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EmojiChat: Toward Designing Emoji-Driven Social Interaction in VR Museums

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ABSTRACT

Museums have traditionally been places of learning, evolving into spaces that also facilitate socializing. This shift is particularly evident in virtual reality (VR) museums, which have become popular venues for activities like friend gatherings. However, education has long established the social norm that museums need to "maintaining silence." Even in virtual environments, this can influence visitor behavior. This perception often prevents people from using verbal communication, leading them to prefer quieter forms of interaction. In museums, including the VR museums that now largely replicate the layout of physical museums, this preference may be reinforced by specific features, such as spaciousness, quietness, and block-based layouts, which may create visual obstructions, restricting interaction modes dependent on shared view, such as gesture interaction. These limitations necessitate the introduction of an additional interaction mode. Emojis, with their capacity for rapid message exchange and adjustable positioning, emerge as a suitable interaction mode in this context. Thus, we introduce *EmojiChat*, an innovative VR museum experience designed to respect the social norms of traditionally keeping quiet while promoting natural interaction. We first design and iterate a customized emoji set for the museum context through semi-structured interviews, participatory design, and an online survey. Then, this emoji set is integrated into a VR museum to facilitate interaction between visitors. Finally, we conduct a comparative study to evaluate the performance of *EmojiChat*. Our results show that the integration of emojis can improve communication enjoyment and efficiency. Additionally, we identify usage patterns for interaction modes and the advantages offered by emojis. We also identify several challenges that point toward future directions for enhancing emoji integration and facilitating social interaction.

KEYWORDS
Virtual reality; emoji; non-verbal communication; multi-user interaction; VR museum; social VR

1. Introduction

Virtual reality (VR) has revolutionized museum experiences by providing innovative ways to explore inaccessible collections (Yan et al., 2021) and transcending the limitations of time and space. Currently, numerous applications enable worldwide virtual museum tours, such as Petite Galerie,[1] Kimbell Art Museum,[2] and Palace Museum.[3] These applications facilitate online interaction with collections and learning experiences. Traditionally, museums have been recognized as locations for exhibiting collections and transmitting knowledge (Li, 2022), but the advent of VR technology has transformed them into dynamic social hubs that support visitor social interaction (Yi & Kim, 2021; Zhou, 2019). However, this change in perception has not been adequately mirrored in current research. Existing work focused mainly on the reconstruction of the museum space (Cristobal et al., 2020; Schofield et al., 2018) and interaction with the collections (Cao et al., 2023; Hayes & Yoo, 2018; Latos et al., 2018), often neglecting the realm of social interactions among visitors.

This research gap leads us to a key research point for VR museum experiences—the need to facilitate effective social interactions. In physical museums, specific characteristics, such as spaciousness, requirements for quietness, and block-based layouts, shape the social norms and interaction patterns (DeVito & DeVito, 2007). For example, physical barriers and spatial distances (Wineman & Peponis, 2010) can create separations that obstruct visitors' views (Psarra, 2005) and impede non-verbal cues reliant on a shared visual context, including gaze (Choi et al., 2022), gestures (Arora et al., 2019; Kurzweg et al., 2021; Maloney et al., 2020), and facial expressions (Zheng et al., 2023). Moreover, the social norm of *keeping quiet* imposes constraints on verbal communication (Li et al., 2019). Interestingly, these physical constraints and social norms find parallels in the VR environment (McVeigh-Schultz et al., 2019), influencing user behaviors and interactions in VR museums. Such default social norms and spatial constraints present unique challenges for the design of interactive systems in VR museums, requiring the introduction of more contextually appropriate interaction modes in VR museums to accommodate the interactive needs of visitors.

Emojis have the potential as an additional interaction modality to enhance social interaction in VR museums. They have the ability to swiftly convey information without

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disrupting immersion, thereby facilitating seamless information exchange in VR museums (Zheng et al., 2023). Additionally, emojis can also create desired atmospheres and increase pleasant interactions (Kim, Gong, Han, et al., 2020), thus strengthening social engagement within VR museums. Furthermore, unlike gaze, gestures, and facial expressions that are tied to avatar movements and expressions, emojis can be displayed independently. This capability may help overcome visibility limitations that are often encountered in VR environments. Importantly, the interpretation of emojis was found to be context-dependent. For example, there are varying interpretations of emojis in different contexts, such as dining (Gomi et al., 2012) and online surveys (Alismail & Zhang, 2020). Such a context-specific interaction modality can effectively support context-related information exchange. Except for these benefits that enhance social interaction in VR museums, emojis are a widely popular interaction modality, with a staggering 92% of the global online population using them (Unicode, 2022). These features demonstrate that emojis hold promise as an integrated interaction modality in VR museums that can allow quick message exchange and enhance enjoyment. However, integrating a set of emojis into a VR social platform necessitates several design considerations. Firstly, there are currently over 3600 emojis representing various themes.[4] Direct integration of all emojis into VR environments may result in excessive time spent searching for the desired emoji, leading to physical fatigue and negatively impacting the user experience (Li et al., 2023). Additionally, accurately pointing to and selecting a target emoji on a panel that displays all emojis by ray-casting poses challenges (Wei et al., 2023). It has been observed that different emojis are selected across various social platforms. For example, compared to the emoji set on Facebook,[5] Instagram[6] does not display the "flag" emojis and WeChat[7] features fewer emojis. Since there is no standardized set of emojis across all platforms, employing a human-centered approach to design a set of emojis closely aligned with usage scenarios can facilitate desired emoji selection, thus enhancing interaction efficiency.

Given emojis' promising benefits and the aforementioned design considerations, we developed *EmojiChat*, a VR museum platform to explore the impacts of integrating emojis on social interaction. *EmojiChat* facilitates verbal, gestural, and emoji-driven communication through embodied interaction. The development of *EmojiChat* involves two key stages: (1) creating a customized emoji set and (2) integrating it into a VR museum scene. We conducted a participatory design to customize an emoji set to help convey context-specific messages in VR museums. Initially, we conducted semi-structured interviews with ten participants to gain insights into their communication preferences during museum visits (Section 3.2). Subsequently, the ten interview participants were invited to design emojis that could aid in conveying information related to the communication themes mentioned above (Section 3.3). We gathered the sketches and cross-referenced them with the standard emoji list[8] to select the appropriate emojis, thus creating a preliminary emoji set. To iterate the design set, we conducted an online survey to assess recognition percentages and subsequently finalized the emoji set. Regarding the museum scene, we built a VR museum featuring paintings and artifact models as collections, simulating the layout of physical museums with diverse architectural elements.

To assess the impact of *EmojiChat* on interaction, we selected four message-conveying tasks to simulate interaction scenarios in VR museums within a confined time. Participants were asked to perform these tasks under two conditions: using *EmojiChat* and the same VR museum without emojis. The findings showed that *EmojiChat* effectively cut down the time and effort needed to send messages and improved both the *pragmatic* (relating to the qualities of interaction related to the tasks or goals that users are aiming to achieve when using the product) and *hedonic* (relating to aspects of pleasure or enjoyment during the use of the product) of VR museums. Furthermore, elements, such as distance between participants, depth of message content, and preservation of immersive visit experiences had an impact on the choice of interaction modalities. The participants preferred to use emojis to convey simple and straightforward messages about physical separation. Two distinct usage patterns for emojis were identified: conveying concise messages quickly in a single exchange and engaging in multiturn messaging for recreational purposes. However, despite these advantages, we also identified several challenges associated with the use of emojis as an interaction modality, including signal limitations, restricted topic coverage, and contextual constraints. We proposed potential solutions to address these challenges (e.g., integrating emojis with other interaction modalities). In summary, the article makes the following contributions:

- We designed *EmojiChat*, a VR museum encompassing a customized emoji set and other interaction modalities.
- Empirical evidence shows the effect of emojis on improving message exchange efficiency, reducing workload, and enhancing the enjoyment of VR museums.
- Implications of improving the design of multiple communication modes in VR museums to enhance social interaction.

