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Psychological Correlates of Acceleration Stress for Thrill Seekers

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ABSTRACT

Recent development in technology and the release of powerful techniques among them virtual reality can help investigate various aspects of life. With 3D virtual reality technology, the influences of acceleration stress on arterial oxygen saturation (SpO_2) and heart rate (HR) can be predicted. This study explored the correlations among acceleration stress, HR and SpO_2. HR and SpO_2 were recorded from 20 healthy subjects (10 males and 10 females) during relaxation and positive and negative acceleration stress. They were university and secondary school students with the mean age (21.71± 2.54 yrs.) for university and (12.2± 1.1 yrs.) for secondary students. It was found that, both HR and SpO_2 are changed with acceleration stress, but that the change was not statistically significant ($p>0.05$). Males have lower HR and higher SpO_2 than females, and adults have lower HR and higher SpO_2 than children. Findings of the study suggest that acceleration stress, at least within the range studied in the present study, could produce effects on the HR and SpO_2. Future studies could aim to better categorize stress levels in virtual reality for thrill Seekers based on more psychological variables.

Keyword: Acceleration stress, heart rate, HR, arterial oxygen saturation, SpO_2, virtual reality, technology.

Introduction

Acceleration stress can be described as physiological changes, which may occur in the human body due to a rapid change or increase in the speed of the body. Acceleration stress is classified into positive (head to foot) and negative acceleration (foot to heat). In addition, it can be impacted and prolonged depending on its duration (1). Mainly, impact acceleration is considered to be usually last less than a second, whereas prolonged acceleration is considered to be last for at least several seconds (1).

Speeding, spinning vehicles and rapid changes of direction can produce stress. Human tolerance to acceleration stress depends on several factors such as the magnitude of acceleration, direction of acceleration, onset rate of the acceleration, and duration of the acceleration (2). Stress due to acceleration may cause changes in HR and SpO_2 as the human body goes into emergency mode.

There is evidence suggesting that acceleration can cause stress to human body systems (3). It is reported that once fighter pilots are exposed to high acceleration, their body fluids and blood are redistributed into the lower body (49. Also, clinical reports illustrated that liver dysfunction is found in pilots (5), noticeable cephalic hypotension (6), and cerebral ischemia (7), which might cause harm to both heart and brain and results in loss of consciousness. In one influential study, researchers evaluated the effects of repeated exposure to positive acceleration on rats and found that it causes hepatocyte injury and affects liver metabolism as well as morphological structure (8). In another experiment, it was found that acceleration has a significant effect on the cardiac function of rats (9).

Today, with development of technology such as virtual reality allows one to examine linkage among several psychological parameters. Virtual reality techniques are widely used by researchers as a tool for several purposes among them for studying human behaviors. The reason for choosing these techniques is due to an immersive and safe examining site in which certain design variables can be simply adjusted and isolated (10, 11). Moreover, virtual reality techniques help researchers to attain larger study sample sizes (12, 13). Moreover, with regards to cost, these

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techniques can have important benefits compared to physical prototyping (14, 15). Furthermore, the safety advantages of virtual reality techniques in contrast to real-world environments can encourage volunteers to participate, which may not be able or willing to attend real-world investigations (16). It is evidenced that some special forms of physiological and behavioral assessments, in particular, those linked to stress might be same throughout virtual practices compared to real-world ones (13, 17-19).

Despite promising research mentioned above on the effects of acceleration stress on human body systems, the extent of this verification is quite restricted. More investigations are necessary to investigate the association between acceleration stress and human body systems. Therefore, in this study, we attempted (aimed) to research the correlations among acceleration stress, HR and SpO_2. As far as we know, no prior study has evaluated this psychological association via using a 3D virtual reality environment. It was hypothesized that virtual acceleration stress (either positive or negative) leads to strong stimulation at the human physiological level. With respect to the age-related differences, it was hypothesized that a child's HR would be higher than that of an adult.

Material and methods

Test Subjects and Experimental Protocol: 20 students (10 males and 10 females) were chosen purely on a random basis, appearing to be in good physical health without any visual disorder. They were recruited from the University of Duhok, and secondary school students who have expressed their willingness to participate in the experiment were recruited from a secondary school. The preadolescents children ranged in age from 12–14 years with mean (12.2± 1.1 yrs.) and adults (university students) aged between 20-23 years and mean (21.71± 2.54 yrs.).

