Original Article

https://doi.org/10.1590/2317-6431-2022-2680en

Audiology Communication Research
ISSN 2317-6431

Evaluation of sensory discomfort caused by stimulation with virtual reality in volunteers with and without kinetosis

Avaliação do desconforto sensorial causado por estimulação com realidade virtual em voluntários com e sem cinetose

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ABSCTRACT

Purpose: to compare the symptoms of motion sickness caused by virtual reality stimulation in volunteers with and without history of the disease. **Methods:** qualitative and analytical, observational, cross-sectional, and prospective study, approved by Research Ethics Committee, 3.443.429/19, with volunteers with and without history of motion sickness who were subjected to immersion in VR with the use of virtual reality glasses. Before and after sensory stimulation, the participant had respiratory rate (RF), heart rate (HR) and systolic blood pressure (PAs) and diastolic blood pressure (PAd) measured. On the first day, the volunteer was exposed to a video that simulated a person in a car, with a predominance of lateral visual flow. A week later, an animation of a roller coaster, with a predominance of frontal visual flow. During the 10-minute experiment, a score from 0 to 10 was given every 30 seconds for the intensity of the discomfort felt by the volunteer. A post-questionnaire was conducted to assess motion sickness symptoms. **Results:** individuals with motion sickness history had a higher intensity of symptoms in the car ($p = 0.026$) and roller coaster experiment ($p = 0.035$). There was no correlation between motion sickness and the variables HR,FR,PA. Patients with motion sickness gave higher scores of discomfort throughout the experiments, mainly in the roller coaster experience. **Conclusion:** individuals with motion sickness present more intense symptoms when subjected to stimuli by VR compared to controls without disease.

Keywords: Motion sickness; Virtual reality; Nausea; Dizziness; Patient health questionnaire

RESUMO

Objetivo: comparar os sintomas da cinetose provocados por estímulo de realidade virtual, em voluntários com e sem histórico da doença. **Métodos:** estudo analítico qualitativo e quantitativo, observacional transversal, prospectivo, realizado com voluntários com e sem histórico de cinetose, submetidos à imersão em realidade virtual com o uso de óculos de realidade aumentada. Antes e após a estimulação sensorial, o participante tinha a frequência respiratória (FR), a frequência cardíaca (FC) e pressão arterial sistólica (PAs) e diastólica (PAd) medidas. No primeiro dia, o voluntário foi exposto a um vídeo que simulava uma pessoa dentro de um carro, com predomínio de fluxo visual lateral. Após uma semana, uma animação de montanha russa, com predomínio de fluxo visual frontal. Durante a estimulação sensorial de dez minutos, uma nota de 0 a 10 era dada a cada 30 segundos para a intensidade do desconforto sentido pelo participante. Após, um questionário foi realizado para avaliação dos sintomas de cinetose. **Resultados:** indivíduos com cinetose apresentaram maior intensidade de sintomas, tanto no experimento do carro (p=0,026), como na montanha russa (p=0,035). Não houve correlação entre cinetose e as variáveis FC, FR e PA. Os pacientes com cinetose atribuíram maiores notas de desconforto no curso das experiências, principalmente na experiência da montanha russa. **Conclusão:** indivíduos com cinetose apresentam sintomas mais intensos quando submetidos a estímulos por realidade virtual, se comparados a indivíduos sem a doença.

Palavras-chave: Enjoo devido ao movimento; Realidade virtual; Náusea; Tontura; Questionário de saúde do paciente

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Conflict of interests: No.

Authors' contribution: GYCC, NSSN and MAOS participated in the collection, analysis and interpretation of data and writing of the article; CCF, LKN and MAOS participated in the conception, design of the work, analysis, and interpretation of data, writing and review of the article.

Funding: None.

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Received: May 24, 2022; **Accepted:** October 14, 2022

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INTRODUCTION

Motion sickness is a complex syndrome, characterized by the feeling of queasiness and nausea caused by sensory conflict(1-4). Other symptoms may be involved, such as pallor, sweating, stomach pain, drowsiness, and headache(1,5).

