From Additive Dashboards to Subtractive XR: Workload-Adaptive AI Assistance for NG911 Dispatch*

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Abstract

Next Generation 9-1-1 (NG911) will increase the volume and diversity of information that emergency medical services (EMS) dispatch personnel must process, expanding beyond voice calls toward text, images, video, and sensor/telemetry data. While richer media may improve situational awareness, it also risks information saturation, increased mental workload, and higher susceptibility to error under stress. We argue that the next generation of extended reality (XR) assistance in emergency communications must shift from additive interfaces that 'pile on' more information to subtractive, workload-adaptive systems that protect attention, preserve human agency, and communicate uncertainty at a glance. This work is grounded in early field engagement with EMS dispatch personnel, where initial site visits and conversations with call-takers and supervisors revealed persistent challenges with rigid, highly demanding systems that are poorly aligned with work-as-done. Dispatchers described frequent protocol overrides and informal adaptations that are necessary for performance but are neither captured nor learned from by current systems. With institutional ethics approval in place (REB25-1954), we propose an attentional triage concept that (i) adapts information density to operator workload and task phase, (ii) externalizes and spatially organizes incident context to reduce working-memory burden, and (iii) provides situated explainability through embodied cues and evidence-linked summaries rather than disruptive text. We outline a field-grounded research plan with Calgary EMS dispatch personnel to map information friction points and derive design requirements for calibrated trust, resilience by design, and situated explainability in mission-critical XR.

Keywords

NG911, XR, Dispatch, Subtractive, Adaptive

1. Motivation: Dispatch as Mission-Critical Cognitive Work

Emergency medical service (EMS) dispatch is a time-pressured, high-stakes sociotechnical system where professionals coordinate across callers, responders, protocols, and computer-aided dispatch tools. Although workload is frequently discussed in prior studies, it is often fragmented into isolated sources, moment-to-moment experiences, or downstream consequences rather than treated as a coherent ergonomic construct. This fragmentation obscures how dispatchers manage cognitive demands in real time and limits our ability to understand cognitive load in mission-critical work, underscoring the need to examine workload as a system-wide, dynamic process that unfolds across the entire work system [1]. Classic distributed cognition research further shows that dispatch performance depends on how information is represented, transformed, and shared across people and artifacts, not solely on individual mental effort [2]. Similar insights emerge from ethnographic studies of mission-critical "control room" environments such as air traffic control, which highlight how operators coordinate information across multiple artifacts and colleagues to maintain situational awareness [3, 4]. These studies also show that new systems can redistribute work unevenly, creating hidden labor for certain roles while benefiting others[5, 6, 7].

Next Generation 9-1-1 (NG911) expands the interaction space. Field and design studies show that NG911 call-taking interfaces must support multimedia while enabling control over media flow, situa-

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tional awareness, and protection from potentially traumatic visuals [8, 9]. At the same time, technology transitions such as text-to-911 can introduce new stressors and 'hyper-tasking' demands for call takers [10].

Extended reality (XR) systems introduce unique opportunity for attention and cognition management, including persistent spatial anchoring of information, peripheral visual cues outside the primary display surface and hands-free interactions that allow dispatch operators to engage with primary tasks while monitoring contextual information.

2. Contemporary Emergency Medical Service Dispatch Workflow

EMS centers typically divide work between two specialized roles: call takers and dispatchers. Call takers are responsible for receiving emergency calls, extracting critical information from callers, and entering structured details into the computer-aided dispatch (CAD) system while following standardized triage protocols. Dispatchers, in contrast, focus on operational coordination: assigning response units, monitoring radio communication with field responders, tracking unit availability and locations, and managing the evolving incident response. Although these roles are distinct, they operate within the same tightly coupled information environment. Call takers must maintain attention on the caller while simultaneously entering information into the CAD system and consulting protocol prompts. Dispatchers must monitor multiple active incidents while coordinating responder movement, radio traffic, and resource availability across several displays. Both roles therefore require continuous attention switching between communication, documentation, and situational monitoring tasks. Dispatch personnel frequently manage several concurrent information streams, including caller audio, radio communication, mapping interfaces, incident queues, and system alerts. As new technologies such as Next Generation 911 (NG911) introduce multimedia data from callers, these cognitive demands are likely to increase further.

