XR4ISL: Enabling Psychology Experiments in Extended Reality for Studying the Phenomenon of Implicit Social Learning

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ABSTRACT

We present XR4ISL, an XR system designed to support psychology experiments examining Implicit Social Learning, a fundamental phenomenon that guides human behavior, cognition, and emotion. We discuss XR4ISL with reference to MR4ISL, a previous system designed for Mixed Reality only, and reflect on differences between Mixed and Virtual Reality for psychology experiments.

CCS CONCEPTS

• **Human-centered computing → Mixed / augmented reality**; **Virtual reality**.

KEYWORDS

Extended Reality, Mixed Reality, Virtual Reality, HTC Vive, HoloLens.

ACM Reference Format:
Cristian Pamparău, Radu-Daniel Vatavu, Andrei R. Costea, Răzvan Jurchiş, and Adrian Opre. 2021. XR4ISL: Enabling Psychology Experiments in Extended Reality for Studying the Phenomenon of Implicit Social Learning. In *20th International Conference on Mobile and Ubiquitous Multimedia (MUM 2021), December 5–8, 2021, Leuven, Belgium.* ACM, New York, NY, USA, 3 pages. https://doi.org/10.1145/3490632.3497830

1 INTRODUCTION

Implicit learning, a phenomenon studied in psychology and cognitive science, refers to the acquisition of information outside awareness [8]. Implicit social learning (ISL) is a specific type of implicit learning that denotes the unconscious acquisition of information in real-world settings involving social interactions, which influences humans' behavioral, cognitive, and emotional processes [5]. The relevance of such learning processes, occurring at an unconscious level, has been repeatedly remarked in the psychology literature [2,5] to characterize the social functioning of humans. However, the experimental methods in use to investigate such processes are not representative for real-world settings [4,8] that involve complex social phenomena and corresponding interactions.

A recent, more ecologically valid approach to studying ISL has been proposed in the form of the Mixed Reality (MR) tool for Implicit Social Learning, MR4ISL [7], the first system that employed simulations delivered by a HoloLens head-mounted display (HMD) to increase the external validity of psychological research on this topic. However, Virtual Reality (VR) has a much longer tradition and has been considerably more used in psychology research [1] compared to the just recently commercially available technology of MR. In this context, psychology researchers are faced with a provoking challenge: stick with the limitations of current experimental methods [4,8] or adopt the new technology of MR, with which they are not necessarily familiar and which may introduce confounding variables in experimental designs due to the complexity of the intertwining between the physical and virtual worlds on human perception, attention, and behavior.

To address this aspect, we propose XR4ISL, the Extended Reality tool for Implicit Social Learning to study ISL phenomena in both VR and MR environments. XR4ISL extends MR4ISL [7] by porting implementations of ISL experimental designs to VR platforms, e.g., the same stimuli rendered by HoloLens in MR4ISL are rendered via an HTC Vive HMD in XR4ISL, enabling the psychology researcher to make an informed choice between VR and MR when designing their experiment for ISL.

2 IMPLICIT SOCIAL LEARNING

The human mind often learns regularities of environmental stimuli in an unconscious manner to adapt more efficiently to such stimuli by predicting their behavior. In this process, other resources remain available at the conscious level to deal with novel, unexpected events [4,5,8]. Social stimuli have one of the highest relevance for human functioning and adaptation, and it has been suggested that humans learn many of the regularities of real-world interactions, e.g., the behavior of other people, via such stimuli. Moreover, learning takes place in an unconscious manner [5]. With this mechanism, the emotional state of others can be effectively recognized in order to better understand their behavior.

MUM 2021, December 5–8, 2021, Leuven, Belgium

ACM ISBN 978-1-4503-8643-2/21/05.
https://doi.org/10.1145/3490632.3497830

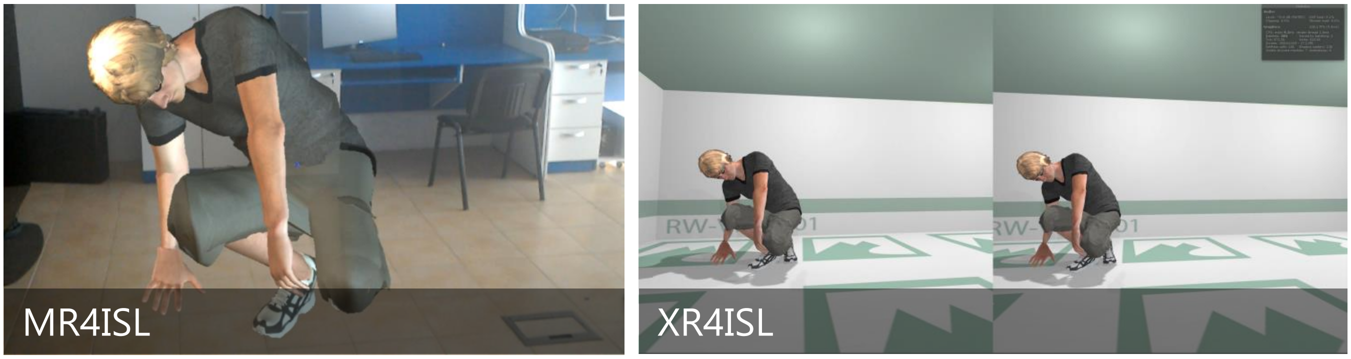

Figure 1: Screenshots from MR4ISL (left) and XR4ISL (right) showing a virtual avatar raising up from the floor.

