Examining the Presentation of Information in Augmented Reality Headsets for Situational Awareness

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ABSTRACT

Augmented Reality (AR) headsets are being employed in industrial settings (e.g., the oil industry); however, there has been little work on how information should be presented in these headsets, especially in the context of situational awareness. We present a study examining three different presentation styles (Display, Environment, Mixed Environment) for textual secondary information in AR headsets. We found that the Display and Environment presentation styles assisted in perception and comprehension. Our work contributes a first step to understanding how to design visual information in AR headsets to support situational awareness.

CCS CONCEPTS

• Human-centered computing → Mixed / augmented reality

KEYWORDS

Augmented reality, situational awareness

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1 Introduction

Augmented reality (AR) headsets allow a user to see and interact with virtual objects projected onto a view of the real world, and are beginning to enter the consumer and industrial markets [18,34]. However, there has been little prior work on how information should be presented in AR headsets, especially in the context of situational awareness. Situational awareness is defined as "the detection of elements in the environment within a volume of space and time (level 1), the comprehension of their meaning (level 2), and the projection of their status in the near future (level 3)" [6,7]. Poor situational awareness has caused aircraft crashes [29] and errors in anesthesia [28].

AR has the potential to increase situational awareness through providing a secondary channel of information that can be overlaid over the real world. Prior work has examined applying AR for situational awareness in different contexts, such as the military [10]. However, there has been conflicting results, for instance higher and lower situational awareness [2,23,25]. Therefore, applying AR to a task may not improve situational awareness. In addition, previous studies have mainly focused on the applicability of AR and how it compares to traditional methods instead of information design (e.g., [14,22,23]). Since AR headsets have the potential to improve situational awareness [14], it is important to study how visual information should be presented to maximize awareness while minimizing distractions.

Visual information, in the context of awareness, can be split into two categories: central or critical (e.g., hazard warnings) and peripheral or secondary (e.g., nonessential information) [4]. While critical information should always be visually salient [8,9], secondary information does not have this constraint; allowing for larger quantities of detailed information (e.g., item descriptions) and increasing integration opportunities with the environment. Therefore, we investigated the presentation of secondary information in AR headsets to assist in levels 1 and 2 of situational awareness (perception and comprehension). We examined three different textual presentation styles: locked to the display view (Display), located in the environment (Environment), and a mix of both (Mixed Environment). We studied text because it is common and necessary in AR headset applications to effectively communicate information [14,21,23].

In our study, participants had to complete multiplication problems while monitoring the textual secondary information in an AR headset. We found that the Display and Environment presentation styles supported the recall of secondary information, when compared to the Mixed Environment style. We contribute a new understanding of how different presentation styles for textual secondary information in AR headsets support perception and comprehension. Our work is a first step in investigating the design of visual information in AR headsets to increase users' situational awareness.

2 Background and Related Work

Prior work has examined utilizing AR for situational awareness in safety critical domains [14,16,22,25,33]. Ruano et al. [25] created an AR system for the flight of Unmanned Aerial Vehicles (UAVs). The AR system overlaid flight mission data (e.g., route orientation) onto a live video stream on a computer screen, instead of having two separate screens as in previous UAV systems. The AR system was found to improve the situational awareness of the UAV operators. Park et al. [22] designed an AR system to increase driving situational awareness. The system was overlaid on the car windshield and would provide warning information (e.g., distance of another vehicle). While these prior studies have investigated utilizing AR for situational awareness, they only examined overlaying graphical elements onto current display screens (e.g., car windshields, computers), not using AR headsets. AR headsets offer more freedom, immersion, and contextual integration with the environment.

Liu et al. [14] investigated if an AR headset would aid anesthesiologists in monitoring patient information. In the study, 12 anesthesiologists provided anesthesia in a simulated environment. The anesthesiologists using the AR headset detected patient events faster. Zhu et al. [32] created AR-Mentor, a wearable AR mentoring system to assist in maintenance for complex machinery. AR-Mentor provides guidance through voice instruction and visual elements in an AR headset (e.g., 3D graphic animations). The authors conducted preliminary training tests with novice users and found that it demonstrated promising effectiveness. Both of the studies above show the potential of using AR headsets for situational awareness. However, the two studies did not investigate *how* the information should be presented in the headsets to aid in situational awareness.