Despite its highly prevalence in the population, with a greater predominance in women(1,6), the neural mechanisms responsible for motion sickness are still not fully understood(5-7).

Motion sickness arises from an incongruity between the stimuli from the vestibular, visual, and proprioceptive systems in the face of an unusual movement of the body, or a distorted spatial perception, which generates a conflict sensory input in the brain(8,9).

The increase of motion sickness symptoms coincides with the modern world and the technological revolution. In addition to perceiving its occurrence in everyday environments, such as in means of transport, motion sickness also occurs in visual and bodily immersion in simulators and virtual reality experiences(9-14).

With the advancement of technology and the growing market for virtual reality head-mounted displays (HMD), motion sickness has become an important complaint in a considerable part of its users, so much so that motion sickness experienced during or after immersion in virtual environments has its specific term in English, cybersickness or virtual reality sickness(9-14).

The virtual experience has become popular not only in the entertainment world, but also in the area of medical care, specifically in therapeutic practices for various clinical conditions prevalent in the population, such as alcoholism and smoking(15).

The motion sickness felt by volunteers is one of the obstacles to immersion in virtual environments and, therefore, understanding the conditions that predispose anyone to develop such symptoms is essential for the delivery of good virtual reality services in society(9-14).

For a better study of motion sickness, as well as to evaluate the possibilities of therapies and drug treatments, some motion sickness provocation models were used(16-19). One of the first models was labyrinthine stimulation with air and water, which attempts to simulate labyrinthine functioning, although the endolymphatic current velocity achieved in the caloric test was very low and nonphysiological(17).

In an attempt to simulate more intense movements, some studies used the swivel chair, initially without strict control of speed and acceleration, which complicated the analyze of the results, especially in case-control studies, which required to determine the effect of an intervention. With the emergence of computerized swivel chairs, an attempt was made to meet this need, but the high cost of the device made its popularization difficult(18,19).

If the effectiveness of the virtual experience in developing symptoms in volunteers with motion sickness is proven, virtual reality could serve as a model for provoking motion sickness symptoms, in order to be used in studies that study the disease, in its drug treatments and rehabilitation proposals.

This study aimed to compare the symptoms of motion sickness provoked by the virtual reality stimulus in volunteers with and without a history of the disease. Furthermore, we intended to verify the influence of stimuli with different predominance of visual flow (lateral and frontal) in the generation of symptoms.

METHODS

The experiment

Analytical qualitative and quantitative, observational, cross-sectional, prospective study, carried out with volunteers after approval by the Ethics Committee for Research on Human Beings of Santa Casa de São Paulo –CEP-SC, under protocol number 3,443,429, in 2019.

Volunteers over 18 years of age, with or without a history of motion sickness, were included. The sample was for convenience and students and professors from a Health Sciences University were selected between 2019 and 2020.

After signing the Informed Consent Form (ICF), the individuals were clinically evaluated by an otorhinolaryngologist and divided into two groups: control group (group without motion sickness), with no history of discomfort or discomfort due to movement; and the study group (group with motion sickness), which showed history and symptoms of discomfort or malaise due to movement. Volunteers were matched by age and gender.

Volunteers with a history of psychiatric, neurological, and other vestibular diseases (excluding motion sickness) were excluded; history of otologic surgeries; visual difficulties that interfere with immersion in virtual reality; musculoskeletal alterations that could harm balance and the end of the experiment.

In the initial assessment, the volunteers answered the question: "Do you consider yourself a person with motion sickness, or do you feel sick or dizzy when you are in means of transport?." The answer could range from "no;" "a few times;" "sometimes;" "most of the time;" "nausea or dizziness doing specific activities, such as reading, using a cell phone, when in a means of transport, such as a car, bus." Volunteers who answered "sometimes," "most of the time" and "doing specific activities such as reading, using cell phones" were considered to have motion sickness.

