v. 2, n. 42, 2022

International Journal of Health Science

CORRELATION BETWEEN SELF-PERCEPTION OF ANXIETY AND AUTONOMIC RESPONSE IN PEOPLE WITH VESTIBULAR DISORDERS

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Abstract: Background: Vestibular system has several connections with other systems of the organism, as it happens with the limbic system, which is in charge of emotion regulation. Therefore, anxiety is a common complaint by people with vestibular disorders. The autonomic nervous system activity is considered as a major component of anxiety response, usually characterized by sympathetic activation and parasympathetic inhibition. We aimed to determine the correlation of anxiety self-perception scales with autonomic response in people with vestibular disorders at rest state and during virtual reality stimulation. **Methods:** This study included 26 people with vestibular disorders and a control group were matched by genre and age. Two 360° virtual reality videos were used as a stimulus for autonomic function (heart rate variability and galvanic skin response) recording and anxiety subjective interpretation. **Results**: People with vestibular disorders presented sympathetic activation significantly higher both at rest and in exposure to virtual reality compared to control group. The Spearman Coefficient made evident in the study group a negative correlation between the indicators of the sympathetic activity and the scales of self-perception, as well as a positive correlation between the variables of parasympathetic activity and the inventory of anxiety. In the control group significant correlations were not found. **Conclusion**: The opposite correlation between the analyzed variables suggests that autonomic response was not consistent with subjective interpretation of anxiety in people with vestibular disorders, although the greater markers of physiological anxiety determined through sympathetic activity were evident.
Keywords: Vestibular diseases, autonomic nervous system, anxiety.

INTRODUCTION

People with vestibular disorders present multiple co-morbidities which significantly impact their quality of life. Traditionally, the evaluation and treatment of these patients has been focused on primary organic illness, minimizing the importance of secondary factors like anxiety (Cruz et al, 2014). The vestibular dysfunction and the anxiety are intimately related due to the neurophysiological connection between vestibular and limbic system (Rajagopalan et al, 2017). The link between both systems is complex and bidirectional, as a result, people with anxiety and other psychiatric disorders frequently present vestibular symptoms such as dizziness. In the same manner, those with vestibular dysfunctions experience higher levels of anxiety compared to general population (Balaban and Thayer, 2001; Gamba, 2018).

Anxiety is a warning system that prepares individuals to physically confront any potential threat, in this case, vertigo episodes (Barton et al 2014). The Autonomic Nervous System (ANS) is considered to be the greatest component of the peripheral nervous system, it can exert influence on the emotional response as occurs during anxiety crisis (Kreibig, 2010). The ANS adapts the appropriate behavioral response to the stressful stimuli, which is known as the fight or flight response. Emotional arousal generally implies the activation of the Sympathetic Nervous System (SNS) and the inhibition of the Parasympathetic Nervous System (PNS), producing various physiological changes (Stephens, Christie and Friedman, 2010). Autonomic response includes changes in the heart activity that leads to a rise in heart rate, also, changes on the sweat glands which ends up in an increase of sweating (Kushki et al, 2013).

The ANS activity can be measured through different tests such as the Galvanic

Skin Response (GSR) and the Heart Rate Variability (HRV). The GSR is a physiological measure of the skin electrical properties, it is regulated by the sweat glands and is strongly linked with the activity of the SNS (Tarvainen et al, 2001). The GSR comprises skin resistance and skin conductance. The first one, refers to the opposition to electrical current flow, whereas the second one makes reference to the ease by which current flows (Dawson, Schell and Filion, 2007). In the sweat secretion that goes along with anxiety crisis, the permeability of the cellular membrane increases and makes easier ion exchange, enhancing the skin conductivity and, therefore, decreasing its resistance (Benedek and Kaernbach, 2010).

Furthermore, HRV is the temporal variation between consecutive heartbeats (Acharya et al, 2006). The period between adjacent QRS complexes of the electrocardiogram is called R-R interval. HRV is the measurement of the changes in R-R intervals that are produced due to the ongoing variations in the SNS and PNS equilibrium, generating that the sinus node presents fluctuations around average resting heart rate (Mccraty and Shaffer, 2015). Thus, the inotropic and chronotropic effects in cardiac function could increase or decrease this variability. If heart rate decreases, the HRV increases and, conversely, if heart rate increases, the HRV decreases (Veloza et al, 2019). Nowadays, variations of R-R intervals can be quantified through techniques that supply indexes which reflect the cardiac autonomic modulation (Bilchick and Berger, 2006).

