

1      **Assessing the Impact of Virtual Reality Horror Experiences on Sensitivity to Fear**  
2      **Stimuli**  
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6      Horror as a genre of entertainment exists in several forms; film, books, comics, video games, and recently as virtual reality video  
7      games. We present findings from an experiment about how users heart rate while completing a task before, within, and after playing a  
8      virtual reality horror video game changes. Between each of those tasks participant's heart rates were allowed to return to a resting  
9      level. Our results show that there was no statistically significant impact on heart rate before and after in participants who did not have  
10     an elevated heart rate while playing the game, however, when participants did have an elevated heart rate while playing the game  
11     they also had a statistically significant increase in heart rate in the task before and after. These findings shed light on how users may  
12     be influenced to feel emotions in both horror and virtual reality even after no longer directly exposed to the direct stimuli.  
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14     CCS Concepts: • Software and its engineering → *Software design engineering*; • General and reference → **Experimentation**; •  
15     Human-centered computing → *Displays and imagers*.  
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17     Additional Key Words and Phrases: virtual reality, physiological information measurement, fear elicitation  
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23     **1 INTRODUCTION**  
24

25     Ever since the commercial release of the Oculus DK1 virtual reality(VR) headset in 2013, the technology has become  
26     more and more prominent as a commercial product. What was once something that mostly used by researchers or seen  
27     in arcades became a product that users could buy for a reasonable price and use in their own homes. This trend can be  
28     further seen by entry level headsets, such as the Meta Quest 2, being sold for as low as \$250 as of April 2024. This is a  
29     technology that, while not as common as smartphones, is common enough that more people than ever before have had  
30     experiences with it.  
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32     Whenever new technology starts to become more widespread, questions on potential side-effects on users start to  
33     crop up. Video games especially suffered from this during the 1990's with several lawsuits about violent video games,  
34     like mortal combat, being a negative influence. Since one of the largest consumer uses of VR headsets is to play video  
35     games, the question of how they might impact a user comes up.  
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37     We aimed, through the research conducted and presented within this paper, to show how this technology can effect  
38     a users emotional response to their environment after playing a horror game created in VR. We believe that this leads  
39     to insights into how VR may influence users emotional states and how they respond to stimuli outside of the virtual  
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53 environment. While we didn't expect large shifts after only a short time in a VR game, we hoped that a slight change  
 54 would be able to be found from looking at the change in heart rate of participants while completing a task before and  
 55 after playing the VR horror game.  
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## 57 2 RELATED WORK

