Do cutaneous senses give more immersive experience in Virtual Reality?

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Abstract: Cutaneous senses give people better perceptions of the world. In this study, we argue that in the world of virtual reality, cutaneous senses can facilitate people's perception and judgment of specific objects. We adopted a blurred image of ice cubes to allow participants to identify what the objects were and record their time of distinguishing. The result is based on the volunteers we found. They were divided into two groups and only the group that received the cutaneous sense treatment was able to tell what the blurred photo was within 30 seconds. We discuss the findings and implications.

Keywords: control variables, cold, cutaneous senses, ice, judgement and distinguishing, time of distinguishing, virtual reality.

1. Introduction

People usually use all their senses to experience the world. The more senses, the more the world becomes real in people's consciousness. In order to make the virtual world more immersive, people invented Virtual Reality (VR). Virtual Reality (VR) technologies have existed for many years in the gaming industry; however, their potential has also been recently recognized in several sectors [1]. The earliest origins of VR were used in the gaming industry. As the technology matures, it is widely used in more industries. The existing VR equipment emphasizes people's visual senses. There are also some incidental senses such as hearing, haptic, and bodysuit feedback… The user can manipulate the system in a virtual state of each object while enjoying the multiple senses of hearing, sight, and smell [2]. These senses mobilized by VR will allow people to experience further the entire virtual world based on seeing immersive images.

As we know, human perception is much more than VR technology has covered. To make the VR world more immersive, we believe adding cutaneous senses will significantly improve people's perception and judgment of objects.

Body schema is generally regarded as an unconscious, bottom-up, dynamic representation, relying on proprioceptive information from the muscles, joints, and skin during self-motion [3]. Cutaneous sense is also called skin sense. The senses of warmth, cold, pain, and touch (pressure) are located in the skin. Though they often play a crucial role in our lives, we depend far less on them than on sight and hearing for our knowledge of the external world [4]. Today's VR can simulate a small part of cutaneous sense, but there are still some senses, such as temperature, pain, and pressure, that few devices can simulate. We will focus on the impact of the sense of cold (a specific kind of cutaneous senses) on people's judgment and perception of the world.

We used a controlled trial approach to study the role of cold sensation in people's judgment of objects in a virtual world in VR. We simulated the VR with an immersive mask that was made by ourselves and put a blurred ice cube picture (Figure 1) inside. We asked 16 volunteers and record their identification time of the blurred ice cube picture (Figure 1) within two different treatments. Notably, the participants are only told to recognize the picture without knowing that they will be divided into groups and be treated with different treatments. It is therefore fair to all participants.

Figure 1: blurred ice cubes picture.

2. Method

2.1. Participant

The sample for this study was a random sample of 16 volunteers. Our participant pool constituted a convenience sample. All participants, including students and staff, were recruited at Keystone Academy in Beijing. They are between 14-45 years old, and the average age of the participants was 25 years old. The proportion of female participants was 58.75%, and the proportion of male participants was 31.25%. Participants need neither any basic knowledge of VR nor to prepare any additional equipment. The entire experiment was conducted under the circumstance of ensuring the participants' fully understanding of the rules.

2.2. Treatments

We included a randomized controlled experiment to compare VR object recognition with and without body perception to find out whether it is effective to enhance VR immersion through the new use of unused body perception. Participants were divided into two groups, and each group had 8 participants. The first group was the experiment group (EG) and the second group was the control group (CG). The feeling treated the experiment group (EG) of the temperature drop due to the proximity of the ice packs. We approached ice packs to the participants in this group to let them feel the temperature drop without their noticing when they started looking at the blurred picture of ice cubes (Figure 1). The control group (CG) was given the same blurred picture of ice cubes without the treatment in EG.