2. Related work

2.1. Virtual museums

As a place to exhibit cultural heritage and transfer information and knowledge (Li, 2022), the museum has been explored by researchers from different perspectives. Pekarik et al. demonstrated four main categories of experience in physical museums: object experiences, cognitive experiences, introspective experiences, and social experiences (Pekarik et al., 1999). Emerging extended reality (XR) technologies, including virtual reality (VR) and augmented reality (AR), present exciting opportunities to museums (Scott et al., 2018) by making collections digitally accessible. Prior works focus on the interaction among humans and objects, as well as humans and environments, enhancing the presence of virtual environments and virtual collections with meta-layer information. For example, odor, haptic information, and virtual tour guidance are integrated to enhance interaction among humans, objects, and virtual museums (Fallows et al., 2022; Wang et al., 2024; Zhang et al., 2023). Combining real places and virtual objects, AR is used to promote interaction with virtual collections (Pollalis et al., 2017), attach meta information to collections (Girbacia et al., 2013; Hammady et al., 2020; Lu et al., 2014), and enhance navigation in real places (Breuss-Schneeweis, 2016; Hammady et al., 2020; Latos et al., 2018). When encountering physical constraints without accessing the real place or real places are destroyed, VR enables users to visit wherever they are. For example, Pietroni et al. reconstructed a tomb and evaluated the user experience by gathering public feedback (Pietroni et al., 2013). Barsanti et al. built a 3D virtual scenario to make exhibits more accessible and interactive, augmenting the public's experience and comprehension (Barsanti et al., 2015).

Multi-user interaction has drawn the attention of researchers recently. Previous works have investigated how users interact with each other in scientific (Olaosebikan et al., 2022), artistic (Fender & Holz, 2022; He et al., 2020), informational and educational (Mei et al., 2021) domains. These works presented an understanding of interactions between users from various perspectives, including communication modes, the layout of space, and synchronization. Galani et al. demonstrated that the main elements of multi-user co-visiting are visual and verbal cues and shared content in virtual museums (Galani et al., 2003), but it lacks an understanding of other potential interaction modalities in this context. In this work, we investigated the interaction modalities between multi-users in virtual reality (VR) museums from the perspective of social experiences, including sharing experiences and expressing opinions or feelings with partners.

2.2. Interaction modalities among users

The interaction modalities between multi-users include both verbal and non-verbal interaction, such as voice, gestures, proxemics, gaze, and facial expression (Maloney et al., 2020). Researchers have extensively explored non-verbal communication in traditional 2D interfaces or 3D virtual worlds. For example, Wuertz et al. (2018) leveraged visual and audio modalities to design a series of awareness cues, conveying information about users' identity, status, location, and important events. Additionally, gaze (Maurer et al., 2017; Newn et al., 2016) and gesture (Maurer et al., 2017; Wuertz et al., 2017) interaction is often employed in multiplayer games. Similarly, Ping design is another prevalent modality used in multiplayer games to promote the efficiency of non-verbal communication between teammates, regardless of their distances (Leavitt et al., 2016; Wuertz et al., 2017; Zheng et al., 2023). It refers to a combination of animated icons and audio feedback indicating a point of interest. Maloney et al. summarized non-verbal interaction into two categories: avatar-mediated interaction and symbols and emoticons (Maloney et al., 2020).

Compared with the traditional 2D or 3D virtual world on the PC screen, research on non-verbal interaction in VR environments is still in its infancy. Previous works have explored the practice of non-verbal interaction in popular commercial VR platforms generally. The common methods include gestures (Maloney et al., 2020; Porwol & Ojo, 2018; Tanenbaum et al., 2020), facial expression (Porwol & Ojo, 2018; Tanenbaum et al., 2020), visual aid (Maloney et al., 2020; Porwol & Ojo, 2018), and proxemics (Maloney et al., 2020; Tanenbaum et al., 2020). The current research primarily considers one specific form of non-verbal interaction but neglects its potential combinations. For example, Kurzweg et al. chose eleven postures to express attendees' status in a VR conference. They provided evidence that these postures could provide a hint showing the willingness to communicate (Kurzweg et al., 2021). Similarly, Ide et al. selected nine gestures to express users' intentions in the VR brainstorming process. The findings suggested that avatars with symbolic gestures could improve the social presence (Ide et al., 2020). Fabri et al. chose six universal emotions and conveyed them by avatar faces, verifying virtual face representations can give rise to recognition rates compared with corresponding real photographs (Fabri et al., 2002). These types of non-verbal interaction attempt to mimic face-to-face communication, such as meeting and brainstorming, in the real world, enhancing the presence and communication efficiency in the virtual environment. However, it is still unclear how to facilitate communication in cases where users are separated into non-face-to-face conditions. The definition of non-face-to-face follows (Henrysson et al., 2005): meaning that users could not see each other due to block or distance.

In VR museums, a dispersed layout leads to the separation of partners caused by personalized preferences or inconsistent visiting paces. Although previous works enable better face-to-face communication by leveraging postures, gestures, and facial expressions, they rarely consider the non-face-to-face conditions in unique contexts. Hence, it is imperative to supplement the interaction modalities that support non-face-to-face interaction in VR museums.

2.3. Interaction with emojis

Emojis are becoming a ubiquitous, cross-cultural, and increasingly popular mode of non-verbal interaction between individuals, especially on online social platforms. Due to its pictorial nature, emoji enables users to convey emotions, feelings, and reactions that cannot be easily articulated by text (Kerslake & Wegerif, 2017; Lu et al., 2016). Emojis consist of thousands of icons. To better manage and understand them, Wang et al. did a complete survey of categorizations of emojis. They came up with their own division, concrete icon, abstract icon, combination icon, and alphabetic icon (Wang et al., 2007). Kimura et al. presented that a cultural gap in user perception exists. As such, the current emoji standard and participatory design could alleviate cultural diversity and enhance comprehension to some extent (Kimura-Thollander & Kumar, 2019). To evaluate the design of emojis, seven dimensions can be used as evaluation standards: aesthetic appeal, familiarity, visual complexity, concreteness, valence, arousal, and meaningfulness (Rodrigues et al., 2018).

The usage of emojis on social media platforms is widely explored. Previous works present the rapid proliferation of emojis on both Chinese (Zhou et al., 2017) and Western online social platforms (Schofield et al., 2018), exploring the current practices of emoji usage. Specifically, Khandekar et al. demonstrated that conveying information by emojis solely without any text was efficient and clear, with around half of the participants indicating that it is faster to read and write in emojis than in text (Khandekar et al., 2019). Moreover, emojis and icons can be used in other specific areas to enhance interaction. For example, automatically generated symbolic icons visualizing various meal attributes were designed to enhance communication about recipes and eating habits (Gomi et al., 2012).

To sum up, emoji is an efficient and popular way of communication that can break through the constraint of distance. Previous works focus on exploring emoji usage in mobile or PC online social platforms, lacking research about emoji usage in virtual reality platforms. Maloney et al. demonstrated that one type of non-verbal communication they observed naturally occurring in social VR was the use of applause to indicate approval. They also found that users linked emojis over their avatars' heads to signal that they were on board with the direction of conversation (Maloney et al., 2020). Thus, emojis can be used as a visually apparent form of interaction between multi-users in a spacious and separated environment, conveying information concretely and efficiently. However, none of these studies leverages the advantages of emojis to enhance social interaction in VR museums. To the best of our knowledge, our work is the first to deeply explore the potential of integrating emoji interaction in VR museums.

3. *EmojiChat* design and implementation

To investigate the impacts of emojis on users' social interaction in VR museums, our study began with participants experiencing a commercial virtual museum application in VR. This preliminary experience was designed to familiarize participants with the VR museum environment and existing patterns of interaction, and to better conduct interviews and participatory design. Following this, we designed *EmojiChat*, comprising an emoji interface integrated into a VR museum scene. The system was designed through an iterative design process (Figure 1), the process included a semi-structured interview ($N = 10$) with participants who had experienced the VR museum, a participatory design ($N = 10$), and an online survey ($N = 54$). All participating experiments of this work passed the ethical review of the Hong Kong Polytechnic University with review approval number HSEARS20240412008.

3.1. Experience the VR museum

The 10 participants recruited for the study conducted an experiential session in a VR museum before conducting semi-structured interviews. We selected an art gallery application[9] available on the *Spatial*[10] platform (see Figure 2). This is a well-known VR multiplayer application platform that we consider to be representative of commercial VR applications at the current stage. Participants used the Oculus Quest 2 headset for the VR gallery application experience, with a researcher available throughout to guide them in its use. Participants were asked to navigate and interact in this virtual art gallery for 15 min. We anticipated that the insights participants gleaned from this immersive experience might enable them to provide more informed and contextualized feedback during the semi-structured interview and participatory design phases of our study.