The volunteers were submitted to the questionnaire translated and culturally adapted to Brazilian Portuguese by França & Branco-Barreiro(20) of the Motion Sickness Susceptibility Questionnaire - Short Form (MSSQ-Short), a simplification of the questionnaire originally created by Reason & Brand(21). (Annex 1).

The MSSQ questionnaire assesses, in a scoring system, the situations responsible for causing motion sickness and considered nine different types of transportation and entertainment that the participant had used (1) in childhood, prior 12 years of age (Motion Sickness A - MSA), and (2) in the current age, in the last ten years (Motion Sickness B - MSB). For each means of transport or entertainment, the person answered between: "I have never experienced it;" "I never felt sick;" "I rarely felt sick;" "Sometimes I felt sick," or "I was always felt sick." Each answer received a score, respectively: 0, 1, 2 and 3. The formula used to calculate the score for these questionnaires is described as:

$$MSA = childhood\ total\ score \times 9 \ / \ (9 - number\ of\ unused\ means\ of\ transport) \quad (1)$$

$$MSB = adult\ total\ score \times 9 \ / \ (9 - number\ of\ unused\ means\ of\ transport) \quad (2)$$

Soon after completing the questionnaire, respiratory rate (RR), heart rate (HR) and systolic (SBP) and diastolic (DBP) blood pressure were measured using the OMRON HEM-

7113 digital sphygmomanometer. RR up to 25 mmHg[22], HR up to 75 bpm, BP < 130 mmHg and BP < 85 mmHg were considered normal values[23].

The volunteer started the virtual immersion in orthostatic position, and was exposed to a 10 minutes recorded video, through the HMD VR BOX virtual glasses, that simulated a person inside a car overlooking the streets of São Paulo. The video was recorded with an iPhone 8 Plus, edited in the Adobe Premiere Pro CC 2017 editing program and converted into a stereoscopic image using the VRPlayer application.

Every 30 seconds, the volunteer quantified the overall discomfort felt, using a increasing scale from 0 to 10, with a score of 10 corresponding to the maximum discomfort. Each individual had their own follow-up table with these notes.

In case of extreme discomfort, the participant had the right to report and stop the experiment if necessary. During the entire assessment, an evaluator stood next to the volunteer to prevent falls.

At the end of the experiment, respiratory rate (RR), heart rate (HR), systemic blood pressure (SBP) and diastolic blood pressure (DBP) were measured using the same equipment mentioned above.

The volunteers answered a symptom evaluation questionnaire that contained 16 statements related to the clinical state of motion sickness. The volunteers were asked to assign a score on an increasing scale from 1 to 9 for each symptom identified during the experiment, with 1 being the minimum score and 9 being the maximum intensity score for the determined symptom. The total evaluation of the motion sickness is based on the percentage film calculated from out of 144 possible points[12].

In the second experiment, at least a week after the first, the participant had their vital signs measured and the whole process was repeated; however, now based on the subject's exposure to a virtual animation (a roller coaster ride 3D ROLLER COASTER) - TOP15 VR 3D Side By Side SBS Google Cardboard VR Box Gear Oculus Rift), with predominantly frontal visual flow, also lasting ten minutes, with individual assessment every 30 seconds, and completion of the motion sickness symptoms questionnaire at the end.

Statistical analysis

The results were submitted to statistical analysis, in which a significance level of 5% (p = 0.05) and a confidence interval (CI) of 95% were considered. SPSS V13 and Excel Office 2010 software were used. The Shapiro-Wilk test was applied to test the normality of the variables.

The Chi-square test was used to compare the gender variable. MSSQ results and variables (HR, RR, SBP, DBP, motion sickness symptoms assessment questionnaire) were compared using Pearson's correlation, which was considered weak when from 0 to 0.4; medium, between 0.4 and 0.7 and strong when greater than 0.7.

The difference between the mean scores reported in the follow-up of the experiment of each volunteer in the case group compared to the control group was analyzed using the Mann-Whitney test.

