# Sharing Personalized Mixed Reality Experiences

Jannis Strecker
jannisrene.strecker@unisg.ch
University of St. Gallen
St. Gallen, Switzerland

Simon Mayer
simon.mayer@unisg.ch
University of St. Gallen
St.Gallen, Switzerland

Kenan Bektaş
kenan.bektas@unisg.ch
University of St. Gallen
St.Gallen, Switzerland

## ABSTRACT

Nowadays, people encounter personalized services predominantly on the Web using personal computers or mobile devices. The increasing capabilities and pervasiveness of Mixed Reality (MR) devices, however, prepare the ground for personalization possibilities that are increasingly interwoven with our *physical* reality, extending beyond these traditional devices. Such ubiquitous, personalized MR experiences bring the potential to make our lives and interactions with our environments more convenient, intuitive, and safer. However, these experiences will also be prone to amplify the known beneficial and, notably, harmful implications of personalization. For instance, the loss of shared world objects or the nourishing of "real-world filter bubbles" might have serious social and societal consequences as they could lead to increasingly isolated experienced realities. In this work, we envision different modes for the sharing of personalized MR environments to counteract these potential harms of ubiquitous personalization. We furthermore illustrate the different modes with use cases and list open questions towards this vision.

## KEYWORDS

Mixed Reality, Personalization, Ubiquitous Computing

## 1 INTRODUCTION

We often encounter personalized services in Web applications in the form of personalized search results [31], music recommendations [24], shopping experiences [14], social media feeds [17], or online advertisements [11]. On the Web (as well as off the Web), these personalized services are predominantly consumed through personal computers and mobile devices. We propose that the evolving capabilities of Mixed Reality (MR) technologies, however, enable personalization possibilities that are increasingly intertwined with our *physical* reality by providing users with simulated or augmented versions of their physical experiences. These technologies thus bring us closer to Weiser's vision of a seamless integration of networked (micro-)computers and displays into our physical environments [36]. Desktop, hand-held, or wearable MR devices can sense, compute, and display information about the users and the objects in their surroundings [18, 22]. While existing conceptions for personalized MR (P-MR) are predominantly vision-based [9, 21], in ubiquitous computing environments, MR devices can provide users with different forms of personalized experiences, such as through vestibular [30] or electromuscular stimulation [6] as well as auditory [37], tactile [25, 38], tastable [27], or olfactory [19] mediation of physical reality. However, potential benefits and harms of personalization in MR environments are not yet sufficiently explored. On the one hand, P-MR may provide a comfortable, seamless experience which makes our lives safer, more fun, and more accessible. Users could, for instance, have their environment visually personalized by entertainment companies to match their favorite movie, have less healthier groceries selectively diminished in MR in a supermarket based on the user's current diet, work safer while they interact with robots in a (smart) factory, or be provided with personalized navigation cues in MR to overcome accessibility-related restrictions. To perceive their P-MR, users may wear different MR head-mounted displays (e.g., AR or VR headsets), interact with devices (e.g., industrial robots, smart buildings, or public displays), and also switch among these devices if needed. We expect that P-MR will amplify known benefits of personalization such as reducing information overload [4, 7, 22], ensuring equal access to users with diverse abilities and interaction requirements [20, 22], providing better preference matching and services to users [34], or increasing revenue for platforms offering personalized services [8, 29].

On the other hand, however, MR technologies are also prone to amplify the known harms of personalization, such as contributing to the creation of echo chambers and filter bubbles [16, 23, 32], the undermining of a user's autonomy [10], or a perceived or actual loss of control for users [33]. Today's communication media (e.g., social media) allow people to reach (or be exposed to) vast amounts of information while it becomes even harder for them to distinguish the meaningful from the insignificant or misleading [22]. Furthermore, a synthesized version of reality (e.g., simulations or holograms) may mask the truth about that reality or what the receivers of that information perceive as the truth or real [3]. If users are only provided with their own personalized version of reality – *literally* – this may lead to serious consequences, such as growing societal alienation through a loss of shared world objects and experiences [7], or increased polarization through a decreased exposure to dissenting media. In a dystopian vision, people might intentionally confine their perception within literal filter bubbles (e.g., using MR headsets), selectively suppressing information from their context that contradicts their pre-existing beliefs while emphasizing the ones that are in line with them. P-MR might hence reinforce increasingly isolated perceptions of reality because it alters the experience of physical reality, and with it the implicitly shared common ground for perceived realities across society.

To counteract this potential development, we propose the sharing of P-MR experiences as a method that allows users to share


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their perceived P-MR with other users. Similar to existing computer-supported systems that provide multiple users with a shared workspace for their cooperative [12] or collaborative activities [5], the shared P-MR experience might happen synchronously or asynchronously for the involved users. P-MR hence does not in principle require users to be co-located in the same environment.

