

Supplementary Materials

Open Source Testbed Component List

Head-Mounted Display (HMD)	Meta Quest 3 – 2064 × 2208 px per eye, 120 Hz refresh rate, passthrough MR
Rotary Encoder	LiebeWH, China — 100 pulses/rev, 6 terminals, ergonomic industrial standard
Knob	Aluminum, 4.5 cm diameter × 2.5 cm height, 190 g
Microcontroller	ESP32-WROOM (ESP32S Module with CP2102, Dual-Mode WiFi + Bluetooth)
Connection Wires	4 × Female-to-open jumper wires (10 cm)
USB Cable	(ESP32-PC) USB cable for serial communication (921600 bps)
Foot Pedal	USB-connected, used for confirmation input during trials
PC Setup	Intel i7 CPU, 16GB RAM, Nvidia GeForce RTX GPU
3D Printed Structure	PLA, printed with BambuLab X1; includes: <ul style="list-style-type: none">– Knob Mount (encoder holder)– Controller Mount (holds left-hand controller)

Development Environment Unity 2022.3.20f1

XR SDK Meta XR Interaction SDK (OVR Rig + Passthrough layer)

Unity Application Features - Manages encoder + pedal input

-Launch cue scenes

- Logs trial data to .csv for each participant