StudyVR: A Framework for Streamlining VR User Study Design

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***Abstract*—While Virtual Reality (VR) technology has rapidly matured into the consumer space, there exists a noticeable lag in user perceptual studies to empirically validate whether these new technologies genuinely enhance user experience or merely serve as marketing hype. This paper introduces StudyVR, a prototype system aimed at addressing this gap by streamlining the design and deployment of mixed-methods user experience research studies in VR. Our approach automates common administrative tasks, common study methodologies, and automatically synchronizes both the research design and the participant questionnaire in an online database. The goal is to enable researchers to rapidly move from the initial concept of research design to participant data collection and analysis, concentrating more on their research questions and hypotheses than on implementation details. StudyVR enables a rich range of research methodologies managed in a centralized database, simplifying data management, and facilitating interdisciplinary collaboration. Finally, we present a proof-of-concept study design using StudyVR.**

***Index Terms*—VR, Games, User Studies, Automation**

I. Introduction

Virtual Reality (VR) has emerged as a transformative technology, offering unprecedented opportunities for users to engage in immersive experiences. These technologies have found applications in diverse fields, from education and training to entertainment and social interaction. However, conducting user experience and perceptual studies in VR presents unique challenges, including the need for specialized equipment, complex programming tasks, and the management of large volumes of data. Furthermore, public research funding agencies have developed policies that mandate appropriate data management plans (DMP) governing data use and storage in an effort to mitigate privacy concerns for collected research data. Many academic/research institutions also require a significant amount of additional details in these DMPs to ensure compliance at the research ethics board approval stages. While necessary, this additional administrative burden is placed on researchers which can potentially stifle the rate of progress for fields in which rapid study and fast iteration on ideas is key.

In response to these challenges, we propose StudyVR, a systematic framework designed to streamline the process of conducting and managing user experience and perceptual studies with the following goals:

1) ***Automated Administration***. Automate and modularize the administration of collected data (i.e. ensuring anonymized data, ensuring that data are deleted according to DMP timelines) where possible.
2) ***Study Designer***. Provide a simple study designer interface to help researchers design studies with ethics board-approved methodologies and protocols.
3) ***Centralized Study Management.*** Provide a simple way to run multiple user studies that are synchronized and managed in an online database. This will also enable the research team to monitor data collection progress and improve collaborative efforts between institutions.
4) ***Easy VR Deployment*** We wish to study user experience in VR, thus we believe that the deployment of all aspects of the user study should be performed in VR to maintain presence [1] thus the facilities and tools must be developed with VR deployment in mind and ensure that all user interactions can be performed without removing the VR headset until the study is complete.

In an effort to establish a system satisfying these goals, this paper presents the initial design of our system, ***StudyVR*** and demonstrates a prototype in the context of studying perceived realism of avatars in VR. This serves as an example of the kind of mixed-methods research that can be conducted using our system, highlighting the contribution to user experience and perceptual research in VR.

II. Related Work

A. Virtual Reality and User Experience

Affordable consumer-level Virtual Reality (VR) devices have ushered in a new era of immersive experiences, sparking a surge of interest in user experience and perceptual studies within these environments. A multitude of studies have delved into various facets of this topic, providing a wealth of insights underpinning our research. Putze et al. [2] studied whether VR Questionnaires create breaks in presence in comparison to non-VR questionnaires. They found that while 'breaks-in-presence' were apparent in both in-VR and non-VR questionnaires, correlated physiological responses indicated that the in-VR questionnaires were less invasive and provided more reliable self-reporting. These findings suggest that while in-VR questionnaires should be studied further to determine their impact in study-specific environments, they provide valuable responses that does not impede the flow of the study (users do not need to continually remove and re-adjust their VR headsets after each trial). Li et al. (2021) pioneered a social VR system that presents multiple users' 3D scanned avatar representations into a 3D virtual movie, fostering a shared sense of presence [3]. Their user study revealed that both end-users and VR experts perceived an enhancement in co-presence due to the photorealistic volumetric representations. This underscores the

