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Effect of Context and Distance Switching on Visual Performances in Augmented Reality

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ABSTRACT

Augmented reality may lead the user to repeatedly look at different environments (real/virtual) and at different distances to process information. We studied how context and distance switching could (together or separately) affect users' performances. 29 participants (16 video game players) performed two tasks that required to switch between two screens (visual search and target detection task). These screens could be virtual (using HoloLens2) or real and placed at 1.5 or 2 meters. Distance switching had an impact only on visual search performances. Participants' levels of experience with video games modified the effect of context switching.

Keywords: augmented reality, context switching, distance switching, visual attention, attentional shift

Index Terms: Human-centered computing—HCI theory, concepts and models; Human-centered computing— Mixed / augmented reality; Applied computing—Psychology

1 INTRODUCTION

In the context of industrial applications of augmented reality (AR), one of the most important issues is to ensure that the use of AR has no impact on operator's safety and comfort. However, many perceptual and visual issues, have been identified with AR, which could impact the visual system, such as: vergence accommodation conflict [1], focal rivalry [2], binocular rivalry [3], context switching and distance switching. [4].

Among these issues, context and distance switching have received limited attention so far. Context and distance switching are link to the fact that, when using AR, users must simultaneously perceive and assimilate visual information both in the virtual and real world, and that this information may be presented in different locations (e.g., close to, or far from the user). Thus, AR forces the user to repeatedly look at different types of environments (real/virtual) and at different distances to extract information.

2 RELATED WORK

To our knowledge only three reported papers evaluated context and distance switching using modern AR head mounted display (HMD). Gabbard, Mehra, and Swan [4], found that both context switching and focal distance switching resulted in significantly

reduced visual search task performances and increased eye fatigue. Huckauf et al. [5] found that switching between two different devices produced attentional cost in a visual search task as well. Both studies were performed with a monocular HMD, which does not provide a stereo disparity signal and causes a binocular rivalry, and thus differs significantly from the viewing conditions of recent binocular displays (e.g., Microsoft HoloLens2, Epson Moverio). Their increasing use makes it necessary to evaluate context and distance switching with such binocular HMD.

Eiberger et al. [6] evaluated distance switching when a binocular HMD is combined with a smartphone. They found that conducting a visual search task across two depths induced significantly higher reaction times and error rate, compared to a single depth. However, this study tested only the difference in depth and the perceptual difference between the two displays (i.e., HDM and smartphone) was not considered. Thus, it is not possible to know, if the decrease in performances was caused by the difference in distance, the difference in context, or both.

These previous works studied the impact of using AR while intentionally searching for a known information in the visual environment. Nevertheless, given the potential future uses of AR in industry, it seems critical to examine operator's detection of unexpected information or event (e.g., an alert message, or danger). Therefore, the goal of the present study was to evaluate the effect of both context and distance switching on attentional resources for detection of unexpected information, with a recent binocular HDM.

3 METHODOLOGY

We conducted a within-subject experiment with 29 participants (6 females, 23 males), aged between 19 and 40 ($M=24.10$, $SD=4.9$). Post-experimental questionnaire revealed that among participants, 16 play video games frequently, 19 had already used virtual reality HDM before, and 7 had already used AR HDM before. Considering that habit and levels of exposure to video games and new technologies can impact attention abilities [8], possible effect of these factors was examined.

The study was designed to evaluate the effects of context switching and distance switching, both together and separately. The two independent variables were context switching (virtual-virtual, virtual-real) and distance switching (adjacent, distant). During the experiment, participants were in front of two screens, one on the left side and one on the right side.

In the virtual-virtual condition, both left and right screens were virtual screens displayed in AR (HoloLens2), thus, context switching was not required to go from one to the other. However, in the virtual-real condition, the left screen was a real computer monitor, thus, context switching was required. In the adjacent condition, both left and right screens were at the same distance, thus no distance switching was required. Whereas, in the distant condition, the right screen was at 2m and the left screen was at 1.5m, so switching was required.

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3.1 Procedure

During each trial, a matrix pair (Fig.1) was displayed, one on each screen. In each of the four experimental conditions, participants had to perform a dual task. The main task was a comparison between left and right matrix, i.e., they had to evaluate if matrices were identical or different (occurring in half of the trial). Once the participant had answered, the matrix pair was removed and after a 500ms black background, a new matrix pair was displayed.

