ABSTRACT
Mixed reality (MR) technologies and applications, including interpersonal communication, are rapidly evolving. Despite its promise, people’s actual needs concerning the advanced uses of MR are less studied. To address this knowledge gap, we conducted two focus group user studies in which we explored people’s perceptions, expectations, and ideas concerning remote interpersonal MR communication and collaboration. In the first study we examined people’s perceptions of MR and the study participants collaboratively created 21 scenarios for MR communication. For the second study, the most promising of these scenarios were selected and refined to develop three different types of scenarios: one with emotional content, one emphasizing entertainment and one focused on work-related situations. The scenarios were evaluated by the participants of the second study in the context of a specific MR communication system that uses near-eye displays. The results indicate that the expected advantages of MR in communication are its efficiency, richness and the increased feeling of presence over distance. However, concerns were raised about the technical reliability, usability and accessibility of advanced MR applications. Work and entertainment use contexts were preferred over emotional communication. Maintaining close emotional relationships was perceived to require real physical presence and interaction instead of being technology-mediated.

Categories and Subject Descriptors
H.5.2 [Information Interfaces and Presentation (e.g., HCI)]: User Interfaces – User-centered design; H.5.1 [Information Interfaces and Presentation (e.g., HCI)]: Multimedia Information Systems – Artificial, augmented, and virtual realities

General Terms
Design, Human Factors.

Keywords
Mixed reality, user expectations, user experience, mediated communication, collaboration, scenarios, focus groups.

1. INTRODUCTION
Milgram and Kishino [13] define mixed reality (MR) as the merging of real and virtual worlds. In their continuum of real-to-virtual environments, MR includes subsets of augmented reality (AR) and augmented virtuality (AV). In AR, a real environment is augmented with virtual objects, whereas AV creates a setting in which real objects are added to a virtual environment. In practice, the term MR encompasses both AR and AV, as applications of MR include everything along the continuum between pure reality and virtuality. Common technologies used in AR/MR applications include head-mounted displays (HMD) and near-eye displays (NED) which are usually either optical see-through or video see-through and enable the overlaying of virtual elements to the user’s view of the real world [2]. In a mobile context, mobile phones and handheld PCs are also used to provide video see-through-based augmentations. MR technologies are advancing constantly and new interaction methods are being developed (see e.g. [2][4]) to provide better user experiences.

Mixed reality is an emerging technology and an increasing amount of studies on its applications in various domains are being published every year but, for now, the advancements are often more technology-driven than they are based on any identified needs of potential users [6]. However, in the future MR might become a widely-accessible technology and therefore it will be important to take into consideration people’s needs, expectations, and opinions during the research and development processes.

By employing the methods of human-centered design (HCD) and performing user studies, users’ perspectives can be incorporated into the design of new technology. The ultimate goal is to create products that are usable and that elicit a positive user experience for the end-user. According to the standard ISO 9241-210 [10], user experience (UX) means “a person’s perceptions and responses that result from the use and/or anticipated use of a product, system or service.” By this definition it includes also the expectations that users might have regarding the future use of a certain technology, MR in our case. Thus, it is important to gather user input on proposed MR concepts early in the design process, not only on existing systems.
With this in mind, we conducted two focus group studies to explore people’s perceptions, expectations, and ideas about interpersonal communication by means of mixed reality. The first study aimed at exploring the participants’ ideas by asking them to collaboratively create use scenarios for MR communication with different technologies. In the second study the focus was narrowed down to three different use scenarios, which were based on the results of the first study. A specific vision of a MR system was used as an example of what the technology might be like in the future. Essentially, this vision described a system that provides the possibility of collaborative group situations with augmented reality features using near-eye display glasses. The three scenarios were discussed, evaluated, and compared by four groups of participants, in order to determine user perceptions about the benefits and shortcomings of using advanced MR technology in those communication situations. The goal of our earlier work and also of the present user study has been to understand user experience and needs in order to drive the development of new interaction and communication solutions.

In the following, we first conduct a brief examination of related research on collaborative MR and user research on the field. Then our two studies and their results are presented, and finally the results are discussed.

