# Augmented Reality in Command and Control Processes: A Comparison of Presentation Types for the Transmission of Auditive Orders
# – Extended Abstract –

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## 1 Introduction

Events like the ongoing Ukrainian-Russian war or the 2025 California wildfires show us that future conflicts will occur not only in cyberspace, but also on solid ground. During emergency operations, fire departments, disaster control teams, and military units continue to rely heavily on radio communication. However, traditional radio communication has several drawbacks—it relies solely on auditory input, is susceptible to overload and distractions from background noise, lacks visual support for conveying complex instructions, and is prone to technical failures. These limitations underscore the need for more resilient, multi-modal communication solutions.

Augmented Reality (AR) holds great potential to address these limitations by blending physical and virtual environments. Beyond audio or text-based communication, AR can add visual cues, store message history, and integrate speech/text recognition, making interactions more efficient and intuitive. Yet, users must divide attention between real-world and virtual overlays, risking increased cognitive load. Identifying the optimal modalities to deliver content without overwhelming users remains a key challenge, as it directly impacts AR's effectiveness in real-world applications.

In two independent studies, we therefore investigate different formats for radio communication in AR—both text and symbolic representations—and explore how they can best support auditory instructions for emergency and military services.

## 2 Literature Review

Acute stress can impair working memory performance (Lupien et al. 1999; Oei et al. 2006; Schoofs et al. 2008), leading to higher error rates. Task force leaders are regularly confronted with stressful, multitasking conditions that can cause cognitive overload and diminish performance (Beurden and Roijendijk 2019; Shiffrin and Schneider 1977; Weightman et al. 2017). This stress becomes a risk factor for operative forces (Chérif et al. 2018). Longer sentences also require more working memory capacity (Sigurd et al. 2004), so complex instructions can further increase these cognitive demands under stress.

Visualizing relevant information can reduce data overload and misunderstandings. According to Cognitive Load Theory (CLT) (Sweller 2011; Sweller et al. 2019), adapting information presentation is key to avoiding overload. Augmented Reality (AR) can provide decision-relevant information directly in the user's field of vision, alleviating cognitive strain (Buchner et al. 2022). In 2019, Kim et al. found that while text-based AR tasks can be mentally demanding, they still yield better performance than using paper.

Military AR applications have primarily focused on improving soldiers' situational awareness (Chérif et al. 2018; Julier et al. 2000; Livingston et al. 2011) and providing visual instructions (Ababsa 2020; Kretschmer et al. 2020; Skljarov et al. 2023). Related work on integrating speech recognition with AR has especially explored supporting users with disabilities (e.g., hearing impairments [Mirzaei et al. 2012; Watanabe et al. 2018]) or language barriers (Che Dalim et al. 2020; Tsai and Tsai 2022; Wibowo et al. 2022), yet no known AR solution currently logs and delivers instructions in real time—a prerequisite for visualizing radio commands. Improving speech recognition accuracy in noisy, dynamic environments remains a major challenge.

There is also no standard guideline for designing AR user interfaces. While high-contrast text and backgrounds (e.g., white text on a black background) aid readability, more research is needed to identify the best text placement strategies in AR. Although some authors suggest adapting text placement to the environment, others criticize this approach for violating consistency in information presentation.

# 3 Methodology

We conducted two independent user studies to examine the impact of different instruction delivery methods through AR glasses. In study A, we compared two types of written text instructions, displayed in AR. in study B, we used auditive instructions as a baseline and compared this to two types of auditive and displayed text instructions in AR. In both studies, participants had to complete drawings on an iPad with no time limit, using an Apple Pencil. Instructions are centrally positioned in AR, tabletop-like about 60 cm away from the user. Study A used a Microsoft HoloLens 2, and Study B used a Xreal Air 2 Pro as AR glasses.