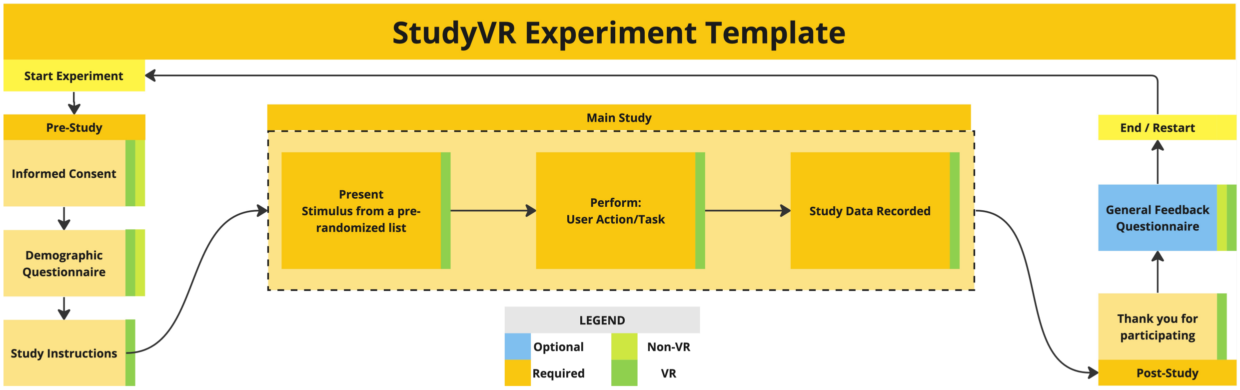

Fig. 1: Our Mixed-Methods Experimental Methodology Framework for StudyVR

pivotal role of realism in VR experiences, a cornerstone of our research. Additionally, Pagano et al. (2020) designed a VR cultural application aimed at bolstering the learning process [4]. Their evaluation sessions shed light on the efficacy of the immersive experience, the usability of the virtual device, and the learnability of the digital storytelling accentuating the use of VR as an educational tool.

B. Game Development in HCI

Game development technologies have become an increasingly crucial part of human-computer interaction (HCI) research. The use of game engines is increasing in research environments for various purposes, such as performing simulations of surgical procedures and psychological experiments [5]. The Unity Experiment Framework (UXF), developed by Brookes et al. (2020), allows researchers to quickly develop an experiment in VR and acquire behavioral data [5]. Furthermore, a recent survey conducted by Radiah et al. (2021), showed that many researchers in HCI demonstrate a notable inclination towards Unity as their preferred game development tool for conducting VR studies [6]. The potential and promise of game development technologies makes them widely used in HCI research. When it comes to creating the StudyVR framework, Unity seems to be the preferred option. The UXF represents a significant achievement to create user studies more efficiently it still requires a significant amount of code to create unique studies creating a barrier for non-technical researchers. Our goal in this paper is to reduce this barrier further by abstracting the ways in which user studies are specified, stored, and synchronized. Our framework (described below) does not require the user to code to create new trials/stimuli while retaining the ability for researchers to program trial mechanics (if desired but not necessary) which can be done leveraging Unity's visual scripting interface.

III. StudyVR

Our system, ***StudyVR***, interfaces with an online database that automates much of the administrative work associated with designing, setting up, deploying, and monitoring user experiments. This allows researchers to focus on research questions and hypotheses, rather than get mired in the depths of technical details of the experimental setup and deployment. We chose to use AirTable as our database of choice as it has a well-documented API which we use to store and manage questionnaires and links. The system is designed around implementing a mixed-methods experimental methodology (shown in Figure 1) making it suitable for a wide variety of experimental contexts, from simple user experience studies to complex perceptual experiments. Furthermore, our system can automatically link all the study data to a customizable third-party survey provider (i.e., Google Form), simplifying data management, and facilitating collaboration between researchers. We elected to use Unity as the base game engine, but intend on expanding our toolset in the future to Unreal.

IV. StudyVR: User Study Methodology

Our research methodology encapsulates a common pre-post intervention study style present in user experience studies. This methodology can be broken down into several distinct stages between the start of the study to its end (as shown in Figure 2). Our approach was to break down the necessary components of each of these stages and identify the common needs that can be abstracted and stored in a structured manner. One of our primary design goals was to keep the participant in VR as much as possible throughout the study; thus, once they are instructed to put on the VR headset, they do not remove it until the end of the study when all trials are completed rather than having to break immersion at the end of each trial to perform a self-reported measure.

Start: The research assistant initiates the study application where they are greeted with a menu that lists the available studies currently in the database. After selecting the particular study desired, all assets for the study are pre-downloaded/cached, and the study is prepared for a participant by the research assistant. The participant is then instructed to place the VR headset on to begin the study.