2. RELATED WORK
   2.1 Collaborative Mixed Reality Applications
   Mixed and augmented reality have been employed in several domains related to communication and collaboration. In a workplace context, MR collaboration has been studied in colocated settings (e.g. [19]) as well as in remote conferencing (e.g. [3]). Research prototypes are often applied to the field of architecture (e.g. [3]), automotive industry (e.g. [19]) or other disciplines where there is a use for presenting virtual structures (e.g. building or car models) superimposed on a surface such as a meeting room table. The virtual objects are usually viewed using head-mounted displays and haptic features, such as touching, grabbing and moving the objects, are realized by using either special virtual reality gloves [12] or marker tags [18][19], or by tracking the user’s hand movements [11][12].

   In remote conferencing the ultimate aim is to create an environment in which users can experience a sense of the social presence of others. This has been pursued, for example, by interfaces where the user wears a HMD and life-sized video images of remote collaborators are presented overlaid on markers on the local user’s desk, in front of him/her [3]. In a more advanced prototype by Kantonen et al. [11] the perception of conference partners’ full-bodied virtual avatars is enhanced by the sharing of a virtual object on top of a meeting table and the conference takes place inside a virtual meeting room, thereby increasing the sense of a shared workspace and collaboration.

   Similar features are applied to MR gaming contexts. For example, Nilsen et al. [16] present an AR game in which players wear HMDs and see a 3D terrain (game world) on top of a table and game characters are AR objects that can be controlled and moved around in the game world. Nilsen et al. [16] note that engaging the player’s imagination and emotions is critical to the gaming experience and that MR is one promising route to achieving it.

   Also in other MR domains the emotional atmosphere and the ability to express emotions are important factors in creating an immersive experience for the user. However, the research on emotional communication by means of MR seems to be rather confined to studies about avatars and how they succeed in conveying the user’s feelings. For example Garau et al. [7] studied the impact of avatar realism (visual and behavioral) on perceived quality of communication in a shared immersive VR environment.

2.2 User Research on Mixed Reality
   During recent decades, the research on virtual, augmented and mixed reality has emphasized developing, testing and evaluating new applications. Dünnser et al. [6] performed a survey on papers concerning augmented reality published between 1992 and 2007 in three major publication databases and found that an estimated 10% of the AR papers included some sort of formal or informal (e.g. informal user observation or feedback collection) user evaluation. The publications they found primarily incorporated types of user research that focused on measuring user performance with various methods during the use of a system or after use, but studies about user needs and expectations seemed to be rare.

   Also, according to Anastassova et al. [1], user needs analysis is seldom carried out in the field of VR and MR, and when user needs are analyzed, it is accomplished by interviewing a few “task experts”, by conducting brief field studies of future users’ activities or by questionnaires. Anastassova et al. [1] present possible explanations for this lack of soliciting user needs. First, they indicate that emerging technologies usually represent designers’ pursuits of technical achievements and therefore their development is technology-driven, leaving user needs as minor concern. Secondly, the potential applications are often futuristic and thus users are not likely to express needs for these innovations because they cannot imagine or describe what might be possible with eventual future technology. However, Olsson et al. [17] remind us that studies of user expectations of novel technology (such as MR) provide an approximation of user experience even before functional applications exist and users can actually experience them. They also state that it is vital to identify users’ expectations of the user experience, what needs they could fulfill with the target technology, and what kind of requirements they have for interaction with it.

3. RESEARCH APPROACH
   The main approach of our work is human-centered design of new technologies (ISO 13047) [9], in which the emphasis is put on early user involvement and understanding user expectations and needs. We conducted the present research using the focus group method. The focus group is a qualitative research method for gathering participants’ opinions, expectations and ideas on a given discussion topic and the interactions between participants act as an important component of the resource data [14]. They are excellent for generating and evaluating early ideas and facilitating rich discussions [17]. Focus groups have proven useful in earlier studies (e.g. [17]) aiming to investigate user expectations and anticipated user experiences within the MR domain.

   In addition, we used scenarios, which are stories about people and their activities with technology [5]. The benefits of scenarios include that they are concrete, flexible, and they evoke reflection and promote communication about their content [5]. According to Nigay et al. [15], scenarios are shown to be a useful way to concretely embody a view of users’ actual and future activities. Furthermore, they note that scenarios are particularly useful in the
MR domain as they enable the description of users’ interactions with technology without explaining in too much detail the way the actions are performed. In our approach, we combined the most applicable qualities of focus groups and scenarios.

