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Bridging Unity VR Experiment Templates and Institutional Infrastructure

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Abstract

VR research rarely fails in dramatic ways. It frays in the margins. It slips. It drifts. A timestamp is off. A controller desyncs for a moment. A study crashes right as a participant reaches the final task. These moments feel small and forgettable, yet they accumulate. In this paper, we present an exploration into the fusion of Fulcrum, a generalized support system for user-facing studies, and a new and improved ScryVR, a Unity package built to support user-facing VR studies. The combined system offers clear templates, organized study structures, and simple building blocks that help researchers understand and adjust their experiments without getting lost in technical details. To evaluate this solution, two case studies were conducted with this setup as the main tool in their experiment. Ultimately, the system effectiveness greatly streamlined VR setup and automated many crucial aspects of experiment facilitation. However, limitations were made clear primarily in robust error reporting systems, which report in real time and a more diverse solution for analytical tasks.

Introduction

In the field of Virtual Reality, specifically user studies, failure is rarely a single, catastrophic event; rather, it is a persistent ”fraying” at the edges of the experimental process. It manifests itself in the quiet accumulation of technical drifts—a misaligned time stamp, a momentary controller desync, or a system crash just as a participant reaches completion. Although these glitches may seem negligible in isolation, they exert a steady and erosive drag on the momentum of the research. This friction represents more than just a series of technical hurdles; it is the silent resistance born from fragmented workflows and mismatched tools [18]. Ultimately, this systemic instability forces researchers to sustain their studies through sheer cognitive effort, turning what should be a smooth experience into a constant struggle juggling hot fixes.

If Human-Computer Interaction (HCI) is to truly honor its human-centered ethos, it must extend that same care to researchers who design, facilitate, and interpret work [6]. Infrastructure is more than a technical requirement; it is a social and cognitive safety net that must sustain the person behind the experiment by respecting their cognitive load and fostering systemic resilience over burnout. When tools fail, workflows collapse, or plans unravel during study, these moments of rupture should not be dismissed as isolated glitches but should be recognized as evidence of a deeper fragility within our current environments. Designing for the researcher is therefore a matter of urgency, demanding that we build systems capable of supporting the human inquirer specifically in the moments when the research begins to falter.

Building upon these ideas, in this paper, we introduce ScryVR 2.0, a practical system designed to translate these rather conceptual requirements into more concrete, researcher-centered workflows. ScryVR operates in tandem with Fulcrum, an institution-spanning platform that manages user study creation, facilitation, data gathering [12]. ScryVR 2.0’s integration with Fulcrum provides a unified framework that aligns technical infrastructure with the practical realities of the VR research process. As part of this paper, we also provided some preliminary evaluation of the unified system through the analysis of two case studies conducted in conjunction with this system.

The remainder of this paper is structured as follows. Section discusses an overview of user study experiment infrastructure and similar approaches to ScryVR. Section covers the design of our software setup with a high level look at the newly updated ScryVR 2.0 and its integration with Fulcrum. Section provides a discussion consisting of two case studies conducted with the combined system and a detailed evaluation of the pain points and the interesting finds. Finally, Section wraps up the paper with the conclusions and work to come.

Background and Related Work

User study experiment infrastructure is not a new concept. The existence of user study experiment infrastructure, since the induction of empirical processes into software, sought to generalize and automate the repetitive operations inherent in the user study process. These operations in particular can range from task sequencing and facilitation to complex data logging [13, 17, 20]. These systems provide essential scaffolding that reduces the technical overhead of structured experiments, offering specialized tools for real-time facilitator observation and post-hoc data visualization [5, 10]. The necessity for such infrastructure was further accelerated by the shift toward remote experimentation, which introduced frameworks capable of managing consent and deployment across distributed environments [15].

Despite the advances in user study infrastructure, a persistent need still remains for integrated tools that align specifically with the rigorous workflows of behavioral and interaction research. And while this concept has been around for some time, it is far from a straightforward progression. User study infrastructure is a common enough process and progression within a project life cycle but an uncommon topic within research venues, the majority of which do not escape the confines of the respective research circles [8].