RESULTS

The study consisted of a total sample of 42 volunteers (21 from the control group and 21 from the study group), of which 18 were female (42.85%) and 24 were male (57.15%); the age ranged from 18 to 55 years, with a mean of 25.71 (±10.08).

The MSSQ score was compared with the variables and revealed no correlation between the score of the questionnaire prior the experiment and the variables (HR, RR, SBP, DBP) of the car and roller coaster experiments, showing that all volunteers started with the same pattern in these variables.

The car video stimulation showed a weak correlation between patients with motion sickness (assessment with MSSQ of the last 10 years) and post-experiment symptoms (p=0.026 / r=0.0344).

The roller coaster stimulation revealed weak correlation between patients with motion sickness, according to the MSSQ questionnaires of childhood and the last 10 years, with motion sickness symptoms, respectively p=0.043 / r=0.314 and p=0.035 / r=0.326. (Table 1)

The association between gender and motion sickness was analyzed. The results showed that gender was not a variable that contributed to the intensification of motion sickness (p=0.582).

There was no difference in the variation of HR, RR, SBP and DBP pre- and post-experiment in any of the evaluated groups (Table 1).

Two volunteers with motion sickness asked to stop the experiment at 7 minutes and 30 seconds in the car video experiment, and one subject in the control group asked to stop the roller coaster experiment at 5 minutes and 30 seconds.

The scores attributed by the volunteers during the follow-up of the experiment showed a significant difference between the groups with and without motion sickness, for both experiments (Figure 1). The Mann-Whitney test showed a significant statistical difference in the following moments: minutes 3'30" (p=0,023), 4' (p=0,029), 4'30"(p=0,026) e 10' (p=0,046) in the car experiment, and minutes 4'30" (p=0,032), 5'30" (p=0,020), 6' (p=0,033), 7' (p=0,013), 8' (p=0,042), 8'30" (p=0,024), 9' (p=0,001), 9'30" (p=0,006), 10' (p=0,012) in the roller coaster experiment.

DISCUSSION

The correlation between pre- and post-experiment questionnaires was weak, demonstrating that virtual reality provoked a symptomatic reaction in the cases and controls. The difference between the two groups was observed by evaluating the scores given by the volunteers in reference to the intensity of the symptoms during the collection.

No correlation was observed between the increased prevalence or intensity of motion sickness in relation to gender or age, contrary to what some studies suggest, which report that women and younger individuals are more susceptible to this disease[6-8].

According to other studies in the scientific literature[4,10-12], motion sickness symptoms are not necessarily related to variations in heart rate, respiratory rate, and blood pressure measurements. Motion sickness has been characterized as a visceral symptom with nausea and, eventually, vomiting.

One of the studies[13] believes that the most reliable parameter to quantify an individual's motion sickness is the frequency of skin conductance levels in the frontal region of the head.

Table 1. Relationship between the presence of motion sickness (according to the Motion Sickness Susceptibility Questionnaire in childhood and the last ten years) and variables: heart rate, respiratory rate, blood pressure and presence of post-exposure symptoms

Car					
		MSSQ childhood		**MSSQ last 10 years**	
		r	**p value**	**R**	**p value**
pre-exposure	HR	-0.071	0.657	0.006	0.97
	RR	-0.19	0.228	-0.118	0.457
	SBP	-0.09	0.572	-0.139	0.381
	DBP	-0.095	0.551	-0.193	0.221
post-exposure	HR	-0.199	0.206	-0.069	0.663
	RR	-0.15	0.343	-0.097	0.54
	SBP	-0.195	0.217	-0.305	0.05
	DBP	-0.24	0.126	-0.297	0.056
	Post-exposure symptoms	0.247	0.115	0.344	0.026
Roller coaster					
		MSSQ childhood		**MSSQ last 10 years**	
		r	**p**	**R**	**p**
pre-exposure	HR	0.002	0.988	0.054	0.735
	RR	0.04	0.801	0.121	0.446
	SBP	-0.095	0.549	-0.162	0.304
	DBP	-0.119	0.452	-0.192	0.222
post-exposure	HR	-0.044	0.783	0.013	0.935
	RR	-0.005	0.977	0.163	0.301
	SBP	-0.198	0.209	-0.218	0.166
	DBP	-0.092	0.562	-0.106	0.504
	Post-exposure symptoms	0.314	0.043	0.326	0.035

