A New Mask for a New Normal: Investigating an AR Supported Future under COVID-19

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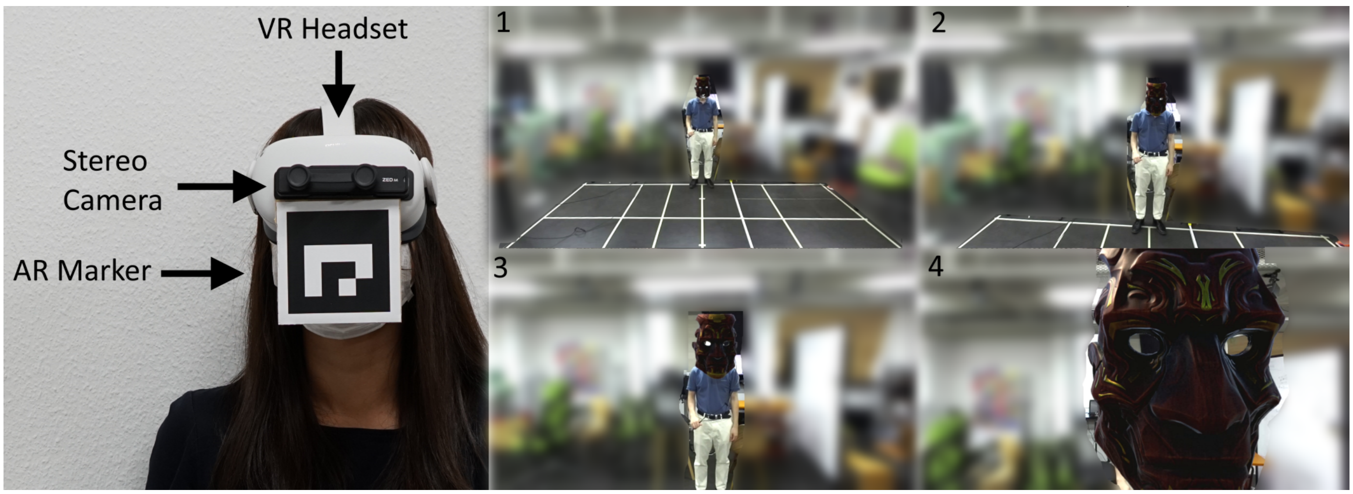

Figure 1: An overview of the system and the user's experience. The far left shows the system. It consists of a head mounted display with a stereo camera and augmented reality marker. The sequences of figures on the right show how users see a virtual mask projected on a wearer's face. The mask moves with the wearer's face when sufficiently distant, but accelerates towards the observer when in closer proximity. Herein, we speculate on a future where such interpersonal interactions are the norm.

ABSTRACT

Wearing masks and social distancing have become the norm during the COVID-19 pandemic. However, these are increasingly seen as a source of frustration in face-to-face communications. While efforts have been made to overcome these impediments to communication, they typically focus on recovering lost communication quality. Herein, we envision a future where everyone augments their vision using face masks with Augmented Reality capabilities, such that people can conduct safe and expressive face-to-face communication in public. To speculate on this vision, we developed an AR mask prototype which can overlay dynamic virtual "masks" on other users. The virtual mask is dynamic in that it accelerates towards any observer who approaches the wearer. Using this system, we conducted an explorative study to further our speculations on the impact of ubiquitous AR technologies.

CCS CONCEPTS

• **Human-centered computing** → *Collaborative interaction.*

KEYWORDS

COVID-19, mask, social distancing, augmented reality, virtual reality, speculative design

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1 INTRODUCTION

Since the advent of COVID-19, many preventative measures have been introduced and put into practice to reduce the rate of infection and its impact on human health. Common measures include the wearing of masks and maintaining a degree of physical distance (social distancing) to minimize exposure to aerosols which may carry infectious agents. The former was demonstrated to be effective at decreasing the chance of infection at an early stage of the pandemic and has been integrated into several national policies [29]. The latter has also been shown to be effective at reducing the chance of infection [11].

However, both masks and social distancing have been reported to increase the psychological distance between interacting persons. Masks hide an individual's face and mouth, making it difficult to identify expressions and impeding vocal communication [31]. Social distancing similarly impedes communication by requiring persons to be more distant than most would find comfortable under pre-COVID norms [15]. Such impediments to smooth communication can result in miscommunication and frustration, which in turn results in increased stress and a greater perceived interpersonal (social) distance. While a return to pre-pandemic normalcy and freedom from such impediments is desirable, the future of COVID-19 is still uncertain and there is a need to consider a future wherein we coexist with these new norms [5, 36]. For example, there may be a need to define a new standard of face-to-face communication which enables smooth communication while meeting standards for safety.

