Initiating and Sustaining Collaboration in Mixed Reality: A Cross-Traffic Interaction Perspective

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Fig. 1. Two passengers stuck in traffic engage in a shared karaoke experience, transforming a frustrating delay into a moment of spontaneous collaboration. This illustrates how position dependency and time synchronicity can enable social connection and collaborative experiences in dynamic traffic environments. [AI-generated image] OpenAI DALL·E. Retrieved from https://openai.com/dall-e.

Mixed Reality (MR) introduces new possibilities for collaboration in dynamic environments, such as traffic, where interactions are often transient and context-dependent. However, initiating and sustaining collaboration between road users remains challenging due to evolving interaction relationships, changing positional dependencies, and varying time synchronicity. This position paper builds upon the design space proposed by Stampf et al. to investigate how these factors influence MR-based collaboration. Using Cross-Traffic Interaction as an example, we propose a study utilizing a multi-agent VR cross-traffic karaoke prototype to explore whether MR facilitates social connectedness among different entity relationships (i.e., close or strangers), position dependencies (i.e., relative position dependency or no position dependency) and collaboration synchronicity (i.e., synchronous or asynchronous). We aim to examine how these factors impact social experience and player experience. The findings of this study aim to provide insights into

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how MR can enhance spontaneous collaboration, inform interaction design strategies, and contribute to the development of scalable MR systems for dynamic environments.

CCS Concepts: • **Human-centered computing → HCI design and evaluation methods**; **Empirical studies in HCI**.

Additional Key Words and Phrases: collaboration, mixed reality, in-vehicle gaming, cross-traffic interaction

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1 Introduction

Mixed Reality (MR) presents new opportunities for enabling distributed collaboration, particularly in dynamic environments like traffic. However, initiating and sustaining collaboration in MR poses significant challenges due to the fluidity of interactions and the need for seamless engagement among diverse interaction entities. To address these challenges, we build upon our Cross-Traffic Interaction (CTI) design space [9], which outlines critical dimensions of interaction relationships, including entity relationships, position dependency, and time synchronicity. Understanding how these factors influence collaboration in traffic environments is key to designing MR applications. We explore this through a gamified approach that engages participants in dynamic situations within a cross-traffic karaoke application. This exemplary scenario illustrates the complexities of initiating and sustaining collaboration in dynamic environments using MR.

2 Interaction Relationships in MR Collaboration

The initiation and continuity of collaborative interaction in MR require an understanding of the interaction relationships between participants. We define interaction relationships based on the following dimensions [9]:
Interaction Partner Relationship. Whether participants are strangers, acquaintances, or close contacts affects how interaction needs to be designed [7, 8]. For instance, spontaneous MR interactions in public traffic spaces may require different initiation strategies than interactions within a pre-established social group.
Time Synchronicity. Ellis et al. [3] distinguished interactions based on whether they occur in real-time (*synchronous*) or with a delay (*asynchronous*). Synchronous interactions require immediate exchange, which can facilitate collaboration but also impose constraints on availability. In contrast, asynchronous communication allows flexibility but may negatively impact social experience.
Position Dependency. Spatial relationships in interactions can be classified based on the necessity of shared location. *No position dependency* refers to interaction occurring independently of shared spatial context. For instance, collaboration can be enabled between a remote participant at home and someone currently in traffic, allowing engagement that is not bound to physical dependencies but mediated through MR systems. Lakier et al. [6] examined *absolute position dependency*, where participants must be co-located, such as occupants of nearby vehicles interacting in real-time. Stampf et al. [9] additionally proposed *relative position dependency*, where individuals share contextual positional attributes—such as being in the same traffic congestion or moving toward a common destination—without occupying the exact same space. Unlike absolute dependency, this allows collaboration across distributed yet contextually linked environments.