2.1 Readability of Information in AR

Prior work has examined the readability of information in AR [1,12,21,27]. Rzayev et al. [27] examined how text should be displayed for reading in an AR headset while the user is walking vs. sitting. They compared three text positions (top-right, center, and bottom-center) and two presentation types, line-by-line scrolling and Rapid Serial Visual Presentation (RSVP). RSVP presents text word-by-word in a fixed location. Presenting the text in the top-right increased cognitive workload and reduced text comprehension. RSVP had higher comprehension during sitting, while line-by-line scrolling had higher comprehension during walking. Debernardis et al. [5] examined how text design affected readability in both optical and video see-through AR headsets. Participants were faster in readability with the optical see-through headset. The authors recommended using white text with a blue billboard (i.e., background). However, prior work has also recommended transparent backgrounds [1]. Albarelli et al. [1] analyzed the difference between transparent and opaque overlays in an AR headset. During the study, the participants stocked items in a test grocery store while product information was shown in the headset. The participants preferred a central display of information with a transparent background for readability. These prior studies examined the readability of text related to the main task in AR, but not in terms of situational awareness. We focused on analyzing different presentation styles for textual *secondary* information in AR headsets.

3 Method

In our study, participants completed multiplication problems on a Wacom Cintiq Companion Hybrid tablet [30] while viewing the textual secondary information in a Meta 2 AR headset [18]. Both the AR and multiplication applications were created using Unity. We conducted the study in a room with consistent lighting, and the study took approximately 60 minutes. Participants either received extra credit for a course they were enrolled in or voluntarily participated without compensation. Our protocol was approved by our Institutional Review Board.

At the start of the study, participants filled out a demographic questionnaire, and then completed multiplication problems on the tablet for 5 minutes without wearing the AR headset. These problems were practice and not used in any analysis. After the practice, participants then put on the AR headset and began the main part of the study. In total, there were three different study blocks (5 minutes each), one block for each presentation style (Display, Environment, Mixed Environment). The participants would complete the block for a presentation style and then complete a NASA TLX survey [11] for that style. The NASA TLX Survey was used to determine the participants' perceived cognitive workload. Also, we asked the participants to recall the last textual information presented in the headset. We did not explain that we would ask for the last textual information presented in the headset, which allowed us to examine if there was a difference in perceptibility and comprehension. After the survey, the participants would then complete the next block with a different presentation style, and so forth. The order of the presentation styles was counterbalanced across participants.

3.1 Participants

The participants included 33 adults (M = 21.55 years, SD = 3.55). Twelve participants were female and one participant identified as non-binary; two participants were left-handed. We excluded three participants: one due to equipment failure, and two due to self-reported peripheral vision loss. Therefore, we had a total of

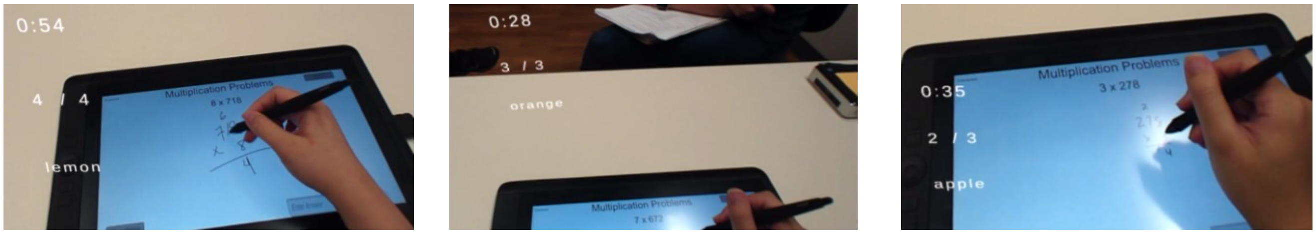

Figure 1. Presentation styles in AR headset: Display (left), Environment (middle), and Mixed Environment (right).

30 participants for analysis (M = 21.63 years, SD = 3.69). All 30 participants had normal or corrected-to-normal vision.