58 Horror is a genre of media that has consistently remained popular and due to that there is lots of research done on  
 59 the topic. One such study found that there was a change in respiration after watching a horror movie [8]. Other  
 60 physiological response are observed by fear as well; a similar study focusing on fear films found heart rate was  
 61 significantly incremented [6]. These physiological responses aren't something only found when exposed to film; it  
 62 was found that elevated heart rate also occurred during horror experiences such as in haunted houses [1]. The idea of  
 63 looking for signs of fear using physiological responses isn't a new idea; work dating back to 1977 found correlation  
 64 between elevated heart rate and reported fear [18]. From these sources we can tell that fear caused by entertainment  
 65 can cause a physical response; specifically in increased rate of respiration and heart rate. This is similar to our work  
 66 where we investigated how horror effects heart rate after an experience; it is important to note that research with  
 67 heart rate variability and horror clips seems to indicate the heart rate variability, different from heart rate, dropped  
 68 immediately after exposure [15].  
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70 There is also work that has been done in how a users heart reacts while in VR, work was done with VR and training  
 71 to use a virtual workstation that used ECG signals to try and measure stress while learning how to use it; none was  
 72 found [12]. It has been found, through the use of heart rate, that characteristics such as animated elements and unusual  
 73 viewpoints hold potential in forming strong memories [13]. Further research into VR through the use of using these  
 74 types of signals from the body found that *VR environment had a stronger correlation with subjective perception, indicating*  
 75 *that it is easier to elicit emotions* [16], however, this is contradicted by further research that while users reported higher  
 76 relaxation in VR; there was no significant difference from a traditional screen environment showing the same thing [10].  
 77 While not directly related to the connection between VR and physiological signals, it was found that realism doesn't  
 78 play as big of an impact in the social connection of VR, rather that co-presence did [4]. Our work is similar to this  
 79 previous work in VR as it has a focus on how a user might be effected, however, we focused more on what responses  
 80 would be observed from users after playing VR rather than during.  
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82 Just focusing on research on fear in VR, there is a surprising amount of work that has been done. In one study it was  
 83 found that while VR horror did not show any lasting effects the next day, it did *serve as an excellent means to induce*  
 84 *fear* [11]. Similar to the work done in [10] comparing VR to a traditional monitor, it was found that VR horror was  
 85 rated as being more intense as well as being more resist to *knowing what is to come* [5]. This comparison of traditional  
 86 horror games to VR horror games appears to be a common area focused on, in a study comparing the same game as a  
 87 traditional two-dimensional (2D) game and as a VR game it was found that users performed at the same skill level no  
 88 matter which one was used; as well as producing feelings of anxiousness in users [17]. Our work followed a similar path  
 89 to this research as well, however, once again most research focused on comparing it to a 2D format or if an emotional  
 90 response was observed while ours focuses on if the emotional response is observed after VR.  
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92 The related work on research for VR shows that it does cause elevated emotions in users, whether if this is truly the  
 93 case or only what users believe is still up the air. Along the same grounds horror as a genre can produce a measurable  
 94 physical changes through measurements such as heart rate. While not specific to VR it has been found that specifically  
 95 with horror video games that heart rate is good way to detect player affect which is a way to measure how well players  
 96 in a game respond to a stimulus [20]. While we didn't make use of this idea of integrating heart rate as an intractable  
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105 element, research has been done that shows that visualizing it and artificial increasing the shown number does lead to  
106 an observed increase [9]. All of this previous research had us hypothesizing that we would observe elevated heart rates  
107 in users even after completing a VR horror game and no longer being in VR when exposed to a similar environment.  
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109 In order to figure out the best way to elicit a response from participants research on the development of horror games  
110 was also looked at; while not directly related, it did influence the design used for the game used during this studies  
111 trials. For monsters in games it has been found that motion and sound can exaggerate how uncanny a character is and  
112 lead to increased fear [19]. It was found in 2D media that sound lead to subtle changes in how the heart behaved [14]  
113 which could also apply to games as well. It has been found that more intricate interactions in VR horror specifically lead  
114 to higher evaluation from user reports and more variation in physiological signals [7]; this is supported by additional  
115 research also showing immersion leading to users rating a game as frightening [3]. Research into player preference  
116 specifically supports the idea that little details increase engagement, one study found lighting to be something that can  
117 lead to higher positive rating by players [2].  
118

### 119 3 METHODOLOGY

#### 120 3.1 Participants

121 Twelve volunteer participants were used for the study. Most participants who took part were between the ages of  
122 21-25 with one outlier of 55, the genders skewed towards male. While not part of the study, users almost all universally  
123 self-reported VR experience when being instructed on how to use the headset; this was everything from having used  
124 VR once, having a personal VR headset used often, as well as never having used VR before.  
125

#### 126 3.2 Apparatus

127 3.2.1 *Hardware.* For measuring participants heart rate we used a *Scosche Rhythm R+2.0* armband heart rate monitor.  
128 This took a reading of the users heart rate and updated roughly every 0.5 seconds according to data collected. This was  
129 positioned on each participants forearm, above a vein, at a point where it was snug but not tight enough to cause any  
130 stress or elevated heart rate, this can be seen in Figure 1.  
131

