Personalizing XR from Neural Responses to Multisensory Stimuli Using a Muse EEG Headband

RUTGERS
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Gap

Neurodivergent individuals are hard to accommodate in mainstream learning systems, and clinicians tune XR environments by intuition - there is no objective readout of what a child's nervous system is doing inside the scene.

Objective

Collect EEG, movement and participant feedback; build personalized profiles from that data; implement them in virtual reality.

Hypothesis

The Muse headband can inform a person's interest level toward certain stimuli, which can in turn inform VR learning.

Methods

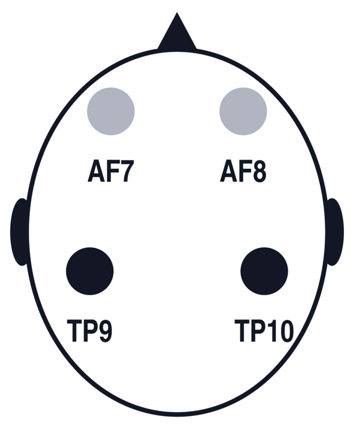

Fig. 1. Muse-2 montage, four dry electrodes. Band power for delta, theta, alpha, beta and gamma logged per channel via Mind Monitor

- **Validation.** Eyes open vs. eyes closed, confirming the headband before testing.
- **Baseline tasks.** Reading vs. watching, three trials per participant, spread across morning and evening.
- **Repeat trials.** A second trial 15–17 min later, separating a real pattern from a one-time result.
- **Stimuli battery.** Each test steps through its conditions for a fixed interval, with the Mind Monitor recording started in sync.

Stimulus Conditions

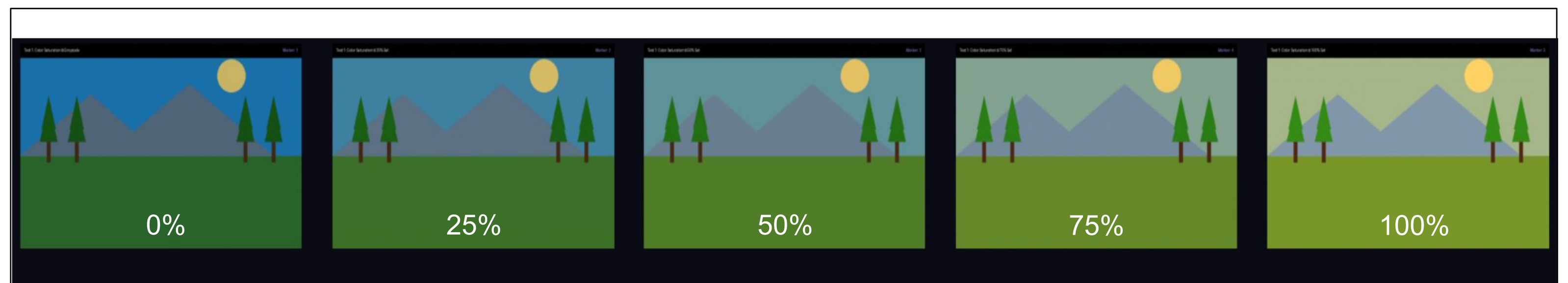

Fig. 2. Test 1 — color saturation at greyscale, 25%, 50%, 75% and 100%, scene geometry unchanged.

Fig. 3. The two contrasting Test 4 stimuli: a pure 432 Hz tone against broadband pink noise.

Test 4 — auditory condition	Role
Silence	baseline control
40 Hz	low / binaural range
432 Hz tone	calm
528 Hz tone	mid
Pink noise	stimulating

EEG Results / Auditory Test

Fig. 4. Participant P001, TP9/TP10, second-by-second across a 30 s block. 432 Hz tone (calm) vs. pink noise (stimulating).

Pink noise raised all three bands relative to the 432 Hz tone, with the largest separation in theta - the two sounds produced distinguishable neural states.

Five Screen - Based Stimuli Tests, One Sensory Dimension Each

Fig. 5. A VR scene delivers color, complexity, motion and sound all at once, so no response can be attributed to any one of them. Each dimension is isolated in its own test and stepped through fixed conditions, with a marker written at every onset and offset so the EEG can be aligned to what was on screen.

