency of near-death experience accounts over two decades: are reports embellished over time? Resuscitation 2007;73:407-411.

[23] Machado C, Newberg A, Machado Y, Chinchilla M, Klesel D, Hesse R. Neural correlates of memories of near-death and mystical experiences preliminary research. World Journal of Advanced Research and Reviews 2022;(In press).

[24] Sharpe E, Lacombe A, Butler MP, Hanes D, Bradley R. A Closer Look at Yoga Nidra: Sleep Lab Protocol. Int J Yoga Therap 2020.

[25] Ganguly A, Hulke SM, Bharshanakar R, Parashar R, Wakode S. Effect of meditation on autonomic function in healthy individuals: A longitudinal study. J Family Med Prim Care 2020;9:3944-3948.

[26] Ruiz-Blais S, Orini M, Chew E. Heart Rate Variability Synchronizes When Non-experts Vocalize Together. Front Physiol 2020;11:762.

[27] Guddeti RR, Dang G, Williams MA, Alla VM. Role of Yoga in Cardiac Disease and Rehabilitation. J Cardiopulm Rehabil Prev 2019;39:146-152.

[28] Jones P. Mindfulness Training: Can It Create Superheroes? Front Psychol 2019;10:613.

[29] Kozhevnikov M. Enhancing Human Cognition Through Vajrayana Practices. J Relig Health 2019;58:737-747.

[30] Li D, Mabrouk OS, Liu T, et al. Asphyxia-activated corticocardiac signaling accelerates onset of cardiac arrest. Proc Natl Acad Sci U S A 2015;112:E2073-2082.

[31] Maas U, Strubelt S. Fatalities after taking ibogaine in addiction treatment could be related to sudden cardiac death caused by autonomic dysfunction. Med Hypotheses 2006;67:960-964.

[32] Neki NS, Singh RB, Rastogi SS. How brain influences neuro-cardiovascular dysfunction. J Assoc Physicians India 2004;52:223-230.

[33] Reader AL, 3rd. The internal mystery plays: the role and physiology of the visual system in contemplative practices. Altern Ther Health Med 1995;1:54-63.

[34] Strubelt S, Maas U. The near-death experience: a cerebellar method to protect body and soul-lessons from the Iboga healing ceremony in Gabon. Altern Ther Health Med 2008;14:30-34.

[35] Bos EM, Spoor JKH, Smits M, Schouten JW, Vincent A. Out-of-Body Experience During Awake Craniotomy. World Neurosurg 2016;92:586 e589-586 e513.

[36] Saver JL, Rabin J. The neural substrates of religious experience. J Neuropsychiatry Clin Neurosci 1997;9:498-510.

[37] Mojtabavi H, Saghazadeh A, Valenti VE, Rezaei N. Can music influence cardiac autonomic system? A systematic review and narrative synthesis to evaluate its impact on heart rate variability. Complement Ther Clin Pract 2020;39:101162.

[38] Bashir MU, Bhagra A, Kapa S, McLeod CJ. Modulation of the autonomic nervous system through mind and body practices as a treatment for atrial fibrillation. Rev Cardiovasc Med 2019;20:129-137.

[39] Blase KL, van Waning A. Heart Rate Variability, Cortisol and Attention Focus During Shamatha Quiescence Meditation. Appl Psychophysiol Biofeedback 2019;44:331-342.

[40] Muzik O, Diwadkar VA. Hierarchical control systems for the regulation of physiological homeostasis and affect: Can their interactions modulate mood and anhedonia? Neurosci Biobehav Rev 2019;105:251-261.

[41] Lo PC, Tsai PH, Kang HJ, Miao Tian WJ. Cardiorespiratory and autonomic-nervous-system functioning of drug abusers treated by Zen meditation. J Tradit Complement Med 2019;9:215-220.

[42] Seara FAC, Pereira-Junior PP, Silva-Almeida C, et al. Anabolic steroid excess promotes hydroelectrolytic and autonomic imbalance in adult male rats: Is it enough to alter blood pressure? Steroids 2020;163:108711.

