Comparison of Input Methods and Button Sizes in Augmented Reality Devices

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***Abstract*— Augmented-Reality (AR) has already been applied to many areas and applications, but there is still a lack of research on the appropriate interface considering the usability of AR devices. At present, the main input methods of HoloLens can be classified into two categories: hand (gesture) and clicker. In this work, participants wear HoloLens and perform target selection works. We measure the task completion time, user satisfaction score and error rate to check the effects of the input methods, button sizes, and distances. The Latin Square design was used to minimize the effect of the order. Then, a questionnaire was conducted after each treatment. In this paper, we compared the performance changes by input methods, button size, and distance in HoloLens. There was a significant difference in input method, distance and button size. Task completion time and user satisfaction were better with the large button than the small button, and the error rate was higher with the large button. In task completion time and user satisfaction, the clicker performed better than the hand. The task completion time and the user satisfaction were better in 80 cm and 100 cm than 60 cm.**

Keywords-Augmented-reality; interface; Button-size; Hololens; Input method; Distance.

I. INTRODUCTION

Augmented-Reality (AR) refers to a computer interface technology that enables users to perceive mixed images by combining a virtual world composed of computer graphics with the real world in the form of virtual reality. Users interact with computers while manipulating them as virtual objects by their actions in real-time [1]. AR is already being used in a wide range of areas, such as education psychology, entertainment, retail, construction, cultural heritage, tourism, etc. with many different applications, such as training, skill learning, maintenance, repair, quality control, or safety awareness [2]. Previous studies have conducted performance evaluations according to the user input method of AR devices, analyzed the strength and weakness of the input method, and proposed an improved interface [3]. Research was also conducted to explore various safety problems that can occur while operating various Internet of Things (IoT) devices in the Augmented-reality environment, and to provide design guidelines to prevent them [4]. In the previous usability study using Virtual-Reality (VR) devices, large buttons (3° 50′) and small buttons (1° 55′) were found to have differences in terms of button input time and error rate, and the large button was recommended [5]. However, in the case of AR devices, it was thought that there would be a difference between the results of VR devices in that the background behind the buttons is the real world and the distance between the user's eyes and the button's visible distance is adjustable, and this research was conducted because there is still a lack of research on the interface considering the usability of AR devices. The rest of the paper is structured as follows. Section II presents the experimental design. Section III describes the results and Section IV offers the conclusion and future work.

II. EXPERIMENTAL DESIGN

Participants in our study conducted experiments using HoloLens, and the task was to repeatedly select targets from different variances. Participants in the experiment consisted of people who had no problem with the experiment and were not familiar with the use of HoloLens.

A. Participants

The research group consisted of 12 male and 12 female participants (Average age: 21.21 years old, Standard deviation: 1.26) who had no experience in using augmented reality except smartphone-based augmented reality and had no physical or visual problems. Participants were recruited using the university intranet, all Asian, and were given incentives to encourage participation. 11 of them had experience using VR devices and 22 of them were right - handed. Due to COVID-19, it was difficult to recruit participants of various age groups, so the participants were recruited as university students in their 20s.

B. Apparatus

The experimental device used the HoloLens Development Edition [6], which can mix holograms with the real world to make them sound like they are part of the world. The resolution of the instrument is HD 16:9 light engine and

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generates a 2.3M total light point. The HoloLens native user interface moves the cursor as the head moves and recognizes simple hand gestures within the angle of view of the camera on the front. The prototype Application runs on HoloLens and is implemented using Unity [7] and C#. HoloLens was light and comfortable to wear, easy to use, provided sufficient computing power, and was studied in many areas [8]. So, it was considered suitable for experimentation.

C. Tasks

This study repeats the target selection work, using HoloLens. Prototypes have a total of nine buttons and exist in the panel in the form of a 3 x 3 array. There are two sizes of buttons, and the size of small buttons is set to 1° 55′ 4″ based on the long side of the 3 x 4 keyboard of a smartphone or feature phone. Microsoft recommended against ever presenting holograms closer than 40 cm [9]. So, we constructed the experiment with a distance of 1.5, 2, and 2.5 times the distance of 40 cm. For the large buttons, it is set to double the small buttons, and the field of view is set as 3° 49′ 48″ [10] (Figure 1, Table 1). The distance was set at 60, 80 and 100 cm (Figure 2), and the subjects conducted the experiment with two types of input methods: hand and clicker. The participants repeatedly clicked the button that turns red among the 9 buttons, and then clicked the button 4 times (Figure 3) for 12 treatment conditions (2 Button sizes x 3 Distances x 2 Input methods) repeating 5 sets.

