Design Considerations for Augmented Reality Supported Tactical Decision Making Systems

Simone A. Smarr, Alexis Davis, Niya Traynham, Nicholas Abram, Saurav K. Aryal, Jaye Nias, Lucretia Williams, Jeremy Blackstone, Gloria Washington

Human-Centered AI Institute, Howard University, Washington, DC, USA
simone.smarr@howard.edu, alexis.davis4@bison.howard.edu, niya.traynham@bison.howard.edu, nicholas.abram@bison.howard.edu, saurav.aryal@howard.edu, jaye.nias@howard.edu, lucretia.williams1@howard.edu, jeremy.m.blackstone@howard.edu, gloria.washington@howard.edu

Abstract

In high-stakes environments, tactical decision making is critical, and managing cognitive load and stress is important. The Tactical Decision Making Under Stress (TADMUS) program established a foundation for decision-support systems grounded in naturalistic decision-making processes and meaningful information presentation. Immersive technologies, like augmented reality (AR), create opportunities to extend this work while introducing new design challenges related to cognitive load and awareness.

This research explores the design of an AR decision support interface for TADMUS contexts using a human-centered design approach informed by alert design, augmented reality, and decision support literature. Focused on alert systems as a key mechanism for communicating time-sensitive information in spatial computing environments, we identify AR-specific alert design challenges that should be considered and present a tiered alerting approach to support tactical decision making.

Tactical Decision Making

Through the ONR Tactical Decision Making Under Stress program, a decision support system was developed grounded in naturalistic decision processes (Morrison et al. 1996). Morrison et al. laid the foundation for decision support for tactical decision-making, focusing on the meaningful presentation of data to support naval officers' decision-making process. The design consisted of various elements like the Track Profiles, Basis of Assessment, GeoPlot, and Response Manager, and ultimately was shown to enhance situation awareness and reduce cognitive workload. This work highlighted the importance of designing for cognitive and tactical support, as well as the role of information presentation in decision-making.

While the presented design in (Morrison et al. 1996) addresses the decision making challenges with the technology at the time, modern technology presents new opportunities to build on the foundation of the TADMUS project, specifically designing for naturalistic decision making, often seen in high-stakes environments. As a part of a larger research to use AI and spatial interfaces to support decision making for tactical, high-stakes environments, this work focuses on information presentation and interaction. Our work explores the opportunity of augmented-reality as the interaction modality to support the modern day challenge of tactical decision making under stress.

Informed by literature in human-computer interaction, alert design, augmented reality, and decision support systems, we explore the design of an augmented reality decision support interface for TADMUS contexts using a human-centered design approach. We identify key design challenges and present a tiered alerting approach intended to support urgency communication while managing cognitive load and intrusion.

Design Challenges for TADMUS

Along the lines of decision support, the overarching challenge is to create systems that support, not replace or impede, the decision-making process. Technical interventions, while able to create more efficient processes, also run the risk of distraction. Interventions need to support existing behaviors. The system in this context is also not meant to remove the human-in-the-loop or do the decision making for them. Thus, the system needs to support the existing processes without distracting the users attention or thought from the task at hand.

Augmented reality has been explored within military applications, and presents various opportunities and challenges (Kenny 2015; Kallberg et al. 2022). Kallberg et al discuss perspectives on the implementation of AR/MR in tactical environments, highlighting various considerations for effective implementation. The immersive modality of augmented reality systems offers great opportunity to work with users existing processes but also runs the risk of amplifying the preexisting cognitive load challenge (Dey et al. 2018; Tang et al. 2025). The intersection of designing to support tactical decision-making while considering modality-specific best practices presents various design challenges that we hope to address with the current work.

