Applied Ergonomics 48 (2015) 154–163

Contents lists available at ScienceDirect

Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo

An investigation of pointing postures in a 3D stereoscopic environment

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ARTICLE INFO

Article history:
Received 26 February 2014
Accepted 2 December 2014
Available online 20 December 2014

Keywords:
Stereoscopic parallax
Pointing technique
3D virtual environment

ABSTRACT

Many object pointing and selecting techniques for large screens have been proposed in the literature. There is a lack of quantitative evidence suggesting proper pointing postures for interacting with stereoscopic targets in immersive virtual environments. The objective of this study was to explore users' performances and experiences of using different postures while interacting with 3D targets remotely in an immersive stereoscopic environment. Two postures, hand-directed and gaze-directed pointing methods, were compared in order to investigate the postural influences. Two stereo parallaxes, negative and positive parallaxes, were compared for exploring how target depth variances would impact users' performances and experiences. Fifteen participants were recruited to perform two interactive tasks, tapping and tracking tasks, to simulate interaction behaviors in the stereoscopic environment. Hand-directed pointing is suggested for both tapping and tracking tasks due to its significantly better overall performance, less muscle fatigue, and better usability. However, a gaze-directed posture is probably a better alternative than hand-directed pointing for tasks with high accuracy requirements in home–in phases. Additionally, it is easier for users to interact with targets with negative parallax than with targets with positive parallax. Based on the findings of this research, future applications involving different pointing techniques should consider both pointing performances and postural effects as a result of pointing task precision requirements and potential postural fatigue.

1. Introduction

Large displays have become popular as they become more affordable. In order to improve the experience of interacting with large amounts of information in virtual environments without losing details, designers are recommended to provide large size displays for remote uses (Vogel and Balakrishnan, 2005). A number of object pointing and selecting techniques for large screens have thus been proposed in the research field of remote control for several years (Banerjee et al., 2012; Jota et al., 2010; Park et al., 2012; Vogel and Balakrishnan, 2005). The hand gesture effects on user's performances (Banerjee et al., 2012) and the provision of arm support to users' muscular fatigue improvement (Park et al., 2012) had been investigated. Relatively few studies have evaluated the performance of pointing methods for remote control in virtual environments. Within these researches, Jota et al. (2010) classified remote pointing into two controlling types: rotational control (were used to point at targets by rotating the angle of the user's hand) and positional control (were used to decide target positions by the placement of the user's hand). Their results showed that pointing techniques with rotational control provided better throughput and faster performance than those with positional control. Vogel and Balakrishnan (2005) compared three methods, including ray-casting and two other modified ray-casting approaches (relative pointing with clutching and hybrid RayToRelative) for better accuracy during remote selection of targets. The traditional ray-casting techniques provided the fastest selection but also the highest error rate among the three methods in that study. Although the above studies discussed the issue of using various pointing methods to interact with very large displays remotely, they all focused mainly on investigating the performance and preference of these different techniques in non-immersive virtual

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http://dx.doi.org/10.1016/j.apergo.2014.12.001
0003-6870/

environments. In addition, these researches did not point out how the postural effects would influence the usability and task efficacy. In our study, these pointing techniques are categorized into two types in terms of the body postures involved, the hand-directed and the gaze-directed approaches which will be described later in the method section.

In order to interact with objects in a virtual environment, issues related to how to point and select 3D stereoscopic objects are important. However, not enough studies have discussed how to effectively manipulate targets with a consideration of parallaxes. In general, stereoscopic objects can be manipulated in two ways: by touching the screen and by selecting them remotely. Only a handful of studies have discussed the use of direct touch to manipulate the virtual targets (Valkov et al., 2012, 2011). Valkov et al. (2011) reported that with negative parallax, users would have difficulty touching designated screen areas located behind the targets. Valkov et al. (2012) found that the problem of losing the stereoscopic impression would influence users' judgments of whether objects were in front of or behind the screen. Valkov et al. (2012, 2011) both indicated that parallax would have an effect on users' experiences of interacting with 3D targets through direct touching on the screen. However, they did not mention that whether there will be parallax effects while using pointing techniques to interact with virtual objects. There was one study exploring users' performances while manipulating objects with various parallaxes through remote pointing (Teather and Stuerzlinger, 2013). However, rather than comparing the influence of different pointing postures, their research focused on comparing mouse and ray-casting methods. Their results showed that the mouse resulted in better performance than ray-casting, and users demonstrated better performance while interacting with targets closer to the screen than while interacting with those farther away from the screen. The above discussions have demonstrated that parallax would play a role on user's experience and performance interacting with virtual environments. However, it is still unclear that whether the postural effects will influence users' interaction of stereoscopic objects. Whether different level of muscular fatigue resulted from postures will influence the interaction of 3D targets is also an issue. Banerjee et al. (2012) have speculated that less muscular fatigue would result in better performances for participants in the laser pointer using group who could hold their arms naturally than the group being asked to hold their arms at shoulder level. In light of their discussion, we found that there is a need to gather further evidences to compare the muscle fatigue levels of two pointing postures, with and without holding the arm at shoulder level, both in the condition of freehand pointing; in other words, without holding any devices.