3.2. Semi-structured interview

To further explore the user communication themes and challenges in museums, we conducted semi-structured interviews to understand users' current practices. Following discussions between two researchers, we structured our interviews into sections to ensure comprehensive coverage of the topics we intended to investigate. We first asked for basic information, including age, frequency of visiting museums, and information about partners, including the number of their partners and visit patterns (whether visiting separately or together). We then asked about the specific context and content of interaction in museums. After that, we asked them about the challenges they encountered. During the

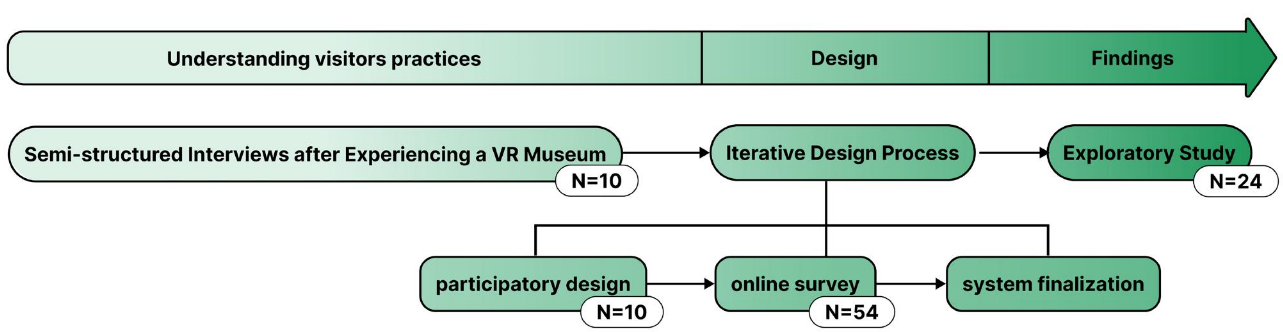

Figure 1. The flowchart outlines the design and studies for *EmojiChat*, from left to right, including the semi-structured interviews on communication themes and challenges, participatory design, and online survey for customizing the emoji set, system finalization, and the exploratory studies.

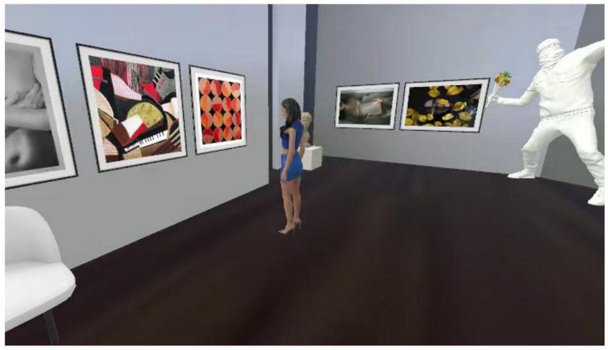

Figure 2. Screenshot of the art gallery application used in VR museum experience.

interviews, we posed follow-up questions to elicit additional information on communication themes and encountered challenges based on the participants' responses.

3.2.1. Participants and procedure

Ten participants ($F = 5, M = 5$) were recruited from a local university, and they were identified by codes P1 to P10. The age ($M = 24.5, SD = 1.72$) of the participants ranged from 22 to 27. Every participant reported daily use of emojis in online chat applications, such as WeChat[11] or Skype.[12] Participants' museum visit frequencies varied widely, ranging from twice a month to twice a year. Three participants primarily visited museums with friends or family, occasionally visiting alone. The remaining seven participants only visited museums with friends. The number of partners varied from one to more than ten. Responses indicated that beyond its traditional role as an exhibition and knowledge transfer hub, the museum had evolved into a venue for social gatherings among friends ($N = 9$ reported similar opinions).

We first introduced the goal of the interview and obtained informed consent from the participants. The interviews were conducted face-to-face, and each session lasted around an hour. All interview sessions were recorded with the participant's consent. All recordings were transcribed into scripts for further analysis. Two researchers coded the scripts following an inductive open coding approach (Thomas, 2006). The transcripts were initially coded and labeled independently by the two researchers. Then, the researchers compared their coded texts. Overlapping texts were retained for subsequent categorization into communication themes. The two researchers reviewed non-overlapping texts together and made decisions regarding their retention or exclusion. Finally, the coded texts were categorized into seven communication themes and three challenges.

3.2.2. Findings

Based on the interviews, we identified five **communication themes** among users in physical museums.

- **Collections**. Participants enjoyed ($N = 6$) discussing the appearances and shapes of collections, both with nearby and distant partners, particularly when the collections had unique or unusual characteristics. Additionally, all participants mentioned that they prefer to discuss their professional knowledge of the collection with their peers when visiting. When there are companions who have knowledge of the history or culture related to the collection, participants ($N = 8$) tend to discuss the historical context and relevant cultural narratives with them. Some participants ($N = 4$) also commented that some collections may spark memories of related collections they had visited before, connecting past visits with present experiences.
- **Taking photos**. In the interview, eight participants mentioned taking photos, including selfies, group shots, and images of collections. P2 shared her experiences of taking photos when visiting a museum: *"I typically guide my friend to take a photo, suggesting angles and distances. I might even ask them to crouch to make me appear taller. After the visit, I occasionally organize everyone for a group photo via a WeChat group message."*
- **Gathering**. Arranging gatherings was crucial when participants found themselves separated. They needed to coordinate meeting locations and times. Response from P4 underscored this aspect: *"When it was time to gather, I often requested my partners' locations via WeChat and instructed them to wait at the current spot. As for sharing my location, I typically took a photo and sent it to my partner."*
- **Surroundings**. Half of the participants indicated that when an announcer or other professionals offered interpretations of the collections, they would invite their partners to listen and subsequently engage in discussions about the content. Discussions with professionals brought a sense of trust. Listening to the interpretations enriched participants' related knowledge. P5 disclosed her attitude toward other surrounding visitors during the visit to museums: *"When my professor and friends discussed a collection piece in the exhibition, my partner and I would pause to listen. If we agreed with their insights, we would stay for a long time. Otherwise, we would move away and share thoughts with each other."*
- **Public facilities**. Four participants mentioned conversations with their partners about facility locations, with restrooms and lounges being the most common topics. Response from P7 highlighted the desire to locate a souvenir shop during the visit: *"When I spotted visitors*

holding cute souvenirs, I would ask my partners if they wanted one. Then we would search for the souvenir shop together."

Drawing from participant feedback, we identified three primary **interaction challenges**.

- **Difficulty in positioning**. The initial challenge stemmed from physical separation, making it challenging to locate each other. P10 expressed the difficulties of discussing interesting collections when separated, *"When attempting to discuss with a distant partner, describing the collection clearly in words proved challenging. Moreover, it was challenging for my friend to quickly locate the collection due to the extensive array of exhibits."*
- **Interrupt the visit experience**. The second challenge pertained to disruptions in the visitor experience, particularly when engaging in multi-turn dialogues. P1 recalled an experience of discussing meal choices with partners in a museum, *"During our visits, my friends and I often spend considerable time discussing dining options and finding appealing restaurants. After long-time discussions, we would become drawn to the idea of ending the exhibition early to enjoy a meal."*
- **Hard to express specific information like emotions**. The third challenge involved the difficulty of conveying certain information, such as emotions. P7 conveyed a preference for using emojis to express emotions, *"I believe emojis can convey emotions in a clearer and more engaging manner. I want to use a sleeping emoji above my head to signal to my partners that I am tired."*

These findings can act as the foundation of the *EmojiChat* design. The emoji set should support communication about these topics, and our prototype should try to mitigate the interaction challenges.

3.3. Participatory design

To create an emoji set supportive of user interaction on the frequently discussed themes outlined in Section 3.2, we recalled the previous ten participants on another day for a continual study. In this stage of the study, participants were instructed to design a preferred emoji-driven interface for museum interactions. The experimenter initially presented the design requirements: drawing any emojis or icons they believed would facilitate communication with partners without any time constraints. In cases where participants were uncertain about what to draw, the experimenter would offer guidance by presenting five themes outlined in Section 3.2.2. Throughout the design sessions, the experimenter sat adjacent to the participants to address any queries they might have. The design sessions concluded when participants indicated that they had comprehensively captured their ideas and had no further additions. Figure 3 presents several examples of collected sketches.

The preliminary design of the emoji set was created by gathering emojis from the sketches. To improve the recognition efficiency, we referred to the Unicode[13] to standardize the emojis. Due to the limited number of emojis in Unicode, it was challenging to cover designed emojis and icons from all the participants. Consequently, we invited an experienced designer to digitize the emojis proposed by the participants following the design elements found in Unicode. Multiple design choices were developed for certain themes, primarily because participants drew different forms of emojis to convey the same theme. For example, P3 and P7 employed textual numbers to denote *time*, whereas P8 and P10 relied on clock emojis. The designs for *confusing* and *agreement* shared the same perspective. Regarding the designs for *hurry* and *finish*, participants employed text directly to convey information. From our standpoint, we aimed to prioritize emojis in the interaction over text, enhancing enjoyment and readability. Consequently, we conducted online searching and selected frequently used icons or emojis with similar meanings. An additional iteration (Section 3.4) was conducted to choose emojis from a range of options. It is noteworthy that we did not consider the color usage mentioned by the participants. Three participants applied color labels to their emoji designs in their sketches. Their chosen colors matched the designs of the emojis in Unicode. For example, P6 drew an *emergency* emoji and labeled it as red, the same as the *emergency* emoji in Unicode. Hence, we considered that the color usage would not impact the emoji set's design due to the resemblance in color choices.