Even with VR, the overarching idea and limitations remain largely the same, but the unique characteristics of VR force researchers to examine solutions to domain-specific issues. To

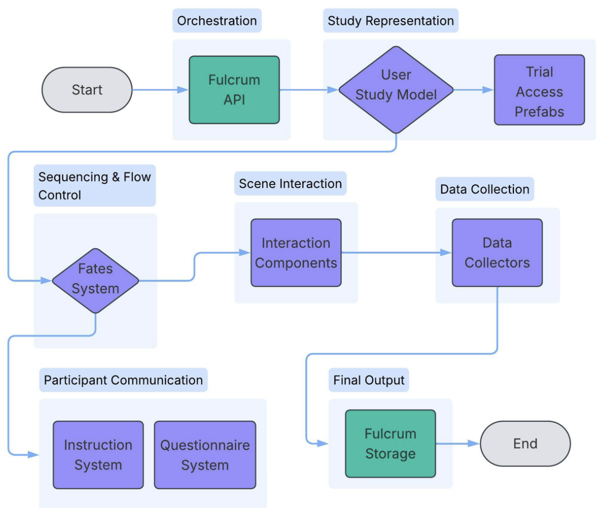

Figure 1. ScryVR Systems Diagram

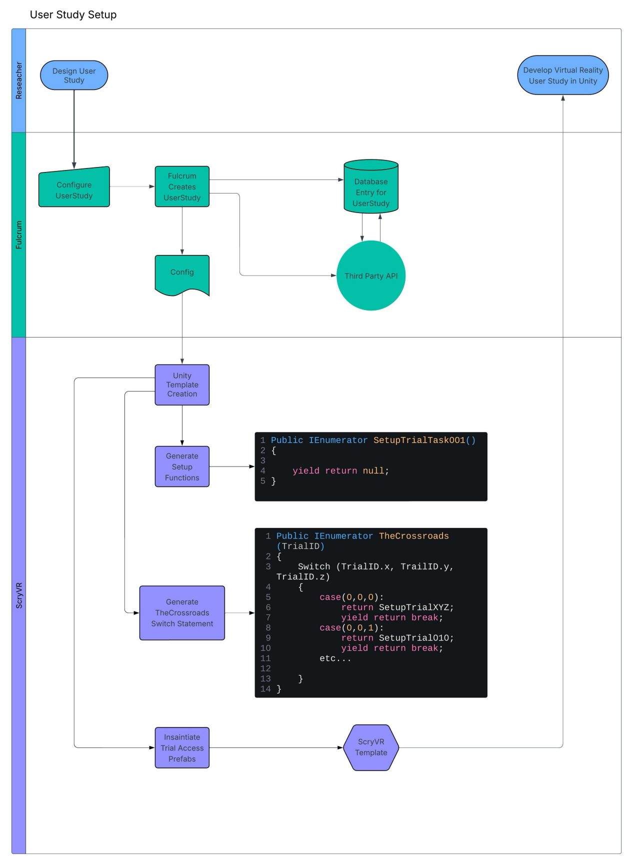

Figure 2. The Fates Code Generation

elaborate, VR experiment infrastructure is usually leveraged to address the challenge of gathering participant feedback without compromising immersion. By embedding data collection tools and questionnaires directly into the simulation, researchers can maintain experiential continuity and minimize the biases typically introduced by modality switching [2, 16]. These in-situ approaches ensure that self-reported data is captured within the context of the virtual environment, allowing for more accurate reflections of the user experience across diverse settings. However, to enable further infrastructure advancements within a virtual reality experiment, system developments outside of the virtual environment will be required. This is where systems such as ScryVR shine specifically, as it focuses on bringing the strengths of prior experiment builders into the VR user study context [18].

Among the research subdomains of the user study infrastructure, VR experiment infrastructure is not new. Early efforts like the Unity Experiment Framework (UEF) and StudyVR established the foundational scaffolding for trial sequencing, condition assignment, and data logging within game engines, significantly lowering the entry barrier for behavioral researchers [4, 14]. This evolution continued with the emergence of specialized analytics platforms such as MIRIA, RELIVE, and Autovis, which moved beyond simple data capture to support in-situ replay and visualization of complex participant behaviors [5, 9, 11]. Although recent recent advances in infrastructure explore a host of new developments, ranging from biometric integration to remote deployment, the field remains characterized by functional fragmentation, where researchers often need to bridge incompatible tools to manage the entire life cycle of a study [1, 15, 19].