Herein, we envision a future where people partake in a form of in-person communication that is not bound by pre-pandemic norms. In the future we envision, people continue to wear masks every time they leave their home. However, inspired by the freedom of appearance that virtual meetings afforded them, people in this future make extensive use of augmented reality (AR) technologies to augment their vision such that they may appear and see as they wish, even when face-to-face. In this future, city streets are populated by people who wear masks with integrated AR capabilities (an AR mask) while also presenting expressive virtual faces to the world. Public transit vehicles are utilized by people who appear larger or closer than they physically are, such that physical distancing is maintained without conscious effort in enclosed spaces.

In this future, the virtual and physical world are mixed to promote effective face-to-face interactions under safe conditions. People may, for example, avoid each other on the street, perceiving a sense of physical proximity due to larger-than-life virtual avatars. They may be able to feel a sense of intimacy despite interacting out of reach of each other. They may be able to express themselves in novel ways due to the freedom of visual appearance that virtual avatars provide. Others may become more sociable due to the partial anonymity that being covered with an AR avatar affords.

On the other hand, there may be individuals who either reject the ubiquity of AR masks or exploit them for malicious intent. Concerns regarding privacy and security around AR technologies are becoming more common as it matures [12, 38]. People may dislike having their images captured and processed at all times. Others may have concerns regarding whether what they are seeing is real. Finally, given that AR includes a digital component which is augmenting what users see, there will always be concerns regarding unauthorized augmentations which may harm users. Forcibly obstructing one's view or making it impossible to identify a malicious actor are but a few examples.

Herein, we take a speculative design approach to further our speculations and fully flesh out our vision of the future. We achieved this by first designing a prototype system which simulates this future. The prototype we developed is an augmented reality system making use of commercially available components, which allows one to place virtual objects upon others. While not technically novel, it suffices to provide the experience of augmenting the appearance of others in real time. This system is used to place virtual masks, which can take any appearance and dynamically change (in position, shape, or behavior) based on interpersonal distance, on other users. The virtual mask adds an element of distant dependent variability to visual appearances, which can be leveraged to promote effective and comfortable communication at a safe distance. We primarily focused on a virtual mask which moves towards any observer who approach within a given distance, as this most simply and directly embodies our vision of augmented appearances with a spatially dependent component affecting interpersonal distance.

Users were then asked to use the prototype and participate in preliminary studies exploring usage and interpersonal interactions using the system. Users were first asked to interact with another individual, both with and without the system. Then, they experienced conversing in a society where all members were using the system. Finally, we conducted semi-structured interviews with the study participants to gain insight into the reasoning behind their behavior and their opinions on the future we envisioned. By observing user behavior and interactions while using the system and conducting interviews, we sought to identify the societal implications of wide-spread use of AR technologies and hurdles to general acceptance of the technology, as well as improvement points to our prototype system.

This work contributes an AR system with an interaction designed to facilitate safe and effective face-to-face interactions under COVID-19. We additionally contribute insight into the societal implications of wide-spread use of AR technologies and unique interactions observed due to the use of our system in interpersonal interactions. Finally, this work contributes an instance of speculative design being applied to everyday living under COVID-19. Namely, we believe that it will serve as a seed for discussing how technology may be used to support a new normal given the continued persistence of COVID-19 and its variants. While this work focuses on exploring the application and impact of ubiquitous AR technology for supporting face-to-face communication in these times, the same line of thought could be applied to considering the possibility and impact of popularizing other technologies (e.g., telepresence and robotics) to support day-to-day living under COVID-19.

2 RELATED WORKS

2.1 Communication under COVID-19

The COVID-19 pandemic has resulted in many barriers to socialization [17, 33, 44, 50]. The Centers for Disease Control and Prevention, for example, continues to recommend wearing masks, avoiding crowds and poorly ventilated places, and staying at least 6 ft from away from others to protect oneself from infection [8]. Given these restrictions, many social functions and events have ceased operation and people are having fewer opportunities to meet face-to-face.

When face-to-face interactions are conducted, they are typically conducted at a distance from behind masks and barriers designed to minimize the likelihood of infection. Such communication is often of lower quality and can result in communication frustrations [20, 32, 39]. Even when relatively safe in-person communication is achieved, communication impeded by infection prevention measures are often noted as being more challenging due to occluded facial expressions [7, 30, 40].

People have turned to other channels to make up for these now highly restricted, traditional communication methods. For example, teleconferencing services such as Zoom and Skype have seen a surge in uptake over the previous years [2, 6, 9]. Social media has similarly seen an increase in usage as a form of wide-range asynchronous communication and a far-reaching information dissemination tool [47]. Even emerging forms of communication and entertainment, such as virtual reality, have seen heavy growth over the past year and are under consideration for use in workplace environments [28].