3.2 Design

Each participant viewed the secondary textual information in three different presentation styles: locked to the display view (Display), located in the environment (Environment), and a mix of both (Mixed Environment). For the *Display* presentation style, the textual information was locked to the left-hand side of the field-of-view. We placed the information on the left-side due to the quantity of information (i.e., it would obstruct the participant’s view in the center), and because prior work has found lower detection accuracy for the right-side [17]. The text height was 5 mm and white, which is aligned with Meta AR design recommendations [18]. The participants could always see the information in the headset (Figure 1a). In the *Environment* presentation style, the text appeared 500 mm away from the participant with a height of 10 mm, which is consistent with design recommendations [19]. The text was fixed in the environment to the left of the participant, in order to be consistent with the other presentation styles (Figure 1b). In Figure 1b the participant is looking at the text in the headset and therefore able to clearly see it. However, if the participant looked straight down at the tablet or turned their head all the way to the right or left, they would not be able to see the text since it was in a fixed location in the environment. The *Mixed Environment* presentation style was a mix of both the previous styles. The text was always present in the field-of-view (similar to Display) but appeared 500 mm away from the participant with a height of 10 mm (similar to Environment). As with the Display style, the participant was always able to see the information in the headset. However, having the text farther away from the participant made the text appear less spread out and further into the participant’s central vision (Figure 1c).

3.2.1 AR Secondary Textual Information. The secondary information included the participant’s average math problem completion time, math accuracy, and a random word (Figure 1). We used Liberation Sans font since it is recommended for readability [24]. There was 75 mm between each textual element. The average math completion time was the average time it took the participant to solve the problems, presented in minutes and seconds. The math accuracy was a ratio of the number of correctly answered problems by the number of completed problems. The average time and accuracy were calculated in real-time and would update in the headset after each problem. Lastly, for the random word, it would randomly cycle between: “banana”, “apple”, “orange”, and “lemon”. We used the random word as a proxy for information that might not be directly related to the main task but still necessary for maintaining situational awareness. In addition, it allowed us to further examine the perceptibility of the presentation styles. The current word would remain visible in the headset for a random time (between 20-40 seconds) before switching to the next word.

3.2.2 Math Application Design. We used math as the main task because it utilizes working memory [15]. Working memory is a part of short-term memory that is concerned with perceptual processing tasks [3]. Having participants use their working memory allows us to analyze the perceptual qualities of the secondary information in the AR headset. In our study, participants completed single-digit x three-digit multiplication problems. We chose multiplication because it takes more time and attention to solve than addition [20]. None of the participants saw the same problem twice. In the application, the current problem would appear at the top and participants could work out the problem with a stylus pen (Figure 1). The participants had to enter an answer, which did not have to be correct, before hitting “next”. There was not a set amount of problems; each participant completed the amount they could do in the block time frame. Participants were instructed to take their time and focus on getting the correct answers.

4 Data Analysis and Results

We analyzed the different presentation styles by examining the participants’ math solve time, cognitive workload, and accuracy of recalled information. After each study block, participants were asked to recall the last textual information that was presented in the AR headset. Since we did not inform the participants that we would ask them to recall the information, the participants were unaware for the first block; however, after the first survey the participants became aware. Therefore, we split the analysis for recalled information into: *unaware recall* (first style) and *aware recall* (other styles). *Unaware recall* captures the raw perceptibility of the presentation styles, while *aware recall* coincides with real-world settings in which the users are aware of the task. A Shapiro-Wilks test showed that the data was non-normal for all metrics. Therefore, we applied the Aligned Rank Transform [31] to each metric. If significant, a Tukey post-hoc comparison was applied (unless stated otherwise).