4. STUDY 1: SCENARIO CREATION

4.1 Objectives

The main goal of the first study was to explore people’s ideas for the kinds of communication situations in which they would like to use mixed reality. The central aim was to have focus group participants collaboratively create use scenarios for MR communication, which would then act as the basis for the second study. The study was explorative and qualitative in nature. We chose focus groups as the method because we believed their social nature would facilitate discussion among the participants, which would help in ideating the scenarios. Retrospectively, we can say that the method fulfilled this expectation.

4.2 Participants, Methods and Procedure

The study included four focus groups with a total of 19 participants (3-6 per group), of which 7 were female and 12 were male. Participants’ ages ranged from 20 to 60 years (mean 31, median 26). Most of the participants (17) were studying at or had graduated from a university. Over half of them (13) reported having previous experience of using or at least testing some kind of consumer applications that were related to mixed or augmented reality (e.g. map services or games).

Each of the focus group sessions began with an introduction to the study, and continued with a brief but thorough introduction to the concepts of multimodality and mixed reality as well as common MR technologies (with many illustrated examples). Next, a semi-structured interview was used to initiate discussion about MR communication first in general and then regarding ideas for situations and communication purposes where MR could be used.

Then, the focus group participants formed groups of two to three people and collaboratively brainstormed use scenarios for MR communication. First they created scenarios for any kind of technology with no restrictions (hereafter called “unrestricted scenarios”) and then for a given example MR system, which was basically a videoconferencing system, enhanced with mixed reality features. In this example system, an extension of a real room is presented on a large screen and remote users are presented on the screen as avatars sitting by a table. The remote users can use either a laptop computer or a head-mounted display. The local users’ positions are tracked which makes it possible to reflect their movements on their avatars, and microphone arrays are used to create spatial audio. The example system was introduced using pictures and verbal presentation. It was presented for two reasons: 1) it was expected that without it, the focus group participants would mostly create scenarios based on technologies that were most familiar to them (i.e., mobile phones and basic computers), and 2) another aim was to generate fresh ideas about uses for this kind of system, other than videoconferencing. Each session lasted for about two hours.

Research data were collected by audio recording the discussions and by documenting the created scenarios. Afterwards the use scenarios were reviewed and analyzed qualitatively by thematic coding. The audio recordings were transcribed and then analyzed qualitatively by grouping and summarizing similar findings.

4.3 Results: Use Scenarios for Mixed Reality Communication

The focus group participants collaboratively created 21 use scenarios in total for potential situations in which MR communication could be used. Of the scenarios, nine were created specifically for the example MR system (described in Section 4.2) and twelve unrestricted scenarios included using other technologies which were freely chosen by the participants. In general the scenarios were very variable in terms of their characteristics, but they did include some commonalities that could be identified. In the following, the scenarios are presented according to these commonalities.

From the scenarios, six different situational contexts (i.e. the setting or communicational goal of the situation) could be identified: 1) meeting friends or family; 2) working; 3) shopping; 4) getting information about one’s surroundings or location; 5) entertainment; and 6) communicating about health (see Table 1 for the list and examples). Most of the unrestricted scenarios were related to home life and leisure time contexts, and none were work-related. In four of the unrestricted scenarios the goal was to inform someone about their surroundings or location, all of which incorporated using a mobile device. All of the scenarios for the example system were related to the need for getting groups of people into the same virtual place for one reason or the other, which is the natural use of the system considering its features.