Within the specific domain of Virtual Reality (VR), these infrastructures must navigate the unique intersection of high-frequency spatial telemetry and immersive user experience. Unlike traditional experiment builders, VR-specific systems are designed to manage the ”messy realities” of spatial computing, such as tracking drift and hardware desynchronization, while simultaneously delivering immersive questionnaires that minimize biases associated with modality switching [3, 16]. These tools are essential for maintaining experiential continuity, yet they often struggle to unify discrete experimental events with continuous motion and gaze traces [2, 18]. Consequently, the main challenge for contemporary VR research is not a lack of individual solutions, but the absence of an adaptive, unified infrastructure capable of holding these high-dimensional data streams together without compromising the participant's sense of presence [7]. Consequently, ScryVR 2.0's integration with Fulcrum explores a potential solution and a step forward in addressing that need.

Software Design

ScryVR 2.0 evolved the platform from a modular toolkit into a comprehensive end-to-end research infrastructure, bridging the gap between study design, orchestration, and analysis. While the original version focused on standardizing execution within Unity, the integration with Fulcrum transforms ScryVR into a unified system that addresses the entire experimental life-cycle rather than isolated technical hurdles. By maintaining a shared architectural foundation and consistent naming conventions, the platform simplifies the communication of complex research concepts and ensures a seamless workflow in every phase of experimentation.

This structural clarity is driven by a refined experimental framework where Tasks represent the core actions used to test a hypothesis, and Factors define the variables, such as input methods or environmental settings. These elements combine to form Conditions, which are then executed by participants as individual Trials. This hierarchical approach provides researchers with the