[43] Yeung A, Chan JSM, Cheung JC, Zou L. Qigong and Tai-Chi for Mood Regulation. Focus (Am Psychiatr Publ) 2018;16:40-47.

[44] Newberg AB, Iversen J. The neural basis of the complex mental task of meditation: neurotransmitter and neurochemical considerations. Med Hypotheses 2003;61:282-291.

[45] Palma S, Keilani M, Hasenoehrl T, Crevenna R. Impact of supportive therapy modalities on heart rate variability in cancer patients - a systematic review. Disabil Rehabil 2020;42:36-43.

[46] Machado C, Estevez-Baez M. Methodologic and Standardized Procedures to Assess the Autonomic Nervous System in Coma by the Heart Rate Variability Methodology. Pediatr Crit Care Med 2020;21:782.

[47] Adjei T, von Rosenberg W, Nakamura T, Chanwimalueang T, Mandic DP. The ClassA Framework: HRV Based Assessment of SNS and PNS Dynamics Without LF-HF Controversies. Front Physiol 2019;10:505.

[48] Machado D, Farias Junior LF, Nascimento P, et al. Can interoceptive accuracy influence maximal performance, physiological and perceptual responses to exercise? Physiol Behav 2019;204:234-240.

[49] Estevez-Baez M, Machado C, Garcia-Sanchez B, et al. Autonomic impairment of patients in coma with different Glasgow coma score assessed with heart rate variability. Brain Inj 2019;33:496-516.

[50] Estevez-Baez M, Carricarte-Naranjo C, Jas-Garcia JD, et al. Influence of Heart Rate, Age, and Gender on Heart Rate Variability in Adolescents and Young Adults. Adv Exp Med Biol 2019;1133:19-33.

[51] Machado C, Estevez M, Rodriguez-Rojas R. Zolpidem efficacy and safety in disorders of consciousness. Brain Inj 2018;32:530-531.

[52] Hidalgo-Munoz AR, Mouratille D, Matton N, Causse M, Rouillard Y, El-Yagoubi R. Cardiovascular correlates of emotional state, cognitive workload and time-on-task effect during a realistic flight simulation. Int J Psychophysiol 2018;128:62-69.

[53] Estevez-Baez M, Machado C, Montes-Brown J, et al. Very High Frequency Oscillations of Heart Rate Variability in Healthy Humans and in Patients with Cardiovascular Autonomic Neuropathy. Adv Exp Med Biol 2018;1070:49-70.

[54] Candido N, Okuno NM, da Silva CC, Machado FA, Nakamura FY. Reliability of the Heart Rate Variability Threshold using Visual Inspection and Dmax Methods. Int J Sports Med 2015;36:1076-1080.

[55] Machado-Ferrer Y, Estevez M, Machado C, et al. Heart rate variability for assessing comatose patients with different Glasgow Coma Scale scores. Clin Neurophysiol 2013;124:589-597.

[56] Sant'Ana LO, Machado S, Ribeiro AAS, et al. Effects of Cardiovascular Interval Training in Healthy Elderly Subjects: A Systematic Review. Front Physiol 2020;11:739.

[57] Gerritsen RJS, Band GPH. Breath of Life: The Respiratory Vagal Stimulation Model of Contemplative Activity. Front Hum Neurosci 2018;12:397.

[58] Chu IH, Wu WL, Lin IM, Chang YK, Lin YJ, Yang PC. Effects of Yoga on Heart Rate Variability and Depressive Symptoms in Women: A Randomized Controlled Trial. J Altern Complement Med 2017;23:310-316.

[59] da Silva WQA, Fontes EB, Forti RM, et al. Affect during incremental exercise: The role of inhibitory cognition, autonomic cardiac function, and cerebral oxygenation. PLoS One 2017;12:e0186926.

[60] Fiorentini A, Ora J, Tubani L. Autonomic system modification in Zen practitioners. Indian J Med Sci 2013;67:161-167.

[61] Smith AL, Owen H, Reynolds KJ. Heart rate variability indices for very short-term (30 beat) analysis. Part 2: validation. J Clin Monit Comput 2013;27:577-585.