Table 1. Frequencies of situational contexts and examples of the 21 scenarios

<table>
<thead>
<tr>
<th>Situational context</th>
<th>Unrestricted (N=12)</th>
<th>Ex. MR system (N=9)</th>
<th>Example scenarios summarized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meeting friends or family</td>
<td>2</td>
<td>3</td>
<td>- A party or other get-together (unrestricted and ex. system).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Reading a bedtime story to a child remotely (unrestricted).</td>
</tr>
<tr>
<td>Working</td>
<td>0</td>
<td>4</td>
<td>- Having remote meetings.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- A shared MR room for a project team.</td>
</tr>
<tr>
<td>Shopping</td>
<td>4</td>
<td>0</td>
<td>- Shopping remotely.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- An automatic shopping list that connects the home and the store.</td>
</tr>
<tr>
<td>Getting information about surroundings</td>
<td>4</td>
<td>0</td>
<td>- Travel diary in mobile phone.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Application for finding friends in crowded places.</td>
</tr>
<tr>
<td>Entertainment</td>
<td>1</td>
<td>2</td>
<td>- Dancing (and learning to dance) (unrestricted).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Playing games (ex. system).</td>
</tr>
<tr>
<td>Communicating about health</td>
<td>1</td>
<td>0</td>
<td>- Meeting a doctor remotely.</td>
</tr>
</tbody>
</table>

Most of the 12 unrestricted scenarios incorporated familiar devices as the main technology, such as advanced computers (4 scenarios) and mobile phones and other mobile devices, e.g. a GPS device (6 scenarios). In a few of these scenarios the familiar device was augmented with something from the MR world (e.g. “dataglasses”). Only two scenarios included unique futuristic MR devices: a haptic dance suit in a scenario about dancing, and VR gloves and glasses in one remote shopping scenario.

Overall, the participants anticipated that the largest benefits of MR communication in the future would be its potential for increasing the feeling of remote closeness (e.g. with friends) as
well as the efficiency of communication (e.g. in work context), and its richness compared to the conventional communication methods. On the other hand, they expressed concerns about the usability and reliability of complex MR systems.

Some of the unrestricted scenarios were on the borderline of being mixed reality. The reason for this is assumed to be differences in individual interpretations of the concept of MR – it can be difficult for people new to the concept to evaluate what constitutes MR and what does not. Also, people-to-person communication, in the sense of exchanging information, was lacking from some scenarios, although some form of interaction between people was present in all scenarios. In the example system scenarios the existence of MR features and people-to-person communication was ensured by the system’s specification.

Five of the scenarios were selected for further examination in the second study. The scenarios were chosen because they covered a variety of communication types and situations. Four of the five scenarios were directly related to the example system, while the fifth included a very similar choice of technology. The scenarios represented three different themes: emotional communication between family members (two scenarios); entertaining get-togethers among groups of friends (two scenarios); and sharing utility information in work context (one scenario).

5. STUDY 2: SCENARIO EVALUATION BASED ON A VISION OF A MR SYSTEM

5.1 Objectives
The second study was based on the results of the first study. The five selected scenarios were combined based on their themes and further developed into three new different types of scenarios, in which a specific vision of a MR system was used. The main goal was to get user feedback about the scenarios in the context of the system, including perceived benefits and shortcomings. The research approach was explorative and mainly qualitative. As in the first study, focus groups were used to facilitate discussion among participants.

5.2 Participants
There were 18 participants in total, of which 5 were female and 13 were male. Their ages varied between 28 and 50 years (mean 38.3, median 39). None of them had participated in the first study. All participants were required to have experience using a video call or videoconferencing application/system and it was considered as a plus if they were familiar with Second Life or another similar virtual world at least at a conceptual level. All except one of the participants were working in the field of technology. Ten of them had graduated from a university and eight from a polytechnic.

5.3 The MR System Vision
The example vision of a MR system (hereafter the “MR system”) was partly based on existing MR technologies, and partly on visions of future technology and current research in the field. Thus, it did not portray any specific system but was an example of what could be available in the future and was designed specifically for this study. The system was basically an advanced version of the example system in the first study. The following description (translated from the original Finnish text to English) of the system, illustrated with related pictures and videos collected from internet, was used to introduce the system to the participants:

The main purpose of the system is to make it possible to interact with people remotely, but as if they were in the same room. There can be multiple users in different locations and they are connected via the system to meet in a mixed reality space. The system includes using computers and near-eye display (NED) glasses (see Figure 1), through which the user can see the real world and virtual objects/environments simultaneously on the display. The environment can be seen as partly or fully virtual – for example, virtual objects can be added to it or a real room can be extended with virtual parts. Virtual 3D avatars represent the system users. They can look like the person they are representing or anything else that is imaginable. People in the same room can be seen through the glasses as real persons and remote people are seen as avatars on the display. The users’ body movements, gestures, and facial expressions are identified and presented in the virtual world so that they have a very life-like appearance. The MR space may include different kinds of virtual objects that can be manipulated (e.g. touched, moved, picked up) by the real users and the avatars. All interactions happen in real time.