Inclusion criteria were healthy students who voluntarily enrolled in this experiment and did not experience problems with the study procedures and controlling VR equipment. Those who had any visual disturbances or might experience motion sickness or dizziness in VR were excluded from the experiment.

Prior of starting tests, a written informed consent was obtained from all test subjects. For children, written informed consent was obtained from their parents. All the practical works were done at the University of Duhok. During measurements, the test subjects were comfortably sat in a chair during the tests in a silent room.

For the first two minutes of the test, the volunteers were asked to sit relax. Then, they underwent a Roller Coaster virtual reality game of acceleration by using VR BOX 2.0 Virtual Reality 3D Glasses, 6.0-inch (15.24 cm) display. The volunteers were exposed to both positive (head to foot for 10 sec) and negative acceleration (foot to heat for 10 sec) during game viewing as illustrated in Figure 1. While the subjects were relaxing and exposed to acceleration both SpO_2 and HR were simultaneously measured by using a pulse oximeter (Weltbild Pulse oximeter).

Statistical Analysis: To statistically compare HR and SpO_2 to relaxation, positive and negative acceleration, one-way repeated analysis of variation (ANOVA) was used, and to compare groups with each other a post hoc multiple pairwise comparison using Sidak correction was employed. Also, student's t-tests were conducted for comparing the physiological test results (HR and SpO_2) results between the female and male students as well as that of children and adults. All the statistical analysis was performed employing IBM SPSS Statistics.

Results

Heart Rate: Shown in Table 1 is the HR for all male and female participants respectively, measured during relaxation and task periods.

The results shown in Table 1 are then used to draw Figures 2, where maximum, minimum, quartiles and medians values of HR for all participants are represented with respect to the mean of three tasks (relaxation, positive acceleration and negative acceleration). The median value of the box-plot indicate that HR is decreased following exposing the test subjects to positive acceleration. During relaxation, the median value was 95 B/M, then decreased to 92.5 B/M during positive acceleration and reduced to 91 B/M during negative acceleration task. However, these variations were statistically nonsignificant ($p>0.05$).

Arterial Oxygen Saturation: Data presented in Table 2 are values SpO_2 recorded from all male and female participants respectively, measured during relaxation and task periods.

The SpO_2 data for all subjects together with maximum, minimum, quartiles and medians values are presented in the Figure 3. The box-plot illustrates that the median value of SpO_2 is raised (from 97% to 98%) due to both positive and

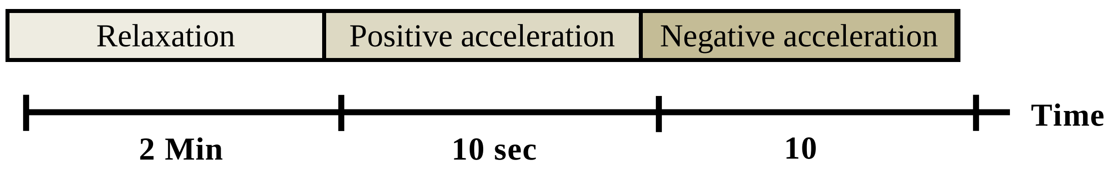

Fig. 1. Schedule of the Experiment

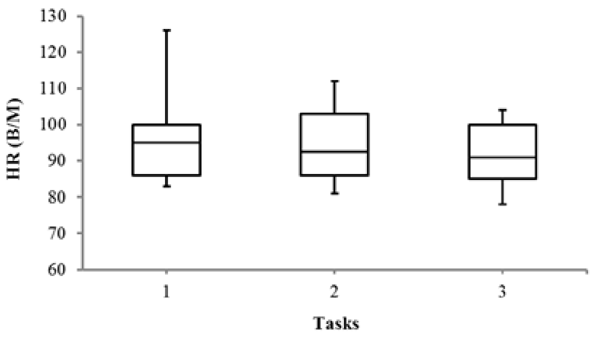

Fig. 2. Box-plot with medians, quartiles and the min and max as whiskers shows mean value of hr for all subjects with respect to three tasks. 1= relaxation, 2= positive acceleration and 3= negative acceleration

