ResXR: An Open-Source Toolkit for Standardized XR Behavioral Research

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Abstract

Extended Reality (XR) offers unique opportunities for behavioral and psychological research by combining experimental control with ecological validity. However, widespread adoption for research is hindered by high technical barriers and the absence of standardized data formats. To address this gap, we present ResXR, an end-to-end open-source software project for conducting behavioral XR experiments. ResXR provides a Unity-based experiment template for multimodal data capture (head, hand, eye, and face tracking from Meta's Quest Pro head mounted display) alongside a Python processing pipeline that automates the creation of a standardized data structure, validation, preprocessing, and quality reporting, inspired by established neuroimaging data formats and tools like fMRIPrep. By lowering entry barriers and promoting reproducibility, ResXR positions standalone headsets as accessible "human research mobile laboratories" for rigorous XR research.[1]

Index Terms: Behavioral research, data standardization, extended reality, eye tracking, open-source software, virtual reality

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[1]https://youtu.be/tK_l0BTGtuY

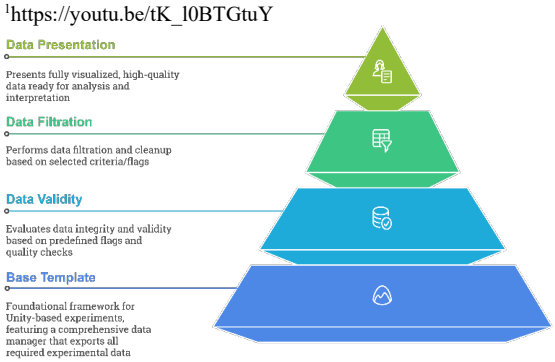

Figure 1: ResXR architecture: Base Template (Unity experiment template), Data Validity (quality checks), Data Filtration (preprocessing),Data Presentation (reports and export to the Motion-BIDS compliant format).

1 Introduction

Over the past three decades, Extended Reality (XR), encompassing Virtual Reality, Augmented Reality, and Mixed Reality has transitioned from specialized laboratories to consumer platforms. Analysis of over 21,000 experimental XR publications reveals that more than half appeared in the last six years alone [1].

XR's appeal for behavioral research stems from its unique ability to elicit realistic physiological, emotional, and behavioral responses within strictly controlled digital environments [2, 3].

Yet this growth has not been matched by mainstream adoption in psychology and behavioral research. Two key barriers persist. First, creating immersive experiments demands specialized programming skills, and researchers lack accessible templates designed for scientific applications [4]. Second, the absence of standardized data formats forces researchers to build custom processing pipelines for every study, creating a prohibitive analysis bottleneck that limits reproducibility [2, 4].

Established disciplines have addressed similar challenges through community standards. In neuroimaging, the Brain Imaging Data Structure (BIDS) [5] standardizes data organization, while pipelines like fMRIPrep [6] automate preprocessing and generate visual quality-assurance reports. The XR community lacks an equivalent framework.

To address this gap, we present ResXR (Research with XR), an open-source software end-to-end toolkit addressing both barriers through an integrated approach spanning data acquisition, validation, preprocessing, and analysis-ready export. Now ResXR targets Meta standalone head-mounted displays, capitalizing on recent hardware convergence [3], and outputs data compatible with the Motion-BIDS format [7].

2 System Architecture

ResXR comprises four hierarchical stages spanning Unity-based data collection and Python-based post-processing[1]

2.1 Base Template

The Base Template provides a reproducible Unity project scaffold with core components that provide API access to tracking and data systems, while all experiment logic (structured through a Session→Task→Trial hierarchy) remains fully researcher-owned and modifiable. All underlying code is transparent, not encapsulated. **ResXRPlayer** offers a unified interface for accessing player transforms, head, hand, and finger positions. **ResXREyeTracker** provides streamlined gaze data access on supported devices (e.g., Quest Pro), deriving combined gaze rays and returning intersected objects with 3D hit points. **ResXRDataManager** continuously records behavioral data (head, hand, eye, facial expressions) with automatic trial logging, synchronized to a common time base. Fig. 2 demonstrates the breadth of continuous data streams captured by these components.

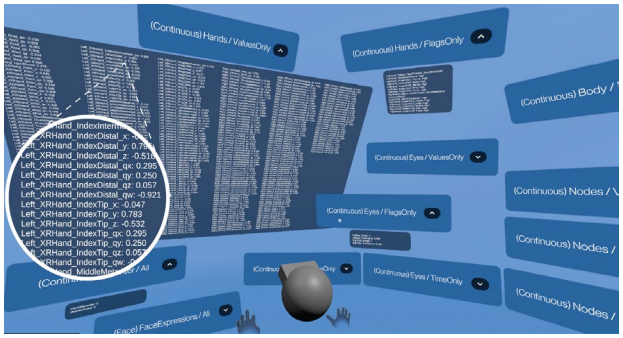

Figure 3- ResXR Live Monitor: a dedicated scene for visualizing available multimodal data streams from the headset.

2.2 Processing Pipeline

The Python pipeline transforms raw CSV exports into analysis-ready datasets through four components. **IO** loads and normalizes data into standardized session formats. **Validation** runs configurable quality checks (e.g., tracking loss detection) and generates quality flags. **Preprocessing** excludes flagged segments and computes derived measures. **Reporter** generates comprehensive HTML reports with diagnostic plots. All operations use human-readable YAML configuration files.

3 Demo Experiments

ResXR ships with three ready-to-use experiment paradigms demonstrating core capabilities of behavioral and physiological data collection, serving as starting points for custom research applications.

3.1 Binary Choice.

A two-alternative forced-choice (2AFC) paradigm presenting stimulus pairs. It includes configurable stimulus loading, reaction-time measurement, choice logging with trial-level multidimensional physiological data export. (Fig. 2 Top)

3.2 Museum Viewing.

An art gallery environment for studying visual attention and aesthetic experience. Participants freely explore artwork displays while the system records gaze fixations on each piece, viewing durations, and movement patterns throughout the virtual gallery space (Fig. 2 middle)

3.3 Maze Navigation.

A spatial navigation task where participants traverse experimenter made mazes to collect target objects. The paradigm captures continuous location and movement trajectories, collision events, and collection timestamps, enabling analysis of spatial navigation strategies and efficiency. (Fig. 2 bottom)

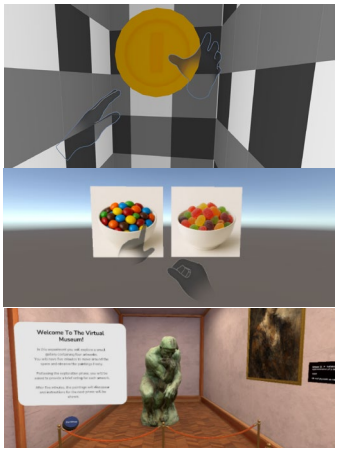

Figure 2- Demo experiments. Top: Spatial wayfinding task capturing continuous movement trajectories and object collection events. Middle: A 2AFC paradigm with paired visual stimuli and hand-tracked selection. Bottom: Free-exploration gallery for eye-tracking studies of visual attention

4 Conclusion

ResXR addresses critical barriers to XR behavioral research adoption by providing an accessible, standardized open-source toolkit spanning all stages needed for experiment creation through standardized data export and preprocessing. Drawing on established standards from the neuroimaging community and offering open-source components, ResXR aims to accelerate rigorous XR research while promoting reproducibility. Future work will expand hardware support and build community resources for shared experiment templates.

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