Physical Demand of Mid-air Hand Gestures in VR

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ABSTRACT
The design of desirable gestural interfaces that allow users to experience less physical fatigue with better engagement in the virtual reality (VR) environment is challenging as there are only few studies conducted concerning the interplay of physical effort and preference in gestural interface design. In this study, we investigate how the perceived physical effort affects gesture preference to perform simple tasks by expanding the prior study's scope and context. This study verified that there is a negative correlation between preference and physical demand, which is consistent with the previous study, can also be applied in the VR context. This study also demonstrated that the object size and the types of gestures have no effect on the physical demand or perceived user preference.

Author Keywords
Gesture interfaces; usability evaluation; mental model; VR; effort-based measurement.

CSS Concepts
• **Human-centered computing**→*Empirical studies in HCI*

INTRODUCTION
Gesture interfaces are considered more natural than other interfaces that use physical controllers because they allow the users to use metaphoric hand gestures as well as ordinary gestures that are learned and embodied from daily life [9]. The use of gestural interactions is considered particularly effective in the VR environment as it can enhance of sense of presence and level of engagement within VR space [4].

Although the design of various gestural interaction techniques and graphical user interfaces to support such systems has been widely researched and proved its potential, it is considered numerous user experience problems are still there. Because the majority of previous studies have been focusing on the development of novel software or hardware that facilitates an environment through novel interaction techniques between users with the system rather than focusing on enhancing the quality of user experience design within the interaction loop.

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Regarding the design of gestural languages and its assessment, a number of attempts have been made. For example, Sheehan et al. [1] attempted to identify factors, such as Fatigue, Naturalness, Gesture Duration, and Accuracy, to create a quantitative model that reflects the usability of a gestural interface. Other researchers [2,6] put their emphasis on the role of effort in gesture preferences and selection. Recently, Liu and Thomas [5] argued that even a small difference in physical demand could significantly affect the users' experience even the users are performing simple tasks with a Leap Motion controller within a 2D desktop environment.

Inspired by Liu and Thomas's work, the goal of our study is to explore the effect of physical demand on the preference in gesture selection and use for performing simple tasks within the VR environment. We are also interested to know whether their empirical results, which are tested and acquired in the 2D environment, can be applied to the immersive environment. Based on a previous study by Liu and Thomas, the pinch, half-grab, and fist were chosen as baseline gestures for our experiment. However, we added three different object size as an additional variable to test a potential interaction effect between different gestures [5,7]. We firstly hypothesized that there could be a specific gesture type that makes the users feel less physical demand, unlike Liu and Thomas' results. Our hypothesis was evaluated in the experiment with 10 participants (468 trials per participant), and the repeated measures two-way ANOVA analysis verified that we could expand Liu and Thomas' work and apply the insight to the VR environment as the results are consistent.

EXPERIMENT

Experimental Design
The task was to catch a red ball and touch it with a green ball via the gesture that was specified on the panel in front of them in the VR environment. When the spheres came into contact with each other, the green sphere changed to red as shown in Figure 1. The participants performed the task using the same gesture until the phrase "FINISH" appeared. As shown in Figure 1, the position of the red sphere during each task was determined at random from 26 positions in 3 x 3 x 3 cubes. The green sphere was in the center of the cube. The experiment was designed in this manner because any fatigue or preference felt might vary per the location of the space.

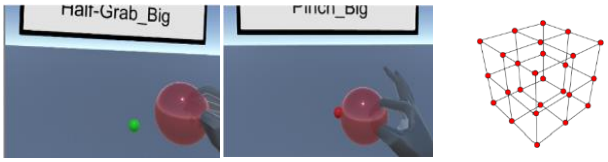

Figure 1. Given tasks and instructions created in VR space

There were nine experimental conditions for three kinds of gestures and three different sized objects. The participants performed each condition twice in total, and the condition order was random. We considered the first trial was considered a practice session to make them adjust to the environment and interactions. Thus, one participant carried out 468 tasks (2 repeats, 9 conditions, and 26 positions).

Apparatus

The Samsung HMD Odyssey VR device was used, and the Leap Motion Controller tracked the hand gestures. The Leap Motion Controller was attached to the front of the VR device. The experiment was conducted with C# with a Unity and Leap Motion interaction engine.

Participants and Procedure

We recruited 10 (5 male, 5 female) right-handed participants with a mean age of 24.3 years (SD 2.11) from the university's social community. They had less experience in gesture interface and VR. All the experiments were conducted in the lab environment, as shown in Figure 2. The participants wore the VR devices with a Leap Motion Controller for a test. They participated in this experiment after having a practice session, which lasted until they felt familiar with all the gestures. After one task was completed, they had to push the space bar on the keyboard to start the next task. The participants removed the VR devices after each experimental condition to respond to the perceived physical demand and their preference for the gesture on a scale of 1–10. After finishing the experiment, exit interviews were conducted.

Figure 2. A participant is performing the given task

RESULTS

Figure 3 illustrates the result. Because the collected data did not follow a normal distribution, the non-parametric method was used for data analysis. The result suggested that when the participants grabbed a large object, they felt the least physical demand ($p<0.001$) and preferred it most ($p<0.001$), regardless of the gesture type (physical demand: $p=0.20$, preference: $p=0.09$). In addition, they preferred to pinch for grabbing objects($p=0.002$), regardless of the object's size ($p=0.09$). Lastly, there was a significant negative Spearman's rank-order correlation between physical demand and preference ($r_s = -0.55$, $p < 0.001$) [10].

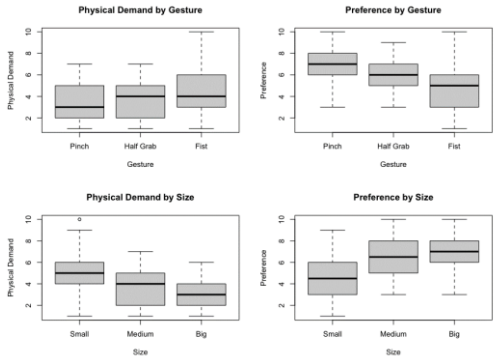

Figure 3. Results of perceived physical demands and preference for gesture and size

During the exit interview, the participants responded that the recognition rate of the gestures affected their preferences (P0, P2, P4, P5, and P9). Besides, P1, P2, P7, and P8 responded that they felt inconvenienced by gestures that were not suitable for the object's size.

DISCUSSION

This study verified the result of a previous study that showed that a negative correlation between preference and physical demand can also be applied in various contexts in the VR environment [5]. Furthermore, this study demonstrated that both object size and gesture type have no effect on each other for the physical demand or preference users perceive. Therefore, the results suggested that the users tend to use to grab large objects via a pinch gesture in the VR environment. One might start to design a gestural interface within this space with pinching gestures and large-size objects as a baseline for a better user experience. However, the interface design should be refined if overall visualization system becomes more complex in order to prevent a Midas touch [3].

LIMITATIONS AND FUTURE WORK

One limitation of this study is that other variables could have been considered. For example, the grip should be considered not only the size of objects but also the shape and intend of use [7,8]. Further research can explore to what extent different level of prior experiences with VR media can affect the selection and use of gestures interacting with different sized-objects. We hope our work can contribute to building design guidelines that can suggest how we can design more intuitive and usable the interface for beginners within the VR environment.

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