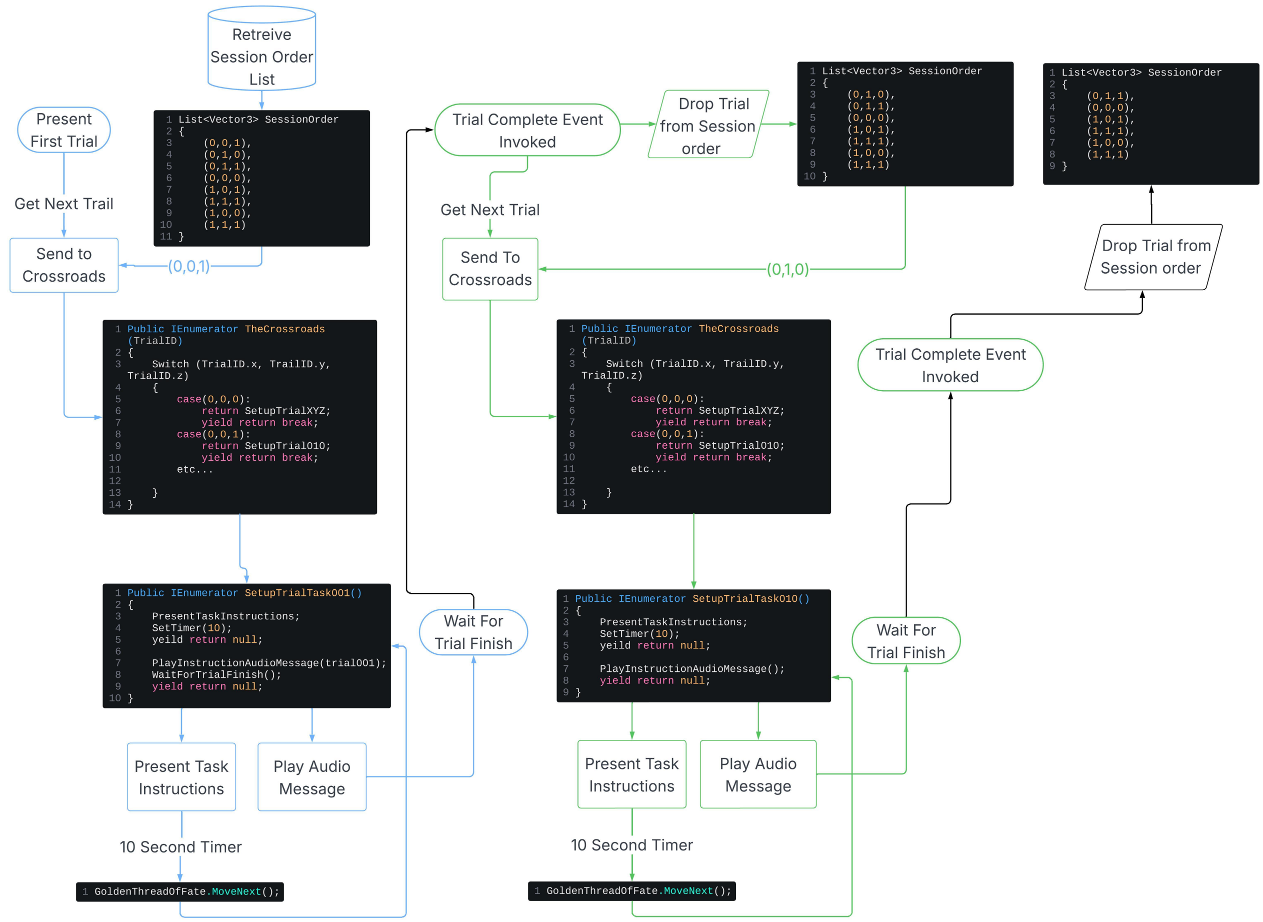

Figure 3. *Flow Chart of Fates System trail sequencing*

flexibility to design intricate studies while maintaining the organizational rigor needed to streamline data collection and focus on high-level insights.

Architecture

Organized around a sequence of layers that transition a study from conceptual definition in Fulcrum to full execution within Unity, the ScryVR 2.0 architecture ensures information flows naturally between stages. This design reduces technical friction, allowing researchers to remain anchored to the experimental design rather than its underlying scaffolding. As shown in Fig. 1, Fulcrum serves as the primary orchestration layer where tasks, factors, trial permutations, and metadata are authored, producing an exported configuration that acts as the architectural blueprint for all downstream components.

Once imported into ScryVR, the study metadata is transformed into an internal model and bound to automatically generated Trial Access prefabs. These prefabs serve as the vital bridge between abstract logic and concrete scene objects, ensuring that every interaction in Unity remains anchored to the correct task, factor, and trial. While many VR pipelines fragment at this stage, ScryVR coheres through a sophisticated sequencing layer called the Fates System. This component governs real-time trial progression and counterbalancing, replacing ad-hoc scripting with an explicit, reproducible framework that connects physical scene interactions, such as collision and throw detection, directly back to the study model.

Beneath this sits a robust data collection pipeline that continuously samples tracking data, tagging every entry with trial metadata to ensure frame-level logs remain perfectly aligned with the experimental structure. Participant-facing elements, including audio prompts and questionnaires, integrate seamlessly into this sequence to provide smooth transitions and capture subjective measures. At the end of a session, these layers converge as ScryVR exports the accumulated data set back to Fulcrum. This workflow, initiated by a Setup Wizard that validates metadata, generates the necessary internal scaffolding for the next portion of the process.

Fates System

The core output of the setup phase is the Fates System, where the wizard generates a ThreadsOfFate class featuring dedicated co-routine placeholders for each trial and a dynamic Crossroads function for routing. By utilizing generated code rather than manual state machines, ScryVR ensures the study structure re-