3 The Challenge of Initiating and Sustaining MR Collaborations in Dynamic Environments Like Traffic

Initiating MR collaboration in cross-traffic scenarios requires overcoming initial engagement barriers and ensuring maintainance. The dynamic nature of traffic environments presents several challenges:

Initiating MR Collaboration. Establishing an initial connection in MR depends on making potential collaborators aware of each other. In dynamic environments like traffic, *relative position dependency* can be leveraged to highlight shared situational contexts. For instance, if two users have a common point of interest in their field of view—such as an iconic landmark or a traffic signal—this can serve as an implicit invitation to engage. Designing intuitive ways to visualize and communicate such shared contexts is crucial. Another challenge is privacy in MR [7]. Users must be able to control what information they share about their presence and intentions. Dynamic opt-in mechanisms could enable users to selectively disclose their availability for interaction while sustaining control over their personal data.

Sustaining MR Collaboration. Sustaining collaboration in dynamic settings requires adaptability. Visibility conditions may change, breaking visual contact between participants. A key question is whether and how users should be informed about a collaborator's movement when direct visibility is lost. Asynchronous mechanisms can help sustain engagement beyond real-time interactions. For example, a system could provide delayed updates that foster social continuity—such as sharing traces of past interactions (e.g., "A friend passed by this location yesterday and recorded a song"). Position dependency could be used creatively to establish a sense of connection across time, enabling users to engage with past interactions asynchronously while still feeling socially present in the collaboration.

4 Investigating Collaboration through Cross-Traffic Karaoke

To explore the dynamics of MR collaboration, we developed a multi-agent VR CTI karaoke prototype designed to simulate real-time and asynchronous interactions between multiple traffic participants. This prototype enables us to investigate how interaction relationships, position dependency, and time synchronicity impact social connectedness, user experience, and immersion in collaborative MR settings. The concept of cross-car multiplayer games has already been identified as a promising approach, allowing vehicle occupants to engage in interactive gameplay, thereby enhancing social interactions and entertainment experiences during travel [6, 9].

In our study, we aim to investigate how we can initiate and sustain collaboration in MR within dynamic, fast-changing environments like cross-traffic scenarios. Additionally, we explore how different spatial and social conditions influence MR interactions, e.g., whether MR fosters a sense of social connection between individuals who are otherwise strangers but become linked through *relative position dependency*. For instance, two users stuck in traffic congestion might engage in a shared karaoke experience, transforming a frustrating delay into a moment of spontaneous connection. We aim to answer the following research questions:

How do interaction partner relationships, position dependency, and time synchronicity affect...

RQ1 *...the initiation and sustainability of collaboration in MR-based cross-traffic scenarios?*

RQ2 *...social connectedness and user experience in dynamic traffic environments?*

To explore these questions, we design interaction strategies that address the challenges of initiating and sustaining collaboration in such settings. We then conduct a study using a three-factor design, analyzing the effects of *entity relationship* (strangers, acquaintances, or close contacts), *position dependency* (none—one participant is remote, relative—both are in the congestion, or absolute—both follow each other in traffic and have direct visual contact), and *time dependency* (synchronous—real-time interaction, or asynchronous—delayed interaction).

We assess *Social Experience* using the corresponding subscale of the Gameful Experience Questionnaire (GAMEFULQUEST) [5] and *Player Experience* with the Player Experience Inventory (PXI) [1]. Additionally, we measure *System Usability* and *Workload* using the System Usability Scale (SUS) [2] and NASA-TLX [4]. To gain deeper insights, we further conduct semi-structured interviews to gather qualitative feedback.

By integrating both quantitative and qualitative methods, this exploratory study aims to uncover how MR interactions should be designed to enable collaboration in dynamic traffic scenarios. The findings of our study aim to have general implications for the design of MR applications in dynamic settings, and can be extended beyond social interactions in traffic. Further areas of application could, for instance, span across urban planning.

5 Conclusion

By investigating collaboration in MR through the framework of our design space, we aim to uncover strategies for effectively initiating and sustaining interaction relationships in dynamic environments. Cross-traffic karaoke serves as an engaging case study to examine how entity relationships, position dependency, and time synchronicity impact MR collaboration. We aim to gather valuable insights from our workshop discussions on cross-traffic collaboration, refining our approach while broadening the conversation to encompass potential future road scenarios.

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