TABLE 1. BUTTON SIZE ACCORDING TO FOV AND DISTANCE

FOV	Distance	Size of Button
3° 49′ 48″	60 cm 80 cm 100 cm	3.68 cm 4.90 cm 6.14 cm
1° 55′ 4″	60 cm 80 cm 100 cm	2.00 cm 2.68 cm 3.35 cm

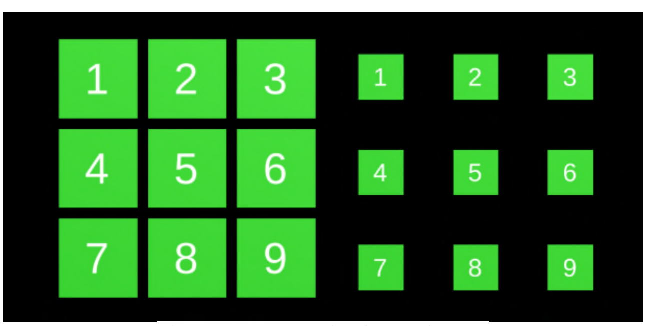

Figure 1. An example of target buttons
(left: large buttons, right : small buttons)

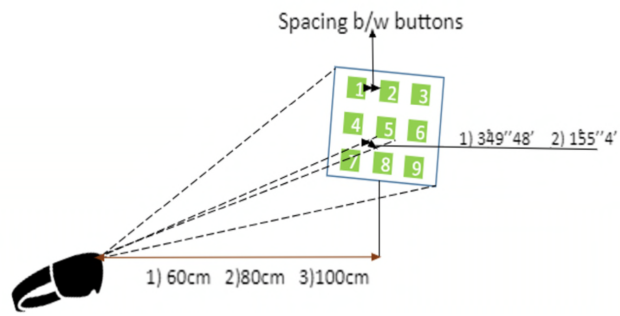

Figure 2. An example of distances

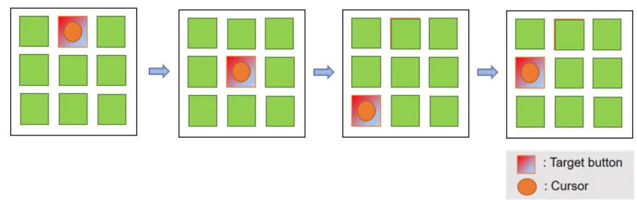

Figure 3. Sequence of target button selection

D. Procedure

All participants listened to the explanation of the experiment before the experiment, wrote the consent form and personal information, and pressed the button. Since, HoloLens is not a familiar equipment to subjects, we explained how to use it to carry out the experiment smoothly, went through simple practice, and then proceeded with this experiment. This experiment consists of a total of 12 treatment conditions, and the experiment was conducted with Latin square design to prevent learning effects. Each treatment condition repeats 5 sets of four button selection tasks, resulting in a total of 240 (12 test conditions x 4 random button selection x 5 sets = 240 tasks). The total time was less than 90 minutes. After performing each treatment condition, the subjects were given a break of about two minutes, and then user satisfaction was evaluated. A five-point Likert scale was used to evaluate user satisfaction for each test condition (1-Strongly disagree, 2-Disagree, 3-Neither agree nor disagree, 4 Agree, 5-Strongly agree). The subjects could take a rest whenever they wanted, and if they had difficulty in continuing the experiment, they could give up the experiment. In Section 2, we described the experimental design, including participants, apparatus, tasks, and procedure.

III. RESULT

Repeated measurement ANalysis of VAriance (ANOVA) showed that there are performance differences according to button size, distance, and input method.

TABLE 2. RESULTS OF ANOVA BETWEEN BUTTON SIZE, DISTANCE, INPUT METHOD

	Task Completion time		User Satisfaction		Error Rate	
	F	p	F	p	F	p
Button Size(A)	334.13	0.00	29.10	0.00	5.95	0.02
Distance(B)	51.92	0.00	10.08	0.00	0.85	0.36
Input Method(C)	402.86	0.00	33.81	0.00	1.73	0.19
A X B	20.63	0.00	3.89	0.05	0.00	1.00
A X C	9.34	0.00	0.59	0.44	1.73	0.19
B X C	15.80	0.00	0.18	0.67	0.21	0.65
A X B X C	12.89	0.00	0.01	0.93	1.90	0.17

There were statistically significant differences in button size, distance, and input method, interactions task completion time and user satisfaction (Table 2). Tukey's range Test (Tukey HSD) was used for post-test, and R, a programming language for statistical calculations and graphics, was used as an analysis tool.

A. Task Completion Time

2 (Button size) x 3 (Distance) x 2 (Input method) Repeat Measurement analysis of Variance (ANOVA) showed statistically significant differences in task completion time among button size, distance, and input method ($p<0.000$, $\alpha = 0.05$).