Alerting Focus

In time-critical decision making there are many variables at play. As seen in the original TADMUS work, tactical decision making requires considering various variables in order to make a sound decision with limited time (Morrison

et al. 1996). In the context of tactical decision making, alerts related to these variables can range from general communication like regular status updates to urgent notification of changes like an incoming attack. It is important to be well-informed in order to make the best decisions at any moment; lack of clarity, particularly in time based scenarios impacts decision-making (Reale et al. 2023). Any change in a variable impacts the outcome of the equation, so small changes in the interpretation of an alert can lead to drastically different outcomes.

Similarly, alerts must support decision-making without unnecessarily interrupting the user's existing cognitive processes (Iqbal and Horvitz 2010). In military contexts attention allocation is important to consider (Obermayer and Nugent 2000). In these high-stakes, time-sensitive environments, overly intrusive alerts risk distracting decision-makers from their pre-existing tasks, underscoring the need to balance clarity and cognitive processing demands.

This current work focuses on alert system design within AR supported TADMUS. Rather than addressing all aspects of modern TADMUS implementation, the work centers on how alert structure and presentation can support decision making under stress while respecting cognitive and spatial constraints.

Alerts and Attention in Spatial Interfaces

In spatial interfaces, like augmented reality, alerting presents both opportunities and challenges. Alerts are often experienced as intrusions, most strikingly when they are separate from the user's task environment. For example, alerts delivered through a phone, may pull attention away from critical real-world monitoring tasks, like visually scanning an environment for incoming threats. However, in spatial interfaces, alerts can be positioned within the user's existing line of sight, seemingly less intrusive and potentially reducing the need to shift attention away from ongoing tasks. At the same time, this approach introduces new design challenges, as the intrusion is now placed directly within the user's visual field.

As a result, alert design in spatial interfaces must account for competition not only for cognitive resources but also for visual space. The AR environment overlays digital information onto the real world, making it essential that alert presentation does not compromise situational awareness. Systems must ensure visual space is not unnecessarily cluttered or impeding the uses vision.

Communicating Urgency Without Cognitive Overload

An essential aspect of tactical decision making is effective communication as decisions are rarely made in isolation, and their outcomes often impact multiple parties. Alerts must support clear, efficient communication while not causing additional cognitive strain. Ambiguity in alert communication can distract decision makers, and time-sensitive environments do not allow for prolonged interpretation or recovery from distraction.

Beyond the content of alerts, the way in which urgency is communicated plays a critical role in cognitive processing. Alerts that fail to convey priority may require users to expend additional effort determining relevance, while overly intrusive alerts may disrupt ongoing decision-making processes. Balancing urgency, clarity, and intrusion is therefore a central challenge in alert system design. The following section describes the design considerations and rationale for a tiered alerting approach intended to address these challenges.

Design Considerations & Rationale

We propose a tiered alert system as a first-level implementation for the use of augmented reality in TADMUS. The primary intent of this system is to convey real-time information in a manner that supports informed decision making under stress. As previously stated, tactical decision making inherently involves continuous communication and information presentation, and the alert system is designed to scaffold both intrusion and content in a way that supports cognitive processing rather than detracting from it.

The alert system is intentionally designed to support, rather than force, specific behaviors. The user remains the expert in their own decision-making process and retains control over how information is engaged. This design philosophy responds directly to the cognitive load, intrusion, and situational awareness challenges previously outlined.

The design must support decision making without impeding real-world awareness or task completion. To address these constraints, the alert system prioritizes peripheral placement to preserve the user's direct line of sight and mitigate the impact of intrusion. The placement falls into two categories, based on urgency; more urgent alerts are positioned to ensure necessary attention (bottom-center), while less urgent alerts are contained to side regions of the user's visual field (right boarder). In addition to spatial placement, alert components are designed to be collapsible and moveable in recognition of limited screen space and varying user needs. The design of the support system centers users as experts thus user control of the layout was necessary.

Alerts in tactical decision-making contexts vary widely in urgency, and effectively communicating this variation is essential. As such, alerting systems that rely on a single alert style or binary alert logic risk either overloading users or obscuring information that may later become critical.