r = linear correlation of Person; p= Mann-Whitney test, Chi-square test

Subtitle: HR = heart rate; RR = respiratory rate; SBP = systolic blood pressure; DBP = diastolic blood pressure; MSSQ = Motion Sickness Susceptibility Questionnaire

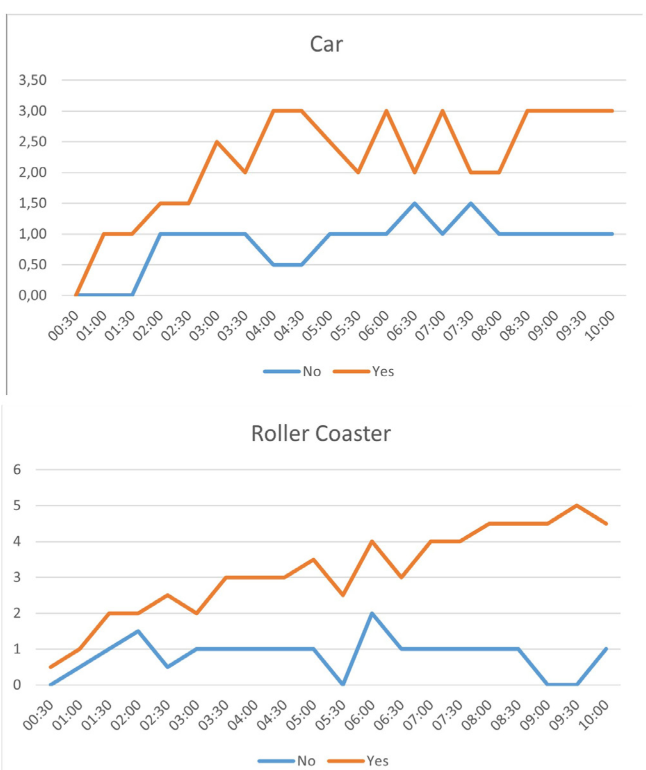

Figure 1. Comparative graph between groups with and without motion sickness for grades assigned during exposure to virtual reality. In the upper field, exposure to the car video (side visual predominance) and in the lower field, the roller coaster video (front visual predominance)

Therefore, the evaluation of post-exposure symptoms, as performed in the present study, becomes the preferred way of analyzing and measuring the effects of stimulation, when evaluating cost, accessibility, and morbidity in the methods.

It is worth remembering that many factors are involved in the onset of symptoms within a virtual environment and that they must be studied further for this observed correlation to be strong. First, one must consider the model of the HMD glasses, which create the environment for the virtual experience. The equipment involves not only lenses, but also a visual field completely sealed to external light and with total immersion for a better experience. In addition, it is necessary to consider variables such as exposure time, image resolution and the intensity of light and ambient sound, which interfere with the volunteers' perception of symptoms[10,11].

Genetic variants, hormonal profile, and even psychological aspects - such as the individual's expectation regarding future exposure to any event that may generate motion sickness - can also interfere with the onset of symptoms associated with this condition[5,9]. In addition to the concern with age standardization and initial objective evaluation parameters (RR, HR, and BP), virtual reality stimulation allows greater control of the environment, light exposure, and perfect standardization of stimuli, both in time and intensity.