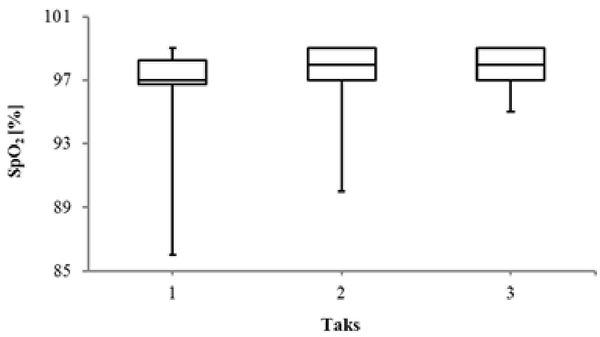

Fig. 3. Box-plot with medians, quartiles and the min and max as whiskers shows mean value of SpO_2 for all subjects with respect to three tasks. 1= relaxation, 2= positive acceleration and 3= negative acceleration

negative acceleration. However, the analysis with the ANOVA test revealed that the increases in SpO_2 were nonsignificant as ($p>0.05$).

HR (Male Vs. Female Results): Data for HR as a function of gender per task (relaxation, positive acceleration and negative acceleration) are presented in Figure 4. Although a greater median HR value was monitored from females than males, these findings were insignificant ($p>0.05$), except in the relaxation task, in which significant ($p<0.05$) differences between males and females were obtained as indicated in Figure.

Arterial Oxygen Saturation (Male Vs. Female Results): Figure 5 shows SpO_2 for male and female groups. It can be seen that SpO_2 for males and females are approximately the same, except for the positive acceleration task where female shows a higher value than male. Moreover, the statistical analysis with the T-test also indicated that all these results were nonsignificant ($p > 0.05$).

Heart Rate (Child Vs. Adult)

The HR data for children against adults are shown in Figure 6. It can be seen that medians HR of child group are higher than adults. However, when data for HR were statistically analyzed through a T-test, insignificant ($p >0.05$) differences between both groups were found.

Arterial Oxygen Saturation (Child Vs. Adult): The results for SpO_2 concerning age and different tasks are shown in Figure 7. As seen median values of SpO_2 for children are lower than for adults. However, when statistical analyses were done insignificant ($p > 0.05$) difference between data of both groups was obtained, except in the negative acceleration task as indicated in the figure.

Discussion

In this study, correlations among acceleration stress, HR and SpO_2 were investigated. The analysis of the data revealed that SpO_2 and HR are changed with acceleration stress.

Based on the results shown in Table 1, HR is changed for all participants. Moreover, according to Figure 2, HR is decreased due to both positive and negative acceleration compared to relaxation in agreement with Steiner and Mueller (20). Also, our results of decreased HR due to acceleration stress agree with (21-23). Bernston et al. (24), reported that variations in HR can be useful to establish the correlation between a specific task type and psychophysical load. In addition, Owens et al. (25) and Muldoom et al. (26), noted that the performance of mental tasks can influence HR. Moreover, in a study by Van Eekelen et al. (27), participants were subjected to a memory task as a result alterations in HR were observed, which associated with parasympathetic modulation. Furthermore, these alterations in HR towards more stable during stressful conditions may be

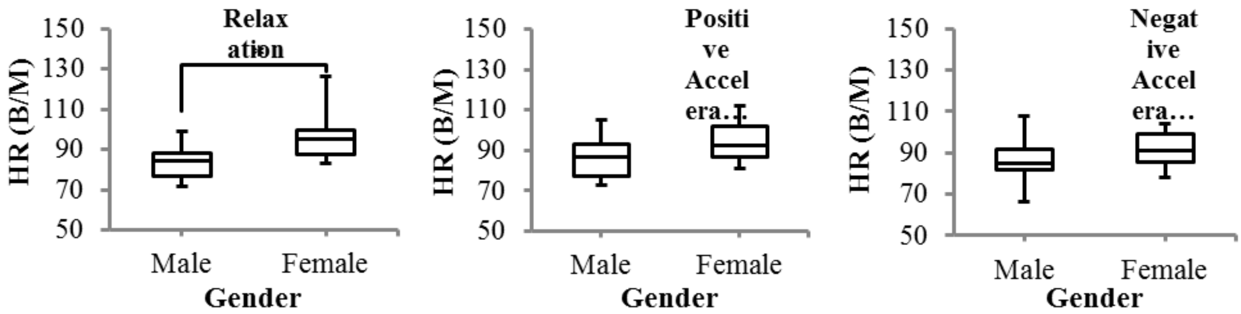

Fig.4. Box-plot with medians, quartiles, and the minimum and maximum as whiskers show HR as a function of gender per task. * $p < 0.05$

