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XR (Extended Reality) training is most effective in military and first-responder domains when used as a **staged, elemental learning system** rather than a full-scope simulation.

# FRAMEWORK AND ELEMENTAL TRAINING APPROACHES FOR MILITARY OPERATIONS

## XR for Challenging Environments

Lukas Kröninger - AIT



The bottom right of the slide features decorative geometric elements: a series of five parallel teal diagonal lines, a large teal parallelogram, and another series of three parallel teal diagonal lines.

# WHY XR TRAINING OFTEN UNDERPERFORMS

Cognitive overload is not a malfunction. It is a design failure.

- Placing trainees directly into high-fidelity and complex XR scenarios frequently **triggers cognitive overload** (Fraser et al., 2015)
- **Volatile, Uncertain, Complex, Ambiguous** (VUCA) conditions compound this further (Giaume et al., 2024)

Result:

**What gets trained is overload; not the skill.**

# DEFINING CHALLENGING ENVIRONMENTS (CHE)

Not just "dangerous" - cognitively maximal by definition

## Biopsychosocial Model (BPSM) (Blascovich & Tomaka, 1996)

State	Condition	Effect
<b>Challenge</b>	Resources > Demands	Cognitive focus
<b>Threat</b>	Demands > Resources	Decision-making impaired, learning halted

**7 Attributes of ChE:** Situated · Stressful · Complex · High Risk · High Stakes · Interactive/Changing · Social/Communicative

# THE XR TRAINING GAP: WHY ELEMENTAL APPROACHES ARE NECESSARY

The paradox of high-fidelity simulation

**High-fidelity simulation is required for contextual realism**

(Skarbez et al., 2021)

**BUT:** Full ChE simulation can trigger a **Threat State**

**In Threat State:** learning shuts down in favour of survival mechanisms

**Demand/Ressource mismatch**

Solution requires a

**Structural manipulation of Demands**

*“The Control Layer”*

# THE TRAINING GAP: WHY ELEMENTAL APPROACHES ARE NECESSARY

The paradox of high-fidelity simulation

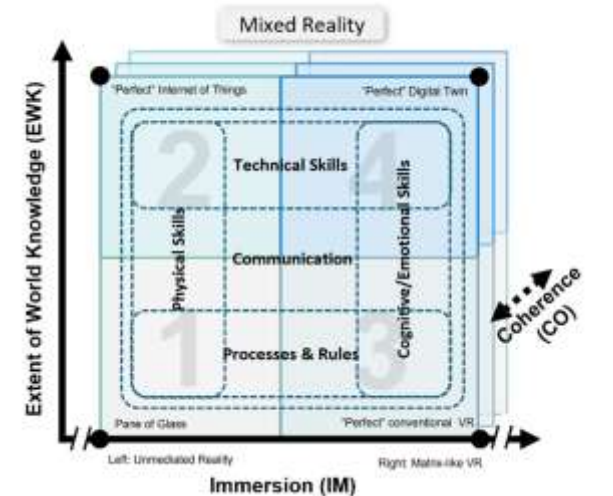
## ELEMENTAL TRAINING

Systematic isolation and progressive mastery of discrete skill components before integration into complex scenarios