2.3. Analog VR device

Because of participants' differences in vision, interpupillary distance, etc., it takes different time to adjust and adapt to the VR headset, which will bring bias and error to our experiments, we use recycled cardboard to create our headset that simulates traditional VR headset to achieve immersion, and at the same time, participants can see the picture without adjusting and adapting. We put the picture inside our VR simulator to give participants visual information to be guessed. We refer to the current popular VR devices to make volunteers focus on the pattern of the only transparent paper by isolating external light and simulate the experience of using VR devices under normal conditions. During the experiment, participants will hold the device in front of their eyes and look straight into our device, and they can see the blurred ice cubes image inside through the light through the transparency. The light intensity used in each test is consistent, and the control of variables is realized by using Keystone Academy dormitory corridor lights with equal brightness.

2.4. Procedure

We developed an independent test strategy to verify the role of cutaneous sensory in VR experiences by recording the time of each guessing until they get the correct answer and the guessing accuracy. Prior to the start of the experiment, participants will be divided into two groups (group A and group B). Without interoperability, each person will be tested separately to avoid any influence on the response of other volunteers. Participants were told before the experiment began that any guesses were allowed, and the timing would stop when they said the correct answer. If the correct answer were not coming up within 30 seconds, then the timing would also stop. These people would be considered to "get the correct answer in more than 30 seconds". During the experiment, volunteers can choose to abandon the experiment at any time if they feel uncomfortable.

(1) Group A (Control Group)

Participants randomly assigned to Group A are given VR simulators with blurring ice cubes images to them, and they begin to observe and guess the object corresponding to the image while the timer starts. These people will not receive any additional assistance to help them get the correct answer. The entire process was recorded for subsequent statistical timekeeping.

(2) Group B (Experiment Group)

The other half of the Participants were divided into group B. The treatment added the temperature brought by the ice packs on top of the visual observation of group A. Once the timer started, we placed the ice packs 3 cm away from the volunteer's right arm to provide a cold temperature.

2.5. Data collection

We quantified participants' judgments and perceptions of images under the influence of a sense of cold using the time participants took to discern blurred images. We timed the time they used to identify the image. At the same time, we also recorded the whole process of the experiment to record the time from the moment they saw the picture to the time they spoke out about what the object was to check the data.

2.6. Analysis and Risk of Bias Assessment

The data we finally took was the time for volunteers to guess the correct answer (ice/ice cubes). To ensure the accuracy of the results, we calculate the average guessing times of 8 volunteers in each group for their final results.

To reduce bias due to the similarities between individuals, each group of eight participants consisted of four female students (one of them is from a country other than China) as well as one or two female teachers and two or three male students, respectively, to reduce errors that might be introduced by culture, gender, or age.

The risks in the experiment include possible frostbite due to contact with the ice pack or discomfort caused by the experimenter's vertigo from the VR headset. There is also possible eye irritation from facing the light through the paper. We decided not to touch the participants with ice packs to avoid these risks. Instead, we try to change the air temperature around them. Besides, we shortened the initial set experiment time from 1 minute to 30 seconds to reduce possible vertigo. Finally, we ultimately chose a hallway light rather than a brighter desk lamp to reduce the visual stimulation to the participants. Even so, the bias still exists. Due to the covid policy situation, our sample is a convenience sample. We did not have enough volunteers to ensure that the final data sufficiently represented the facts. Since They are all students and staff from Keystone Academy, the small data sampling range does not include people who are not familiar with modern technology. The 16 data sources may be subject to significant individual variation, which the bias is currently unable to eliminate.

2.7. Data Synthesis and Analysis

The study was compared to two groups, including the success rate of getting the correct answer within 30 seconds and the time taken to get the correct answer. To maintain consistency, all data will be averaged within groups. So far, Group B, with the addition of body sensory assistance, has an 87.5% success rate of getting the correct answer within 30 seconds, while Group A with conventional vision has a 0% success rate. At the same time, the average time to get the correct answer for group B was 12.6 seconds, while the average time for the corresponding group A was greater than 30 seconds of the test.