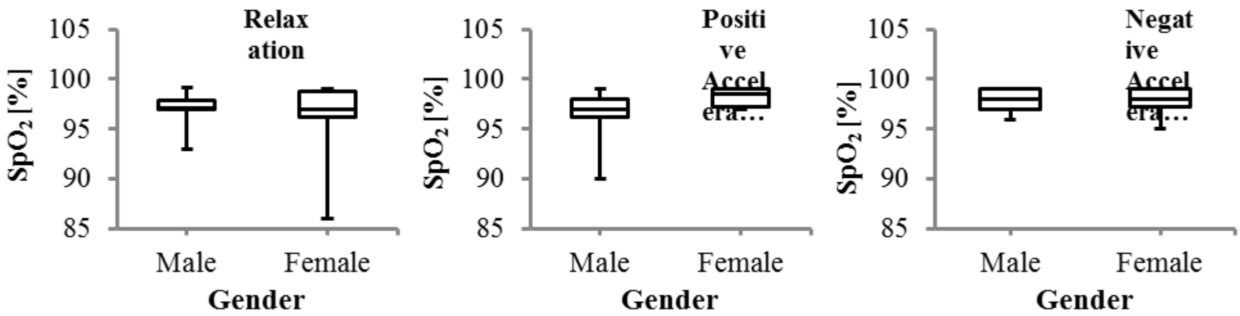

Fig. 5. Box-plot with medians, quartiles, and the minimum and maximum as whiskers show SpO_2 as a function of gender per task.

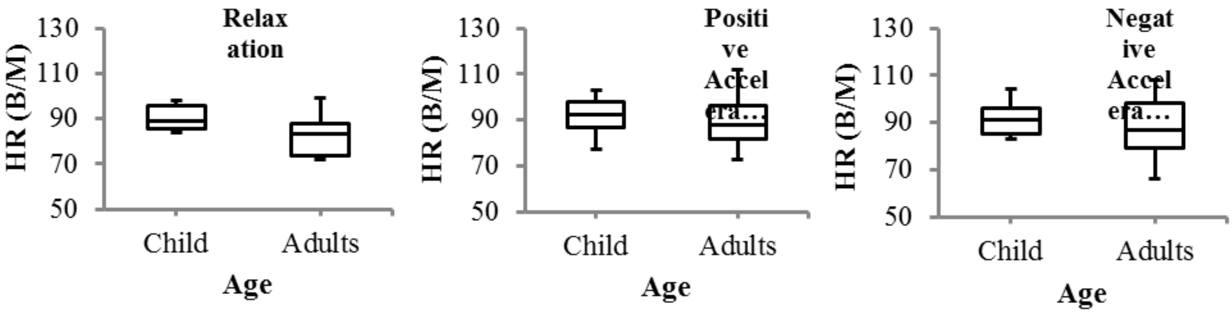

Fig. 6. Box-plot with medians, quartiles, and the minimum and maximum as whiskers show HR as a function of age per task.

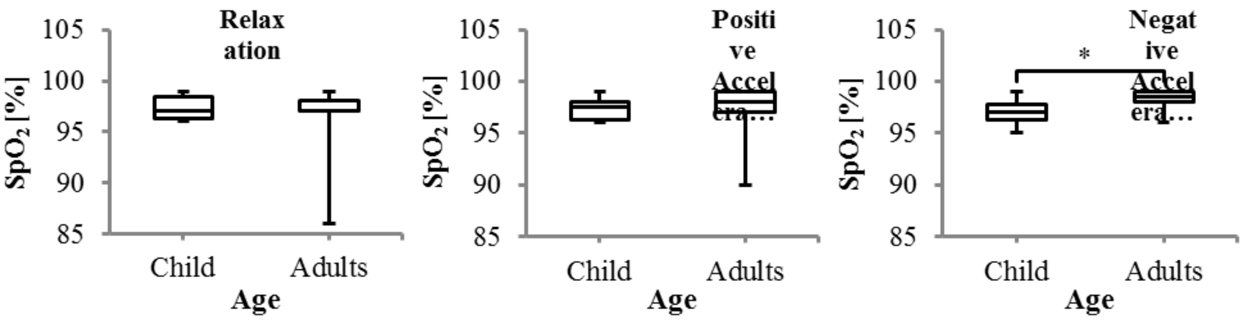

Fig. 7. Box-plot with medians, quartiles, and the minimum and maximum as whiskers show SpO_2 as a function of age per task.

related to stronger regularity, decoupling of multimodal networks and control-loops deactivation inside the cardiovascular system (28-30). Therefore, a decrease in HR under a stressful environment may express a lower fitness and adaptability of the cardiac pacemaker and also a functional constraint of the cardiovascular elements (31).