# THE XR FRAMEWORK: THREE DIALS OF COGNITIVE CONTROL

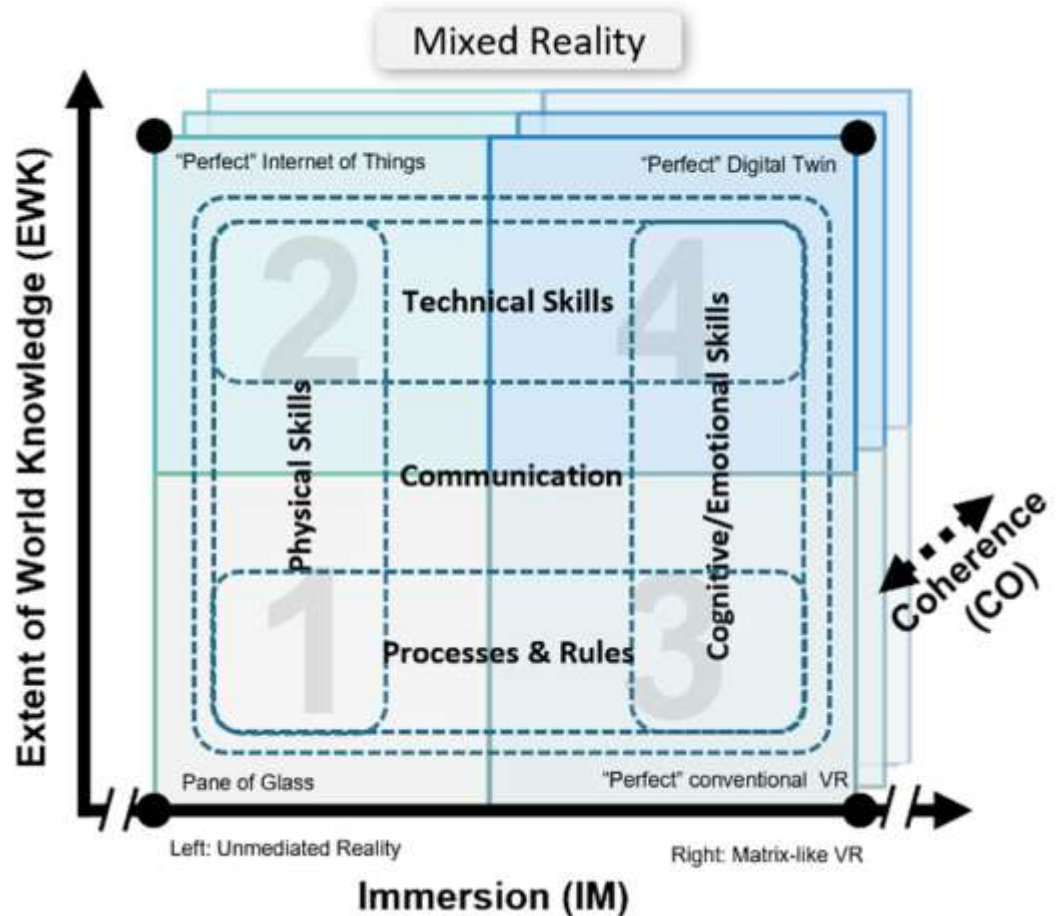
XR is not a simulation tool. It is a Cognitive Load Management System.

Dial	Definition	Cognitive Load Function
<b>Immersion (IM)</b>	Sensory fidelity / Place Illusion (Slater, 2009)	Controls Exogenous Load: e.g. distraction or fog-of-war
<b>Extent of World Knowledge (EWK)</b>	System model of real- world objects/space	Controls Germane Load: abstract vs. embodied action
<b><u>Coherence</u></b>	Internal logic / plausibility of simulation	Violations → Extraneous Load; must remain <u>HIGH</u> throughout



# TOPOLOGY OF TASK DECOMPOSITION: THE FOUR QUADRANTS

Staged pedagogical zones,  
not competing technologies



# THE COHERENCE INVARIANCE PRINCIPLE

A simulation need not look like the real world: **it must behave like it**

- **IM and EWK** may be reduced to manage load during early training phases
- **Coherence** (contextual plausibility) must remain high across all quadrants

**Coherence is a training safety requirement, not an aesthetic choice**

# THE BENEFITS

Honest accounting of Elements

## Benefits

- **Safe decoupling of risk and realism**
- **Repeatability and experimental control**
- **Adaptive Virtual Environments (AVEs) and Elements using physiological monitoring**
- **Interoperability:** Synthetic Training Environment logic; shared digital assets across organisations

# LIMITATIONS OF THIS WORK

A conceptual framework, not an empirical trial

- CLT–XR dimension mapping is theoretically motivated; requires **systematic experimental verification**
- Four-quadrant topology **simplifies a continuous design space**: real systems may traverse quadrants dynamically
- Elemental decomposition **assumes competencies are separable**; may not hold for tacit-knowledge or highly integrated perceptual-motor tasks
- **Generalisation across professional domains** requires domain-specific adaptation

# THE FUTURE – ADAPTIVE XR, AI/ML AND OPTIMISED TASK DECOMPOSITION

From static curricula to adaptive, self-optimising training systems

## Adaptive Elemental XR

- **Now:** Supervised training on labelled physiological data → stress pattern models
- **Future:** Holistic real-time classification → dynamic “Dial” adjustment + AAR performance insights (first approaches seen in Maity, 2019 / Zechner, 2023)

## Decomposition granularity

- **Now:** Benefits of elemental training: established
- **Future:** Optimal granularity per domain / skill-target via XR (Approaches seen in Laine et al., 2022 for e.g. AI-driven sequence optimization, which can identify prerequisite elements and integration timing from individual performance data)

# SO WHAT?

Two actionable takeaways for this room

**1. System Design:** Coherence is a non-negotiable design constraint. Certify behavioural fidelity of training assets, independent of visual fidelity.

**2. Innovation & Procurement:** Effective XR training is a sequencing question. Evaluate XR systems on their capacity to support staged, elemental progression for your training goal.

# THANK YOU!

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