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Influence of Regularly Moving Object on User's Time Perception in VR Space

Xin TONG, Tetsuro OGI
Graduate School of System Design and Management, Keio University
4-1-1 Hiyoshi, Kohoku-ku, Yokohama, Kanagawa 223-8526, Japan
E-mail: tongxin@keio.jp
ogi@sdm.keio.ac.jp

Abstract
Time perception can differ significantly in different circumstances and environments. Though it is difficult to create a variety of environments in real world, VR technology can simulate various environments with low cost. And it is easy to control elements in VR environment to explore how they effect on people's perception. In this research, we built a VR space where all objects are stationary, and then set up an object that can move regularly. We did an experiment in which we changed the speed of the object and let users look at the object using HMD (Head Mounted Display). We found users' time perception of one minute differed when the object moved at different speed. In addition, we did another experiment in which we let users look the same content on a normal monitor. From the experiment, we concluded that when users look at regularly moving object, it has a more obvious influence on the users' time perception when using HMD to look it than using normal monitor.

Key words: HMD, regularly moving object, time perception

1. Introduction

In many cases, users want their time perception felt faster or slower. When experiencing happy and glad time, users want their time perception becomes slower to make this time felt longer. And when experiencing boring or painful time, users also want their time perception becomes faster to make this time felt shorter. Therefore, it is desired that users can control their time perception in case of needs.

In different circumstances and environments, users' time perception has different manifestations. Previous researches have shown that there are many factors that have an influence on people's time perception. For example, the speed of motion object [1,2], the main color of the environment [3], the sounds in environment [4] are known as factors. In order to study the effects of various influence factors on user's time perception carefully, we need to create an environment that has only a single influence factor for user's time perception. However, in many cases, creating such an environment in real world will cost a lot of time and money.

Previous studies have shown that when human perceives information and obtains outside intelligence, human gets it through the surrounding environment. 95% of information and intelligence are obtained through visual and auditory sensation (85% of vision and 10% of auditory) [5]. When user wears an HMD (Head Mounted Display) and views a VR space, the information obtained by the user through visual and auditory sensation is completely determined by the VR space. Therefore, we can explore the influence of each factor and research how it affects user's time perception, by creating a VR space and controlling the factors in the virtual environment.

In this research, we first created a VR space with no moving objects, and then placed a floor clock with regularly moving pendulum in it. The period of the pendulum can be controlled freely. Then we let subjects to use HMD to view the VR space and controlled the period of the pendulum to explore the relationship between the subject's time perception and the speed of moving pendulum. In addition, we made subjects view the same VR space on a 15.6-inch monitor and compared the influence on the subject's time perception.

2. Experiments on time perception

In order to verify whether the regularly moving object has an influence on the user's time perception in a VR space, we designed three experiments. We measured user's time perception of 60 seconds in under three different conditions. And then we analyzed the experimental data. 17 subjects performed the experiments, including 11 males and 6 females. The subjects' age was all 20-30 years old.

2.1 Time perception measurement in real world

First, we measured the user's time perception in real world. In this experiment, the subject is in a silent room with closed eyes and holds a stopwatch in his/her hand. After starting the timer, the subject presses the stop button when he/she feels that 60 seconds have passed. Each subject performs three measurements, then the average and standard deviation of the measurement results are recorded.

The results of this experiment are shown in Fig.1. From the result of this experiment, we learned that the user's time perception of 60 seconds is basically accurate when there is no timing tool. The average error was 1.26 seconds and standard deviation was 5.17 seconds.