3. Why Additive Interfaces Fail Under Stress

Mental workload is shaped by task demands and resource competition. Multiple Resource Theory predicts that high-tempo multitasking and cross-modal interference can lead to performance breakdowns [11]. In practice, dispatcher personnel often manage multiple streams simultaneously (caller audio, radio traffic, CAD entry, mapping, coordination), making them vulnerable to information overload, especially when new channels are introduced without redesigning the work system.

In such contexts, adding more displays, more alerts, or more 'helpful' AI output can paradoxically increase cognitive load and erode situation awareness. Empirical evidence from emergency response domains shows that additive technological solutions often increase cognitive workload rather than reduce it. Responders report that smart technologies intensify attentional fragmentation and monitoring demands when they add new tasks instead of eliminating existing ones [12].

Under high workload, additive AI interfaces can also degrade situation awareness and decision quality. Highly reliable but imperfect automation can induce automation bias and over-reliance, particularly when uncertainty is not clearly communicated [13].

4. Concept: Subtractive XR Assistance Via Attentional Triage

We define subtractive XR assistance as a design philosophy in which the system treats the operator attention as a scarce resource. The system behaves like an 'attention safety mechanism' that supports the operator's primary task goals. Rather than continually adding new layers of information, the system will regulate information density by removing, deferring, or peripheralizing information that is not immediately relevant to the operator's role, task phase, or workload state. Within this design, the question is not what additional information can be provided, but what information is necessary for this task. Information prioritization will be determined through a combination of life-safety-relevance of callers, dispatch personnel and first responders, temporal urgency within the incident's lifecycle, and cognitive interference with primary dispatch personnel tasks. Workload can be estimated using non-intrusive behavioral proxies such as interaction tempo, and volume, task switching frequency and supplemented when appropriate by optional physiological indicators. The design of life-safety, temporal urgency, and cognitive interference judgments will be realized through focus group discussions with dispatch personnel during initial phases. When workload thresholds are exceeded, the interface will reduce notification frequency, collapse secondary panels and relocate lower-priority information to peripheral spatial regions of the display while still preserving easy retrieval. Progressive disclosures which allow for immediate access to deferred information, contextual resurfacing of suppressed items when risk indicators change, as well as transparent trails which allow dispatcher operators to review filtering decisions will be incorporated as safeguards to combat silent failures. These mechanisms will be put in place to ensure that subtractive systems will regulate attentional demand without obscuring operationally important information.

4.1. Design Pattern A – Workload Adaptive Information Density

Workload can be estimated using non-intrusive proxies such as interaction tempo, task switching frequency, and queue pressure, supplemented where appropriate by optional physiological measures; EEG-based indices, for example, have been used to trigger adaptive automation in other safety-critical domains [14]. When elevated workload is detected, the system should dynamically reduce visual clutter and notification frequency while preserving access to deferred information through progressive disclosure. Crucially, these adaptations should be aligned with incident phase, such as initial call intake, stabilization, and handoff, rather than relying on a static, one-size-fits-all interface.

4.2. Design Pattern B – Spatial Externalization to Reduce Working Memory

XR can be used to create persistent, glanceable representations of incident context, particularly who is involved, what is occurring, where the incident is located, and salient risks, thereby reducing reliance on internal rehearsal and working memory. Lower-priority information can be spatially "parked" in peripheral regions of the display while life-safety-critical cues remain in the primary field of view. For example, caller context, responder status, and hazard indicators can be persistently placed in stable peripheral locations around the dispatcher's workspace. Because these representations remain anchored in consistent spatial locations, operators can retrieve information through quick glances or head movements rather than active window switching. This spatial persistence allows lower-priority information to remain accessible without competing for attention within the primary CAD interface.