On the one hand, physiological measurements have been developed to evaluate autonomic symptoms accompanying vertigo such as nausea, vomiting and tachycardia, leaving aside the anxiety. On the other hand, studies that have determined the anxiety level, have been characterized by subjectivity, due to the use of different self-report scales to establish the degree of emotional severity. In this sense, if both, physiological records and self-reported scales are involved, a deeper knowledge of the emotional affection by the anxiety is possible and contributes to interdisciplinary management in a timely manner. For this reason, the purpose of this study was to determine the correlation between the subjective interpretation of the anxiety level and the physiological recording of parameters linked to the autonomic response, generated by virtual reality stimuli.

MATERIALS AND METHODS

PARTICIPANTS

This investigation was revised and approved by Ethics Committee of Faculty of Medicine, National University of Colombia. Fifty-two participants were included in this study, all signed the informed consent. The experimental group consisted of people with vestibular disorders (n=26, average age 34 years, range 21 – 53 years) and the control group included people without preceding vertigo or dizziness (n=26, average age 33,2 years, range 22-53 years). Both groups were matched by genre 18 women and 8 men. Inclusion criteria included: (1) range of age 18 to 55 years, (2) history and diagnosis of any type of vestibular disorder (peripheral, central or mixed) by otorhinolaryngology and/or neurology and (3) presence of vertigo symptoms in the screening tests. The exclusion criteria were: (1) central nervous, cardiovascular and/or pulmonary system diseases, (2) diagnosis of phobic postural vertigo, psychogenic vertigo or persistent postural-perceptual dizziness, (3) psychological therapy and/or vestibular rehabilitation, (4) pharmacological treatment for anxiety and/or for vestibular disorder and, (5) perimenopause and/or hormone replacement therapy (in the case of women).

Due to the influence of the female sexual hormones on the cardiac autonomic function, most studies have been reported a parasympathetic predominance in the follicular phase and a sympathetic predominance in the luteal phase of the menstrual cycle (Vishrutha, 2012; Tenan,2014; Brar, Singh and Kumar 2015; Yazar and Yazıcı, 2016). For this reason, it was decided to homogenize the measurement of women in the follicular phase, exactly, between the fifth and the eighth day of their menstrual cycle. Based on the premise that manifestation of anxiety symptoms is caused by a marked activity of the SNS, with this homogenization the bias of attribution of anxiety symptoms due to female hormonal control is reduced.

MATERIALS

Virtual reality videos

Video 1 (V1): Represents a tour through the interior of a two-floor house beginning by the dining room and the living room in the first floor, then going upstairs and, ultimately, a hallway on the second floor leading to a room. Finally, the video goes back to its starting point through a reverse effect. It lasts 2 minutes.

Video 2 (V2). Represents an experience in a water slide which makes a route by the city, a lake, a jungle, a desert and, finally a crowded stadium. It is characterized by having ups and downs and sharp curves, moments of high and low speed, environments visually neutral alternated with other very shining. It lasts 4.20 minutes.

Physiological-autonomic register

VerimLab. 3.0: Software for monitoring and providing feedback of the GSR in real time with bipolar sensor for the representation of the psychological activation level.

LabChart 8.1.11: Software that allows acquisition and recording of the electrocardiogram by means of a module which automatically reports the outset and the amplitude of the PQRST complex.

Kubios HRV Standard 3.1.0: Software for the analysis of time-domain, frequency-domain and non-linear HRV parameters by means of the R-R intervals extracted from the electrocardiogram (Tarvainen et al, 2014).

Self-perception Scales

Vertigo Symptoms Scale (VSS): It is a self-reported questionnaire that evaluates the gravity of the vertigo symptoms through a period of one year. It is composed of two subscales: the vertigo subscale (VSS-VER) which measures the symptoms associated to the vestibular system disorders, and the autonomic/anxiety symptoms subscale (VSS-AA) that measures generic symptoms caused by autonomic excitation and/or of somatic anxiety (Kamalvand, Ghahraman and Jalaie, 2017).

Beck Anxiety Inventory (BAI): It is a self-reported questionnaire that determines the gravity of the anxious symptomatology from an emotional, physiological and cognitive aspect. Each item chooses an anxiety symptom and for each of them the degree of affectation must be assessed during the last week. It has been accepted for measuring anxiety in adults and adolescents, in either, clinical or research settings (Magán, Sanz and Paz, 2008).

PROCEDURE

For the data collection with each video, four phases were carried out: preparation, rest, stimulation and recovery. The time interval between the presentation of one video and another was 30 minutes. The procedure for each phase was as follows:

Phase I - Preparation: Galvanometer sensors were placed in the non-dominant hand and electrocardiogram electrodes in the second derivation. The participant was placed in a sitting position at 90° and was asked to fill out the BAI considering his emotional state at that moment (pre-stimulation).