[62] Soni R, Muniyandi M. Breath Rate Variability: A Novel Measure to Study the Meditation Effects. Int J Yoga 2019;12:45-54.

[63] Leonard A, Clement S, Kuo CD, Manto M. Changes in Heart Rate Variability During Heartfulness Meditation: A Power Spectral Analysis Including the Residual Spectrum. Front Cardiovasc Med 2019;6:62.

[64] Telles S, Singh D, Naveen KV, Pailoor S, Singh N, Pathak S. P300 and Heart Rate Variability Recorded Simultaneously in Meditation. Clin EEG Neurosci 2019;50:161-171.

[65] Farinatti P, Cordeiro R, Vogel M, Machado S, Monteiro W. Postexercise blood pressure and autonomic responses after aerobic exercise following anodal tDCS applied over the medial prefrontal cortex. Neurosci Lett 2019;711:134444.

[66] Novak V, Saul JP, Eckberg DL. Task Force report on heart rate variability. Circulation 1997;96:1056-1057.

[67] Lagi A, Tamburini C, Cipriani M, Fattorini L. Vagal control of heart rate variability in vasovagal syncope: studies based on 24-h electrocardiogram recordings. Clin Auton Res 1997;7:127-130.

[68] Heart rate variability. Standards of measurement, physiological interpretation, and clinical use. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. Eur Heart J 1996;17:354-381.

[69] Krone RJ. The role of risk stratification in the early management of a myocardial infarction. Ann Intern Med 1992;116:223-237.

[70] Machado C, Cuspineda E, Valdes P, et al. Assessing acute middle cerebral artery ischemic stroke by quantitative electric tomography. Clin EEG Neurosci 2004;35:116-124.

[71] Cuspineda-Bravo ER, Martinez-Montes E, Farach-Fumero M, Machado-Curbelo C. Improving electroencephalographic source localization of epileptogenic zones with time-frequency analysis. Clin EEG Neurosci 2015;46:153-168.

[72] Cuspineda ER, Machado C, Virues T, et al. Source analysis of alpha rhythm reactivity using LORETA imaging with 64-channel EEG and individual MRI. Clin EEG Neurosci 2009;40:150-156.

[73] Cuspineda E, Machado C, Galan L, et al. QEEG prognostic value in acute stroke. Clin EEG Neurosci 2007;38:155-160.

[74] Cuspineda E, Machado C, Aubert E, Galan L, Llopis F, Avila Y. Predicting outcome in acute stroke: a comparison between QEEG and the Canadian Neurological Scale. Clin Electroencephalogr 2003;34:1-4.

[75] Cuspineda Bravo ER, Iturria Y, Praderes JC, et al. Non-invasive multimodal neuroimaging for Rasmussen encephalopathy surgery: simultaneous EEG-fMRI recording. Clin EEG Neurosci 2010;41:159-165.

[76] Bravo EC, Martinez-Montes E, Farach-Fumero M, Machado-Curbelo C. Computing sources of epileptic discharges using the novel BMA approach: comparison with other distributed inverse solution methods. Clin EEG Neurosci 2013;44:3-15.

[77] van Lommel P, van Wees R, Meyers V, Elfferich I. Near-death experience in survivors of cardiac arrest: a prospective study in the Netherlands. Lancet 2001;358:2039-2045.

[78] van Lommel P. Getting Comfortable With Near-Death Experiences: Dutch Prospective Research on Near-Death Experiences During Cardiac Arrest. Mo Med 2014;111:126-131.

[79] van Lommel P. Near-death experiences: the experience of the self as real and not as an illusion. Ann N Y Acad Sci 2011;1234:19-28.

[80] Tippett K, Metzinger T, Thompson E, van Lommel P. To be or not to be: the self as illusion. Ann N Y Acad Sci 2011;1234:5-18.

[81] Sharma N, Pokharel SS, Kohshima S, Sukumar R. Behavioural responses of free-ranging Asian elephants (Elephas maximus) towards dying and dead conspecifics. Primates 2020;61:129-138.