A tiered alerting approach better reflects the real-world experience of tactical decision making by allowing information to be categorized along a spectrum of urgency and communicating urgency through differentiated alert presentation. The system then supports quicker understanding without requiring users to fully read and interpret every alert before determining its relevance, potentially supporting rapid interpretation of alert importance and reducing the cognitive work required to assess priority under time pressure.

This approach avoids ignoring information solely because it is not urgent. While a status update may not require immediate action, it may still represent an active variable in the broader decision-making equation. The tiered structure allows such information to remain visible and accessible without competing unnecessarily for attention.

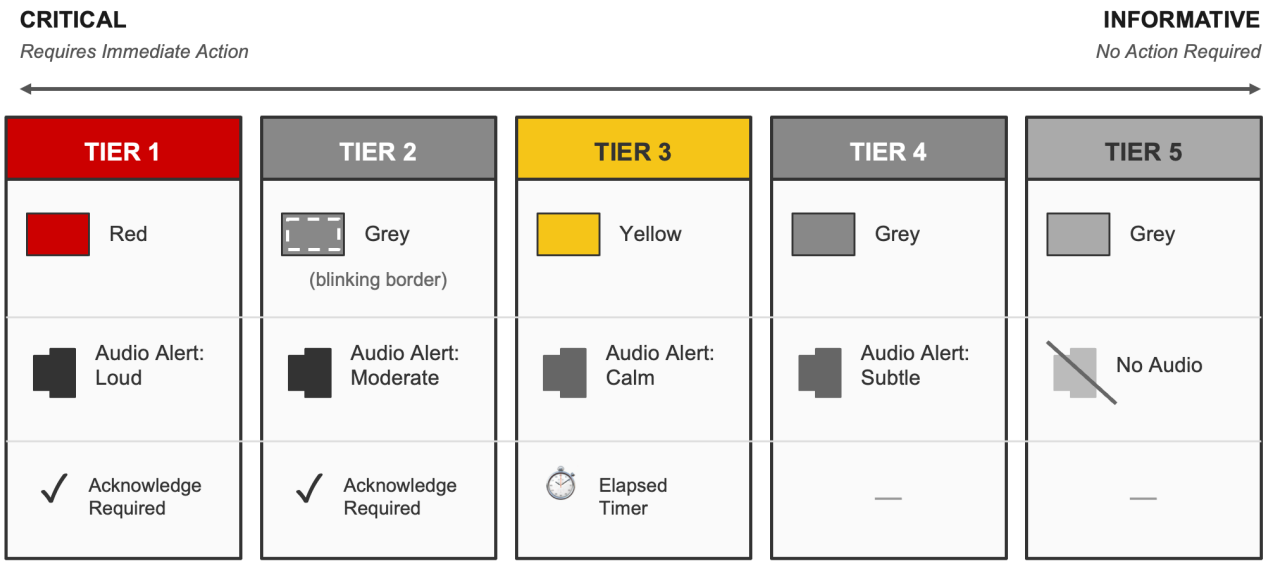

Figure 1: Alert Tier Design: With tiers ranging from Most Critical to Informative Only. Tiers 1–2 appear in the bottom-center display region and require user acknowledgment; Tiers 3–5 appear in the collapsible right-side alert center.

System Implementation and Alert Configuration

The design considerations described above are implemented in the alert system configuration illustrated in Figure 1. The system uses two primary alert locations: a bottom-center region and a right-side alert center. Alert tiers range from 1 to 5, with Tier 1 representing the highest urgency and Tier 5 representing the lowest. Tier 1 alerts are presented in the bottom-center of the display, use a red visual treatment, include full text, are accompanied by an audio alert, and require user acknowledgment to dismiss. Tier 2 alerts also appear in the bottom-center, are presented in gray with a blinking border, include a less alarming audio alert, and similarly require acknowledgment.