Regarding visual problems, in the previous literature, visual symptoms have been identified as one of the major concerns for users in immersive virtual environment (Pölönen et al., 2013; Rushton and Riddell, 1999). Besides visual discomfort, some symptoms resulting from visually exposure to visual displays without body motion, referred as visually induced motion sickness, is also an important issue that has been explored recently (Dziuda et al., 2014; Kennedy et al., 2010). However, little information is available on postural effects of pointing techniques for interacting with targets in truly stereoscopic environments. This research explored how different pointing postures influence users' performances and experiences while they are remotely interacting with objects with various parallaxes. Two featured pointing methods (gaze-directed and hand-directed) were included in this research to investigate the effects of different pointing postures. In addition, unlike the direct touching of the screen, as in Valkov et al. (2011, 2012), freehand remote pointing was adopted in this research. Our primary focus was to investigate user performance during interactions with stereoscopic objects with two pointing methods generalized from the literature of remote pointing techniques. Furthermore, in order to examine interactions with multiple forms of targets in the virtual environment, we included tapping and tracking in static and dynamic tasks.

2. Experiment 1: static tapping task

2.1. Method

2.1.1. Participants

Before the data collection, the experimental protocol and participant consent procedure were developed according to the ethical guidelines of the National Taiwan University of Science and Technology (NTUST), and approved by the Research Ethics Office of NTUST. After the approval, fifteen right-handed subjects (10 males and 5 females) were recruited from NTUST. Their average age was 25 (S.D. = 3.59). Their average eye height was 161 cm (S.D. = 9.12 cm). All participants had normal or corrected-to-normal vision. Before the experiments started, they were first provided with a verbal description of the possible risks of this study. After hearing the description, all participants voluntarily signed the written informed consent form. Finally, they were asked to avoid heavy visual and muscular work for 24 h before the experiment.

2.1.2. Apparatus and environment

NVIDIA 3D vision glasses and a ViewSonic PJD6353s projector with a 1024 × 768 resolution at a refresh rate of 120 Hz were used in this study to establish an immersive 3D navigation scene. The aspect ratio of the projector is 4:3. The Microsoft Kinect depth camera was used to detect the coordinates of the subject's right hand for manipulating the cursor position. Participants wore the right-hand 5DT Data Glove for gesture triggering to capture the virtual targets. The software automatically took records of clicking time, errors, and coordinates of clicking events. The experimental setting for this research was built in a laboratory with an 81.5 inch (165.61 cm × 124.21 cm) front-projected screen. Participants were instructed to stand at a fixed position 3 m in front of the screen. The Microsoft Kinect depth camera was set 1.3 m in front of the screen, as shown in Fig. 1.

2.1.3. Experimental design

The experiment was a 2 × 2 × 6 repeated-measures design (Table 1). The purpose was to investigate if pointing methods, parallax manipulation, and index of difficulty (ID) would influence the user's performance and experience while doing a static task (multi-directional tapping task) in a virtual environment. There were three independent variables: pointing method (gaze-directed and hand-directed) and parallax (positive and negative), and index of difficulty (2.58, 3.17, 3.46, 4.09, 4.14, and 4.79). A total of 24 trials (2 pointing methods × 2 parallaxes × 6 IDs) were randomly arranged for each participant.

The multi-directional tapping task was adopted from ISO-9241-9 (2000). In this task, the 12 spherical targets were three sizes, 3 cm (1.86 pixels), 5 cm (3.09 pixels), and 10 cm (6.18 pixels), and between each target were two distances, 50 cm (30.92 pixels) and 80 cm (49.47 pixels). Six task levels were obtained by calculating the different sizes of the targets and the distances between them using Shannon's formulation (Soukoreff and MacKenzie, 2004) of index of difficulty (ID), including 2.58 bits, 3.17 bits, 3.46 bits, 4.09 bits, 4.14 bits, and 4.79 bits. Twelve targets were placed around a circle, as shown in Fig. 2.