Despite their strengths, however, these channels of communication are often still seen as insufficient alternatives to face-to-face communication. This is especially the case in institutions where face-to-face communication was an integral part of their operation (e.g., education and healthcare). Research investigating online education during the pandemic, for example, identified numerous challenges which were not present in a classroom setting [2]. In terms of healthcare, a review of research investigating patient satisfaction with remote healthcare showed that many patients would still prefer face-to-face services when presented with a choice [19]. Both research and popular opinion, then, indicate that neither the current state of face-to-face communication nor any of the alternatives are ideal for effective communication in these pandemic times. However, these are judgments made with an idealistic pre-pandemic world in mind. To overcome the challenges of a post-pandemic future, there is a need to consider novel solutions which define their own, new futures in which the solution is commonplace and coexists with the restrictions put in place by the pandemic.

2.2 Facial Representation and Augmentation

One approach to overcoming physical occlusions and barriers in face-to-face communications is to add a virtual layer using digital technologies which allows effectively seeing through the obstructions such as masks. Commonly taken approaches include projections (e.g., optical camouflage) [37, 42] or displays [16, 26, 43, 45] which are placed over face coverings. In [42], the authors developed an omnidirectional projection system which projects lip animations onto people's faces. In [43, 45], the authors developed a full face mask which displays a digital avatar reflecting the wearer's head motions and facial expressions. Presented in [16, 27], are face masks with integrated displays that are capable of depicting the wearer's facial expressions.

Another approach which could be used to overcome obstructions in face-to-face communications is Augmented Reality. Namely, augmented reality could be used to place virtual representations of other user's faces over face masks or any other occlusions. Due to its primarily virtual nature, this approach does not suffer from some physical limitations of the above-mentioned approaches (i.e., needing to be in the projection range of a projector or visual representations being limited to the area of the wearable display). Use of augmented reality has, however, primarily been used to augment appearances in specific, episodic circumstances. Examples include selfie filters for taking pictures or short videos [48] and virtual clothing fitting systems [35]. While the potential for augmented reality to resolve issues such as facial occlusions exists, it is only recently that the possibility of persistent, first-person augmented reality has become available to consumers in the form of affordable augmented reality hardware. Given industry trends, augmented reality may become as ubiquitous as smartphones in the near future [34, 49].

In our work, we explore the possibility of utilizing augmented reality to support face-to-face communication. Namely, we consider a world where augmented reality is commonplace and everyday interactions are conducted through a reality consisting of both virtual and physical entities. This is not the world we live in now, but a possible future given the current state of the world and technological trends. We propose this future as one possible approach to creating a new normal wherein people are able to practice safe and comfortable in-person communication with the assistance of technology. However, developing such approaches inherently requires speculating about the future in which the approach was applied to.

2.3 Speculative Design

Herein, we take a speculative design approach to investigating how effective our approach may be at facilitating communication under COVID-19. Speculative design, a term proposed by Dunne and Raby, refers to a design approach wherein one speculates on a future and designs a product/service which serves that future [14]. It serves not only to generate products, but to generate ideas and debates regarding the future and critically examine current practices [3].

Examples of speculative design include the "Stop Nigmas" project, which explored the future of privacy and surveillance [25]. This project made use of social media to engage the public and draw participants into the process of speculative design. They generated the future they desired to speculate using public art and social media, and disseminated the future vision in a way that allowed both the designer and audience to participate in speculation. Similarly, in [41], the authors investigated how emotional relationships with urban places can inform the design of novel technologies and services. In this work, the authors first gathered qualitative data from potential stakeholders (everyday residents in urban areas) and then created speculative design fictions depicting possible future scenarios.

In this work, we propose and speculate upon a future wherein ubiquitous and wearable technologies have been used to facilitate masked and distanced in-person communication to consider how the scientific community may contribute to the world as COVID-19 continues to persist. In particular, we closely examined the use of AR/VR techniques to support face-to-face communication in these times and sought to bring to light how humans behave and feel in this future. We did not seek agreement with our vision or to encourage widespread use of it. Rather, we sought to provide an opportunity to consider and discuss possible solutions to an existing, and likely persistent, problem.

We achieved this by first designing a prototype system which allows users to have first-hand experience of the future we envisioned. Then, we presented our prototype to users and exposed them to this future over an extended period. Finally, we conducted a series of interviews to obtain their thoughts and feedback regarding both the prototype and the potential future it allowed them to experience. After acquiring our data, we analyzed both the user responses and their behavior during the experiments to gain insight into our speculative future and our representation of it through our prototype.