## 3.1 Study A: Comparing Written Text Instructions in AR

In Study A (n=200), a between-subjects design examined the cognitive load of two text presentation formats (continuous text vs. bullet points) in an AR drawing task. An AR application was developed for each condition, projecting only relevant text onto a Microsoft HoloLens 2.

The experiment had three phases. First, participants completed an iPad questionnaire capturing demographics, radio message experience, technical proficiency, AR familiarity, subjective attention control (Derryberry and Reed 2002), and emotional state (Bradley and Lang 1994). Next, they received one of the two AR text instructions and performed the drawing task. Finally, a follow-up questionnaire assessed emotional state, user acceptance (Venkatesh et al. 2012), cognitive effort, cognitive load (Klepsch and Seufert 2020), fatigue, attention, and presentation preferences.

To evaluate information processing, drawings were checked for completeness across 11 possible errors, with one point deducted per error. Six examiners conducted a visual assessment, focusing on the final outcome while allowing slight variations in dimensions if overall proportions remained consistent.

## 3.2 Study B: The Impact of AR Text Integration on Audio Guidance

In study B (n=9), we used a within-subjects design and investigated users' performance and perceived experience. We implemented an AR application involving three different methods of delivering instructions. These are *'Audio-only'*; a spoken, audible continuous text message, *'Audio+Text'*; a spoken, audible continuous text message, with the same continuous text displayed on AR glasses, and *'Audio+Symbols'*; a spoken, audible continuous text message, with a shortened symbolic representation of the continuous text displayed on AR glasses. We used the integrated speakers in the Xreal Air 2 pro as sound source. After briefing the participants, they are required to complete three specific similar complex drawing tasks while receiving instructions through one of the three methods. These methods are presented in randomized order to the participants. After each drawing task, the participants fill out a questionnaire. For each condition, we measure error count, task completion time and accuracy of the participants' drawings. Additionally, participants' user satisfaction is assessed through User Experience Questionnaire (UEQ)(Laugwitz et al. 2008), alongside their feedback on their preferences for the different instructional methods.

# 4 Findings

## 4.1 Study A: Context is Key

The results of Study A indicate that the *bullet point* format enables faster processing but leads to a higher error rate, whereas the *continuous text* format improves precision but increases cognitive load. An objective evaluation by examiners found that the final output quality was nearly identical across both groups. These findings suggest that the choice of presentation format should be context-dependent, particularly when balancing time efficiency and execution accuracy.

## 4.2 Study B: AR Instruction Methods Outperform Audio-Only

The results of study B revealed that both augmented methods minimized misunderstandings and enhanced clarity during task execution by significantly reducing error counts compared to the audio-only method, while task completion time and accuracy showed no significant differences across the methods. Additionally, both augmented methods received high user ratings than the *'audio-only'* method, which makes them powerful integrations to improve both usability and user satisfaction to guide auditory instructions in AR-assisted tasks.

Furthermore, qualitative evaluation of the UEQ indicated that both augmented methods achieved higher ratings from the participants than the *'audio-only'* method. Both augmented methods performed equally well in terms of usability and enjoyment, with individual preferences influencing users' perception of the two methods. These findings highlight the potential benefits that augmented guidance offers in AR-assisted tasks.

# 5 Conclusion

The results align with the CLT (Sweller 2011), which advocates for adaptive information presentation to mitigate cognitive overload. AR's ability to present decision-critical information directly within a user's field of vision has clear applications in emergency response and command-and-control operations. By combining these visual and auditory modalities, an improved task performance and an enhanced user experience can be achieved, particularly in environments where precision and clarity are essential. However, these benefits must be balanced against the risk of introducing excessive cognitive demands, particularly when users must simultaneously process real-world and virtual information.

This research provides compelling evidence of AR's potential to transform instruction delivery in high-pressure environments. By carefully selecting and adapting presentation modalities, AR systems can effectively reduce cognitive overload, minimize errors, and improve user satisfaction. Addressing existing challenges and refining AR technologies will be key to unlocking their full potential in real-world applications.

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