For *unaware recall*, we calculated the proportion of correct answers for each participant’s first presentation style. An answer was considered correct if it exactly matched the last information presented in the headset. An ANOVA found no significant effect of type of presentation style on *unaware recall* accuracy ($F_{2,27}$ = 1.64, *n.s.*). When the participants did not know they had to recall the information, there was no significant difference between the Display (M = 60%, SD = 21.1%), Environment (M = 67.5%, SD = 23.7%), and Mixed Environment (M = 50%, SD = 20.4%) styles. We analyzed *aware recall* the same way as *unaware recall*, but for each participant's second and third presentation styles. A RM-ANOVA found a significant main effect of type of presentation type on *aware recall* accuracy ($F_{2,44}$ = 8.91, $p < 0.0001$). Participants had a significantly higher *aware recall* accuracy for Environment (M = 83.8%, SD = 18.6%) than Mixed Environment (M = 51.2%, SD = 30.9%). We did not find a significant difference between Environment and Display (M = 68.8%, SD = 21.3%). Since *aware recall* was significant, we examined each secondary information separately (average math time, math accuracy, random word). We only found a significant effect of presentation style on the random word accuracy ($p < 0.001$, Fisher's exact test [13]). A pairwise test of independence with a Bonferroni correction only found a significant difference between the Environment and Mixed Environment styles. Environment had a higher count of correct random word recall events (18 correct, 2 incorrect) than Mixed Environment (6 correct, 14 incorrect).

Also, we examined the math solve time (i.e., time from when the current problem appeared to when the next button was hit), in order to see if participants were consistently focusing on the math application. Since we instructed participants to take their time, we did not analyze solve time as an individual metric (i.e., we were not interested in speed). Rather we use solve time as a proxy for determining if there was a shift in focus between the AR and math application for the types of styles. A RM-ANOVA found no significant effect of presentation style on solve time ($F_{2,58}$ = 0.77, *n.s.*). The participants' consistency in solve time reinforces that participants focused on the math problems as their main task. Lastly, we analyzed the participants' perceived cognitive workload for each presentation style. A RM-ANOVA found no significant effect of type of presentation style on perceived cognitive workload ($F_{2,58}$ = 0.12, *n.s.*).

5 Discussion

Overall, we did not find a main significant difference between the three presentation styles for textual secondary information. However, we did find a significantly higher *aware recall* accuracy for Environment compared to Mixed Environment. When further examining *aware recall*, we only found a significant effect of presentation style on the random word accuracy. Participants frequently remarked that they were more interested in the other textual information (e.g., math accuracy) since it directly pertained to the main task. Therefore, the Environment style aided in the awareness of non-pertinent information, which highlights the high perceptibility of the style.

For the Mixed Environment style, having the text 500 mm away and always present put the information more in the participants' field of vision, which made it more distracting to the participants. For example, P13 stated "*The mixed environment was too distracting and put too much pressure on me to get more problems right*". With the Environment presentation style, the participants could look at the information when they desired. P8 stated "[The Environment style] *didn't get in my way so I didn't have to block it out of my vision while completing the math problems. It was nice to look up at it when I felt the need to*." Although the Display style was always present in the field-of-view, participants remarked that it was easier to tune out since it was located more in the periphery. Both the Display and Environment presentation styles allowed the participants to tune out and view the secondary information when they preferred, resulting in a stronger focus and higher recall accuracy.

In our study, both the Display and Environment styles improved perception and comprehension for secondary textual information. However, prior work in virtual reality has found that text notifications locked to the display result in a higher sense of urgency than text notifications floating in the environment [26]. Secondary information should be unobtrusive and not require a sense of urgency [8]. Therefore, we recommend that designers utilize the Environment style for nonessential secondary information and the Display style for more important information in AR headsets.

6 Limitations and Future Work

Our work supports the design of secondary information in AR headsets for situational awareness. Still, there are some limitations to the scope of our work. First, we only focused on perception (level 1) and comprehension (level 2) for three presentation styles. In addition, the environment and amount of information could have affected perceptibility. We view our study as a starting point for examining how to design information in AR headsets for situational awareness. Future work can investigate other types of information in different environments, as well as focus more on prediction (level 3).

7 Conclusion

We conducted a study on how to present textual secondary information in augmented reality (AR) headsets for situational awareness (perception and comprehension). We examined three different presentation styles: Display, Environment, and Mixed Environment. Our analysis revealed that the Display and Environment presentation styles improved perception and comprehension for secondary information; participants had a higher recall of information when compared to the Mixed Environment style. Our work is a first step in designing information in AR headsets to increase situational awareness.

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