Figure 1. Near-eye display (NED) glasses

The participants were told that the system acts as an example of how MR could be used in communication in the future. It was highlighted that the depiction above was not describing any specific existing system and that they should not dwell on how it would be technically possible, as it is positioned in the future.

5.4 The Scenarios Chosen for Evaluation
The three new scenarios included using the MR system in a group of two or more people, but for different purposes. The new scenarios were called: 1) Emotional communication with family; 2) Having fun with friends; and 3) Having a meeting at work. Their summaries are presented on the next page in text boxes. In the first scenario, emotional communication means communicating the kind of emotions that are involved in close relationships between family members, such as connectedness, closeness, longing, and intimacy. Regarding the second and third scenario it is also true that those situations can be very emotional, but in those cases the emotions are likely to be related to the activity, and are not the content of communication.

5.5 Methods and Procedure
Four focus group sessions were arranged with 4-5 participants in each. All sessions followed the same procedure:

1. Introductions and background questionnaire
2. Scenario: Introduction → questionnaire → interview (Repeted three times as there were three scenarios.)
3. Questionnaire for comparing the scenarios

The sessions started with an introduction to the study and then the participants’ background information was collected. Next, the participants were familiarized with the concept of mixed reality and MR-related technology in conjunction with the features of the MR system. The introduction included many pictures and videos that illustrated the possibilities of MR.
The scenarios were verbally presented by a moderator one at a time. In addition, some props were used and the scenarios were presented as if the participants were actively involved in them (e.g. cues were in the form, “and now you put on the display glasses”) to make it easier for the participants to immerse themselves in the situation. The props included a nonfunctional prototype of the NED glasses, a real physical version of the game.

### Scenario 1: Emotional communication with family
- A father and his adult daughter are spending a moment together using the system. Father is in his house (the daughter’s childhood home) and daughter is in her own apartment in another city.
- They are connected using the MR system (with computers and NED glasses) and they can see each other as realistic avatars. The daughter experiences a digital representation of the home through her NED and the father sees it as it is through his.
- The father and daughter miss each other and want to know how the other is doing. The daughter has had an important job interview and she is very anxious as she now has to wait for a few days until she will be notified if she got the job. The father senses the daughter’s mood from her voice tone and the appearance of the daughter’s avatar. The father comforts her and says that he is sure that she will get the job. The daughter calms down. They then talk about other day-to-day things for a while. Mutual longing has been relieved and the daughter also got to visit her old home virtually.

### Scenario 2: Having fun with friends
- A group of old friends meet each other using the system.
- Some of them have congregated in one friend’s home and others are alone in their own homes. These others experience a digital representation of the first mentioned home through the system.
- They are connected using the MR system (with computers and NED glasses). They can all see each other as realistic avatars and feel like they are in the same room.
- They play a virtual version of the game Jenga, in which wooden blocks are placed on top of each other in a tower form, and players take turns to remove a block from the tower and balance it on top, creating a taller and increasingly unstable structure. The loser is the person who makes the tower fall. In this augmented version of the game the blocks are virtual and the players interact virtually with them. The physics of stacking and falling are simulated virtually. There is haptic feedback through a haptic glove when the players touch the blocks, pull them out of the stack and move them to the top. Thus, they can feel the blocks, even if they are not real. The players can also walk around the table in the MR space to find the best spot from which to pull out a block. The friends play a few rounds of the game and enjoy some small-talk while playing.

### Scenario 3: Having a meeting at work
- Project managers of an architecture company are having their weekly meeting using the system.
- Most of them are together in a meeting room in the company’s head office but some are participating remotely from their building sites in other countries.
- They are connected using the MR system (with computers and NED glasses). They can see each other as realistic avatars and feel like they are in the same room. Remote participants see a digital representation of the meeting room.
- The project managers take turns introducing the statuses of their building projects and the future projects’ plans. They can use virtual building models and a virtual wall with virtual post-it notes to illustrate their presentation. All of the virtual objects can be touched, picked up and moved around. In addition, it is possible to “zoom” inside the building models and look at their insides. The meeting ends after the project statuses have been shared.