Phase II - Resting state: Participant was asked to be as calm and relaxed as possible, to avoid the appearance of artifacts. Electrocardiographic and galvanic skin recordings were started and remained active for a period of 5 minutes to get a baseline.

Phase III - Stimulation: Participant wore virtual reality glasses along with headphones to provide a visual and hearing experience of the videos. Presentation of virtual reality video began. Recording was continued uninterrupted.

Phase IV - Recovery: Virtual reality glasses were removed and the recording continued until the person reached their former physiological excitation level. This was determined by real-time feedback from the galvanometry software for a maximum time of 5 minutes. Subject was asked to fill out the BAI again taking into consideration his experience with the videos.

Finally, it is important to clarify that the VSS was performed only by the study group before the measurement, at the time of anamnesis. For the data analysis of the self-perception scales the VSS-AA was used along with the BAI.

STATISTICAL ANALYSES

Non-parametric tests were made as follows: For the correlation analysis between the objective (autonomic response) and subjective (self-perception scales) variables of each group the Spearman Rank Coefficient was used and, for the analysis of data comparison between the groups, Wilcoxon Signed-Ranks test was used. Additionally, for the estimation of the anxiety level and the vertigo of the self-perception scales Item Response Theory (IRT) was used.

All analysis was made with R software. Numerical variables were described using the mean and the standard deviation (in parentheses). P-value < 0.05 was considered statistically significant (in boldface).

RESULTS

Taking into account that HRV variables are diverse, three variables were selected for analysis as parasympathetic activity indicators and three as sympathetic indicators, as described below. (Table 1).

When comparing the results of the most representative components of the HRV (Table 2), it can be considered that, although only statistically significant differences were found in HF and LF variables at rest and given the stimulation with V2 between the two groups, the overall trend of data in the four states shows a larger mean in the vertigo group for sympathetic activity indicators and, in turn, a higher mean in the control group for parasympathetic activity markers. This suggests, a high level of physiological anxiety determined by the sympathetic predominance in the study group.

Regarding to the GSR, it can be seen that, although the mean of two groups is negative in both videos, that is, skin resistance predominates skin conductance, it is evident that in the control group is much larger. With regard to the recovery phase, the time taken (in seconds) by the vertigo group to achieve a physiological restoration was longer, indicating more chronic anxiety levels.

According to the IRT and taking into account the mean of groups, people with vestibular disorders hold positive traces of anxiety, both at rest and in stimulation with the two videos, which suggests constant levels of anxiety throughout the measurement. The control group has negative traces at rest and positive at stimulation, hence, the significant statistical difference with the study group

Predominance	Variable	Definition	Unity
Parasympathetic	RMSSD	Root Mean Square of the Successive R-R interval Differences	ms
	HF	High Frequency: refers to HRV frequency band, by default 0.15-0.4 Hz	n.u.
	CVI	Cardiac Vagal Index: Poincaré plot long term variability / Poincaré plot short term variability	n.u.
Sympathetic	LF	Low Frequency: refers to HRV frequency band, by default 0.04-0.15 Hz	n.u.
	CSI	Cardiac Sympathetic Index: Log_{10} Poincaré plot short term variability x Poincaré plot long term variability	n.u.
	Stress	Square root of Baevsky's stress index	--

Note: nu: normalized unit; ms: millisecond.

Table 1. HRV variables.

State	Variable	P-value	Vertigo group	Control group
Resting V_1	RMSSD	0.6148	32.77 (21.58)	34.96 (24.11)
	HF	0.6605	41.37 (22.21)	44.95 (25.14)
	CVI	0.5337	2.82 (0.60)	2.91 (0.54)
	LF	0.6539	58.59 (22.23)	55.00 (22.15)
	CSI	0.728	2.73 (2.63)	2.19 (0.77)
	Stress	0.9562	13.98 (5.97)	14.43 (8.60)
Stimulation V_1	RMSSD	0.5218	34.54 (24.13)	35.43 (21.55)
	HF	0.3011	48.67 (23.40)	54.27 (22.13)
	CVI	0.6211	2.87 (0.51)	2.91 (0.49)
	LF	0.2926	51.30 (23.40)	45.61 (22.13)
	CSI	0.6538	2.07 (0.68)	1.91 (0.53)
	Stress	0.5398	15.47 (6.51)	15.01 (8.04)
Resting V_2	RMSSD	0.7349	34.08 (21.73)	34.20 (20.23)
	HF	**0.03728**	**38.31 (21.19)**	**50.27 (20.81)**
	CVI	0.8691	2.91 (0.49)	2.90 (0.51)
	LF	**0.03813**	**61.67 (21.21)**	**49.62 (20.82)**
	CSI	0.8333	2.12 (0.83)	2.03 (0.61)
	Stress	0.8836	13.27 (5.54)	14.02 (8.39)
Stimulation V_2	RMSSD	0.5893	34.88 (24.29)	36.36 (22.09)
	HF	**0.02162**	**40.90 (21.64)**	**54.45 (21.33)**
	CVI	0.9562	2.88 (0.52)	2.91 (0.45)
	LF	**0.02073**	**59.07 (21.64)**	**45.47 (21.34)**
	CSI	0.1033	2.12 (0.83)	1.77 (0.55)
	Stress	0.9927	13.27 (5.54)	14.19 (7.21)

