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Gender Differences of Cognitive Loads in Augmented Reality-based Warehouse

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ABSTRACT

The rapid emergence of augmented reality (AR) has brought considerable advantages to warehouse workers. However, due to inherent biological and cognitive differences, the male and female workers perceive cognitive loads differently. Understanding the differences is essential to improve the workers' productivity and well-being. Therefore, we developed the AR headset that helped participants facilitate parcel scanning and evaluated the gender differences in the context of long-lasting repetitive parcel scanning. The results show that the female workers had significantly lower operational efficiency, higher visual attention, and higher memory loads than the male, but they quickly gained advantages in these aspects.

Keywords: Gender difference, cognitive loads, augmented reality, contemporary warehouse.

Index Terms: K.6.1 [Management of Computing and Information Systems]: Project and People Management—Life Cycle; K.7.m [The Computing Profession]: Miscellaneous—Ethics

1 INTRODUCTION

The augmented reality (AR) is maturing into industries and has incurred noticeable changes in contemporary warehouse. Early research has developed a variety of AR systems to improve the workers' operation efficiency and explored how AR amplified human workers' cognitive abilities such as memory capability in parcel sorting tasks [1]. Due to inherent biological and cognitive differences, the male and female workers perceived cognitive loads differently. Early studies explored the male and female workers' operation efficiency, but few investigated the differences of cognitive loads in warehouse context. Understanding the differences is essential to optimise workers' productivity and well-being. Therefore, we developed the AR headset for parcel scanning and investigated how differently the male and female workers perceived cognitive loads. The study provides new understanding of gender differences of cognitive loads with respect to working efficiency, visual attention, and memory loads in the specific context of repetitive warehouse task.

2 RELATED WORK

The physical and psychological differences between the male and female have been long studied. For example, the female used to have greater abilities of colour perception and other psychomotor abilities than the male [2], they also make fewer mistakes in object location memory tasks with more accurate decision making when confronting complicated tasks [3]. In contrast, the male has advantages over the female in aspects of spatial ability-related tasks, hand-eye coordinating tasks, and speed-related tasks [4]. Early research explored three typical gender differences: physiological performance [5], perception ability [6], and operation efficiency [7]. For example, female workers tended to have higher muscle activities than the male workers in repetitive warehouse tasks [5] and consequently, the female workers were likely to suffer physical fatigue than the male workers when dealing with excessive warehouse tasks [8]. The emergence of augmented reality technologies has brought changes to warehouse. The male workers gained advancements upon task completion time and error rate when browsing warehouse data [9], and both the male and female workers' overall productivity was enhanced and the gender differences in task efficiency was eliminated with augmented reality tools [7].

Cognitive load is recognised as the capability of utilising mental effort in cognitive tasks [10]. The cognitive load theory involved three separate and incremental types of cognitive loads, which are intrinsic, extraneous, and germane loads. Different techniques were adopted to measure cognitive loads, e.g., task performance and subjective rating scales, psychophysiological techniques, eye tracking, and Electroencephalogram (EEG) [11].

3 METHOD

3.1 Augmented Reality Headset Design

We designed the augmented reality-based warehouse headset based on the ARbox HBOX2 device that used a mobile phone (Google Pixel3) to display interactive augmented reality contents (Figure 1). The headset was mounted on the participants' head with a strap and its binocular contents were projected on the front reflective see-through mirror.

Figure 1: Augmented reality headset with eye tracking modules

The headset integrated eye tracking to record the participants' eye movements and world views and enable gaze-based interaction. Two webcams (1280×720pixel resolution, 25FPS, 55×12×10mm size, 120degree FOV) were fixed on the headset and connected to a computer (6-Core 2.60GHz i7-9860H CPU, 64GB memory) via USB cables. The headset displayed graphic user interfaces according to parcel scanning results (see examples in Figure 2).

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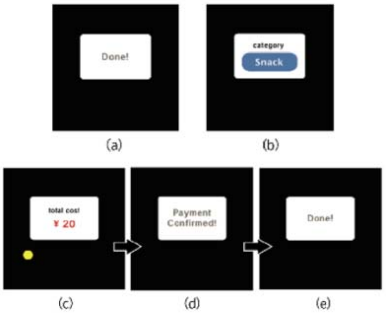

Figure 2: Screenshots of the headset's user interfaces

3.2 Participants and Apparatus

There were 24 participants recruited from the university via email and paper flyers (N_{male}=12, N_{female}=12, $M_{male\ age}$ = 21.7, $SD_{male\ age}$ = 2.11, $M_{female\ age}$ = 20.3, $SD_{female\ age}$ = 1.54).

We adopted the NeuroSky Mindwave, a multi-channel EEG signal detection device, to record the participants' real-time EEG activities. A scene camera was fixed in the experimental scene to record the participants' and experimenters' activities. A table was used to mimic the realistic workbench of parcel sorting in warehouse (Figure 3). On the table was 20 parcels with different sizes and weights.

Figure 3: The table and parcels in the experiment scene

3.3 3.3 Procedures

The main experimental task was to scan all the parcels with the headset. There were parcel scanning tasks with incremental difficulties. Each task had three sequential processes. The task 1 required participants to scan parcels, the task 2 followed the same steps as Task 1 and further required the participants to place the parcels on the right areas of parcel categories, and the task 3 followed the same steps as task 1 and required the participants to handle exception errors with a few parcels. The participants were randomised to do the experiments and in the same procedural flows.

4 Result and Discussion

We compared task durations between the male and female participants. The female had significantly shorter time in task 1 (Mann-Whitney U test p=0.02) but no differences in task 2 or task 3 (p_{task2}=0.22867, p_{task3}=0.47). By analysing the variation of task duration of three sequential tasks with different groups, we found that the male participants' task durations were significantly decreased in task 2 (Mann-Kendall Z test, p=0.04), but no differences were found with the female participants. We investigated the task durations throughout the three main processes of each task and found that the male participants operated more quickly in parcel relocating but the female performed more quickly in task 2 and 3.

We calculated the participants' eye blinking frequencies and validated it with EEG data. The male participants had higher cognitive loads than the female in easy tasks, but the gap closed in task 3. Both the male and female participants' eye blinking frequencies changed across the tasks and the female was more sensitive to task difficulties. Pupil diameter was derived to evaluate working memory in the study. There were significant differences of pupil diameters between the male and female participants in all the three tasks (Mann-Whitney U test p<0.001). The female participants showed a noticeable decrease tendency than the males.

The male participants had advantages of operation speed with the easy task, but as the task difficulty increased, the advantages quickly lost. In visual attention, the female participants had significantly lower level than the male in task 1 and task 2, but the difference disappeared in task 3. And in working memory, despite the female participants maintained significantly higher memory loads over the male ones across all the tasks, they showed a significant decrease of memory load in difficult tasks, which is more noticeable than the male participants' changes.

5 Conclusion

To understand how differently male and female workers perceive cognitive loads with augmented reality systems in warehouse context, the paper developed an augmented reality headset and investigated gender differences of cognitive loads in augmented reality-based warehouse. The results reveal gender differences with respect to task durations, visual attention, and working memory.

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