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Speed reading on virtual reality and augmented reality

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ABSTRACT

Many virtual reality (VR) and augmented reality (AR) applications in education require speed reading. The current study aimed to explore whether the reading performance on VR and AR is different from that on traditional desktop display, and whether the difference is moderated by the reading speed. Sixty-three college students read Chinese passages at normal (650–750 characters per minute [cpm]) or fast speeds (1000–1400 cpm), and then answered multiple-choice questions. They spent approximately 10% more time in making choice on VR and AR than they did on the desktop display. Teachers should be aware of this difference and allow 10% more time when using VR and AR applications containing text components.

1. Introduction

Virtual reality (VR) and augmented reality (AR) have been introduced into education in the 1990's. Since then, VR and AR technologies have been applied in education of mathematics (Kebritchi, Hirumi, & Bai, 2010; Pasqualotti & Freitas, 2002), geometry (Hwang & Hu, 2013; Kaufmann & Schmalstieg, 2003; Kaufmann, Schmalstieg, & Wagner, 2000), science (Kartiko, Kavakli, & Cheng, 2010), physics (Coller & Shernoff, 2009), chemistry (Merchant et al., 2012), anatomy (Lee & Wong, 2014), astronomy (Johnson, Levine, Smith, & Stone, 2010), foreign language (Ibanez, Kloos, Leony, Rueda, & Maroto, 2011; Yang, Chen, & Jeng, 2010), and art (Di Serio, Ibáñez, & Kloos, 2013). Recent products such as HTC vive and Microsoft HoloLens have made VR and AR technologies more accessible. The effect of VR and AR on improving students' academic performance, however, is inconsistent (Merchant, Goetz, Cifuentes, Keeney-Kennicutt, & Davis, 2014) and depends on the design of courses, such as instruction mode (Merchant et al., 2014; Sitzmann, 2011), entertainment value (Sitzmann, 2011), and process control (Vogel et al., 2006).

Reading is one of the most important ways to access knowledge, which is often stored in the form of text in books, articles, and websites. Many VR and AR applications in education require reading, and almost all VR and AR applications contain some text on their interfaces. Reading performance on VR and AR can be different from that on a traditional desktop display, because reading performance usually depends on the device displaying text. For example, people used to read slower on screen than on paper (Dillon, 1992; Gould & Grischkowsky, 1984; Mangen, Walgermo, & Brønnick, 2013; Wilkinson & Robinshaw, 1987), although recently the gap has been diminishing (Chu, Rosenfield, & Portello, 2014; Köpper, Mayr, & Buchner, 2016). Reading on VR and AR may be different from that on liquid crystal display (LCD), the mainstream desktop display, for at least three reasons. First, text in VR and AR is 3D instead of flat, which affects the readability (Jankowski, Samp, Irzynska, Jozwowicz, & Decker, 2010). Second, text in AR is overlaid on the real background, whose texture affects readability (Leykin & Tuceryan, 2004). Third, VR and AR have the potential to enhance learning motivation (Chang, Morreale, & Medicherla, 2010), which in turn would probably improve reading performance. The present study aimed to explore reading performance on VR and AR, compared with that on LCD. The difference, if exists, will

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influence the effect of VR and AR on improving students' academic performance.

Reading tasks on VR and AR are often carried out under time pressure. For example, teachers usually assign reading tasks, on VR/AR or not, with a time limit and then test students' comprehension; instruction and subtitles in videos and games update quickly as the plot unfolds; credits at the end of movies scroll up rapidly; and in some adventure games, letters burn up as players are still reading them. Reading under time pressure, or speed reading, generally results in worse comprehension on the individual level (Carver, 1992): it is a speed-accuracy tradeoff. For example, Poulton (1958) found that reading at about 146 wpm resulted in a better comprehension rate than reading at about 293 wpm did. Dyson and Haselgrove (2001) also found that reading at a normal, comfortable speed resulted in better comprehension than reading at a fast, or twice the normal speed did. Similarly, research on reading languages other than English, such as Chinese (Shui, Fu, Li, & Shen, 2001) and Japanese (Miyata, Minagawa-Kawai, Watanabe, Sasaki, & Ueda, 2012), found that faster reading resulted in worse comprehension. Nevertheless, some other researchers argued that time pressure, if used properly, had the potential to improve reading performance by promoting mindfulness among other mechanisms (Walczyk, Kelly, Meche, & Braud, 1999).