132 A valve index with a resolution of 2880x1600 and 144hz refresh rate was the VR headset that was used by participants  
133 in the study, this was run with two base stations; each mounted at ceiling level in opposite corners of the room. The VR  
134 application itself was run on a desktop computer equipped with an NVIDIA 4080 graphics card,  
135

136 3.2.2 *Software.* The main piece of software used to record heart rate data from participants was a mobile application  
137 called *Heart Rate Variability Logger* published by A.S.M.A. B.V, this allowed us to record heart rate data and export it as  
138 a csv file to be analyzed. The application was ran on an apple iPhone 14, this helped during sections of the study where  
139 participants heart rate was monitored in real time. The VR horror game participants played as part of the study was our  
140 second piece of software. It was developed in Unity and was modeled one to one on the house where the study took  
141 place which can be seen in Figure 2. To add the interactivity talked about in [7], the door to leave the tutorial room  
142 was designed with physics that the participant could interact it by physical grabbing the handle as seen in Figure 3.  
143 Two methods were used to try and cause fear in participants during the game, sound design with creaking steps and  
144 a slamming door while walking away from the tutorial room and a monster suddenly appearing with a sound effect  
145 near the bottom of the stairs. This monster can be seen in Figure 4 and was designed with the research of [19] in mind;  
146 being human-like to try and appear uncanny.  
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Fig. 1. Demonstration of how the heart rate monitor was worn

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Fig. 2. Examples of sections of the house users traversed in VR

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### 3.3 Procedure

203 When participants arrived they given a consent form as well as a verbal explanation of the goal of the study and what  
 204 they would be asked to do; this was done at the front entrance of the house. Once participants had signed the consent  
 205 form they were shown a light switch on the wall and told that they would be tasked to flip this light switch three times,  
 206 twice in real life and once in a VR recreation of the house [Figure 5](#). This action was defined to them as the task.  
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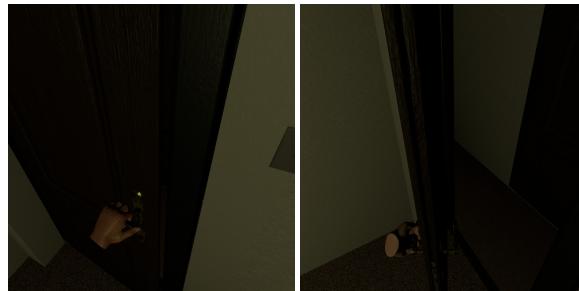


Fig. 3. Interactivity implemented through door to keep users engaged.

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Fig. 4. Monster used to jump-scare participants near end of task2

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Fig. 5. Left is real-life task, right is VR task.

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After this participants were taken to a room of the house where the VR equipment and a couch were setup, they were then equipped with the heart rate monitor. At this point they were told to sit on the couch until their heart rate settled, this heart was determined to be a good resting heart rate to let participants to return to after each completion of

	T1	T2	T3
P1	73.9	103.9	80.1
P2	95.1	108.7	102.7
P3	103.8	90.5	90.8
P4	106.5	111.8	108.3
P5	91.9	83.1	73.5
P6	87.6	99.4	88.5
P7	77.1	94.1	78.8
P8	81.9	89.1	85.2
P9	71.8	65.9	73.3
P10	87.3	74.7	68.6
P11	118.4	93.6	102.2
P12	80.9	75	85.4

Table 1. Average heart rate over each trial.

the task. Once settled participants were told to go complete the task; the time they left and returned to the room was logged in order to find the average heart rate.

After returning participants were asked to sit on the couch again until their heart rate returned to the resting BPM determined before completing the task for the first time. During this period the controls for the VR horror game were explained and demonstrated. Once heart rate settled they were assisted in putting on the VR headset and given a walk through of how to use the controls again. At this point participants were told to complete the task in the VR horror game modeled after the house, start and end time were logged.