3 THE AR MASK PROTOTYPE

The AR Mask prototype assembled for this work, Fig. 1, consists of off-the-shelf AR hardware (e.g., a VR Ready computer, a commercial head mounted display, and an AR camera) and software for projecting virtual objects onto other users. The AR hardware was arranged to resemble a full-face mask, with the mouth covering doubling as an AR marker which serves to identify the user and provide a positional reference. The software, developed upon the Unity platform, recognizes, and locates the AR marker and overlays a virtual object onto a real scene, the result of which is presented to the user through the head mounted display. The software also controls the behavior of the virtual object. In our implementation, the virtual object was a mask which follows the face of the wearer and move towards observers who approach within a given distance, Fig. 1.

When the observer is at a far enough distance, the mask is on the wearer's face. Once the wearer and observer close within a certain distance, the mask moves ahead of the wearer to approach the observer. After approaching to a given distance, the mask stops. Specifically, the distance between the mask and the observer follows:

$$d_v(d_r) = \begin{cases} d_r > 2.7 & d_r \\ 2.7 > d_r > 1.6 & {d_r}^4/20 \\ 1.6 > d_r & 0.3 \end{cases} \quad (1)$$

where d_v is the distance between the observer and the virtual mask and d_r is the distance between the observer and the AR marker (i.e., the wearer). The approach function was designed such that the mask would appear at a distance of $d_v = 0.8$ m when the users are 2 m apart, and there was a perceptible acceleration in the mask approach when near this point. A distance of 0.8 m was selected based on the distance at which Hall suggested interactions between friends would occur (i.e., the personal space) [18]. This design choice was made to promote the perception of friendly communication while at a distance that diminishes the risk of infection [22]. The point at which the mask transitions from following the wearer to moving ahead of them, $d_r = 2.7$ m, was selected such that the distance function is piece wise continuous. Finally, the near range stopping point, $d_v = 0.3$ m, was selected to ensure the mask would not pass the near clipping plane (i.e., such that the mask would remain in view).

Figure 2: The area in which the experiments were conducted. Tape was placed on the ground to simplify measurement. Participants in the figure are in the middle of Part 2 of the user study.

Closing the distance further causes the mask to grow at a rate inversely proportional to the distance between the observer and the wearer to give the perception of even closer proximity. Namely, the mask's size scales as follows:

$$s_v(d_r) = \begin{cases} d_r > 1.6 & 1 \\ d_r \leq 1.6 & 1.6/d_r \end{cases} \quad (2)$$

where s_v is a scaling factor determining how large the mask is relative to its original size ($s_v > 1$ indicates that the mask is enlarged). We designed the mask to increase in size after reaching a distance of $d_v = 0.3$ m to invoke a heightened sense of proximity without having the mask cross the clipping plane. This behavior was presented to users during the experiment described in Section 4.

It should be noted that this approach to assisting socially distanced communication is not restricted to being used with the system presented herein. A multitude of other viable hardware and software components exist which could have a similar effect. The components presented herein are for the proof-of-concept system developed in our lab.

4 EXPLORATIVE STUDY OF AN AR MASKED SOCIETY

The explorative study we conducted consists of two parts. In the first part, users were asked to interact with a single other individual also using the system under several conditions and scenarios. In the second, users were asked to simultaneously interact with multiple other individuals using the system, as if in a society where AR Masks had become commonplace. All experiments were conducted in a 5 m × 5 m space with markings every 1 m, Fig. 2.

A total of nine individuals, with ages in the range of 20 and 50, participated in the study, with each participant being awarded with 2,040 JPY for their participation. The nine individuals participated in the study as three groups of three individuals. One user study session was held for each group, with each session lasting approximately one hour.

Figure 3: A subset of the mask assets used in the user study. Shown in the top row are mask assets from a freely available asset pack. Shown in the bottom row are masks made in the likeness of a real male and female individual.

4.1 Part 1: One-on-one Interactions

4.1.1 Procedure. In the first part of each session, spanning approximately 30 min, each participant, was asked to carry out a series of scenarios with the experimenter. The scenarios were as follows:

(1) The participant approaches the experimenter from the front while both wear a normal face mask of their choice.
(2) The participant approaches the experimenter from the front while both wear the AR mask system with no virtual mask.
(3) The participant approaches the experimenter from the front while both wear the AR mask system with the virtual mask.
(4) The participant approaches the experimenter from behind while both wear the AR mask system with the virtual mask.