The scenario questionnaire was used to evaluate the MR system’s suitability for use in the described situation, as well as its benefits and shortcomings. The questionnaire included a semantic differential for measuring the anticipated user experience with 12 word-pairs that were partly based on the AttrakDiff questionnaire by Hassenzahl et al. [8]. Participants were also asked to compare using the system to using other communication media – a traditional videoconference, a virtual world (e.g. Second Life), or a phone call – in a similar situation. The interviews focused on what was experienced as the best and worst aspects of each scenario, what should be done differently, and how the system fit the purpose for which it was being used in the scenario. Also, the preferred appearance of the avatars was briefly discussed. After this process was complete for all three scenarios, the participants filled out a final questionnaire that asked them to compare the scenarios. Each session lasted for about two hours.

Research data were collected by audio recording the discussions and via the questionnaires. The audio recordings were later transcribed and analyzed qualitatively. The questionnaire data were entered into a spreadsheet and were analyzed quantitatively.

### 5.6 Results

#### 5.6.1 Scenario 1: Emotional Communication with Family
According to the participants, the best things in the first scenario were the possibility of seeing facial expressions and gestures, and the feeling of being in the same space (provided that these would actually be achieved). The participants did acknowledge that achieving these things requires very advanced and high-quality technology. They also noted that being able to hug the other person somehow would be a nice additional feature.

The worst aspects of the first scenario identified by the participants were the lack of real physical presence and that the situation might feel too artificial and virtual for effective emotional communication to take place. They thought that emotional encounters require the real presence of another person, which cannot be fully replaced with virtual means. The participants also felt that the appearance of the avatars and the environment is more important than in the other two scenarios and they should be as realistic as possible. Related to this opinion, they wondered how it would be possible to make the avatars and the environment realistic enough that their potential flaws would not interfere with the experience. The users of the system may, for example have memories related to the virtualized use environment – like the childhood home in the scenario – and the virtual representation of the environment should match the memories. Lastly, the system was seen as being quite technical and requiring a high level of skill in order to use it to its full potential.

In the scenario questionnaire participants indicated that, of all the given options for emotional communication, videoconferencing, the MR system and a normal phone call are the best options, in that order. Their explanation for this choice was that in emotional communication it is important to see facial expressions and/or to hear tones of voice to be able to interpret emotions and with these three options that is possible.
5.6.2 Scenario 2: Having Fun with Friends

The participants indicated that the best things in the second scenario were: 1) being able to share the same virtual space and interact with virtual objects and 2) that it was a nearly realistic representation of actually spending time with friends. The participants also saw it as an environmentally-friendly option for meeting friends since there is no need for travel.

However, the participants had doubts about whether the technology would be accurate enough to permit playing a game that requires a high level of precision. The system also lacks physical presence and spontaneity, which often is part of spending time with friends: users cannot, for example, spontaneously, decide to go out for a meal together. Regarding the experience, it was noted that the remote users of the system might feel like unequal participants, compared to those who are using it together in the same physical place. The situation could be more equal if everybody was using it alone from their own homes.

The results of the scenario questionnaire indicated that the MR system was considered to be the best application option for this scenario because it provides a good combination of gaming and socializing and is fitting within the context of “having fun” in general. The participants said they would use the system mostly with friends who they cannot meet in reality (due to time, distance, etc.), and also as a supplementary application in other cases where it is not practical to meet with people face-to-face.

Regarding the avatars in the context of this scenario, the general opinion was that facial expressions and gestures should be as realistic as possible, but otherwise the characters do not necessarily have to look like the people they are representing. The participants thought that in this type of scenario it would be fun to have the option to look like a real person or, for example, to take on the appearance of a favorite fantasy character.

5.6.3 Scenario 3: Having a Meeting at Work

According to the participants, the best things about the third scenario were the system’s illustrative features: the ability to show 3D building models to others, to interact with the models and even to go inside them. The participants anticipated that the models could be very useful tools, if it was possible to make changes to them during a meeting (and, likewise, to cancel the changes, copy the models or move them). In addition, other benefits of the system in this scenario included that it is efficient and saves time and money by eliminating the need for travel.