Pre-Study: Prior to beginning the study, participants are informed of any risks involved. The informed consent is presented to the user prior to donning the headset (or optionally in VR at this stage). Demographic data can be collected using the questionnaire from any of the survey providers, as can the general study instructions for the participant to follow. ***Trial Block:*** The main phase of the study, where the actual trials are conducted. Each trial block includes the following stages:

- ***Pre-Trial:*** Preparation of the Unity scene for the specific trial if needed. *Optional* per-trial instructions presented to

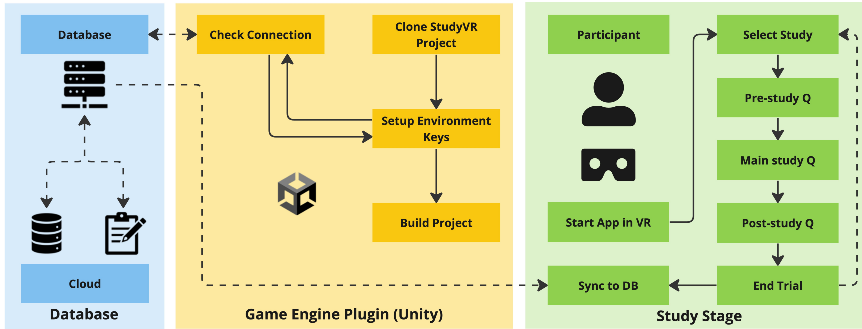

Fig. 2: A flowchart illustrating the process of designing and conducting an experiment using our system.

the user.

- ***Trial:*** Presentation of the stimulus (i.e., show asset/animations) and recording of data (both quantitative and qualitative).
- ***Post-Trial:*** Optionally present post-trial instructions and loop back to the trial block for the next trial if not all trials are complete.

Post-Study: This stage occurs after all Trials are completed and optionally presents the participant with a general post-study feedback questionnaire, thanks the participants for their time, and allows them to select a method for future communication of study findings.

End: The participant is instructed to remove the VR headset.

A. StudyVR:Database

Goal: to provide centralized management of the questionnaire list and assets.

Solution: StudyVR is interfaced with a modularized system that could read structured data from the Internet. StudyVR provides the interface that links to the questionnaire management system and the pre-download system. Meanwhile, we select Airtable[1] and Google Drive as our back-end database due to their ease of use for both interface and API and their competitive price for non-commercial use. The assets to be investigated are uploaded and stored on Google Drive. The questionnaires are created by any of the survey platforms with the appropriate instructions for each survey question. In the database, we only store the sharable links of the assets and the questionnaires to best simplify the process of creating studies. This enables us to completely change/customize a user study by modifying the data stored in the database, enabling non-technical researchers the ability to iterate on their study designs more easily. All participant responses are stored and managed by researchers' preferred survey platforms, ensuring researchers have comfortable and direct access to all the data for further analysis.

B. StudyVR:Designer

The StudyVR framework has been developed to provide researchers with a versatile and modular interface. This interface allows quick identification and modification of a specific stage of the study, facilitating efficient research updates. With the Webview rendering component, researchers can quickly create their customized studies on any of their preferred platforms. In addition, they can switch between different studies incorporating customized scenes to enhance participant immersion. Importantly, researchers can make these modifications without directly altering or rebuilding the framework, as they only need to operate the interface in their online database.

[1] http://www.airtable.com/

C. Process: Creating a user study.

First we setup our Airtable database by cloning the StudyVR template table and creating a token key. The token key is used in Unity to allow StudyVR to authenticate and synchronize with the database. Next, we setup a shared folder in Google Drive to store our assets. All assets and scenes are stored as Unity AssetBundles and have a generated link for sharing that will be stored in the table. Finally, we clone the Unity project template with both the Airtable and Google API keys set up in a configuration wizard

D. StudyVR:Deployment

Goal: a simple deployment strategy to perform a customized user study, automating the collection and management of participant responses/data.

Solution: we build the study project to our VR headset within Unity, currently we have the default set to Meta Quest 2, which was our VR headset of choice for this work. Once built, the project is copied over to the headset, and it is selectable in the app listing in the Meta launcher.

On Start: Download the online-based table to get the list of defined questionnaires.

When Researcher selects a Questionnaire ID: When the Questionnaire ID is defined, download all unity asset bundles from the specified study, adding all the required data (e.g. questionnaire links, assets links) and begin preloading / caching the assets.

When User makes a survey response: StudyVR records all the user responses immediately and synchronously.