The initial design of the emoji set, comprising 38 emojis, was derived from the participants' sketches. These emojis were identified by codes E1 to E38. Although we utilized the common themes from Section 3.2.2 to prompt participants to recall additional emojis that could aid in interaction within the museum, participants did not categorize the

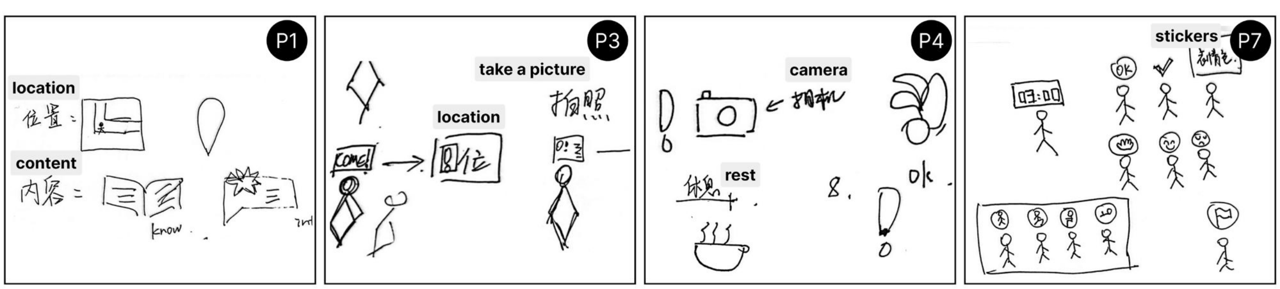

Figure 3. Examples of sketches collected from interviews, with translation taps in shown grey boxes. The circle in the upper right corner of each sketch was marked with the participant's ID.

emojis by theme or other criteria during the design process. Consequently, in line with the participants' designs, we did not categorize the emojis and presented them in a flat layout. In summary, Figure 4 illustrates the preliminary design of the emoji set.

3.4. Iteration of the proposed emoji set

To iterate the emoji set, our research team conducted an online survey with 54 participants recruited from a local university. These participants possessed experience in visiting museums with friends and regularly using emojis in their daily communication. Participants were instructed to precisely identify the meaning of each emoji and respond briefly, typically using a few words. To provide context and enhance participants' understanding, each emoji was presented with the following condition: *"Recall a previous museum visit with your friends and envision that your friends send you an emoji during the visit. Interpret this emoji within this specific context."* To accurately identify an emoji, participants were required to use the precise term or provide a detailed description to prevent any ambiguity. Take E6 as an example. Participants' responses included descriptions like *a red cross mark*, signifying concepts, such as *cannot* or *refusal*. Whether describing the visual design or conveying the meaning, details, such as *red*, *cross mark*, *cannot*, and *refusal* were adequate for comprehending the respondents' intent. All these answers were accepted as the exact interpretation of the information E6 conveys. A total of 54 complete responses were collected, comprising 24 from males and 30 from females. The respondents were predominantly young, with an average age of 24.6 ($SD = 3.49$). The majority of respondents (93%) came from China.

Recognition percentage represents the percentage of correctly interpreted meanings conveyed by the emojis. As depicted in Figure 5, the overall recognition percentages were notably high, with 30 out of 38 emojis achieving recognition percentages exceeding 50%. All participants accurately E7 and E8. The newly designed emojis created by the designer achieved satisfactory recognition percentages. Recognition percentages of E31, E16, E24, and E25 exceeded 90%. Eighty-three percent of participants correctly identified E32 as the intended representation, with 42% associating it with a state of fatigue and the need for rest. The third *hurry* design (E20) garnered recognition from 78% of respondents, with four participants associating it with the concept of a gathering. The emojis E12, E22, and E21 exhibited lower performance, with recognition rates of 61, 44, and 39%,

Figure 4. Preliminary emoji set design with 38 emojis with codes from E1 to E38. "love," "confusing," "time," "hurry," "finish," and "agreement" correspond to multiple emojis.

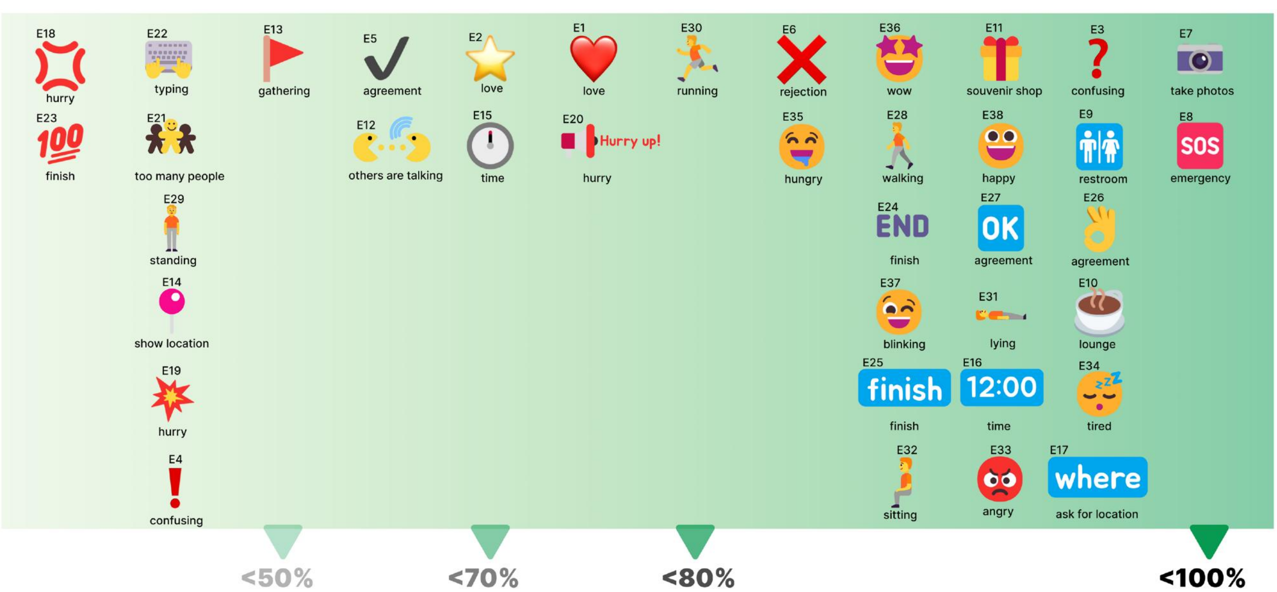

Figure 5. Recognition percentages of the preliminary emoji set, illustrating an ascending trend from left to right.

respectively. Emojis with recognition rates below 50% were excluded. Among the various design choices for each topic, we selected the one with the highest recognition percentage to represent that topic. With a higher recognition rate of 78%, we opted for E1 to convey the concept of love and discarded E2. The recognition percentage for E16 significantly surpassed that of E15, likely due to the enhanced readability of numerical representations. Recognition of E4 was notably diverse, with 43% of respondents interpreting it as *amazing*, 31% associating it with *confusing*, and the remainder perceiving it as an *emergency*. To eliminate ambiguity, we excluded the less clear emojis and employed E3 to signify confusion. The design options for *agreement* consistently achieved recognition percentages exceeding 60%, with E26 leading at 98%, followed by E27 at 94%, and E5 at 69%. So we decided to keep the E26 design. For the design choices of a *hurry*, while 83% of respondents recognized E18 as *angry*, none associated it with *hurry* as the designer had assumed. The second *hurry* design proved to be similarly unclear, with 46% of respondents interpreting it as *angry* and 41% as an *emergency*. To avoid ambiguity, we decided to discard this unrecognized emoji. Finally, we kept the third design of hurry (E20) with a 78% recognition rate. Due to its superior recognition percentage, we selected the design E24 as the final representation for *concluding a visit*, while discarding the E25 and E23 designs. Gathering the collected feedback, we iteratively refined the emoji set design, resulting in the final set of designs (Figure 6).

3.5. System implementation

Following iterative design refinements, we implemented the emoji set into a VR museum. To replicate the scenarios of visitor separation and gathering within the museum, we constructed a two-story virtual museum featuring multiple blocks. A pilot study involving our research team was conducted to determine the optimal size and position of the emoji interface. To ensure the visibility of the emoji above each visitor's head from all angles, we stuck the emojis to all six sides of a cube, as opposed to using three-dimensional emojis. Taking E37 as an example, if we had employed a three-dimensional emoji, users would have been unable to perceive the emoji's expression from behind. Figure 7 illustrates the *EmojiChat* interface.