What is more important, time pressure, or the reading speed, could moderate the differences in reading performance across display devices. Ackerman and Goldsmith (2011) found reading comprehension on screen was worse than that on paper only under self-regulation but not under fixed study time. The authors attributed this difference to less accurate prediction of performance and more erratic study-time regulation on screen than on paper under self-regulation. However, Ackerman and Lauterman (2012) later found that reading on screen and paper differed only under time pressure, but not under free regulation. The authors explained that the sample in Ackerman and Lauterman (2012) study had attenuated reluctance to study on screen relative to those in Ackerman and Goldsmith (2011), making the results inconsistent. The present study would explore the interaction between the display device and the reading speed.

The present study aimed to explore (1) people's reading performance across different display devices, i.e., LCD, VR, and AR, and (2) the effect of time pressure on reading performance and especially its interaction with display devices. The results can provide guidance and suggestion for the designers and users of VR and AR applications in education, business and entertainment.

2. Methods

2.1. Design

The present study was a 3 (devices: LCD, VR, and AR) × 2 (speeds: normal or fast) two-factorial mixed design. The device was a within-subject factor, and the speed was a between-subject factor. We used an Oculus Rift CV1 for the VR condition, a Microsoft HoloLens for the AR condition, and an Acer S230HL monitor for the LCD condition. In the normal speed condition, students read paragraphs at speeds of 650, 700, and 750 characters per minute (cpm). In the fast speed condition, the speeds were 1000, 1200, and 1400 cpm. Those speeds were based on pilot studies. The reading speeds were manipulated by controlling the display time for each paragraph. For example, if the paragraph contained 140 characters and was tested at 700 cpm (normal speed), the display time would be 12s (140 character/700 cpm * 60 s/minute).

The dependent variables were the response time of making choices and the accuracy of answering questions. The response time was the time between the appearance of the choices and the selection made by the participants. The accuracy was calculated by dividing the number of correctly answered questions by the total number of questions within each condition.

2.2. Participants

Participants were 63 college students, 34 women and 29 men, aged 20–31 years (M = 24.3 years). All reported normal or corrected to normal vision. They were randomly assigned to the normal (n = 32) or the fast speed group (n = 31). All participants gave written informed consents before participation.

2.3. Apparatus

The experiment was carried out in a sound-insulated chamber with no exposure to daylight. Ambient illumination around the participants' eye position was 680–720 lux (measured using an HCJYET HT-8500 Environment Tester) during the experiment.

Two desks, of 120 cm × 60 cm × 75 cm (length × width × height), were placed against one wall. Two height-adjustable chairs were placed in front of each of the desks. Two keyboards were placed on each of the desks. An Oculus Rift CV1 and a Microsoft HoloLens were placed on Desk 1. An Acer S230HL monitor (23 inches on the diagonal) was placed on Desk 2. The inclination angle of the monitor screen was set at 75° relative to the desk with the top tilted away from the participant, as in Köpper et al. (2016). The app window in the AR condition was projected on the white wall behind Desk 2, and at the same height as the monitor on Desk 1. The distance from participants' eyes to the monitor screen was about 50 cm. The distance from eyes to the optics of VR and AR glasses was about 1.5 cm, but the distance to the virtual wall in VR and the window in AR displaying text was also about 50 cm. The computer used to control the devices and present the stimuli was a Raytine Blade 707, an assembled computer (CPU: Intel i7-6700K; GPU: GIGABYTE GTX1080 8GB).