In each scenario, the participant was asked to approach the experimenter starting at a distance of approximately 5 m. They were asked to then stop and interact with the experimenter once they felt they were at a distance where they could comfortably do so [46]. This distance was recorded, and the participant was asked to return to their original position before beginning a new trial. Five trials were conducted for each scenario, such that the total number of trials per participant was 20. Each group of three participants took approximately 30 min to complete all trials. Participants in the same group and not actively conducting the scenario were allowed to observe.

In the fourth scenario, the experimenter additionally turned around after measurements were made. If the participant changed their position because of the experimenter turning around, this final position was also recorded for analysis.

In all trials with a virtual mask, the experimenter wore Mask 1 from the "Masks pack 2" asset from the Unity Asset Store [13], top middle in Fig. 3.

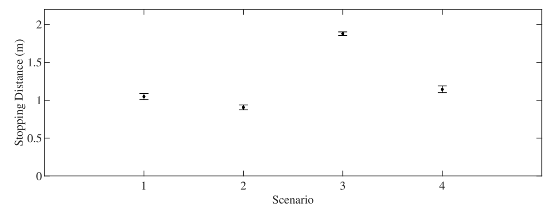

Figure 4: Mean and standard error of the distance at which participants stopped for each scenario. A significant difference was observed between Scenario 3 and all other conditions with p<0.001 and between Scenarios 2 and 4 with p<0.05.

4.1.2 Results. First, we introduce the qualitative observations we made in this first study. In the first scenario, users typically expressed mild social discomfort at being placed in a contrived interaction scenario but showed no notable behaviors. In the second scenario, users typically behaved as they did in the first scenario, although with less spatial awareness and coordination. Some users were seen tripping over equipment. During and after the experiment, some users commented that the wires connecting the computer to the headset were difficult to handle and that the headset caused a narrowed field of view. In the third scenario, users typically exhibited surprise when the mask advanced towards them for the first time. Specifically, most users appeared to try and approach the same distance they reached in the first two scenarios, suddenly stopped when the mask advanced towards them, and backed away to reach a final position. More cautious approaches were observed after this initial surprise, but some users continued to exhibit overshooting behavior. Finally, in the last scenario, nearly all participants uttered an exclamation when the experimenter turned around and backed away. This behavior was observed over multiple trials. Namely, over the course of the study, the users did not change behavior to keep a "safe" distance which took into account the experimenter turning around.

Next, we introduce the quantitative results obtained from our stopping position measurements. The mean and standard error of each participant's stopping distance in each scenario is shown in Fig. 4. On average, across all participants, participants stopped at 1.04 m, 0.90 m, 1.88 m, and 1.14 m before stopping to interact with the experimenter in Scenarios 1 through 4 respectively. The stopping distance of Scenario 3 was determined to be of statistically significant difference when compared to all other scenarios through a Tukey-Kramer test ($p < 0.001, d_{13} = 3.6, d_{23} = 5.1, d_{34} = 3.1$).

In Scenario 4, participants, on average, stepped back from 1.14 m to a distance of 1.80 m, Fig. 5. This was a statistically significant difference, as determined through a two-sample t-test ($p < 0.001, d = 1.9$).

4.2 Part 2: Multi-person Interactions

4.2.1 Procedure. In this second part, all three participants wore the AR mask system and interacted with each other while wearing a variety of virtual masks, 3. The masks included:

(1) masks from the "Masks pack 2" asset pack

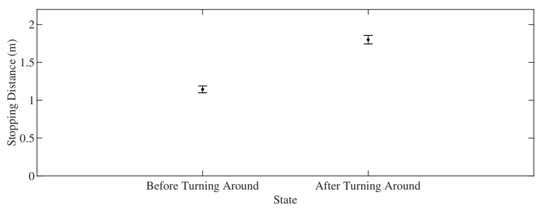

Figure 5: Mean and standard error of the distance at which participants stopped moving before and after the experimenter turned around in Scenario 4. The difference in position was statistically significant (p<0.001).

(2) masks made in the likeness of the participants
(3) masks made in the likeness of a male and female individual who did not participate in the experiments.

Masks in the likeness of real people were generated using the Avatar Maker asset [21]. The masks being presented to the participants were changed by the experimenter over the course of the study.

The users were also presented with a variety of tasks to conduct:

(1) Passing a physical pen among themselves
(2) Walking past one another as they might on a street
(3) Exchanging masks (by exchanging AR markers)

However, participants were primarily allowed to interact with one another freely during the course of this part of the study.

A follow-up interview lasting about one hour was held with each group approximately one week following the user study. This follow-up interview was conducted to query the participants about their behavior during the study, as well as to obtain feedback regarding the system and the future vision that the system was representing. The interview followed a semi-structured format, with common questionsdetermined after reviewing footage recorded during the user study in the one-week period between conducting the study and the interview. These questions were designed to query participants regarding commonly observed behaviors. Additional questions directed at understanding unique behaviors were added as needed.