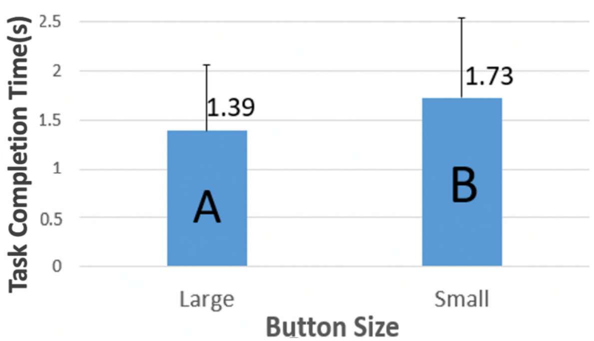

Figure 4. Task completion time according to button size (Error bars refer to standard deviation)

Task completion time for the large button was 1.39 s (±0.667) and for the small button was 1.73 s (±0.809). The task completion time was statistically significant in the button size ($p < 0.000$, $\alpha = 0.05$). Longer time was required to select the small button (1° 55′ 4″) than the large button (3° 49′ 48″) (Figure 4).

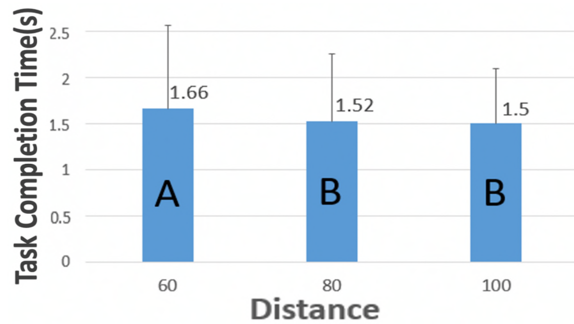

Figure 5. Task completion time according to distance (Error bars refer to standard deviation)

Task completion time for distance 60cm was 1.66 s (±0.906) and for distance 80cm was 1.52 s (±0.738) and for Distance 100cm was 1.5 s (±0.596). The average task completion time increased with the distance in the following order 100cm, 80cm, 60cm. Task completion time was statistically significant in the distance in A (60 cm) and B (80 cm,100 cm) ($p < 0.000$, $\alpha = 0.05$) (Figure 5).

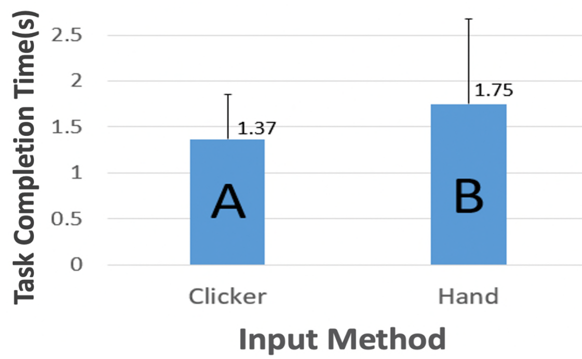

Figure 6. Task completion time according to input method (Error bars refer to standard deviation)

Task completion time for using the clicker was 1.37 s (±0.488) and for using the hand was 1.75 s (±0.921). The task completion time was statistically significant in the input method ($p < 0.000$, $\alpha = 0.05$). Longer time was required to using the hand than using clicker (Figure 6). In addition, there were statistically significant differences in interaction between button size and input method ($p < 0.01$, $\alpha = 0.05$), interaction between distance and button size ($p < 0.000$, $\alpha = 0.05$), interaction between the distance and input method ($p < 0.000$, $\alpha = 0.05$). There was also a statistically significant difference in the interaction of button size, distance, and input method ($p < 0.000$, $\alpha = 0.05$).

B. User Satisfaction

2 (Button size) x 3 (Distance) x 2 (Input method) Repeat Measurement analysis of Variance (ANOVA) showed statistically significant differences in user satisfaction score among button sizes ($p < 0.000$, $\alpha = 0.05$), distances ($p < 0.001$, $\alpha = 0.05$), and input method ($p < 0.000$, $\alpha = 0.05$).

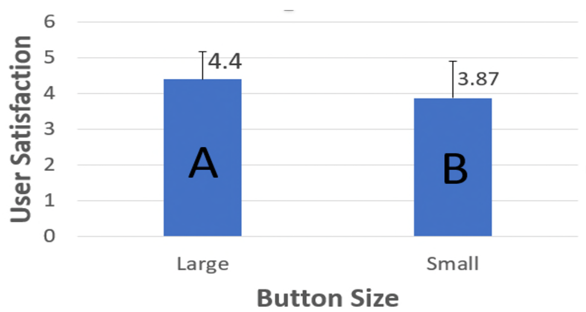

Figure 7. User satisfaction according to button size
(Error bars refer to standard deviation)

The user satisfaction score for the large button was 4.40 (±0.778) and for the small button was 3.87 (±1.03). The task completion time was statistically significant in the button size ($p < 0.000$, $\alpha = 0.05$). The user satisfaction score was higher in the large button than in the small button (Figure 7).