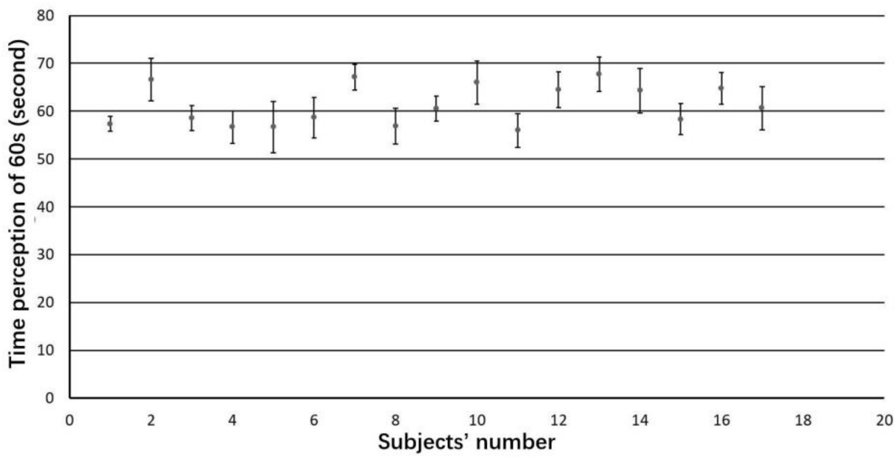

Fig.1 17 Subjects' time perception of 60 seconds in real world
(Average: 61.26s, Std. Deviation:5.17s)

2.2 Time perception measurement using HMD

2.2.1 Time perception measurement when user sees VR space without regularly moving object

Second, we measured the user's time perception using HMD. In this experiment, we make the subject wear an HMD and experience a VR space where all objects are stationary as shown in Fig.2. We use Unity3D to make the VR space and set V-Sync to make VR contents render at a fps depending on the platform. And we use Carl Zeiss VR One Plus and iPhone Xs (Frequency:60Hz) to constitute the HMD that has a 100-degree field of view. VR contents that we made are rendered at 60fps on this HMD. The subject is in the center of the virtual space and sits on a chair. The subject can rotate head to see around. We ask the subject to close eyes and hold a stopwatch in his/her hand. When the subject opens eyes to watch virtual world using HDM, he/she presses the stopwatch button to start timer. Then the subject presses the stop button when he/she feels that 60 seconds have passed. Each subject performs three measurements, then the average and standard deviation of the measurement results are recorded.

The results of this experiment are shown in Fig.3. From this experiment, we understood that when there is no timing tool, the subjects' time perception had -1.53 seconds of average error and 5.83 seconds of standard deviation per 60 seconds in the VR space. Though time perception in VR space tends to be a little shorter than time perception in real world, the error and standard deviation were almost same. From this result, we can see that it is possible to conduct an experiment on user's time perception using a VR space.

Fig.2 The appearance of VR space

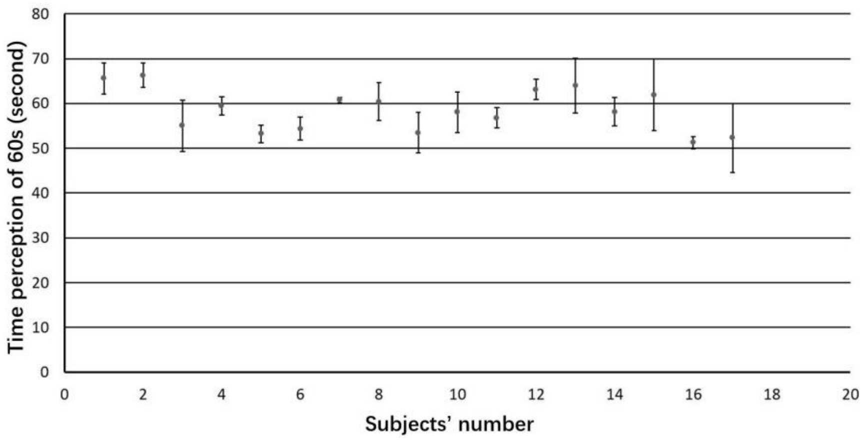

Fig.3 17 subjects' time perception of 60 seconds in VR space without moving object
(Average: 58.47s, Std. Deviation: 5.83s)

2.2.2 Time perception measurement when user sees VR space with a regularly moving object

In the next experiment, we make the subject wear an HMD and experience a VR space where a floor clock with a regularly moving pendulum is placed with other stationary objects as shown in Fig.4. The subject is in the center of this space and sits on a chair. The subject can rotate head to see around. Though the period of the pendulum is physically fixed in the real world, it can be changed freely in the virtual world. When the pendulum moves with a normal period, it has the same speed as the pendulum with same length in the real world. Firstly, we adjust the pendulum speed as a normal frequency. Then we ask the subject to close eyes and hold a stopwatch in his/her hand. When the subject opens eyes to watch virtual world using HDM, he/she presses the stopwatch button to start timer. Then the subject presses the stop button when he/she feels that 60 seconds have passed. Each subject performs three measurements, then the measurement data are recorded. After that, we change the pendulum frequency to 0.1 times speed, 0.5 times speed, and 2 times speed. The same experiment is performed, and experimental data is recorded. And we used Tukey's multiple comparison to test measure specific differences between pairs of means. The results of this experiment are shown in Fig.5.