4. Exploratory study in VR museum

To investigate the effects of emoji-driven communication on social interaction and identify potential areas for improvement to enhance the suitability of emoji communication in VR museums, we conducted an exploratory study to collect user feedback on the *EmojiChat* experience. We were particularly interested in whether the *EmojiChat* could enhance communication efficiency and provide a positive user experience during VR museum visits.

4.1. Participants, apparatus, and tasks

To assess the effectiveness of *EmojiChat*, we recruited 24 additional participants (aged 22–32, 15 males and nine females) from a local university and organized them into pairs. We employed a 5-point Likert scale (ranging from 1—Completely unfamiliar to 5—Experts) to assess participants' literacy to VR. Participants self-reported literacy (5-pt scale) to VR ($M = 3, SD = 1.35$).

The *EmojiChat* was constructed using Unity with the OpenXR SDK. The *EmojiChat* was deployed on desktop computers equipped with NVIDIA RTX 3080. In our exploratory study, we utilized the Meta Quest 2 headset.[14] Synchronization of the two setups was achieved using Photon Networking SDK.[15] *EmojiChat* (Figure 8) enabled remote access for multiple users. Avatar movement in *EmojiChat* was controlled using the

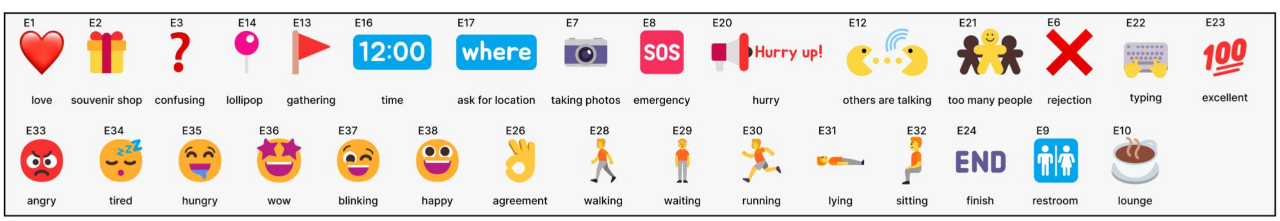

Figure 6. Final emoji set design with 25 emojis. The emoji design set is implemented in the emoji selection interface of the VR museum.

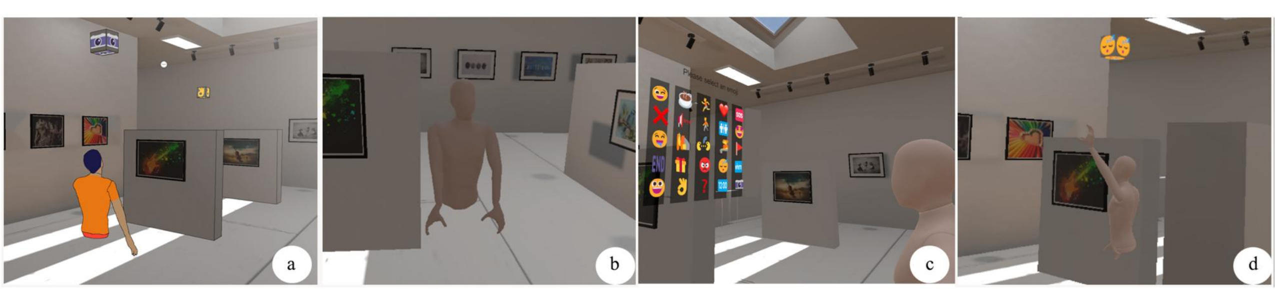

Figure 7. Screenshots of the *EmojiChat*; (a) a comprehensive view of the system, demonstrating two users interacting *via EmojiChat* across the exhibition partition; (b) one user encountering another within the VR museum, facilitated by *EmojiChat*; (c) user selecting their desired emoji from the emoji set; (d) the system presents the user-selected emoji, prominently displayed above the user's avatar.

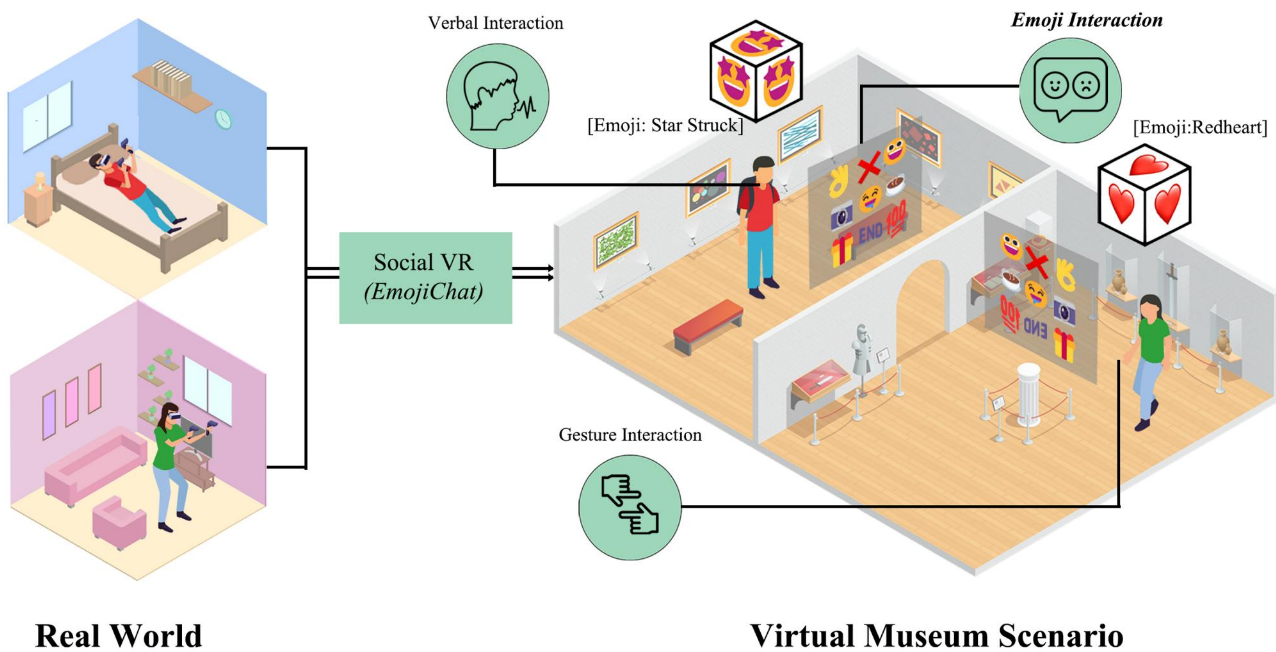

Figure 8. An overview of the *EmojiChat*. Our system enables remote access for multiple users and supports interactions through verbal, gesture, and emoji.

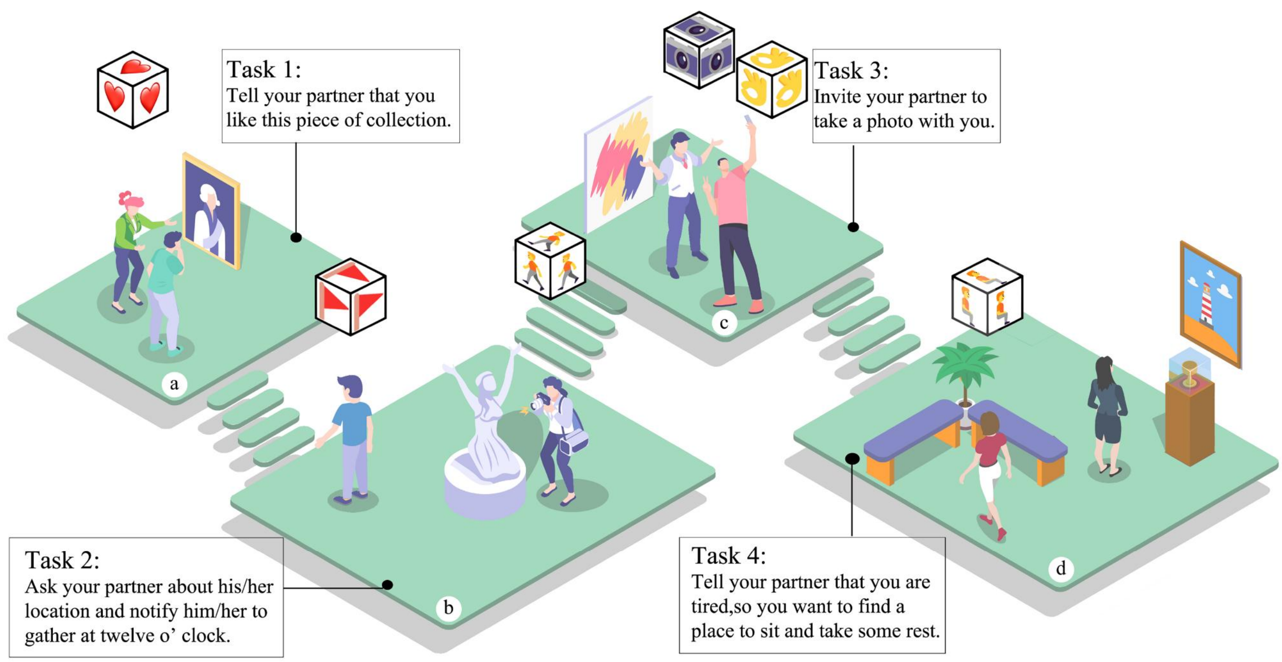

Figure 9. The four tasks in the exploratory study. They were derived from the most commonly mentioned communication themes in Section 3.2. (a) Task 1 refers to collections. (b) Task 2's topic is the gathering. (c) Task 3 is about taking photos. (d) Task 4 describes visitors' status.