One of the shortcomings identified in this scenario was the lack of live contact, but in this case it was not seen as crucial an issue as for the other two scenarios. Also, concerns were again raised about the technology that would be required: would it be accurate, what skill level would be required to operate it, and would there be any significant glitches. It was also opined that the system should be flexible and integrated with existing work-related systems. Participants wondered whether all users would enjoy the virtual elements and if they would have a similar 3D experience; users might have varying skill levels or may have individual physical differences or limited senses (e.g. eyesight) that might inhibit them from taking full advantage of the system’s capabilities.

The questionnaire results indicated that the MR system was thought to be the best application option for having meetings at work. Participants explained that the MR system’s illustrative features were clearly the best for showing virtual building models (and other work-related presentations), but it was noted that such presentations would also be possible in some form in videoconference and a virtual world. The participants stated that the MR system is well-suited for communications involving this kind of factual information exchange and it was described as practical, useful, efficient, and cost-effective. In work context, more focus is placed on the presentations, materials and information being exchanged than on feelings; also, effective communication in this context is not as dependent on subtle body language. The participants thought that the physical appearance of avatars in this scenario was not very important, but stated that if avatars were used they should look as realistic as possible – especially their facial expressions.

5.6.4 Comparison of the Scenarios

In the final questionnaire most of the participants (13/18) indicated that advanced technology such as the MR system works best in a work-related context. The participants considered the system’s illustrative features (i.e. being able to show and interact with various 3D objects) as most useful in a work context, because they facilitate the presentation of factual work-related information. The general consensus was that the MR system is more appropriately used for communicating utility information than emotions, because friendships and family relationships require a real physical presence.

However, five participants thought that the system worked best in an entertainment context, such as having fun with friends. Their opinion was that the system had most potential in this context because of its possibilities in terms of the appearance of avatars and the ability to play mixed reality games. As with the work-related scenario, effective emotional communication was not seen to be as important for entertainment-based interactions (even if those interactions were with family and friends). None of the participants thought that the system would be most suitable for emotional communication.

The scenarios were also evaluated on a semantic differential with 12 word pairs describing the anticipated UX of using the system in each of the scenarios. On average, as illustrated in Figure 2, “having a meeting at work” received more positive evaluations than the other two scenarios on seven of the word-pairs.

A Kruskal-Wallis test was used to determine if statistical differences existed between any of the scenarios in terms of their scores. The test indicated significant differences regarding four word pairs (bolded in Figure 2): “impractical-practical”, “senseless-sensible”, “unnecessary-necessary”, and “useless-useful”. Then, to identify the differing scenarios regarding these four word pairs, pairwise comparisons were conducted using Mann-Whitney U-tests. Significant differences were found between the scores for the emotional communication scenario and the meeting scenario for the word pairs “impractical-practical” (means: 0.4 and 1.4, p=0.013) and “senseless-sensible” (means: 0.7 and 2.0, p = 0.004). In addition, there was a significant difference between the scores of the fun-related and work-related scenarios regarding the pairs “senseless-sensible” (means: 0.9 and 2.0, p = 0.006), “unnecessary-necessary” (means: 0.7 and 1.9, p = 0.002) and “useless-useful” (means: 0.6 and 1.9, p = 0.001). There were no significant differences between the having fun and emotional communication scenarios. These findings emphasize the participants’ notions on the pragmatic value that the system could add to work-related context.
DISCUSSION AND FUTURE WORK

6.1 Discussion of the Results

In general, the idea of using MR in interpersonal communication was seen as interesting and welcomed, but its novelty and futuristic nature also raised doubts. According to the participants, the most important benefits of MR communication included an enhanced feeling of social presence, efficiency, and richer communication compared to other more traditional communication methods. Rich communication can be realized in different ways depending on the use context. For example, realistic multimodal interaction can enhance emotional communication, engaging games are effective in the context of entertainment, and illustrative virtual elements can enhance workplace tasks and meetings.

The participants in both studies expressed some concerns about MR communication, such as technical reliability and the usability of advanced MR systems. The second study elicited additional concerns, such as the accuracy of interactions with virtual objects, the realism of avatars and virtual environment, the lack of a real physical presence, and a loss of spontaneity. Furthermore, they expressed concerns about the equitability of user experiences with MR systems: MR technology may create challenges for some users whose skill levels or physical differences (especially those related to eyesight or other senses) might impair their ability to use the technology to its fullest potential. The location of participants relative to those of other users when using collaborative group applications might also be a source of unequal user experience.