When User completes the study: When the user finishes all the studies, the researchers' preferred platform is synchronously finished.

On Restart: When the restart button is selected, the question and the asset loading process is skipped and the system starts again at the first question.

V. Proof-of-Concept: A Case Study using StudyVR

To demonstrate the core idea of StudyVR and determine any limitations/issues, we designed a simplified user study to be

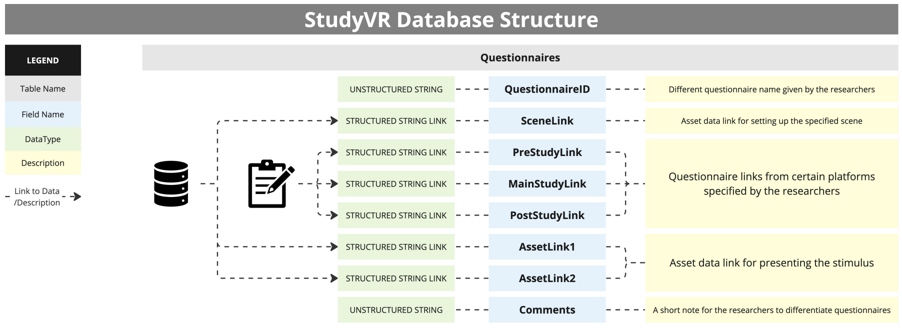

Fig. 3: Database structure

performed to investigate Uncanny Valley in VR, specifically exploring the notion of perceived reality on different types of Assets and Motions. Here, we outline the design of the user study and how StudyVR helped facilitate the design, its deployment, and ultimately data management.

Type	Name	Levels
Independent	AssetType	Volumetric Video
		Animated
	MotionType	Idle
		Speaking
Dependent	Uncanny Valley	Humanness
		Eeriness
		Likeability

TABLE I: Case Study: Variables in Pilot User Study

For our case study, we used the following metrics: Modified Godspeed indices for Humanness, Eeriness, Likeability scale, and Preference Scale with independent variables of **AssetType** and **MotionType**. The levels for AssetType are Volumetric Recording and Animated Character, and for MotionType were Idle and Talking.

AssetType. The assets used in our study were volumetric video recordings and animated characters using character animation software.

MotionType. We chose to present both asset types in two conditions: (1) an 'idle' condition where the character stands still but looks 'alive' by breathing and looking around the room, and (2) a 'speaking' condition where the character recites a particular chosen poem. We selected the poem "Nothing Gold Can Stay" by Robert Frost as it is meaningful to the authors.

A. Asset Creation

The assets were created using a combination of volumetric video recordings (Soar Capture Suite, RGB-D volumetric capture solution) and state-of-the-art character creation/animation techniques (Reallusion CharacterCreator and iClone).

B. Volumetric Video Recordings:

Volumetric Video is a 4D video; each frame is a 3D model captured from a process akin to photogrammetry, multiview stereo, synchronized RGB-D fusion, or the use of AI methods to estimate 3D models of each frame of a video. The goal of volumetric video is to capture an accurate representation of performance from any angle in a form that can be easily played back. We used the Soar Capture suite, which provides a real-time solution for capturing volumetric video. In the first condition (**IDLE**), the actor was instructed to stand still but not motionless, look around and breathe. The second condition (**SPEAKING**), the actor was instructed to recite the chosen poem. For the speaking condition, the audio was recorded and syncrhonized with the volumetric video capture.

1) Mesh Processing & Unity Playback.

The volumetric recordings were exported as textured OBJ sequences. These were brought into Blender3D and with a custom automated script the sequence was retopologized to reduce the polycount, smooth the resulting meshes, and re-projected the textures to create an OBJ sequence that is of higher quality for rendering and performance. To playback the mesh sequence, we implemented a custom script in Unity (MeshSequencePlayer) to efficiently read all object sequences based on a given sample model and store all the meshes and their materials in the Player. Before playback, the MeshSequencePlayer first applies a desired transform offset to move the entire sequence to the appropriate location in the game world. During playback, it swaps the meshes and materials at a speed determined by the user-defined FPS. Additionally, the MeshSequencePlayer can play sound if provided. It reads the duration of the sound and overrides the FPS accordingly to achieve proper alignment and audio-visual synchronization.