Table 2. HRV differences between the vertigo group and control group.

Video	Variable	P-value	Vertigo group	Control group
V_1	RGP	**0.03876**	**-9.299231 (40.09634)**	**-42.03808 (55.08794)**
V_2		**0.011**	**-10.67154 (45.09769)**	**-39.71077 (51.46616)**
V_1	RGP – recovery time	**0.01117**	**174.3077 (121.0705)**	**90.38462 (123.53075)**
V_2		**0.01248**	**161.6154 (129.5997)**	**72.11538 (122.99734)**

Table 3. GSR differences between vertigo group vs control group.

State	Variable	P-value	Vertigo group	Control group
Resting V_1	BAI	**0.000001476**	**0.07785566 (0.95655076)**	**-2.17427573 (0.26276846)**
Resting V_2		**0.000001483**	**0.00941721 (0.88714559)**	**-0.18131397 (0.09516384)**
Stimulatión V_1		0.7048	0.4843394 (0.97528503)	0.04637762 (0.83814032)
Stimulatión V_2		0.6647	0.00032052 (0.97991598)	0.07681847 (0.85593634)

Table 4. BAI difference between the vertigo group vs control group.

State	Objetive variable	Subjective Variable	Vertigo group		Control group	
			Correlation	P-value	Correlation	P-value
Stimulation V_1	GSR	BAI	-0.5812523	**0.001845**	-0.1641306	0.423
Resting V_2	HF	BAI	0.505641	**0.009196**	0.04000684	0.8461
	LF	BAI	-0.505641	**0.009196**	-0.0400068	0.8461
	CSI	BAI	-0.4274966	**0.02938**	0.2800958	0.1658
	CSI	VSS-AA	-0.4086868	**0.03818**	0	0
Stimulation V_2	GSR	BAI	-0.3811966	**0.04589**	-0.369817	0.06295

Table 5. Spearman Correlation of the vertigo group vs control group.

is established uniquely in the resting states. Additionally, that experience of anxiety at rest (pre-stimulation) in vertigo group, suggests a predisposition state or negative anticipation of the exposure of the videos because of the possible triggering of vestibular and vegetative symptoms.

Finally, through the Spearman Coefficient, correlation of the objective variables (HRV and GSR) and the subjective ones (latent traces of the BAI and the VSS-AA) was established, in order to determine which of these were statistically significant.

P-values of statistically significant correlation were found uniquely in vertigo group. A negative correlation was determined between the variables that reflect sympathetic activity and the self-perception scales, as well as a positive correlation between the variable that represents parasympathetic predominance and the anxiety inventory. The correlation force decreases according to the order of Table 5, being stronger in V1 stimulation with (moderate correlation) and less marked in V2 stimulation (low correlation).

Finally, as it was mentioned before, the VSS-AA was filled out only by the study group, therefore, the correlation in the control group is 0.

DISCUSSION

The present investigation makes a series of contributions to the field of knowledge of psychophysiology, since its main purpose was to determine the correlation between the autonomic response of anxiety and subjective interpretation by people with vestibular disorders.

In studies that have autonomically measured the cardiac response of the anxiety in the healthy population or with anxiety disorders, an increase of the heart rate and a decrease in HRV established by the increase of LF and LF/HF was reported, while, at electrodermal level greater skin conductance has been evidenced (Kushki et al, 2013). These reports agree with findings in the present research, since it was evident the sympathetic activation against stressful stimuli such as those virtual reality through the high LF and the low HF values. The difference in the physiological regulation between the groups confirm the high autonomic levels of anxiety in the experimental group. Moreover, there is correspondence with HRV studies that specifically assessed the variables of the frequency-domain (Goto et al, 2010; Ohara et al, 2015).