The questions were posed to the participants while viewing a third person recording of the events of the study. A first-person view of what a participant was seeing at the time was occasionally supplied to supplement the third-person view. Each interview was transcribed for ease of analysis and reviewed for key phrases and recurring themes.

4.2.2 Results. Herein, we highlight notable behaviors we observed and the participants' reasoning behind them, as investigated through the follow-up interviews. We present notable behaviors grouped according to common themes. We conclude this section by presenting participant feedback regarding the prototype system and the future we envision. Note that participants are herein are referred to as P1-9, with P1-3, P4-6, and P7-9 participating in sessions together.

Factors Influencing Perceived Interpersonal Distance

As suggested by the results of the first part of the study, we observed that the system successfully allowed participants to naturally maintain distance between them. At almost all times during the investigation, users with the AR mask on maintained at least 1 m of distance between them when facing each other. Responses obtained in the follow-up interviews indicated that users felt the need to stop approaching each other much earlier than they would normally, and that this need was one that required conscious effort to suppress.

P5: *"Even though I knew it was virtual, I needed some determination not to back up."*

The need to stop approaching was attributed to several sources, including fear of collision and fear of the mask itself for the initial masks:

P1: *"When I first saw it, I was focused on not bumping into the mask."*

This fear of collision was mentioned frequently both during the study and interview and seemed to be one of the primary factors for maintaining distance. For the human-like masks, however, participants also mentioned that they felt that they preferred not to approach the masks as they felt that it may be rude to do so as it was more personal to someone:

P8: *"I felt like I couldn't be rude to the face or comment on it lightheartedly."*

While not observed in this user study, one participant suggested that the relationship the observer has with the wearer and the person the mask represents may be a factor in determining stopping distance:

P2: *"(The stopping distance) might vary significantly depending on the wearer's avatar. I think that the relationship between the observer and the avatar would be a big factor in addition to the relationship between the observer and the wearer."*

However, the need to maintain distance was not present all throughout the user study. For example, when participants were standing side-by-side, participants would occasionally stand as close as they might without the system. The participants noticed this during the interview as well:

P1: *"When facing the others, I felt that they were close. But looking at this video, I see that P3 and I were not facing each other very much. That may be why I was distancing from P2, but not so much from P3."*

When they turn to face each other, they jumped back as in Scenario 4 of Part 1 as their proximity caused the mask to appear very large and cover their field of view. Some participants used this behavior to their advantage, using it to scare other participants or play games. One participant likened the experience to a stare-out game. This behavior suggested some awareness of one's own mask. However, this conflicted with most responses garnered during the interview.

Impact of Appearance on Interactions

Interview responses suggested that most participants were, for the most part, not consciously aware of their own mask and its behavior. Instead, they were primarily preoccupied with observing how others' masks were behaving.

P1: *"I didn't think about my own mask, I was only thinking about the masks of others."*

A desire to be more aware of one's own mask was noted in almost all participants, however. There were several instances during the study where participants commented that they wanted a mirror to see how they looked.

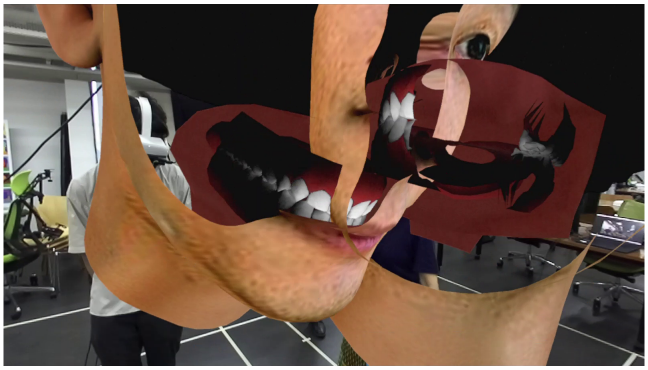

Figure 6: The human-like mask passing beyond the near clipping plane. This allows the observer to see the inside of the hair, the teeth, and the eyes of the mask.

Figure 7: Participants conducting the pen passing task. Participants typically started by leaning back and reaching to pass the pen, top left. Strategies for overcoming the visual obstructions included pushing through the virtual mask, bottom right, and avoiding looking at the AR marker entirely, right.

P8: *"The mask looked creepy, so I became worried what my own mask was like."*

In one instance, a participant took out their smartphone to take a selfie to see their own mask. This was unsuccessful due to the way in which the virtual mask overlay was implemented and the system's inability to recognize the AR marker in the phone's video feed. Participants were only able to observe the masks they were wearing when they exchanged masks.