C. Animated Assets:

For the animated asset type, we chose to use Reallusion's iClone and CharacterCreator software, as it provides a fully featured character creation pipeline for realistic movement and lip-synching. We originally created a 3D scan of the actor using an iPhone using RealityScan and input this 3D model into the Headshot plugin within Character Creator. This gave us an initial start, but due to the lack of quality of the input scan, we needed to manually modify the morphable model weights considerably to achieve a close enough look to the original actor. Once the character was created, it was exported to iClone where the animations can be added. We chose to add a predefined idle animation to the character and used the built-in tools for audio synchronization. The audio is automatically processed, phonemes are identified, and blend shapes for the mouth are automatically weighted.

1) Mesh Processing & Unity Playback.

iClone has a Unity integration and we created a simple playback component (CharacterAnimationPlayer) to allow us to define playback speed (FPS) as we did in MeshSequencePlayer. When audio is provided, users can set and modify an audio delay. It supports real-time modification, so the user can

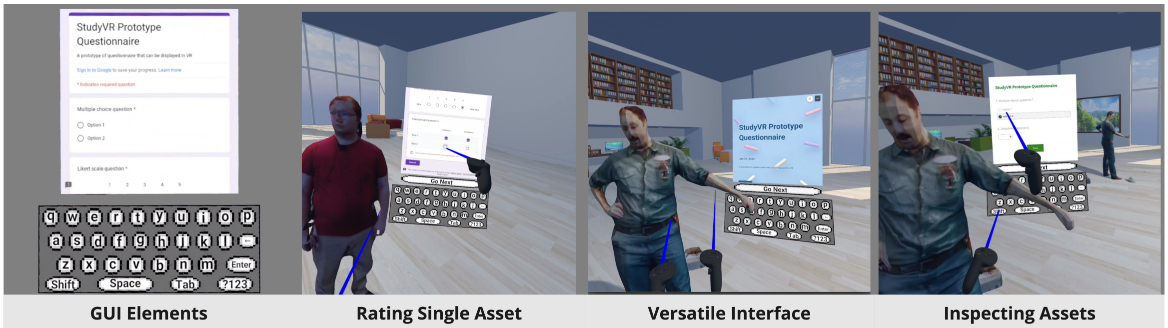

Fig. 4: Screenshots of the user interface showing our example with volumetric recordings and animated characters.

easily locate the audio delay and create a decent audio-visual synchronized animation.

D. Proof-of-Concept:Final Thoughts

While developing this proof-of-concept user study, we found that the system is capable of providing a rich sampling of the possible user-studies with its methodology and abstractions. The use of integrated forms enabled us to create any form of questionnaire for pre/post study and per-trial user feedback. The use of Unity AssetBundles as the primary means to store assets enables a much richer set of possible studies than simply stimulus presentation since an AssetBundle can include entire scenes and prefabs this provides the researcher the ability to go beyond the provided functionality and create highly complex/interactive trials if desired.

VI. Discussion

In the present, there is an increasingly notable trend of growing focus on studies related to realism, that visual realism becomes the most researched area [7]. Guilherme et al. (2021) highlighted that head-mounted displays are by far the preferred platform for realism studies, and in terms of subjective measures, the most used evaluation instrument is questionnaires [7]. Given our focus on the efficacy of conducting realism studies and digital avatars in VR, we expect our framework to contribute to the existing body of knowledge in this area. Our study is unique in that it is a streamlined interface for running user experience (UX) and perceptual studies in VR and AR, and we anticipate that our work will have implications for the design and implementation of future studies in this field.

VII. Conclusions and Future Work

This paper introduced a system for automating the design, deployment, and monitoring of user experience and perceptual studies and enables the collection of data removing barriers for non-technical users. StudyVR leverages the capabilities of online databases (e.g. Airtable) enabling the connection to further automate administrative processes enabling researchers to focus on scientific inquiry and study design. Our proof-of-concept case study design presented serves as a concrete example of the system's efficacy. StudyVR includes automated administration via a cloud-based database, potential of a simplified study design interface, centralized data collection, and rapid VR deployment for the non-technical user. By using Unity's AssetBundles as the foundational asset provider mechanism, researchers have the option of creating trials that contain highly complex interactive scenarios with little effort. Broader implications of this work include enhancing collaborative research and expanding the accessibility of VR studies to interdisciplinary teams. Future research will extend StudyVR's capabilities, such as the completion of a web-based design interface and exploring additional use cases to further validate the system. We believe that StudyVR offers a robust foundation for conducting more efficient and collaborative VR research.

VIII. Acknowledgements

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