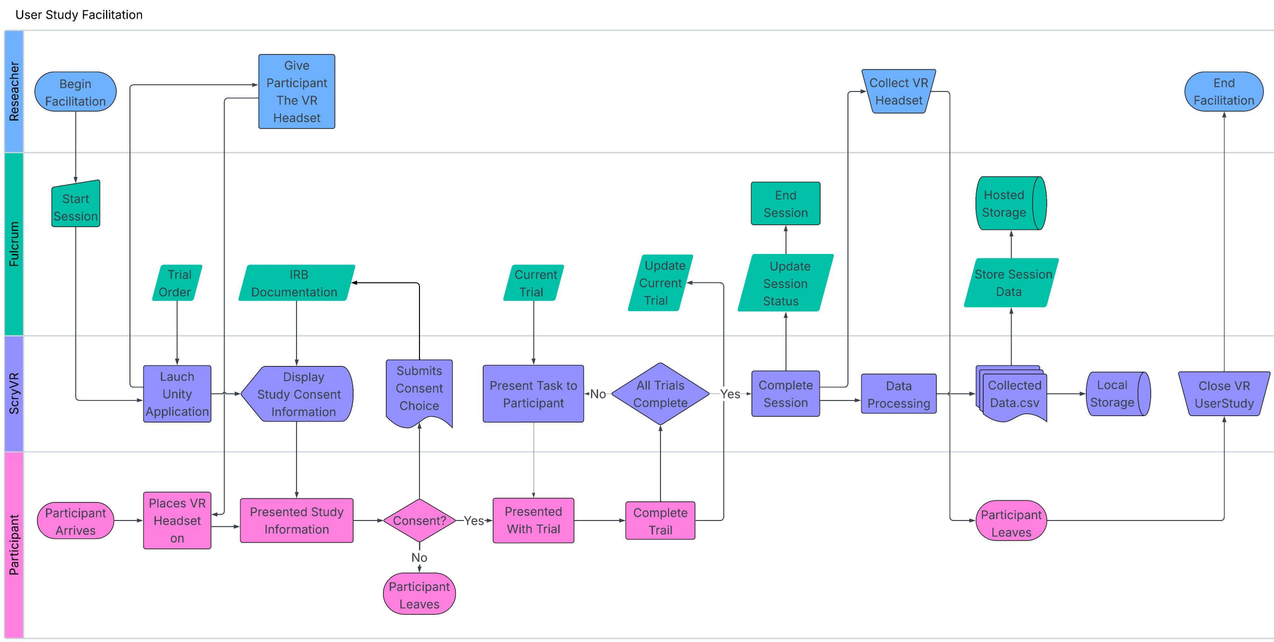

Figure 4. *User study Facilitation Flow Chart*

mains explicit, traceable, and resistant to structural drift. During development, researchers implement trial logic within these coroutines—a structure perfectly suited for the precise timing and event-driven nature of VR. As shown in Fig. 3, this encapsulation allows trials to be reordered or duplicated without destabilizing the system, while integrated utility tools like event triggers and questionnaires plug directly into the workflow to minimize implementation overhead.

The facilitation phase manages the active execution of the study through real-time interaction between Fulcrum, ScryVR, the researcher, and the participant. A session begins by synchronizing metadata and generating a unique identifier, after which ScryVR executes the trials according to the Fates System. Participant actions are automatically tagged, recorded, and transmitted back to Fulcrum, ensuring that transitions occur seamlessly and data remain synchronized. This rigorous communication between tools allows researchers to maintain high procedural fidelity and focus on participant behavior rather than the complexities of technical orchestration.

Fulcrum Integration

This interaction is facilitated by a series of web APIs hosted on an institution-wide domain, which serve as the communication bridge between the experimental builder and the VR environment. A session begins when the researcher constructs their experiment on Fulcrum, which generates a unique session identifier and synchronizes critical metadata with ScryVR 2.0. A sample of Fulcrum's experiment builder is presented in Fig. 5. Once the VR environment is loaded and configured as per the process mentioned above, the system assumes control, executing trials according to the precise logic defined within the Fates System. As shown in Fig. 4, this automated pipeline ensures that every participant action is captured, tagged with the appropriate metadata, and transmitted back to the central hub without manual intervention.

By relying on this clearly defined communication between tools, researchers are freed from the burdens of technical orchestration to focus instead on participant behavior and procedural fidelity. While ScryVR manages the immediate demands of the VR experience such as triggering automatic transitions and maintaining the rigor of the experimental design, Fulcrum performs the heavy lifting in terms of data curation. Acting as a centralized data store, it organizes the incoming stream of events and logs, providing researchers with streamlined access to curated datasets for download, visualization, and analytics. This synergy ensures that the transition from a conceptual design to a lived experiment is transparent and reproducible, keeping the focus squarely on the cognitive insights derived from the study.

Evaluation

This section presents a condensed evaluation of the unified framework composed of ScryVR and Fulcrum. Two complementary components structure this evaluation, each approved under its corresponding Institutional Review Board protocol. The usability study for ScryVR and Fulcrum was conducted under IRB protocol 2347666-1, while the interview study examining expert opinions was conducted under IRB protocol 2340784-2. Together, these studies provide a combined view of how researchers experience both the conceptual and infrastructural contributions of this work.

The evaluation of the ScryVR 2.0 and Fulcrum infrastructure was conducted through a dual-lens approach: a qualitative interview study with ten researchers to identify systemic ”research friction” and a hands-on usability study with two researchers from differing technical backgrounds. The interview study revealed that while researchers are confident in conceptual design, they face significant cognitive and emotional strain when translating those ideas into executable VR experiments. Five primary