As participants were mostly unaware of their own appearance, we observed no significant changes in behavior once masks were exchanged. One exception was the sense of anonymity provided by wearing a mask. P2 noted that being told they were wearing a mask which was not themselves made them feel bolder due to the sense of anonymity that the mask provided:

P2: *"When compared to using my own face, I felt more bold when using another person's face and was more able to approach others."*

As briefly noted above, the appearance of others did have a notable effect on participants' perception of each other. The first set of masks, for example, was seen as being more frightening than the human-like masks. The human-like masks, on the other hand, were noted as being uncanny. Participants stated that this was in part due to their static facial features and eyes, as well as the mask's three-dimensional appearance:

P8: *"They were like mannequins. They may have been less creepy if the mouth moved with the wearer's speech."*

The human-like mask's three-dimensional nature also resulted in some strong negative reactions when combined with proximity. When an observer and wearer approached too close, the human-like mask passed beyond the near clipping plane of the visualization. This resulted in the mask being partially cutoff such that the inside of the hair, the teeth, and the eyes of the mask were visible, Fig. 6. This was generally met with an exclamation of fear and surprise from the participants. This exclamation was noted as being greater than the discomfort felt by proximity of the mask.

P7: *"Being able to see the cross-section was grotesque."*

Notable Behaviors in Close (Physical) Proximity

Other notable behaviors in which users perceived proximity were observed during the pen passing and street passing tasks, both conducted with the initial masks. In the pen passing task, participants were observed struggling to maintain distance while reaching to pass the pen. Participants reported attempting to maintain distance because their counterpart's mask obstructed their view to the point of not being able to see their own hand. Fig. 7. Several strategies, including angling the head and looking away, were developed by the users to successfully pass the pen. One unique strategy taken by P8 was to push through the mask to see their counterpart and successfully pass the pen. When queried about why they pushed through, they responded:

P8: *"I did see the mask as being large, but since I had the task of passing the pen, I tried various things to pass the pen and wasn't thinking too hard about the mask."*

This indicates that having an objective was sufficient for this user to view the mask as an intangible obstacle and overcome their sense of needing to keep their distance.

During the street passing task, we observed participants initially heading towards each other in a straight line and rapidly veering to avoid each other before passing. This behavior was observed both when participants walked directly towards each other and when they were walking towards each other on offset paths, although to varying degrees. When offset, participants diverted less strongly. Responses from the interview indicated that users saw their counterpart's mask approach them very quickly, and that this caused them to divert to avoid it. After looking at the third-person view during the interview, several participants noted that they appear to be diverting earlier and more significantly than they had intended. This was a common occurrence, in that the participants remembered many of their reactions as being more muted than they saw in the third-person video recording.

Asymmetric Behaviors due to System Failures

Technical issues during one of the user studies led to an asymmetric situation, one participant was effectively left without a virtual mask. Namely, two of the participants could see the third participant without a virtual mask, while the third participant continued to see the first two participants with the mask. The result was the participant left without a mask, backing away up as two participants still wearing masks approached closer. The asymmetry in mask wearing had resulted in an asymmetric sense of proximity. After inquiring about the participant's intentions during this event, we discovered that the participant who lost their mask was unaware of the situation and wondered why others were approaching so close. The participants who retained their masks, in contrast, found that they naturally moved closer.

Feedback Regarding the Prototype and the Vision

After viewing recordings of themselves and being queried during the interview, participants were asked to provide feedback regarding the prototype system. Most of the feedback presented was feedback common to many AR systems. These include the heaviness of the headset resulting in fatigue, system latency and the unstable wearing experience resulting in VR sickness, and the narrow field of view resulting in inconvenience. Other feedback was directed at the ability to customize the experience provided by the system. P7 noted that it may be desirable to allow users to adjust how quickly and when the mask begins to approach the observer. P3 similarly noted that it might be desirable for a wearer to choose which mask they wear. All the comments were directed towards making the system more usable in daily life.

Finally, with daily use in mind, participants provided their thoughts on a society where wearing a mask like the prototype system has become commonplace. Much of the feedback, as well as comments during the user study, described such as society as dystopian, referring to worlds described in science fiction works like the Matrix and Ghost in the Shell. For example, P1 mentioned that people wearing masks at all times would mean it would become difficult to identify people and make it possible to easily change places with others. They also mentioned that they felt that, despite the appearance of becoming closer, physical distance between people would grow wider, as struggles during the pen passing task showed. P6 mentioned that it would be horrifying to wear the system at a busy location where many people are crossing paths at once, such as a busy intersection, and that they would likely not want to use the system in such a situation. P8 stated that they could not imagine it being used in everyday life, especially with the current low-resolution, static implementation.