joystick on the controllers. When users approached within a relatively short distance ($< 4m$, keeping the same distance as in real social communication (Hall & Hall, 1966)), they could engage in verbal communication. Furthermore, users' gestures were mapped to their avatars, enabling gesture-based communication. Upon pressing the "A" button on the controller, *EmojiChat* displayed the emoji set interface in front of the avatar, allowing users to select an emoji using the ray. The selected emoji would then be updated on the cube positioned above the user's avatar. Figure 7 presents the detailed system illustrations.

Participants were invited to complete four information-conveying tasks under two conditions: *EmojiChat* and the same VR museum without emojis. We selected the top four most frequently mentioned communication themes from the interview session (Section 3.2) as the tasks. All ten participants mentioned three of the tasks (Figures 9(a,b,d)). The remaining task (Figure 9(c)) was mentioned by 90% of the participants ($N = 9$). These four tasks can demonstrate the interaction challenges discussed in Section 3.2 to varying degrees. These tasks are shown in Figure 9.

4.2. Procedure

The exploratory study consisted of the following phases.

Introduction (5–10 min). Participants initially received an introduction to the study. Subsequently, they entered the VR museum to acquaint themselves with avatar control and emoji interface interactions. During this phase, participants were encouraged to interact with each other using various modalities, such as verbal communication, gestures, and emojis. The experimenter facilitated participants' learning by providing verbal explanations of the system. The introduction continued until participants were thoroughly acquainted with the system, including avatar control and emoji interface interaction.

Exploration (30–40 min). During the formal study, pairs of participants were asked to sequentially complete four information-conveying tasks under two conditions: with and without the use of emojis. Under the first condition, one participant was randomly designated as the message sender and provided with the message to convey to their partner. Upon successful communication of the message and accurate reporting to the experimenter by the message receiver, the task was considered complete. Under the other condition, roles were reversed. Latin squares were employed to mitigate potential order effects associated with the study conditions. The completion time for each task was recorded to assess communication efficiency.

Questionnaire and interview (15–20 min). The study concluded with post-task questionnaires and interviews. The questionnaire included the User Experience Questionnaire-Short (Schrepp et al., 2017) and the NASA-TLX (Hart, 2006), which were used to gather feedback from participants regarding both *EmojiChat* and the natural interaction system without emojis. Subsequently, participants participated in interviews during which they responded to open-ended questions, provide qualitative feedback on *EmojiChat*, their patterns of interaction modality usage, and encountered challenges.

5. Findings

5.1. Feedbacks on EmojiChat

Participants found *EmojiChat* to hold promise, with the UEQ scores indicating that it was relatively user-friendly, albeit with room for improvement. Throughout the rest of this section, we will denote pairs of participants as "G," with "G1" representing the first pair.

5.1.1. User experience questionnaire-short

The User Experience Questionnaire-Short covered three primary subscales: Pragmatic Quality, Hedonic Quality, and Overall Quality (Schrepp et al., 2017). We conducted a paired samples t-test to analyze the Overall Quality scores. The results (Figure 10(c)) revealed a significant difference between the two conditions [$t(23) = -4.83, p < .001$]. *EmojiChat* achieved a higher Overall Quality score ($M = 5.29, SD = 0.79$) compared to the system without emojis ($M = 4.01, SD = 1.13$). *EmojiChat* received high scores on pragmatic quality ($M = 5.26, SD = 0.91$) and hedonic quality ($M = 5.33, SD = 0.99$). This indicates that *EmojiChat* offers a positive experience in terms of interaction and entertainment.

5.1.2. NASA-TLX

To further investigate the impact of *EmojiChat* on participants' workload, we analyzed the results of the NASA Task Load Index (NASA-TLX) questionnaire. NASA-TLX covered six subscales: Mental Demand, Physical Demand, Temporal Demand, Performance, Effort, and Overall Workload. Paired-sample *t*-tests were conducted to compare differences in the NASA-TLX subscale scores between the two conditions (Figure 10(a)). We found that *EmojiChat* could significantly reduce the overall workload ($M = 3.04, SD = 1.02$) by lowing Mental Demand ($M = 3.20, SD = 1.35$) and Physical Demand ($M = 4.16, SD = 1.60$). This suggests that *EmojiChat* simplified interactions among participants in VR museums. P3 noted that positioning their partner was mentally demanding in the condition without emojis, "*It is quite painful for me because I have no sense of direction*" (G3). The integration of emojis could mitigate this challenge. In addition, *EmojiChat* could reduce the avatars' movement, "*I see my partner, but I don't want to move. I can use emojis to communicate with her*" (G6). This explains the reduction of Physical Demand. Regarding Performance, *EmojiChat* performed slightly worse because participants believed that

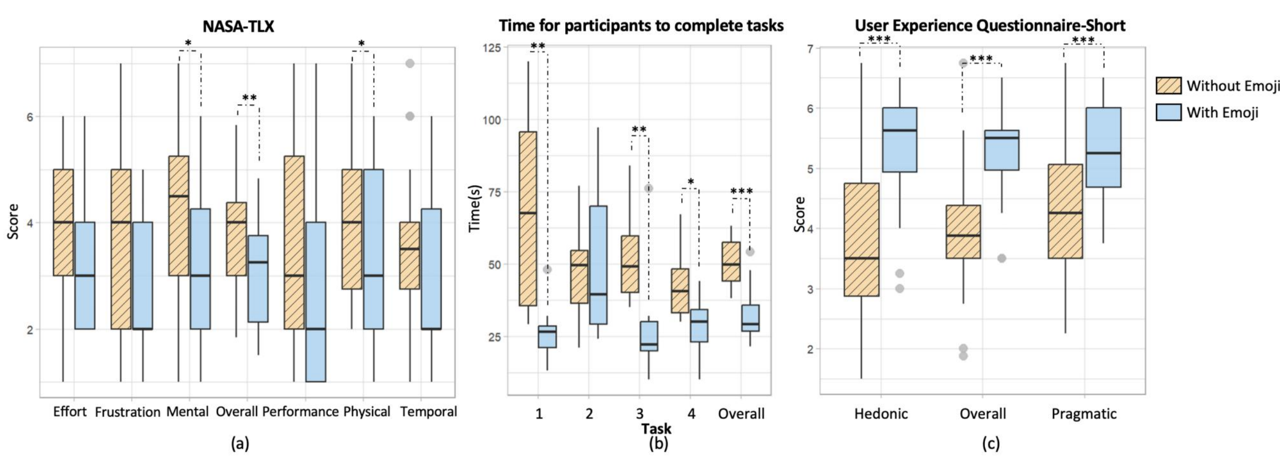

Figure 10. Results of (a) NASA-TLX, (b) Task completion time, and (c) user experience Questionnaire-short for exploratory study (*$p < .05$, **$p < .01$, ***$p < .001$).

verbally conveyed messages were more accurate than those conveyed by emojis, particularly for complex messages.