3 XR4ISL

We present the technical details of XR4ISL by starting with a brief overview of MR4ISL [7]. The mixed reality scene of MR4ISL displays one avatar with predefined animations (i.e., social stimuli for ISL) activated based on user input in the form of speech or gestures. MR4ISL was tested with the first generation HoloLens HMD (32-bit Intel architecture, 64 GB flash and 2 GB RAM memory, and Windows 10) and implemented as a C# Universal Windows Platform (UWP) application with Unity 3D and the Windows SDK; see Pamparău *et al.* [7] for details regarding the software architecture. The virtual avatars are powered by Adobe Mixamo;[1] see Figure 1, left.

We started from the design and features of MR4ISL with the goal to port its functionality to VR, where the user (i.e., the participant of an experiment on ISL) is fully immersed and, thus, confounding factors from the alignment [3] between the physical and the virtual world are reduced. We employed the HTC Vive Cosmos[2] for our implementation that, compared to HoloLens, features better technical characteristics, discussed in the next section. We also employed Unity 3D and Adobe Mixamo to replicate the virtual avatars and their animations in VR; see Figure 1, right. The HTC Vive was connected to a desktop PC (Windows 10, Intel Core i9-9900KF CPU, 64 GB RAM, NVIDIA GeForce RTX 3070). While porting the application to the new platform, we adapted the interaction technique from MR4ISL based on the mid-air *air tap* gesture to controller-based input and corresponding interaction metaphors, e.g., grab a virtual object and teleport in the VR by pressing buttons on the VIVE controllers. Next, we discuss such differences from the perspective of conducting psychological experiments in MR and VR:

(1) *PC-based vs. standalone HMDs.* Whereas MR devices, such as HoloLens[3] or Magic Leap,[4] enable runtime environments, most of the available HMDs designed for VR experiences require a connection to a computer. For instance, the HTC Vive Cosmos that we employed for XR4ISL requires a PC. Of course, this is no criterion to discern between MR and VR HMDs,[5] but this aspect is relevant, among others, for how MR environments differ from VR in terms of user mobility requirements and user experience. For instance, the VR space must be defined a priori as a physically "safe" perimeter in the real world where users can move.

(2) *Sense of presence.* MR involves a combination of the physical and the virtual [3]. The user experience of presence must be carefully designed [6] to prevent divided attention to the physical and virtual as two distinctly identifiable components of the mixed world and, thus, affect learning and behavior in the ISL experiment. In VR, a single world with consistent stimuli is presented to the user, which alleviates potential problems of attention and presence that may intervene because of poorly aligned virtual and physical worlds. On the other hand, discomfort symptoms related to VR environments, such as motion sickness, are counteracted in MR by grounding user presence in the physical world.

(3) *Field of view (FOV).* By porting experiments to VR, XR4ISL enables the use of HMDs with better technical characteristics. For instance, while the FOV of the first generation HoloLens is of just 34 degrees, HTC Vive features 110 degrees. It is of course expected that MR technology will catch up (e.g., HoloLens 2 features an increased diagonal FOV of 52 degrees) but, at this moment, researchers that wish to conduct ISL experiments can use XR4ISL to make an informed choice between MR and VR based on technical aspects.

(4) *Display resolution & refresh rate.* The refresh rate for HoloLens 1 is 60 Hz with a resolution of 1280×720 per eye, whereas HTV Vive Cosmos features 90 Hz and 1080×1200 pixels per eye. The same considerations from above about the evolution of technology apply for such characteristics as well.

(5) *Interaction with virtual content.* For both MR4ISL and XR4ISL, virtual avatars react to the user's speech and gestures. While the speech input experience is similar across the two systems, the gesture types are different, from mid-air gestures for HoloLens to controller-based input for HTC Vive. The interaction metaphors also differ: while gestures in MR target the object on which the user's eye gaze falls, i.e., the gaze and commit interaction technique, the metaphor of teleportation is often employed in VR.

The source code of XR4ISL is available for download from the web page http://www.eed.usv.ro/mintviz/projects/ISELMIR.

[1] https://www.mixamo.com
[2] https://www.vive.com/us/product/vive-cosmos/overview
[3] https://www.microsoft.com/en-us/hololens
[4] https://www.magicleap.com/en-us
[5] See Oculus Rift, for example, https://www.oculus.com/rift

ACKNOWLEDGMENTS

This work was supported by a grant of the Romanian Ministry of Education and Research, CCCDI-UEFISCDI, project number PN-III-P2-2.1-PED-2019-4599 (347PED/2020) within PNCDI III.

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