Once participants had completed the VR horror game, they were asked to sit on the couch for a final time to allow heart rate to return to resting level. Once heart rate had returned to resting level they were told to complete the task in the real house again; the time they left and returned was logged. After they returned they were told that the study was completed. While completion time of the study varied depending on how long heart rate took to return to resting level, time to complete tasks, and time to complete horror game; most participants completed everything in 10-15 minutes.

### 3.4 Design

The experiment was a single factor with two levels within-subject design. The independent variable in this was if participants had been exposed to the VR horror game or not, a before and after measurement. The dependent variable was participant heart rate averaged over the completion of the task before and after playing the VR horror game. An issue that we ran into with this design was the issue of noise in the data, since heart rate can vary by person and can be influenced by so many things outside of the control of the study there could be any number of things impacting that we would have no clue about. The total number of trials was 24 (=12 participants X 2 measurements).

## 4 RESULTS AND DISCUSSION

Heart rate data during each task was averaged for each task and can be seen in Table 1. Data for task 2, while not useful for the goal of the experiment since it's the average heart rate while playing the game, still allows us to see which participants felt fear during the game and which didn't. This proved a useful identifier when performing ANOVA on the data; for all participants  $p = 0.2929$  which can be seen in Table 2, this is greater than 0.05 the horror game did not have a statistically significant impact on the heart rate during the task before and after.

Effect	df	SS	MS	F	p
Participant	11	3424.043	311.277		
F1	1	62.727	62.727	1.220	0.2929
F1 x Par	11	565.383	51.398		

Table 2. ANOVA Table of all participants

Effect	df	SS	MS	F	p
Participant	5	1466.114	293.223		
F1	1	38.521	38.521	10.414	0.0233
F1 x Par	5	18.494	3.699		

Table 3. ANOVA Table of participants afraid of game

Effect	df	SS	MS	F	p
Participant	5	1944.728	388.946		
F1	1	303.008	303.008	5.651	0.0634
F1 x Par	5	268.087	53.617		

Table 4. ANOVA Table of participants not afraid of game

The average heart rate for T2, when participants were playing the horror game, in Table 1 allows us to split the data into people who showed fear in the game (referred to after this as group1) and those who did not (referred to after this as group2); this decision was made base on if heart rate was higher than T1 heart rate. Participants P3, P5, P9, P10, P11, and P12 were deemed to not have shown fear in the game. ANOVA was performed again on each of these subgroups, those who displayed fear can be seen Table 3 while those who didn't can be seen in Table 4. The VR horror game once again did not have a statistically significant impact on group2 with a  $p = 0.0634$ . This changed for group1 with a  $p = 0.0233$  which was below the threshold of 0.05 to be significant.

We believe a possible explanation for why the VR horror game was only statistically significant for group2 is because group1 was never afraid in the first place. This could be due to the game used in the experiment not utilizing techniques that would elicit a response from them, having a higher tolerance for fear in general, or not being as engaged by the experiment in general. There is also a possibility that since not every participant showed fear to the game, we don't have large enough sample of either group. What we did find though was that when people do show fear in VR horror it does seem to elicit a change in response to their environment afterwards.

## 5 CONCLUSION

Overall, we found that when people have a high heart rate while playing a VR horror game it is reflected in a high heart rate while replicating a similar task even after given time to return back to a resting heart rate. If someone's heart rate isn't effected by a VR horror game then their heart rate does not show statistically significant change when completing a similiar task afterwards.

Given additional time there are several things we would change; the big change would be getting a larger sample size of both groups of people. Though it is hard to tell before playing who will show fear in the heart rate, we would try to focus more on building a better game in order to limit the amount of people who don't show a response to it. Some of the several ideas we had were to increase the length or to add more interaction, all of the main elements to cause fear

365 where static such as audio cues and a jump scare and dynamic elements might cause a response in more participants  
 366 which would give more data to support or disprove Table 3.  
 367

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