Table 1. HR for All Participants

Subjects	Relaxation	Positive acceleration	Negative acceleration
	HR [B/M]	HR [B/M]	HR [B/M]
1	72	78	81
2	75	73	72
3	83	90	88
4	88	97	108
5	73	73	66
6	88	88	86
7	99	105	103
8	85	85	84
9	98	94	93
10	84	77	83
11	86	84	79
12	126	112	102
13	100	86	88
14	106	103	100
15	93	88	85
16	83	81	78
17	99	94	93
18	86	99	97
19	97	103	104
20	92	91	89

Inspection of Table 2 reveals that SpO_2 is influenced by both positive and negative acceleration. Additionally, Figure 3 clearly depicts those median values of SpO_2 are increased due to both types of acceleration stress. These findings are totally opposite to what is seen in Figure 2, where HR decreased as a result of acceleration stress. The present results indicated that the higher SpO_2 evoked a lower HR. This may be due to the fact that the subjects were exposed to high speeds and unusual accelerations over short periods.

In this study, gender differences were present in HR and SpO_2 during acceleration stress. It can be seen in Figure 4 that females exhibited higher HR than males, which might be due to a greater stress level among females than males. Also, in several studies, it is reported that females react to stress with raised HR than males, whereas males react with raised vascular resistance (32-35). Convertino (36), concluded that females demonstrate minimal active responsiveness of mechanisms that involve to the regulation of blood pressure throughout stressful conditions. On the other hand, there is not much difference between females and males with regard to SpO_2, and they have approximately the same level.

According to the results presented in Figure 6, child HR is higher than adults during relaxation as well as during acceleration stress. In addition, child HR is increased due to both positive and negative acceleration stress, which is in line with (37, 38).

As a final result, we have compared the SpO_2 of children to adults. Figure 7 shows that adults have a higher SpO_2 during relaxation, and also during acceleration stress. Moreover, the difference between both groups is statistically significant with respect to negative acceleration stress (foot to heat). However, on average the level of SpO_2 for both groups is in the normal range (95-99%). Comparing our findings with the previously published studies is difficult, because of the insufficient of results on analogous experimental investigations utilizing the same procedure and experimental protocol.

The outcomes of this study support the idea that the human brain can imitate a model of the space around it which can stimulate the physiological functions of the body. The findings also reveal the children's ability to immerse themselves in virtual

Table 2. SpO_2 For All Participants

Subjects	Relaxation	Positive acceleration	Negative acceleration
	SpO2 [%]	SpO2 [%]	SpO2 [%]
1	98	97	98
2	99	97	99
3	97	90	96
4	97	98	99
5	93	98	97
6	97	99	99
7	97	97	99
8	96	98	97
9	97	96	98
10	99	96	97
11	95	99	99
12	97	99	98
13	98	99	98
14	99	99	99
15	99	98	99
16	97	97	97
17	86	97	98
18	97	98	95
19	99	99	99
20	96	97	96

worlds that closely resemble their physical environments more than adults.

Limits of the Study: Despite these results, they do come with certain limitations. The study recruited a limited age group. In further studies, it would be interesting to involve a large number of participants of a wide range of ages to explore the effects of VR. Another aspect that future research should consider is measuring more physiological parameters such as electromyography, skin conductance, skin temperature, respiration amplitude. Nevertheless, despite these limitations, several concrete conclusions based on statistically significant differences were drawn from our data.

The study findings indicate that acceleration stress, at least within the range studied in the present study, could produce influences on the HR and SpO_2, but such effect is statistically insignificant. Moreover, HR is decreased, whereas SpO_2 is increased due to positive and negative acceleration stress. Also, the study findings suggest that there are gender and age variations in the HR and SpO_2 responding to acceleration stress. Males have a lower HR, but higher SpO_2 in contrast to females, and adults have a lower HR and higher SpO_2 in contrast to children. Future studies could aim to better categorize stress levels in virtual reality for thrill Seekers based on more variables in addition to heart rate and oxygen saturation.

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