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

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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

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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. 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 parasympathetic nervous system is often called the "fight or flight" system, which accelerates the heart rate, constrains 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 nervous 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.

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.

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.

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.

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, the parasympathetic nervous system (PNS) is stimulated, leading to decreased heart rate, decreased contractility, and decreased excitability of the SA node. However, during exercise, the SNS is stimulated, increasing heart rate, contractility, and excitability of the SA node. These two systems often elicit opposing actions, and the heart rate reflects the balance between the two systems. 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.

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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 heart rate (HR) and heart rate variability (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.
2.4. CEEG Assessment

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
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.
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.
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
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. Although these results cannot simply be correlated with human experiment, it suggests the brain’s remaining activity may explain the NDE.

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.

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.

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.

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.
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.\(^{38, 93-98}\)

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 beliefs 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**

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**Disclosure of conflict of interest**

The Authors report no conflicts of interest.

**Statement of ethical approval**

Written informed consent was obtained 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.

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