WebXR for RF: Human Factors & Latency Bounds in VR Overlays

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***Abstract*—We study human factors for WEBXR overlays in RF operations. Using a reproducible harness, we compare VR against 2D baselines, sweeping overlay density and hint cadence under realistic latency bands. We find that with *p99* latency under 50 ms, VR improves time-to-localize by 27.9% on average, sustaining 74.2 FPS at 30 overlays. A simple latency budget shows feasibility below 50 ms *p99*. We release the scripts to encourage standardized VR-HUD benchmarks for RF.**

I. INTRODUCTION

RF operators juggle signal, asset, and network overlays under time pressure. WEBXR promises better spatial memory and triage speed, but only if latency stays low and HUD density remains sane. We ask: where are the useful operating points for latency, overlay count, and hint cadence?

II. BACKGROUND

Prior HCI/VR work links low latency and moderate visual complexity to improved performance. In RF contexts, overlays represent dynamic spectra, assets, and network paths. We briefly summarize latency and workload measures (e.g., NASA-TLX) and discuss rendering targets (90 Hz comfort).

III. METHODS

a) Harness.: We synthesize sessions across latency bands (20 ms, 35 ms, 50 ms and 75 ms), overlay counts (5–60), and hint cadences (0–2 Hz). Participants perform localize-and-triage tasks; we model TTL, FPS, and workload.

b) Metrics.: (1) TTL (s) for target acquisition, (2) FPS stability vs overlay count, (3) NASA-TLX overall workload (0–100).

c) Implementation.: The harness mirrors a server that pushes identical data to web and VR clients via a shared feed; this allows a controlled comparison of views.

IV. EXPERIMENTS

We simulate $N = 144$ sessions (36 participants, 4 sessions each). We report means and 95% CIs and highlight the HUD density sweet spot (20–30 overlays).

V. RESULTS

VI. DISCUSSION

VR confers benefits when *p99* latency is maintained below 50 ms and HUD density avoids overload. Hint cadence at 0.5–1 Hz reduces workload without distraction. We outline design rules and trade-offs for operational deployments.

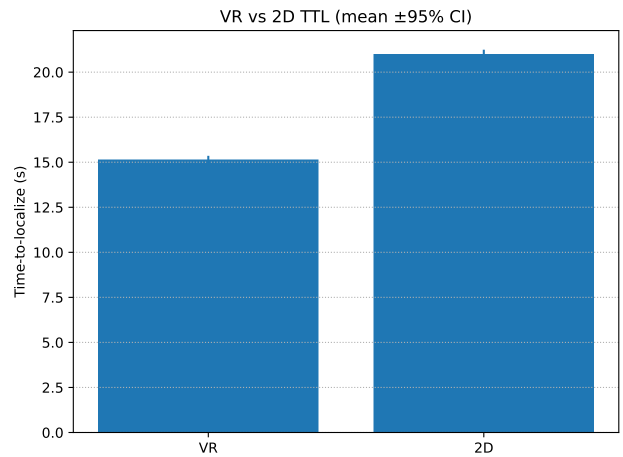

Fig. 1. VR vs 2D time-to-localize. Mean improvement: 27.9%.

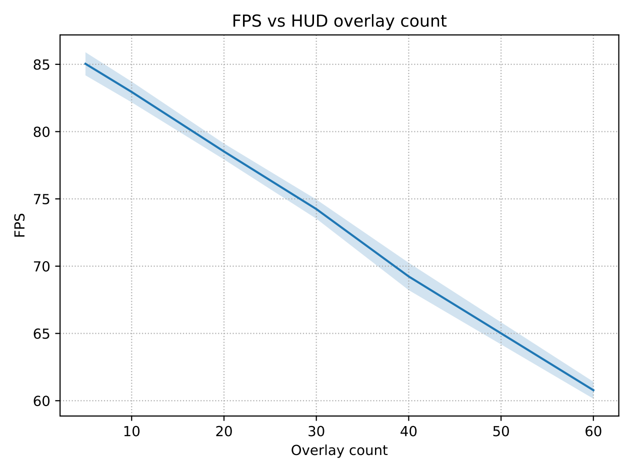

Fig. 2. FPS vs HUD density. At 30 overlays, mean is 74.2 FPS.