Analysis Pipeline

Every recorded interval is mapped back to the condition that produced it, then reduced to comparable numbers:

- Label every recording interval with the condition that was on screen
- Drop samples flagged by the headband indicator
- Trim the transition at each block boundary
- Average band power per window across the block
- Express each condition as change from the baseline block in that same session.

Baseline: Reading vs Watching

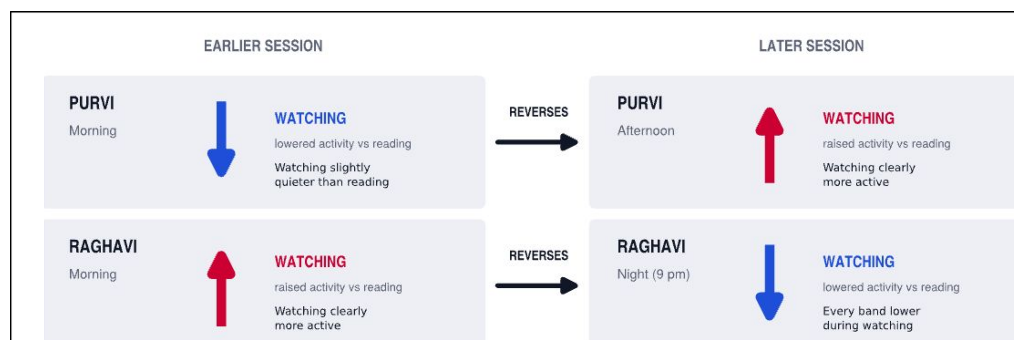

Fig. 6. Direction of the watching-vs-reading difference for each participant, earlier session vs. later session.

Reading and watching separated in every trial, but the direction was not fixed every measure is change from that participant's own baseline, and session time is recorded.

Unity XR Environments

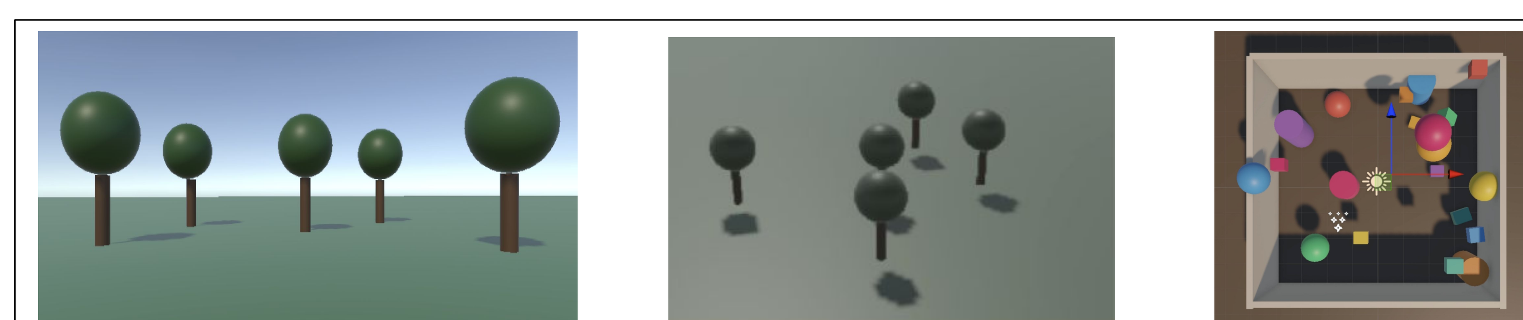

Fig. 7. The three Unity scenes, loaded from a menu controller. A saturation cycle script steps Scene_Saturation through fixed saturation levels, mirroring Test 1 in an immersive setting

Errors & Fixes

- Bluetooth dropout. Wi-Fi interference corrupted the first recordings; the baseline was re-run.
- Inconsistent node. AF7 recorded unreliably, so band-power analysis was standardized on TP9/Tp10

Current Stage

Results are inconclusive due to minimal data - n= 1 for the battery, and both baseline participants are neurotypical. This work validates the instrument, the tests and the pipeline.

Next Steps

- Collect more data so conditions can be compared across participants.
- Obtain IRB approval for research with neurodivergent individuals..
- Configure the Meta Quest with Unity.
- Feed personalized EEG profiles into the Meta Quest with ML models.