5.1.3. Qualitative feedback

Upon concluding the user study, we solicited qualitative feedback from each pair of participants by inquiring, "What is your opinion of this system?" Subsequently, we conducted a contextual analysis to examine how *EmojiChat* addressed the interaction challenges discussed in Section 3.2. **Positioning aid**. Nine pairs of participants noted that avatars with floating emojis above their heads remained visible from a distance, facilitating partner location. To illustrate, consider a scenario outlined in Section 3.2, where a participant wished to discuss a nearby collection with a partner positioned at a distance. With the emoji displayed above the avatar's head, the partner could quickly locate the participant and initiate a discussion about the collection. **Facilitating a Seamless Visiting Experience**. With *EmojiChat*, participants could swiftly switch displayed emojis through ray-casting, offering a convenient means of interaction. This eliminated the need for interruptions during the museum visit. As G8 explained, "*While admiring a painting, if I suddenly want to ask my partner about our dinner plans, I could select an emoji in a few seconds and continue enjoying the painting without any interruptions.*" **Enhancing Information Diversity**. Eight pairs of participants expressed their enjoyment of the extensive range of facial emojis in our system, allowing real-time emotional expression with partners.

Overall, *EmojiChat* is well-designed and can serve as a system to investigate the impacts of emojis on social interaction in VR museums. In the following subsection, we outline the impacts of emojis on participant interactions. This includes an investigation of its impact on communication efficiency, patterns of emoji usage, a comparison of interaction modalities with and without emojis, challenges associated with emoji interaction, and participants' suggestions for future design enhancements.

5.2. Impacts of emojis on social interactions in VR museums

5.2.1. Communication efficiency

We analyzed the time participants took to complete four tasks using both the system with and without emojis (Figure 10(b)). We conducted a paired-sample t-test to compare the mean total time and completion times for individual tasks between the two conditions. The results indicated a significant difference in the mean total time taken to complete all tasks [$t(11) = 5.33, p < .001$] between *EmojiChat* ($M = 32.55, SD = 10.12$) and the system without emojis ($M = 50.06, SD = 8.90$). Regarding the task-specific completion time, paired-sample t-tests showed that participants completed Task 1 ($M = 26.16, SD = 8.95$), Task 3 ($M = 26.83, SD = 16.68$), and Task 4 ($M = 29.08$, $SD = 10.26$) significantly faster with *EmojiChat*. This suggests that *EmojiChat* enhances communication efficiency among participants. Analysis of the experimental recordings revealed that participants exchanged only one round of messages in Tasks 1, 3, and 4, i.e., where one participant sent an emoji message, and the other replied with an emoji. Thus, the task completion time was significantly shorter compared with the case without emojis. In Task 2, participants engaged in multiple rounds of discussion by sending different emojis, which increased the task completion time. However, this suggests that *EmojiChat* enhances the desire to interact.

5.2.2. Patterns of emoji usage

All participants consistently used a specific set of emojis for each task. For instance, emojis, such as E17, E13, E16, and E28 were commonly utilized to accomplish Task 2. Participants often used E7 to invite their partners to take photos, and the recipients typically responded with E26. Task 4 required the most extensive use of emojis, with participants averaging six emojis per pair and engaging in an average of three rounds of message exchange. In Task 1 and Task 3, the majority of participants (11 out of 12 pairs) accurately conveyed their messages using only two emojis: one for sending and another for responses. For Task 2 and Task 4, four pairs of participants opted for task simplification, focusing on conveying essential information. For instance, in Task 2, G10 neglected to ask for his partner's location and directly instructed him to meet at the landing at 12 o'clock using emojis E13 and E16. Similarly, G5 neglected to mention her fatigue and straightforwardly informed her partner of her location, "I am sitting here" accompanied by emoji E32. Interestingly, certain participants (G7, G9) had a preference for displaying status emojis, such as E28, throughout the user study. They expressed that conveying their status and emotions to partners via expressive emojis was quite appealing. Specifically, G6 demonstrated a pattern of combining multiple emojis to construct sentences. For instance, she used E16, E13, and E3 to convey the message, "Can we meet here at 12 o'clock?" She displayed these three emojis sequentially and awaited responses from her partner. In contrast, other participants typically initiated with E13 and awaited responses. After getting feedback, they sent E16 to discuss the time for gathering.

5.2.3. A comparison of interaction modalities with and without emojis

We analyzed the study recordings to understand how participants interacted in the system without emojis and to identify differences between the two conditions. Without emojis, all message senders opted to inquire about their partners' locations verbally and physically moved to locate them. After that, they informed their partners of the message. G8 utilized universal gestures, such as mimicking taking a photo (using the index fingers and thumbs of both hands to create a rectangle), to convey messages when his partner was in the field of view. For example, the message sender in G6 employed gesture interaction to minimize her physical movement. She explained, "*In the condition without emojis, I would initially move around the VR museum to locate my partner. When I spotted them from a distance, I would wave* *to them to come over, and then I could talk to him/her. This approach allowed me to reduce my movement to some extent.”* Notably, we observed that once participants had moved to their partners and conveyed their messages, they seldom returned to the original artwork or exhibit they had been viewing. This suggests a disruption in their museum visit experience.

In the context of *EmojiChat*, nine pairs of participants directly opted to employ emojis for message communication. The remaining three groups (G2, G5, G9) indicated that their choice of using emojis or physically approaching their partner depended on the circumstances, considering various factors. These factors included the proximity to their partner and the complexity of the message they intended to convey. G9 described their approach to conveying information: *“If I needed to convey a simple message, like taking a photo, I would use an emoji directly. However, for more intricate discussions with my partners, such as sharing knowledge about a particular exhibit, I found emojis less effective. If my partner was in close proximity, I would opt for a face-to-face discussion.”* This implies that emojis offer an additional interaction modality that can streamline long-distance communication, consequently reducing the need for physical movement. However, several participants indicated that employing emojis to convey intricate information remains a challenge to address.

5.2.4. Challenges associated with emoji interaction

The participants identified three main challenges of communicating with emojis.

- Lack of signal for interaction. Some participants (G1, G2, G6, G7, and G11) mentioned that they occasionally overlooked the emojis displayed above their partners’ heads, resulting in missed messages. G7 and G11 emphasized that when they were immersed in enjoying the collections, they frequently missed incoming messages. G1 mentioned that while she noticed her partner looking in her direction, she remained uncertain whether her partner had noticed the emojis, *“Maybe she is looking at my avatar.”*
- Emojis’ limitations in conveying diverse types of information. G5, G6, G7, and G9 voiced concerns about the difficulty of conveying complex and misleading messages using emojis. G9 elaborated on this concern, *“An emoji can only convey limited information. For complex messages, we need to use multiple emojis to convey them.”* G2 provided further insight, explaining, *“An emoji can convey multiple messages. For instance, when I see E17, I am unsure whether my partner is inquiring about my location or the location of a collection piece.”*
- Emoji interaction faces limitations in certain contexts, such as when participants were on different floors or separated by walls, the emojis became invisible.

5.2.5. Participants’ suggestions for future design enhancements

Participants suggested multiple designs to improve the usability of *EmojiChat*. G5 recognized the need for action confirmation, stating, *“Sometimes I forget which emoji is displayed above my head and have to look up to check.”* To address this challenge, G3 and G9 proposed a solution (Figure 11(a)): *“displaying a list of emojis and highlighting the selected one.”* To enhance information accuracy and richness, G5, G6, and G9 suggested arranging a series of emojis in a line with multiple blank spaces (Figure 11(b)). This pattern of using a sequence of emojis to convey a sentence aligns with a previous research finding (Khandekar et al., 2019) and can be directly integrated into *EmojiChat*. To prevent issues, such as physical obstructions (e.g., walls and floors) and enhance emoji interaction in various settings, G3, G4, and G10 recommended implementing a mini-map design (Figure 11(c)). Mini-maps are commonly used in games to indicate collaborative locations and provide specific information, such as potential hazards (Leavitt et al., 2016). In VR museums, they could serve to display the positions and messages of all visitors. *EmojiChat* was designed to accommodate multiple users. During our exploratory study, participants were invited in pairs. G6 expressed concerns about not being able to identify the senders of emojis in the context of multiple online visitors. To address this issue, G12 suggested implementing a filter for the visibility range of emojis. This would enable participants to determine who can view the emojis they send and from whom they wish to receive emojis (Figure 11(d)).

6. Discussion

In this section, we discuss the key lessons and observations from our study and the limitations of our work.

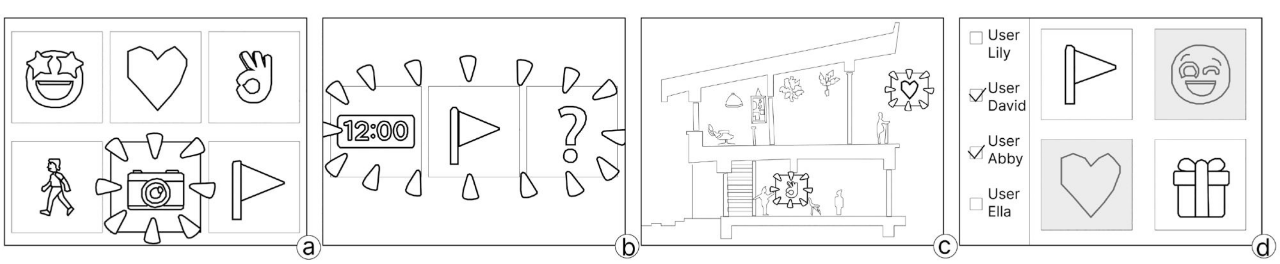

Figure 11. Participants’ suggestions for future design enhancements. (a) Highlight the selected emoji. (b) Use a sequence of emojis to construct a sentence. (c) Use a mini-map to display emojis from all participants. (d) Filter the visibility range of emojis by selecting target users.