While performing this main task, participants also had to perform a second task, which was a target detection task. The target was a red circle, which appeared with a variable time interval (8s; 10s; 12s; 14s; 16s), in a pseudo-randomly way. We used the participants gaze position in real time (with the built-in HoloLens2's eye tracker) to generate the target's position. This target always appeared on the screen that the participant was not looking at. Once the answer was made, the target was removed. The matrices remained displayed and new targets could appear, until participants responded to the main task.

Between each block, during a 5-minute break, participants could rest, removed the HoloLens2 and completed the NASA-TLX [7]. At the end of the four blocks, participants filled a post-experimental questionnaire about their visual health and their habits and experiences with technologies (i.e., video games, virtual reality, and AR). The experiment lasted about 90 minutes.

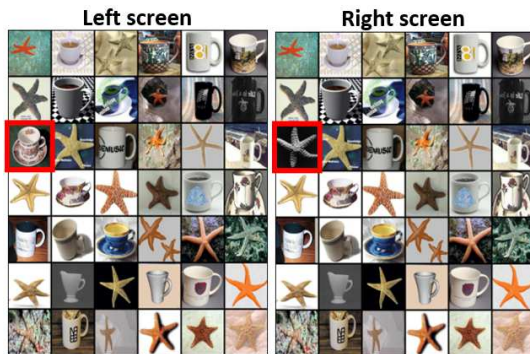


Figure 1: Example of a *different* pair of matrices. Red frames have been added to help the reader to identify the difference between the matrices.

4 RESULTS

Regarding, the main task (i.e., image comparison), a two-way ANOVA revealed a main effect of distance switching on accuracy rate, $F(1, 28)=4.91$, $p=0.035$, $\eta^2=0.05$. Participants completed the image comparison task more accurately when images were presented at the same distance than when they were distant. Main effect of context switching and interaction were non-significant ($ps >0.47$). Considering the second task (i.e., target detection), analyses revealed no main effect and interaction of distance and context switching neither on reaction times nor on the number of omissions of the target detection task ($ps >0.19$). Analyses on cognitive workload, revealed a main effect of context switching only on temporal demand score of workload $F(1, 28)=4.34$, $p=0.046$, $\eta^2=0.03$.

Effect of video game and new technologies habits were examined with supplementary ANOVA analyses. Regarding the second task, the three-way interaction (with context switching and distance switching as within-participant factors and video games habits as a between-participants factor) was significant $F(1, 27)=18.52$, $p<0.001$, $\eta^2=0.06$. Simple effect analyses showed that in distant condition, players and non-players present an inverse pattern of reaction times to target detection. For non-players, reaction times when no context switching was needed were faster than when it was needed, $F(1, 27)=13.28$, $p=0.003$. For players,

reaction times when no context switching was required were slower compared to when it was needed, $F(1, 27)=10.41$, $p=0.006$. Regarding for the main task, the three-way ANOVA was not significant $F<1$. The analyses did not reveal any impact of AR and virtual reality experience on context and distance switching effect.

5 DISCUSSION

In this study we evaluated with a recent binocular HDM, the effect of context and distance switching on a simultaneous visual search task and target detection task. As expected, and in agreements with previous studies [4,6], results show that participants are less accurate when performing an image comparison between two screens at different distances (1.5m and 2m) than at the same distance. Our results suggested that distance switching impacts accuracy of visual search with ecological stimuli. In our study a distance of 50cm only between information was enough to affect user's visual performances.

Contrary to previous studies, no context switching effect was found neither on image comparison nor on target detection. However, a reverse effect of context switching was observed for players and non-players. These results could possibly be explained, by a better visual attention ability of players due to training with action video games [8], by a different strategy (liberal or conservative) or by an overall familiarity with different technologies (computer, game console).

In the context of industrial applications, the two main results suggest that care should be taken to reduce distance switching to a minimum, and that training could mediate context switching effect. Future work could extend this study by assessing how context switching evolves during prolonged use of AR, or consider expanding upon some parameters (e.g., other distance ranges and other stimuli parameters).

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