As for realism, the participants expressed a preference for the most realistic possible depictions of users (as represented by avatars) and of the virtual environment, especially in emotional communication contexts. Another option for complete realism is “enhanced realism”, which would mean improving the appeal of the realistic characters and the environment with virtual means, for example by adding fantasy elements to the characters (e.g. wings), or making the virtual room look more visually pleasing than the real thing. However, if virtual improvements are made, their targets should be selected carefully and it should not be done to the extent that they are perceived as overly false.

The 21 scenarios that were created by participants in the first study were rather diverse, yet a few conclusions could be made from their common characteristics. The scenarios’ situational contexts fell into six categories: meeting friends or family (5 scenarios); working (4); shopping (4); informing a user about his/her surroundings or location (4); entertainment (3); and communicating about health (1). The diversity of the scenarios shows that the participants saw potential in applying MR in many different contexts. However, when they had an opportunity to envision what kind of technology would be used in the scenarios, they mostly contended themselves with familiar devices such as computers and mobile phones, but often enhanced these devices with MR-related gadgets (e.g. “dataglasses”).

In the second study, the participants determined that the scenario about a work-related meeting was the best context in which to use the MR system. The second best scenario was having fun with friends, leaving emotional communication with family in the third place. An interesting notion is that perhaps the emotional scenario was not, in fact, very emotional, which might implicate that participants’ reactions might have been stronger had a “more emotional” scenario been presented. Emotional communication seems to be a thing that people prefer to do face-to-face or with less technical and more humane applications (e.g. a phone call).

Having a meeting at work was a familiar situation for the participants and they were also used to engaging with technology in that context. They thought the benefits of MR would be most significant in a workplace scenario, although the system was seen to have clear potential in entertainment contexts as well. It was also highlighted that advantage should be taken of the many possibilities that AR and VR offer that allow people to interact and engage with each other in a way that is not possible with current communication technologies. In addition, the perception of the social presence of others – through an immersive virtual environment – is a goal that is worth pursuing in all use cases.

6.2 Methodological Discussion

A limitation of studying the usage of this futuristic technology is that the concept of mixed reality can be difficult to grasp for people who are not very technically-oriented or otherwise familiar with the topic. Despite thorough introductions to the topic, we cannot know for sure how well our participants understood the concept of MR and its possibilities; that said, we did not observe evidence to suggest that this issue affected either the discussion or the scenario creation in a negative way. However, there is still the possibility that participants might not have been able to express some of their potential needs for this futuristic technology because they could not imagine what might be possible to do with it [1].

Regarding the first study, the reliability of the results might be affected by the fact that the participants had a limited amount of...
time for creating the scenarios (20 minutes / scenario) and thus did not necessarily plan them very thoroughly. Some of the resulting scenarios might have been representing the first thing that came into the participants’ minds, instead of something they felt they would need or would like to do with the technology. In future focus group studies more time should be allocated to similar ideation activities. However, the goal of this study was to generate many ideas from the participants without criticizing or directing the brainstorming process, which was achieved despite the limited time.

In the second study, the scenarios and the example MR system were designed to be fairly detailed and props were used when presenting them to help the participants immerse themselves in the use situations. Supposedly these means helped participants to reach a common understanding of the scenarios and the system, but the prescriptive details might also have partly restricted the participants’ thinking. Also, the “meeting” context of the highest-rated scenario was very familiar to most of the participants due to their backgrounds and thus it is possible that they favored it more than participants of another background might have. But overall, the conversational approach to future technology – achieved with the focus group method and scenarios – allowed rather winding and fruitful discussions to emerge in both studies which proved the usefulness of this kind of method in the context of MR.

6.3 Future Work
Our aim for future research is to eventually test some scenarios with users by using a fully functional mixed reality communication system. This study allowed us to gather insight about the participants’ expectations of using advanced MR communication technology, which can help us and others when designing such systems. However, a study on actual user experiences with a functional system and more specific user designing such systems. However, a study on actual user experiences with a functional system and more specific user needs as well as the usability of the technology.

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8. REFERENCES