From the results of this experiment, we know that when there is a regularly moving pendulum in the VR space, its motion frequency has a significant influence on the subject's time perception. The user's time perception of 60 seconds become slower when the pendulum moves slower. And the user's time perception of 60 seconds become faster when the pendulum moves faster. Namely, adding a regularly moving object in VR space has an influence on user's time perception. Table 1 shows the influence rate of the speed of the virtual pendulum on subject's time perception. When the virtual pendulum moves at 0.1 times speed, it has conspicuous influence on user's time perception. And this influence rate is larger than the influence when the virtual pendulum moves at 0.2 times speed. Thus, we can understand that when the virtual object moves at extremely slow speed, it will have a large influence on user's time perception. By using HMD, subjects are in a VR space that all objects are actual size, so they can physically feel the speed of reality is different.

Fig.4 The appearance of virtual floor clock with a regularly moving pendulum.

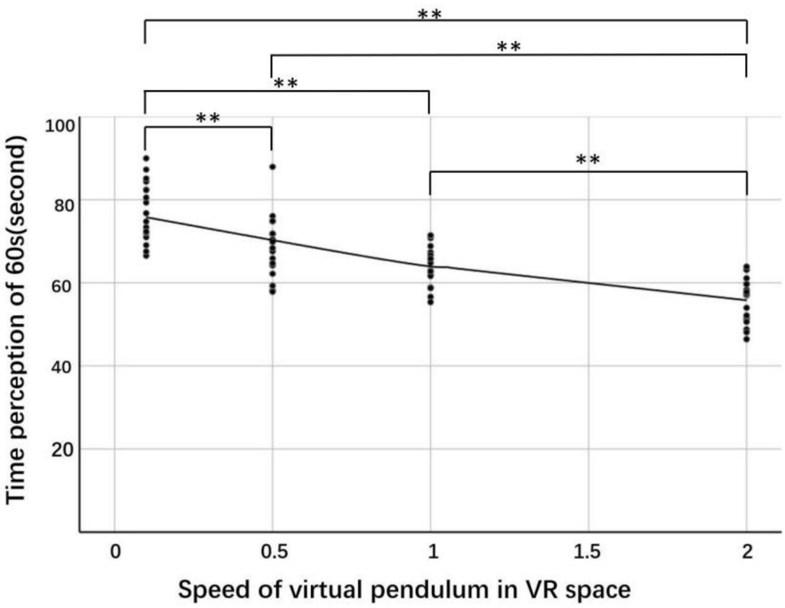

Fig.5 Subject's time perception of 60s when the virtual pendulum moves at different frequency (0.1 times speed, 0.5 times speed, 1 times speed, 2 times speed).

Table 1. Subjects' time perception influence rate of 60s using HMD
(using average data measured in VR space without virtual pendulum.as standard)

	VR space (without virtual pendulum)	0.1 speed	0.5 speed	1 speed	2 speed
Influence Rate= (Mean - Standard)/Standard × 100%	Standard (58.47s)	32.22%	17.26%	9.82%	-4.79%

2.3 Time perception measurement using monitor

Thirdly, we measured the user's time perception using normal monitor. In this experiment, we present the same image of the VR space on a 15.6-inch monitor (Model:SHP1450, Frequency:60Hz). Then we make the subject watch the image of the VR space on the monitor in a real room where all objects are stationary, and VR contents are rendered at 60fps smoothly on this monitor (measured by Fraps). Then we ask the subject to close eyes and hold a stopwatch in his/her hand. When the subject opens eyes to watch the image, he/she presses the stopwatch button to start timer. Then the subject presses the stop button when he/she feels that 60 seconds have passed. In this experiment, the pendulum frequency is also changed to 0.1 times speed, 0.5 times speed, and 2 times speed, and the experimental data is recorded. We used Tukey's multiple comparison to test measure specific differences between pairs of means. The results of this experiment are shown in Fig.6.