Tier 3 through Tier 5 alerts are presented within the right-side alert center and can be expanded to view full text. Tier 3 alerts are displayed in yellow, include scrolling text, use a calm audio cue, and display a timer indicating time elapsed. Tier 4 alerts are displayed in gray with a similar audio cue but without a timer. Tier 5 alerts appear in gray without audio.

The alerts in the alert center can be ordered by time of alert or grouped by Tier. While the right alert center is housed in the right side it's size can be changed and it can be collapsed. In the bottom center and the right alert center the most recent alert is always at the top.

Next Steps and Future Work

The proposed design addresses the challenges while also providing an initial step toward exploring AR-supported TADMUS. The design will be evaluated for usability, decision-making impact, and cognitive load. Based on these results, the system will continue to be implemented to further establish a prototype for AR-supported tactical decision-making under stress.

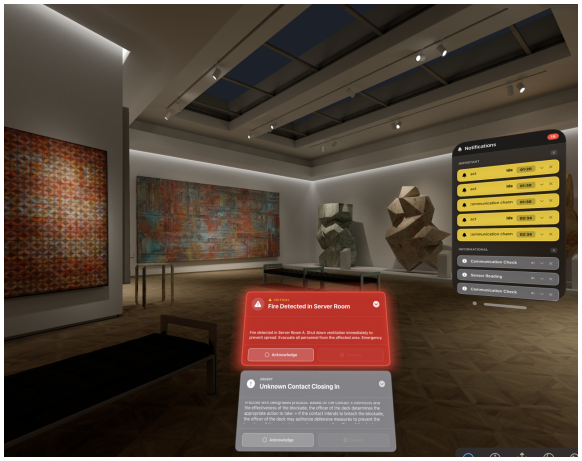

Figure 2: Simulated AR Implementation

Acknowledgments

This material is based upon work supported by the Office of Naval Research under Grant No. N00014-22-1-2714. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the Office of Naval Research.

References

Dey, A.; Billinghurst, M.; Lindeman, R. W.; and Swan, J. E. 2018. A Systematic Review of 10 Years of Augmented Reality Usability Studies: 2005 to 2014. *Frontiers in Robotics and AI*, 5: 37.

Iqbal, S. T.; and Horvitz, E. 2010. Notifications and awareness: a field study of alert usage and preferences. In *Proceedings of the 2010 ACM Conference on Computer Supported Cooperative Work*, CSCW '10, 27–30. New York, NY, USA: Association for Computing Machinery. ISBN 9781605587950.

Kallberg, J.; Beitelman, M. V.; Mitsuoka, M. V.; Officer, C. W.; Pittman, J.; Boyce, M. W.; and Arnold, L. 2022. The tactical considerations of augmented and mixed reality implementation. *Mil. Rev*, 662: 105.

Kenny, R. J. 2015. Augmented reality at the tactical and operational levels of war.

Morrison, J. G.; Kelly, R. T.; Moore, R. A.; and Hutchins, S. G. 1996. Tactical decision making under stress (TADMUS) decision support system.

Obermayer, R. W.; and Nugent, W. A. 2000. Human-computer interaction for alert warning and attention allocation systems of the multimodal watchstation. In Hamburger, P., ed., *Integrated Command Environments*, volume 4126, 14 – 22. SPIE. Backup Publisher: International Society for Optics and Photonics.

Reale, C.; Salwei, M. E.; Militello, L.; Weinger, M.; Burden, A.; Sushereba, C. E.; Torsher, L.; Andreae, M.; Gaba, D.; McIvor, W. R.; Banerjee, A.; Slagle, J.; and Anders, S. 2023. Decision-Making During High-Risk Events: A Systematic Literature Review. *Journal of Cognitive Engineering and Decision Making*, 17: 188 – 212.

Tang, Y.; Situ, J.; Cui, A. Y.; Wu, M.; and Huang, Y. 2025. LLM Integration in Extended Reality: A Comprehensive Review of Current Trends, Challenges, and Future Perspectives. In *Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems*, 1–24. Yokohama Japan: ACM. ISBN 979-8-4007-1394-1.