During the experiment, the scores assigned by the volunteers in reference to the intensity of motion sickness symptoms were collected every 30 seconds. The difference between the means of the two groups in the car experiment was relevant at four specific points. This difference increased to nine intervals in the roller coaster experiment, indicating that the difference in the intensity of symptoms felt by the groups with and without motion sickness was greater in the roller coaster experience with frontal visual flow, when compared to the stimulus provoked by the car video, with predominance of lateral visual flow. A study(11) has already proven that a roller coaster ride, facing forward, is more stimulating than backward, and therefore, considering the influence of the visual flow in the appearance of more intense symptoms is important.

Still, it must be considered that two volunteers gave up on the car experiment after 7 minutes and 30 seconds, an interval in which the difference in the average scores of both becomes significant, as they are more concentrated in half the time for the car and more towards the end of the roller coaster experiment. Habituation is a phenomenon that occurs in motion sickness, however, the average time in which it occurs within a single experiment is not known(13). However, as pointed out by some authors, the response of an individual to motion sickness is due to three main factors: sensitivity to the stimulus, adaptation constant (which is the rate of adaptation to the stimulus) and the decay constant of symptoms(4).

With this, it is possible to formulate different hypotheses for the car and roller coaster experiment. In the first one, the volunteers must have sensitivity to the stimulus and, thus, present a peak in the intensity of the symptoms in the middle of the path, reaching, therefore, a constant of adaptation and decay of the symptoms and consequent reduction of the discomfort. In the second experiment, the progression of the difference in the average scores started close to the middle of the experiment and was maintained until the end of the full ten minutes. Thus, it can be inferred that the sensitivity to the stimulus was high, but there was a longer delay reaching the symptom decay constant and the adaptation constant, prolonging the volunteers' discomfort interval.

Most existing studies on the subject have small samples, as the research depends on the inclusion of volunteers who, not always, wish to be submitted to known unpleasant stimuli(2,3,10,11,14). The inclusion of volunteers was also a difficulty in the present study. In addition, a limitation of all studies on motion sickness is the lack of an objective gold standard method that establishes a criterion for classifying people who actually have or do not have the disease. In this study, the only subject in the study who dropped out of the roller coaster experiment also reported discomfort in the car but had not reported previous motion sickness, leading to the consideration of whether exposure to virtual reality is a promising method for diagnosing individuals with motion sickness.

Knowledge on the subject is still incipient and needs further case-control studies; but it is shown that subjects with a history of motion sickness have more symptoms after exposure to virtual reality than patients without the disease and that, when comparing cases and controls, the frontal visual stimulus was more effective in discriminating those with and without motion sickness.

CONCLUSION

Individuals with motion sickness present more intense symptoms when submitted to virtual reality stimuli, when compared to individuals without the disease. The roller coaster experiment with predominance of frontal visual flow caused greater intensity of symptoms than the car experiment with predominance of lateral flow.

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Annex 1. Motion Sickness Susceptibility Questionnaire (MSSQ)

Name: HR:

Age: RR:

Gender: ( ) Male ( ) Female **BP:**

Date:

The questionnaire is intended to predict an individual's susceptibility to motion sickness, and which types of movements are more intense in causing symptoms of nausea. Please place an "X" in one of the blanks for each motion sickness-generating transport and entertainment.

A. In your childhood (before age 12), how often did you feel sick?

Transport and entertainment generating motion sickness	Never experienced	Never felt sick	Rarely felt sick	Sometimes felt sick	Always felt sick
Cars					
Bus or Vans					
Trains					
Planes					
Small boats					
Ships or ferries					
Swings in playgrounds					
Merry-go-round in playgrounds					
Rides and amusement parks					

B. In the last 10 years, how often did you feel sick?

Transport and entertainment generating motion sickness	Never experienced	Never felt sick	Rarely felt sick	Sometimes felt sick	Always felt sick
Cars					
Bus or Vans					
Trains					
Planes					
Small boats					
Ships or ferries					
Swings in playgrounds					
Merry-go-round in playgrounds					
Rides and amusement parks					

The score is calculated based on a point system:

Answer	Score
Not applicable – never used	0
Never felt sick	0
Rarely felt sick	1
Sometimes felt sick	2
Always felt sick	3