## 2 SHARING PERSONALIZED MR

We expect that the sharing of MR experiences will be more relevant in activities where individuals need to deliberately disclose their P-MR with others to allow for an empathetic and collaborative experience. Users of P-MR may need to *explicitly* share what they see (e.g., in their MR headsets) because otherwise individuals in the user's surroundings – even someone who might be shoulder-surfing – would remain oblivious of their personalized content. In ubiquitous computing environments where personalization is applied directly to physical devices, in contrast, users' personalized interactions are typically *implicitly* shared with others, given that these devices are not invisibly embedded in the environment.

The sharing of P-MR can happen essentially at two stages. First, a P-MR system may receive data from multiple users and use this data as *input* to personalize and recommend content for this group of users (e.g., in [2]), which can be delivered through MR devices. Second, the *output* of such a system can be personalized based on a single individual, and then, in a second step, shared among multiple users. The shared content may be any type of content that the involved users' MR devices are able to reproduce, e.g., visual holograms and spatial audio for MR headsets, or tactile impulses for haptic MR devices. While the shared input for personalized systems increasingly receives attention [1, 2, 13, 35], the sharing of personalized output did not receive attention so far. Thus, we focus on the second stage, while our vision can also be applied to the first stage.

### 2.1 Sharing Modes & Use Cases

We propose five different modes of sharing P-MR: *Union*, *Partial Union*, *Uni-directional Replacement*, *Uni-directional Exchange*, and *Swap*. In the following, we describe each mode through use cases and how P-MR users may smoothly transition among these modes.

Users may share their full P-MR with others as a *Union* of all involved users' P-MR. For example, in a long-distance relationship, a couple may want to experience their own P-MR as well as their partner's, which may enhance their sense of co-presence and connectedness. To avoid a sensory overload through the full *Union* of multiple P-MRs, a *Partial Union* of P-MRs might be more suitable in some cases, where only parts of each respective P-MR are shared with the other(s), e.g., if colleagues work together in a remote setting and may want to share work-related parts of their respective P-MR among themselves to facilitate their collaboration, while not sharing other private parts (cf. [26]). Furthermore, expert users in a training scenario, for instance, may share their P-MR to demonstrate to novices how exactly they interact with a robot. In that case, the sharing would be a *Uni-directional Replacement*, where the novice perceives the expert's P-MR instead of their own, and uses it to learn from the expert's interactions. As the novice grows in learning, they might want to perceive only parts of the expert's P-MR in addition to their own P-MR, resulting in a *Uni-directional Exchange* from the expert's P-MR to the novice's P-MR. A user could, in a similar vein, perceive their full reality (*Uni-directional Replacement*), or parts thereof (*Uni-directional Exchange*), through their P-MR as their colleague with visual impairments would. We speculate that this might support mutual understanding and raise the user's awareness for accessibility issues their colleague might encounter. Multiple users may furthermore *Swap* their P-MR completely and allow each other to see the world "through the eyes of the other" and thus bring them closer together, e.g., in P-MR experiences such as in exhibits, or in workshops on controversial societal topics. The (temporary) swapping of P-MR could also be beneficial in situations such as team-building (e.g., in companies or classrooms) for groups of people with heterogeneous backgrounds.

## 3 CONCLUSION & OPEN QUESTIONS

In this paper, we introduced the sharing of personalized MR (P-MR) experiences and discussed selected characteristics and implications of this method. Additionally, we proposed five different modes of sharing P-MR and illustrated those with use cases. We hypothesize that these sharing modes might enable users to enjoy the benefits of P-MR while reducing potential (societal) harms of P-MR such as isolated realities through the loss of shared world objects and experiences. Thus, we propose that the sharing of P-MR might foster mutual understanding and connectedness by providing a means for (literally) perceiving different worldviews.

The sharing of P-MR raises questions on two particular topics, besides issues that arise for the ubiquitous usage of MR (cf. [15, 22, 28]). First, the interoperability of such methods needs to be investigated. This includes device-related (e.g., How can personalized content be shared across different device types?) and content-related issues (e.g., How to deal with issues where a shared content conflicts (spatially/sonically/...) with another?). Second, ways for controlling the granularity of P-MR sharing on different levels should be examined. Here, issues arise concerning users' privacy and agency (e.g., How can users be enabled to intuitively decide what content to share with whom, and when?), security and regulations (e.g., What are users allowed to share in certain contexts?), transparency (e.g., How do users know which content is from a shared P-MR and which is from their own P-MR?), and social acceptance (e.g., In which contexts do users feel comfortable sharing their P-MR?).

Addressing these issues ensures that P-MR sharing is a safe, enjoyable and beneficial experience for individual users but also for society at large. Especially, in light of the strive of democratic societies towards cohesion (e.g., through public schools or public broadcasting, where different identities and ideologies are present in the same space), our proposed sharing methods might provide a means to apply a similar approach to people's digital realities, and might even be a way to bring divided societies closer together.

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