6.1. Benefits and challenges of EmojiChat

Existing VR museum applications concentrate on various design aspects. Viking VR and Hawaiian Coral Reef, for instance, emphasize scene reconstruction (Cristobal et al., 2020; Schofield et al., 2018), while DreamVR allows interactions beyond reality within virtual museums, such as stepping into a painting (Cao et al., 2023). Additionally, another VR museum customizes visitor experiences by discerning content preferences (Javdani Rikhtehgar et al., 2023). In comparison to these platforms, *EmojiChat* exhibits a recognized limitation pertaining to the aesthetic style of its collections. G10 remarked, *"When we approach the paintings, they appear unrealistic."* Rather than emphasizing interaction with scenes and collections, *EmojiChat* prioritizes social interaction within VR museums. By enhancing communication efficiency and user enjoyment, *EmojiChat* elevates the overall user experience within VR museums and demonstrates potential utility across a range of other VR applications. As an example, during the post-interview session of the exploratory study in Section 4, G12 expressed, *"I believe EmojiChat could be employed to streamline communication with my friend in the library, as it's typically a quiet environment. When I'm fatigued or bored, I can simply choose an emoji to convey my status to my friend."* Although several social VR platforms have attempted to utilize emojis for user interaction (Maloney et al., 2020), such as showing applause, the displayed emojis are often generic and lack context specificity. *EmojiChat* offers a design approach for crafting context-specific emoji sets and has the potential to inspire the incorporation of emoji-driven interaction into VR platforms supporting diverse scenarios.

6.2. Interpretation of emojis

While the world standard for emoji, Unicode website[16] primarily employs shapes, colors, and design features for descriptions, emojis consistently carry specific meanings within the communication process. For example, on WeChat, typing "angry" prompts the suggestion of E33. Prior studies have shown that the interpretations of emojis are context-dependent (Cramer et al., 2016), aligning with the findings of our study. In our study, during the emoji set design session (Section 3.3), users' interpretations of emojis remain largely consistent and are not influenced by predefined museum contexts. Considering E17 as an example, in the online survey, 94% of participants identified it as meaning "Where are you." However, while immersed in the VR museum experience detailed in Section 4, participants attributed additional meanings to this emoji, such as inquiring about their location or the collection's location. Throughout our exploration of *EmojiChat* with participants, we observed that two other emojis, E1 and E7, also garnered expanded interpretations from the participants. This illustrates that in specific contexts, participants often derive interpretations of emojis that are more contextually relevant based on their surroundings.

6.3. Challenges and potential solutions of using emojis in VR museums

Our study reveals numerous advantages of emoji-driven interaction, including improved communication efficiency and enhanced enjoyment. These benefits align with those previously mentioned in existing literature (Kim, Gong, Han, et al., 2020; Zheng et al., 2023). However, our exploratory study identified several challenges. The absence of an interaction signal impedes mutual interaction. As visual cues for interaction, emojis require the partner's attention to be directed to a specific location before interaction can occur. Therefore, capturing the audience's attention before displaying an emoji is crucial. Previous studies have demonstrated that gaze (Mandal, 2014) and gestures (Streeck, 1994) can effectively convey communication intentions to others. Ping, which combines audio cues and icons, can quickly capture the player's attention to points of interest (Zheng et al., 2023). Furthermore, a previous study integrated emojis with animations and vibrations to enhance their visibility (An et al., 2022). Therefore, collaborating with other interaction modalities, such as audio or gestures, can enhance interaction signals. Previous studies have demonstrated emojis' capacity to convey messages independently. For example, a previous study indicated that 36.2% of messages containing emojis consisted solely of emoji inputs (Kim, Gong, Kim, et al., 2020). Such messages are primarily used for expressing emotions or conveying straightforward ideas (Khandekar et al., 2019). However, despite the existence of over 3600 emojis in Unicode,[17] their topical coverage is limited in comparison to text or verbal communication. To address this limitation, emojis can be complemented with text and voice to facilitate the clear and vivid expression of information (Kim, Gong, Kim, et al., 2020). Participants in our study demonstrated the practice of combining emoji-driven interaction with verbal communication to expand the scope of topics and convey intricate or nuanced messages. Another challenge associated with using emojis in VR museums is their visibility being obstructed. Mitigating this challenge necessitates thoughtful emoji interface design. Our participants have suggested various design approaches (as discussed in Section 5) to address this limitation. Furthermore, integrating emojis with other interaction modalities, such as verbal communication, presents an additional potential solution to overcome the limitation of sharing the same point of view.

6.4. Integrating emojis with other modalities to enhance social interaction in VR museums

Our participants expressed the desire for facial expression tracking and the generation of corresponding emojis. This proposal aligns with previous studies that captured users' facial expressions and integrated emojis into their text (El Ali et al., 2017; Liu et al., 2018). This suggests the integration of emojis with other interaction modalities. Emojis are typically used in conjunction with text, especially on online social media platforms. To enhance usability, previous studies have explored the automatic recommendation of emojis based on text input (Kim, Gong, Han, et al., 2020; Kim, Gong, Kim, et al., 2020). Furthermore, automatic emoji selections can be achieved through emotion keywords (Urabe et al., 2013) and speech signals (Hu et al., 2019, 2023). However, these combinations of interaction modalities have primarily been applied in traditional social media platforms, such as Slack.[18] Current VR museums support avatar-mediated interactions, encompassing voice, gaze, gesture, and posture interaction (Cao et al., 2023; Schofield et al., 2018). Certain social VR platforms have incorporated emoji interaction (Maloney et al., 2020), but these interaction modalities remain separate. In the future design of the VR museums, we can closely integrate interaction modalities to enhance social interaction. For instance, detecting users' non-verbal communication signals, such as facial expressions and gestures, to suggest relevant emojis. Furthermore, analyzing the semantics and sentiment of input text and voice and generating emojis to express emotions and prevent miscommunication can enhance the vividness and clarity of interactions among users.

6.5. Limitations

Our exploratory study has several limitations. First, our participants are primarily from China. Therefore, our investigation, e.g., their understanding of the emojis, is significantly influenced by the demographics of the Chinese participants. Cultural differences may lead participants from Western countries to interpret these emojis differently (Barbieri et al., 2016; Lu et al., 2016). In future research, we could include participants from diverse cultural backgrounds to investigate potential variations in emoji comprehension. Additionally, our collection of communication themes relied on participant retrospection, introducing the possibility of retrospection bias. Future work could supplement data with alternative methods, such as observational research. Furthermore, the duration of our exploratory study was limited. As a result, the findings may not provide the same depth as those of a long-term study, necessitating further research to assess the sustained effectiveness of emoji interaction.

7. Conclusion

In this research, we designed *EmojiChat*, a VR museum that facilitates verbal, gesture, and emoji interactions, and employed it to explore the impacts of emojis on social interactions. We first conducted semi-structured interviews to comprehend communication themes and challenges within museum contexts. Based on the findings, we customized an emoji set and refined it through an online survey. Subsequently, we integrated the customized emoji set into a VR museum scene, thus establishing a VR museum that facilitates the integration of various interaction modalities. By engaging participants in four message-conveying tasks, we investigated how emojis affect social interaction in VR museums. Our findings indicate that *EmojiChat* enhances interaction enjoyment, reduces workload, and alleviates interaction challenges. Furthermore, we identify the benefits and challenges associated with emoji integration, such as enhanced communication efficiency and lack of interaction signal. Additionally, we observe the usage patterns of various interaction modalities. Overall, these findings support the benefits of integrating emojis as an additional interaction modality to enhance social interaction in VR museums. They also pave the way for future research aimed at refining emoji interaction design and achieving more seamless integration with other interaction modalities.

Notes

1. https://www.louvre.fr/visites-en-ligne/petitegalerie/saison5/.
2. https://kimbellart.org/virtual-tours.
3. https://pano.dpm.org.cn//#/.
4. https://home.unicode.org/emoji/about-emoji/.
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17. https://home.unicode.org/emoji/about-emoji/.
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Disclosure statement

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