[82] Panditrao MM, Singh C, Panditrao MM. An unanticipated cardiac arrest and unusual post-resuscitation psycho-behavioural phenomena/near death experience in a patient with pregnancy induced hypertension and twin pregnancy undergoing elective lower segment caesarean section. Indian J Anaesth 2010;54:467-469.

[83] Simpson SM. Near death experience: a concept analysis as applied to nursing. J Adv Nurs 2001;36:520-526.

[84] Athappilly GK, Greyson B, Stevenson I. Do prevailing societal models influence reports of near-death experiences?: a comparison of accounts reported before and after 1975. J Nerv Ment Dis 2006;194:218-222.

[85] Adler-Neal AL, Waugh CE, Garland EL, Shaltout HA, Diz DI, Zeidan F. The Role of Heart Rate Variability in Mindfulness-Based Pain Relief. J Pain 2020;21:306-323.

[86] Burgstahler MS, Stenson MC. Effects of guided mindfulness meditation on anxiety and stress in a pre-healthcare college student population: a pilot study. J Am Coll Health 2020;68:666-672.

[87] Cahn BR, Goodman MS, Peterson CT, Maturi R, Mills PJ. Yoga, Meditation and Mind-Body Health: Increased BDNF, Cortisol Awakening Response, and Altered Inflammatory Marker Expression after a 3-Month Yoga and Meditation Retreat. Front Hum Neurosci 2017;11:315.

[88] Carlson LE, Speca M, Faris P, Patel KD. One year pre-post intervention follow-up of psychological, immune, endocrine and blood pressure outcomes of mindfulness-based stress reduction (MBSR) in breast and prostate cancer outpatients. Brain Behav Immun 2007;21:1038-1049.

[89] Wu SD, Lo PC. Inward-attention meditation increases parasympathetic activity: a study based on heart rate variability. Biomed Res 2008;29:245-250.

[90] Wu SD, Lo PC. Cardiorespiratory phase synchronization during normal rest and inward-attention meditation. Int J Cardiol 2010;141:325-328.

[91] Azam MA, Katz J, Fashler SR, Changoor T, Azargive S, Ritvo P. Heart rate variability is enhanced in controls but not maladaptive perfectionists during brief mindfulness meditation following stress-induction: A stratified-randomized trial. Int J Psychophysiol 2015;98:27-34.

[92] Azam MA, Katz J, Mohabir V, Ritvo P. Individuals with tension and migraine headaches exhibit increased heart rate variability during post-stress mindfulness meditation practice but a decrease during a post-stress control condition - A randomized, controlled experiment. Int J Psychophysiol 2016;110:66-74.

[93] Basavaraj KH, Navya MA, Rashmi R. Stress and quality of life in psoriasis: an update. Int J Dermatol 2011;50:783-792.

[94] Behringer M, Montag J, Franz A, McCourt ML, Mester J, Nosaka KK. Exhaustive exercise--a near death experience for skeletal muscle cells? Med Hypotheses 2014;83:758-765.

[95] Lumma AL, Kok BE, Singer T. Corrigendum to "Is meditation always relaxing? Investigating heart rate, heart rate variability, experienced effort and likeability during training of three types of meditation" [Int. J. Psychophysiol. 97/1 (2015) 38-45]. Int J Psychophysiol 2017;117:126-130.

[96] Lumma AL, Kok BE, Singer T. Is meditation always relaxing? Investigating heart rate, heart rate variability, experienced effort and likeability during training of three types of meditation. Int J Psychophysiol 2015;97:38-45.

[97] Shenefelt PD. Relaxation strategies for patients during dermatologic surgery. J Drugs Dermatol 2010;9:795-799.

[98] Auxemery Y. The "near-death experience" during comas: psychotraumatic suffering or the taming of reality? Med Hypotheses 2013;81:379-382.

[99] Bush NE, Greyson B. Distressing near-death experiences: the basics. Mo Med 2014;111:486-490.

[100] Duggleby WD, Penz K, Leipert BD, Wilson DM, Goodridge D, Williams A. 'I am part of the community but...' The changing context of rural living for persons with advanced cancer and their families. Rural Remote Health 2011;11:1733.