4.3. Design Pattern C – Situated Explainability for Calibrated Trust

Uncertainty should be communicated at a glance using lightweight cues such as confidence indicators or "needs confirmation" flags to support calibrated reliance on system outputs [15]. Rather than presenting lengthy textual explanations, systems should provide evidence-linked summaries that directly connect recommendations to their underlying data, such as highlighting transcript segments that triggered a suggested hazard. Explanations should be delivered on demand, ensuring that detailed reasoning is accessible without intruding on attention during peak workload. XR interaction modalities such as gaze, head orientation, or simple voice commands also allow dispatch personnel to retrieve deferred information without interrupting typing or caller communication, supporting hands-free information access during peak workload. These design choices align with the emerging XR frameworks that specify when, what, and how explanations should be presented in augmented environments [16].

5. Field Grounded Research Plan (Calgary EMS)

To avoid technology-driven solutionism, this work is grounded in ongoing engagement with Calgary EMS dispatch, including site visits and preliminary conversations focused on understanding work-as-done rather than work-as-imagined. These early interactions highlighted that existing dispatch technologies are experienced as inflexible, highly demanding, and poorly adaptive to the realities of dynamic, high-pressure call handling. Dispatchers reported routinely overriding system recommendations and rigid workflows to maintain safety and efficiency, yet these overrides are not captured, surfaced, or used to improve system behavior over time.

This project has received institutional ethics approval, (REB25-1954) enabling formal data collection with EMS dispatchers and call-takers. Building on initial field insights, we will conduct:

Survey: Quantify workload drivers, information friction points, perceived system rigidity, frequency and rationale for overrides, and attitudes toward AI and explainability.

Focus groups and interviews: Map information flows, breakdowns, adaptive strategies, and boundaries of acceptable automation using a distributed cognition and cognitive work analysis lens, with particular attention to how dispatchers compensate for system inflexibility.

Synthesis: Produce an incident-phase × information-need matrix and derive subtractive design requirements that explicitly account for dispatcher adaptations, override behavior, and the need for systems that learn from expert intervention rather than constrain it.

6. Research Agenda and Open Questions

A key challenge in designing decision support systems for public safety is determining what information to hide, defer, or peripheralize without introducing brittle "silent failures." Understanding how to build resilience by design requires careful consideration of when and how information should surface to the user. Equally important is the dynamic calibration of trust under stressful conditions: systems must support appropriate trust without increasing cognitive workload through excessive explanation overhead. Evaluating these systems demands metrics that go beyond traditional usability, including response time, error detection, situational awareness, workload, and the ability to recover from automation failures. Governance mechanisms, for instance audit trails, override capabilities, and validation on local data, are also critical to support adoption in high-stakes environments. To address these challenges effectively, our proposed survey and focus groups aim to first understand the information needs of dispatchers: what they need, when they need it, and in what format, so that any system we develop can provide timely, actionable support with a subtractive design. Figure 1 depicts the goals and research agenda.

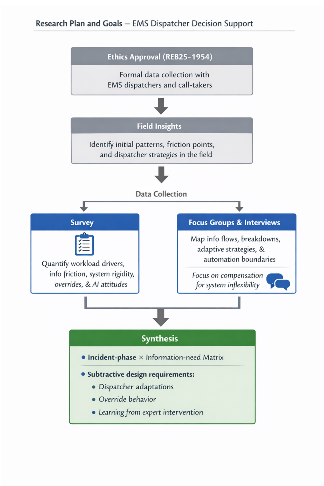

Figure 1: Figure 1: Research plan for REB25 -1954. Beginning with ethics approval to initial field insights, data collection via survey and focus-groups and finishing with synthesis of a subtractive design.

7. Conclusion

NG911 is poised to significantly increase the complexity and volume of information in emergency communications, challenging dispatch personnel's ability to maintain situational awareness, and make timely decisions. Emerging XR technologies uniquely enable the spatial distribution of information across the operator's visual environment, creating new opportunities to regulate attentional demand in high-tempo work settings. However, their effectiveness hinges on design that preserves dispatch personnel's attention, agency, and avoids cognitive overload. Subtractive, workload-adaptive XR assistance provides a concrete pathway for intervention, directly addressing the core challenges of next-generation emergency response.

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Declaration on Generative AI

During the preparation of this work, the authors used ChatGPT and Gemini in order to paraphrase, reword and check grammar. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the publication's content.

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