By definition, psychophysiological measurements assume some kind of relationship between the psychological and physiological domain. According to Cacioppo and Tassinary (1990) five general relationship can be distinguished: there is not a significant relationship between the two domains, one to one relationship, one to many relationships, many to one relationship and several to several relationship (Norman, Necka and Berntson, 2016). As stayed by the results elicited in the measurement of the anxiety level, the psychophysiological relationship of this study is several to several, since the variables with statistical difference that were correlated were HF, LF, ISC and GSR of the autonomic objective and VSS-AA and BAI of subjective self-perception. In addition, these correspondences occurred in different stimulation backgrounds and were found only in the study group, although vertigo symptoms were not found in the acute phase at the time of the measurement. Possibly, with the vestibular symptomatology and active autonomic there are closer psychophysiological relations.

The non-statistically significant between the same correlation variables of the control group, it is possibly given by the subjective perception about virtual reality videos, since at the moment of measurement none of the participants referred to them as a threatening and/or frightening stimulus. For the 92.3% of the group, V1 did not attract attention and was classified by some as "boring", while V2 was cataloged as "interesting" or "striking" by 84.6% of the population. The remaining percentage rated V1 as "attractive" and V2 as "unpleasant". It is important to highlight that, at the moment to fill out the BAI, the few participants who marked response options as "mildly" or "moderately" in few items, did not assimilate the videos as a threat but as a positive stimulus that yielded a pleasant physiological excitation.

Most studies interested in determine the type of correlation between emotional response systems, have for the most part included people with psychiatric disorders such as anxiety, in addition, they have found mixed results in terms of the coherence of these systems. Several studies have shown a strong consistency in their results while others have not, as positive, negative correlations or any type of correlation has been reported. The findings that manifest a negative correlation, for example, between physiological response and facial expression, have been interpreted as support for the classic model of "hydraulic" or "discharge" emotions. These models indicate that when emotions are strongly expressed through a single response channel, they deplete the available energy and are weakly expressed through other channels (Levenson, 2014).

A possible theory has to do with the power of the stimulus used to generate a broad perception of anxiety. This was explained by Levenson (2014), who stated that in order to identify a high coherence between response systems, the person must be in the middle of a strong emotion, because the subjective, behavioral and physiological responses are more appropriate when the person is strongly stimulated than when at rest. Therefore, levels of coherence must be measured when individuals are actually in the midst of marked emotional experience. When comparing the physiological response to virtual reality videos, it can be seen that the sympathetic activity measured through HRV had a statistical difference only with V2, video characterized by a greater sensory conflict compared to V1. Nonetheless, the incorporation of somatosensory stimuli in the videos could further amplify the sensory discrepancy and produce more anxiety.

Another argument has to do with body consciousness in the emotional experience. According to the findings of Sze et al (2014), the degree of coherence between the physiological and subjective measurements is directly proportional to person's training on their body consciousness. Of the study groups, those of Vipassana meditation showed the greatest degree of coherence, since their training is emphasized in the attention of cardiac and respiratory activity. Modern and ballet ballerinas, had an intermediate level, as their training focuses on the attention to somatic cues such as muscle tone, position and alignment of the body. The control group whose inclusion criteria was not to receive any form of corporal training, reflected the least coherence. In this research, participants were not in previously trained in any of these activities, which may be related to culture.

In light of all these findings, there has been a growing tendency to perceive emotional response systems as weakly coupled. According to what was pointed by Mauss et al (2005), although no one would except perfect associations between systems in all types of emotions and in all contexts, the evidence of reliable correlations during emotional response is not entirely clear or whether the strength of coherence increases with the intensity of emotion. The nature of anxiety and its psychophysiological manifestations is still a topic of interest and the relationship between its affective process and physiological measurement remains to be clarified, especially in people affected by vestibular disorders, due to the unquestionable impact it has on daily activities and their quality of life.

CONCLUSIONS

People with vestibular disorders manifested a decrease in HRV, through the high values of sympathetic activation indicators and the low values of parasympathetic activity markers. Additionally, they showed a greater sympathetic predominance through the low values of the skin conductance, as well as the longer time in the physiological recovery after the exposure to the videos, which reflects chronic anxiety levels.

There is a negative correlation between variables that indicate sympathetic activity and anxiety self-perception scales, likewise, a positive correlation between the variable reflecting parasympathetic predominance and the anxiety level. This suggests inconsistency between subjective interpretation of anxiety and its physiological response, by people with vestibular disorders. Possibly, this is due to some disturbance between the mechanisms of response to anxiety, such as physiological and affective.

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