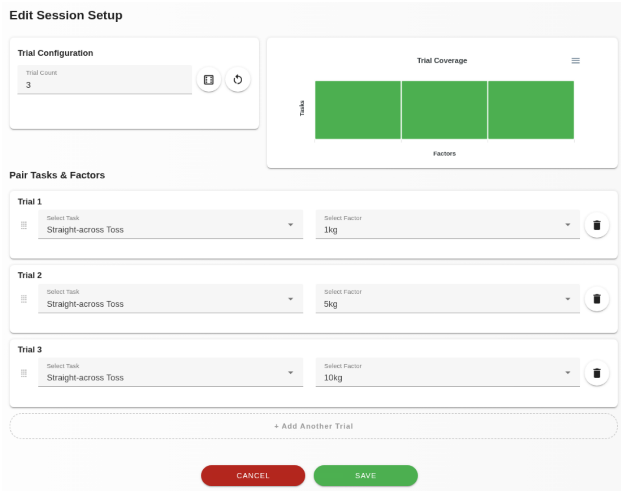

Figure 5. *Fulcrum trial and session setup interface*

themes emerged—Study Design & Execution, Cognitive Friction, Adaptation, Collaboration, and Tool Constraints—paints a picture of a research landscape currently characterized by fragmented workflows, reliance on individual memory, and "patchwork" toolchains that discourage iteration and increase the risk of procedural failure.

The system usability study grounded these theoretical challenges by tasking participants to recreate existing studies within the ScryVR–Fulcrum ecosystem. One participant brought deep Unity expertise but limited study experience, while the other was an experienced HCI researcher new to VR development. Despite these contrasting skill sets, both participants reported that the automatic generation of scaffolding and trial structures provided a surge of early momentum, significantly reducing the "glue-code" construction typically required. High Likert scores on engagement and system clarity suggest that the platform effectively externalizes experimental logic, making the study structure explicit and allowing researchers to maintain a focus on high-level cognitive design rather than technical troubleshooting.

However, the evaluation also identified critical areas for growth, particularly regarding the learning curve of structured orchestration. The Unity-centric researcher sought more transparent event-handling signals to bridge scene-level triggers with progression logic, while the HCI-centric researcher found the structured terminology of Fulcrum initially unfamiliar, suggesting a need for more robust on-boarding. Despite these hurdles, both researchers highlighted the system's ability to act as a "safe place to experiment," where trial logic could be modified without destabilizing the broader architectural foundation.

Ultimately, the findings confirm that the ScryVR–Fulcrum integration successfully addresses major categories of research friction by providing a unified, reproducible framework. By shifting the burden of data curation and synchronization from the researcher to the infrastructure, the system transforms experimental workflows from memory-dependent, ad hoc processes into visible and traceable systems. This transition not only improves the reliability of the data, but also restores the researcher's capacity for reflection and creative adaptation during the experimental lifecycle.

Conclusion

This research addresses the persistent challenge of research friction in Virtual Reality experimentation, arguing that researchers are often hindered less by hardware limitations than by the cognitive and organizational burdens of the experimental process itself. By providing a structured, end-to-end infrastructure, this work introduces a system designed to prioritize procedural clarity and sustainable iteration. The development of ScryVR 2.0 demonstrates how integrated architecture can transform fragmented, ad hoc workflows into a coherent system through a formalized grammar of Tasks, Factors, and Trials. This technical foundation ensures that the architectural blueprint of an experiment remains consistent from initial design in Fulcrum to real-time execution in Unity, reducing the reliance on individual memory and manual coordination.

The empirical findings validate this approach, revealing that the implementation of automated trial sequencing, governed by the Fates System, and centralized data curation significantly alleviates the mental overhead traditionally associated with study orchestration. While the evaluation surfaced the need for continued refinement in distributed system debugging, the results confirm that a unified infrastructure dramatically reduces the "invisible work" of manual setup and data synchronization. By bridging the gap between conceptual design and lived experiment, ScryVR 2.0 provides a resilient environment for innovation, making the complex process of VR experimentation more visible, predictable, and efficient for researchers across varying levels of technical expertise.

Future Work

The evolution of ScryVR 2.0 offers several pathways for technical and conceptual growth, particularly in expanding support for high-complexity experimental environments. Future development will focus on extending the system to accommodate multi-user VR environments, where synchronized behaviors and coordinated tasks introduce new challenges for data structure and timing. Furthermore, implementing adaptive study logic would allow for conditional flows that respond dynamically to real-time participant behavior or researcher input. To support this increased complexity, the system must evolve its diagnostic capabilities; broader error reporting, log visualization, and automated quality checks are planned to transform the platform into an active partner in identifying procedural problems before they interfere with a live session.

Reliability remains a central objective, with future efforts aimed at strengthening remote participation support and data synchronization to ensure precision across time zones. In addition, this paper only provided a high-level look at the evaluation process and only specific insights gathered during the researcher studies. An additional article detailing the entire process and all of the insight gathered would a natural progression for the work described in this paper.

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