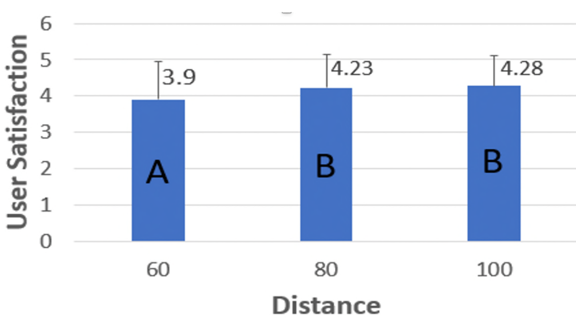

Figure 8. User satisfaction according to distance
(Error bars refer to standard deviation)

The user satisfaction score for distance 60 cm was 3.90 (±1.06), for distance 80 cm was 4.23 (±0.923) and for distance 100 cm was 4.28 (±0.817). The user satisfaction score was better in the order 100 cm, 80 cm, 60 cm. User satisfaction score was statistically significant in the distance in A (60 cm) and B (80 cm, 100 cm) ($p < 0.05$, $\alpha = 0.05$) (Figure 8).

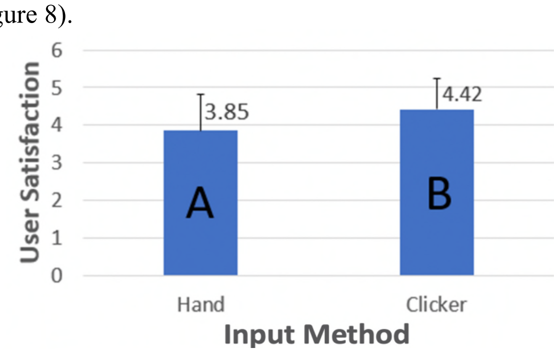

Figure 9. User satisfaction according to input method
(Error bars refer to standard deviation)

The user satisfaction score for using the hand was 3.85 (±0.978) and for using the clicker was 4.42 (±0.833). The user satisfaction score was statistically significant in the input method ($p < 0.000$, $\alpha = 0.05$) (Figure 9). In addition, there were statistically significant differences in interaction between button size and distance ($p < 0.05$, $\alpha = 0.05$).

C. Error rate

2 (Button size) x 3 (Distance) x 2 (Input method) Repeat Measurement analysis of Variance (ANOVA) showed statistically significant differences in error rate among button size ($p < 0.05$, $\alpha = 0.05$).

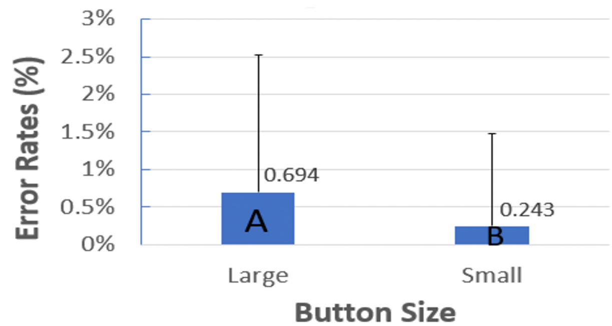

Figure 10. Error rate according to button size
(Error bars refer to standard deviation)

The average error rate for the large button was 0.694% (±1.83) and for the small button was 0.243% (±1.23). The error rate was statistically significant in the button size ($p<0.05$, $\alpha=0.05$). There was a higher error rate with the small button than with the large button (Figure 10). In Section 3, we described results of task completion time, user satisfaction, and error rate according to button size, distance, and input method.

IV. Conclusion and Future Work

We compared the performance changes by two input methods (hand, clicker), two button sizes (large, small), and three distances (60, 80, 100 cm) in HoloLens. Three factors (Task completion time, Error rate, User satisfaction) were measured by conducting experiments on a total of 12 treatment conditions. There were statistically significant differences in task completion time, user satisfaction and error rate. Task completion time and user satisfaction were better in the large button than the small button, and the error rate was higher in the large button. In task completion time and user satisfaction, the clicker performed better than the hand. The task completion time and the user satisfaction were better in 80 cm and 100 cm than 60 cm. The results of this study are thought to help determine the appropriate target distance, size, and input method for AR devices. However, all participants were in their 20s and there is a limitation since only three variances (button size, distance, input method) are considered. In future studies, we would like to recruit participants of more diverse ages and conduct experiments with more variances in mind.

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