From the experimental results, we know that when the same VR contents were viewed on the 15.6-inch monitor, the influence on the user's time perception is not greatly affected compared with using HMD to view. From Table 2 we know that when the speed of the virtual pendulum is changed in the image of the VR space, it does not have a conspicuous influence on user's time perception. From Fig.6 we know that changing the speed of virtual pendulum have a more conspicuous influence when subjects using HMD than they see the same VR contents on a 15.6-inch monitor. When subjects view same VR space on monitor, they feel objects' size by compare with surrounding. Therefore, they can feel the speed of reality is different, but they are not aware of it physically. For this reason, viewing the VR contents on monitor will have a minor influence on subjects' time perception.

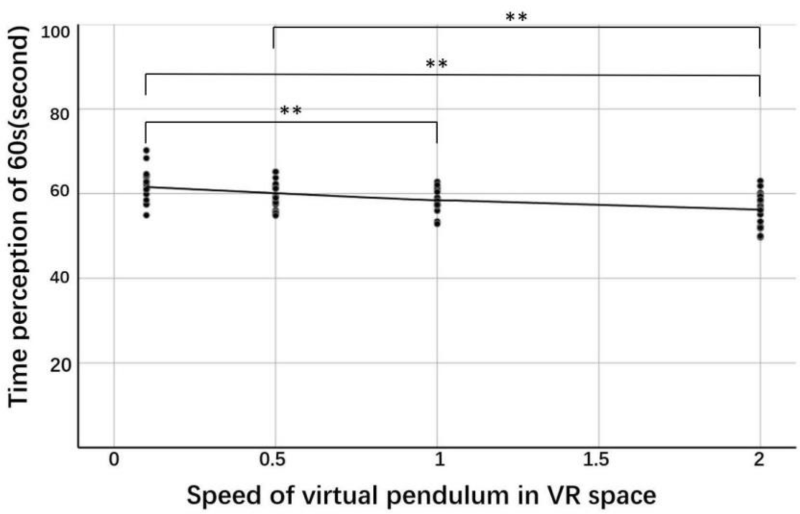

Fig.6 Subject's time perception of 60s on display when the virtual pendulum moves at different frequency (0.1 times speed, 0.5 times speed, 1 times speed, 2 times speed).

Table 2. Subject's time perception influence rate of 60s using 15.6-inch monitor
(using average data measured in VR space without virtual pendulum on display as standard)

	VR space on display (without virtual pendulum)	0.1 speed	0.5 speed	1 speed	2 speed
Influence Rate= (Mean - Standard)/Standard × 100%	Standard (59.18s)	4.87%	-0.76%	-1.22%	-5.10%

3. Conclusion

In this research, we conducted three experiments by constructing a VR space with a regularly moving pendulum that speed can be controlled. By analyzing the experimental results, we concluded that the regularly moving object can affect the user's time perception in VR space. When a regularly moving pendulum with the same motion speed as the pendulum in the real world is placed in a stationary VR space, there is no significant influence on the user's time perception. However, making the speed of the pendulum significantly slower or faster will have a significant impact on subjects' time perception when they were using HMD. Faster the object moves, user's time perception will be faster; slower the object moves, user's time perception will be slower. If users need to adjust the speed of their time perception, it can be realized by wearing the HMD and controlling the speed of the regularly moving object in VR space. And when viewing the same VR contents, the influence of using HMD on user’s time perception is significantly greater than the influence of using a 15.6-inch monitor. And if the speed of the virtual pendulum is changed, it does not have large influence on users’ time perception when viewing the VR space displayed on monitor.

Future work will include doing a more specific research about relationship between object motion speed and user's time perception, and the influence on the user's time perception when placing more moving objects in VR space. We will also study whether irregularly moving objects will affect the user's time perception like regularly moving objects. At the same time, we will present VR contents on display with different size to research if the size of display will have influence on user’s time perception.

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