3. Results

The goal of this study was to decide that in the world of virtual reality, cutaneous senses can facilitate people's perception and judgment of specific objects. Based on the experiment of changing the surrounding temperature of the participants, we analysed the relationship between the two group means and the inclusion of cutaneous senses awareness. We found that subjects generally guessed the correct answer faster with the support of cutaneous senses awareness.

Table 1: Time taken to give the correct answer (sec).

	Volunteer No.1	Volunteer No.2	Volunteer No.3	Volunteer No.4	Volunteer No.5	Volunteer No.6	Volunteer No.7	Volunteer No.8
Group A	8	12	30	9	29	4	16	10
Group B	30	30	30	30	30	30	30	30

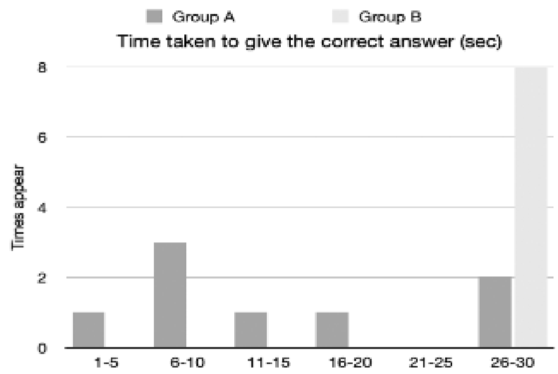

Figure 2: Time participants use to get the right answer.

3.1. Groups and data

The two groups had different tendencies in the time they took to guess and get the correct answer. As presented in Figure 2, Group A had the most guesses between 6 to 10 seconds (Volunteer No.1 & No.4 & No. 8). No one in group B guessed the correct answer within 30 seconds (Volunteer No.1 & No.2 & No.3 No.4 & No.5 & No.6 & No.7 & No. 8). The mean time Group A used to guess the correct answer (12.6 seconds) in far less time than the mean of Group B (>30 seconds).

The accuracy rate of the judgments between the two groups is also very different. Most of the participants in Group A have come out with the right answer. The accuracy rate of group B is 0% which means none of them to get the correct answer.

3.2. Gender

Because the volunteers are recruited, the participants' proportion of females (58.75%) is much higher than males (31.25%). All participants were informed and permitted for this experiment to take place. This result may be caused by females being more curious about new products than males or that the ratio of males to females in schools is more male than females.

3.3. Temperature

Cooling temperatures can affect people's judgment without their noticing. This proves that Cutaneous senses are an imperceptible but important sense.

In conclusion, from the above data, we concluded that cutaneous senses greatly impact people's perception and judgment of objects in VR. As a result, adding cutaneous senses can make the VR experience more immersive. Virtual reality (VR) aims to create an immersive experience that transports the user to another world with established terminology describing various VR aspects. The term Presence in VR means how much a user believes that he/she is inside a virtual world [5].

4. Discussion

The results of our study provide evidence that cutaneous senses give people better perceptions and judgment in Virtual Reality. We infer this result from two groups of experiments in which the sense of cold alter the judgment of objects.

We also show that volunteers in the convenience sample were biased according to their daily preferences and their original distribution. Our study has data selection bias, so the result is not convincing enough: the ratio of males and females is not balanced enough, and the data represents more females. The data comes from students and staff of a specific school. Due to the Covid-19 policy, students cannot leave the school if they choose to stay. Only a small number of those who stay in the school can become volunteer samples. The people involved in the sample are not diverse enough; most of them are Chinese. Only one or two participants are non-Chinese.

We only use ice to change the temperature of the surrounding air to predict all of the cutaneous senses in Virtual Reality. Further experiments such us using fire to change the temperature hot should be done.

Author Contributions

Z. Runqi designed the study and did the proofreading. X. Zhitong did the experiment and analysed the data. X. Zhitong and Z. Runqi wrote the manuscript.

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