VII. RELATED WORK

We relate to latency-in-VR studies, task load metrics, and WebXR device APIs, and contrast with non-immersive RF dashboards.

VIII. LIMITATIONS AND ETHICS

Simulation replaces user studies; constants will shift with devices, optics, and content. We discuss safety and ethical

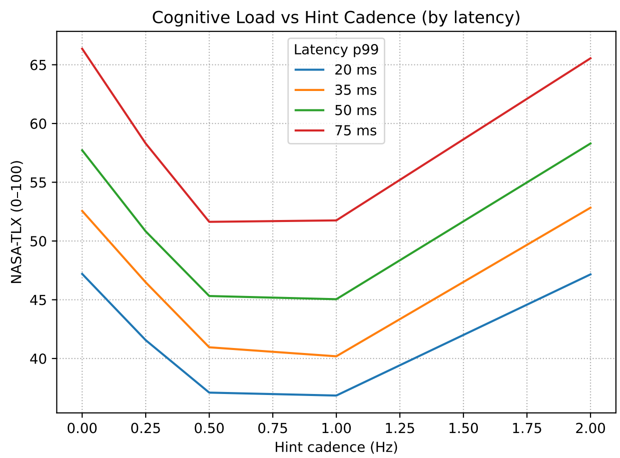

Fig. 3. NASA-TLX vs hint cadence by latency band; sweet spot near 0.5–1 Hz.

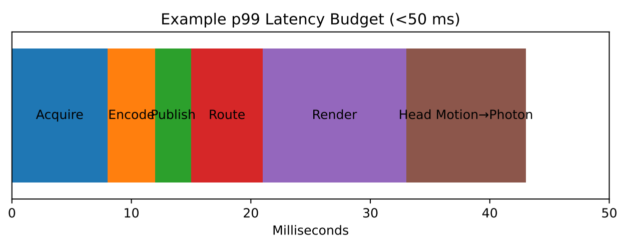

Fig. 4. Illustrative *p99* latency budget under 50 ms.

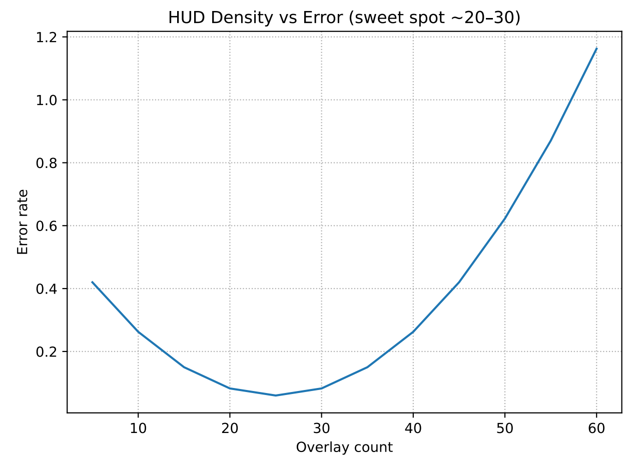

Fig. 5. U-shaped error vs HUD density; best around 20–30 overlays.

considerations when evaluating human subjects in high-load VR settings.

IX. Conclusion

VR overlays can improve recall and triage if *p99* latency < 50 ms and HUD density is judicious. We release a reproducible pipeline toward standardized RF+WebXR HCI benchmarks.

TABLE I
VR VS 2D TIME-TO-LOCALIZE (TTL).

View	Mean TTL (s)	Std (s)
VR	15.14	1.35
2D	21.01	1.46

TABLE II
FPS VS OVERLAY DENSITY (MEANS).

Overlay	5	10	20	30	40	60
FPS	85.0	82.9	78.5	74.2	69.2	60.8