Other feedback was more supportive but pointed out concerning side effects of such a system becoming ubiquitous. P2 noted that the anonymity that the mask provides might result in a decrease in a sense of responsibility. P3 mentioned that the culture behind having someone remember your face might fade away if everyone was able to change appearance at will. Furthermore, they speculated that it would be difficult to return to one's original self if users always wore a mask of their choice. P4 noted that the mask approaching the wearer could be interpreted as paying attention to the observer and could be taken as such a signal regardless of the wearer's intentions. P5 similarly noted that the act of approaching someone could be interpreted as being friendly, regardless of the intention of the wearer.

Other feedback focused on the benefits of the system and how it could be used or improved for use. P2 stated that the system was convenient for closing the perceived distance with only small motions, and that it also seemed good for allowing embodiment of an avatar without the need for full-body tracking. P3 noted that the system seemed effective at allowing users to maintain a distance without conscious effort. P7 stated that the approach function would need to be tuned to be appropriate based on setting or personalized to fit an individual's needs. P9 suggested that the system could be used to highlight the social proximity of people who tend not to realize they are overstepping their bounds, even under normal circumstances.

5 DISCUSSION

Herein, we provide a discussion based on the data we collected throughout the user study. We begin with a direct discussion of the results and our intended effect, naturally distanced interpersonal communication. Then, we discuss the technical improvements which could be made to our system and industry trends towards more widespread adoption of AR systems. Finally, we conclude this paper with a discussion of our revised speculations on the future we envision, including ethical concerns which were highlighted during the user study and subsequent followup interviews.

5.1 Effects on Perceived Interpersonal Distance

Results from both parts of the user study, Secs. 4.1.2 and 4.2.2, indicated that the system successfully allowed participants to maintain a significantly larger distance while communicating with each other. The reasons for being able to maintain this distance were somewhat varied. Some participants commented that they felt that others were closer to them. Most comments, however, indicated that participants maintained distance out of a sense of fear. Some fears mentioned during the user study included fear of collision, the mask's appearance, and being rude. While our system was able to invoke fears, it was not able to induce a sense of intimacy.

Ideally, the proposed system should promote safe, physically distanced communication which can convey a sense of intimacy. For example, one can imagine remapping the regions of physical distance to regions of perceived interpersonal distance. 'Social distance', typically considered to be within 1.2 - 3.7 m, to be between 2.5 - 5 m, and 'personal space', typically 0.5 - 1.2 m, to be between 1.0-2.0 m, Fig. 8. Achieving this remapping for every individual could contribute to safe and enjoyable in-person communication, even under the COVID-19 pandemic. However, in this regard, the proposed system can be said to be relatively ineffective. As noted above, the masks tended to invoke negative feelings in the observers, and observers settled into a comfortable distance as a means of avoidance. In our prototype, distancing was achieved, but the sense of intimacy which typically accompanies proximity was lost. This was most noticeable in the pen passing task. As P1 noted in the interview:

P1: *"(Even though others look closer) I feel like we would be even less likely to physically touch each other. We couldn't even pass an object between us. I imagine this to be a more divided world."*

As such, the current implementation of the system, while successfully achieving its primary purpose of promoting distancing, has significant issues which must be addressed before being an ideal solution to the problem of physically distanced communication.

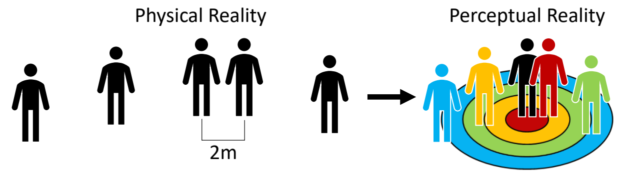

Figure 8: An example of remapping perceived interpersonal distances. Here, individual A would be perceived to be in the unmarked individual's intimate space despite being a distance of 2 m away. Likewise, persons B, C, and D would be perceived as being in the unmarked individual's personal, social, and public space respectively.

5.2 Future Work on the System

Many of the issues and points of improvement reported by the participants were ones common to modern AR systems. Some examples include system weight, stability, latency, and comfort. These issues, however, are expected to be resolved in the near future. Virtual and augmented reality has received an increasing amount of attention in the commercial market in recent years, and an increasing number of companies are showing interest in this sector. This has led to the release of readily available and affordable VR/AR hardware in the last year. As commercial interest in the area grows, development of the devices is expected to accelerate, and resolve most of the hardware-centric issues which were identified in the prototype. Issues with the interaction and underlying system, however, are design issues unique to our vision which must still be addressed. Careful consideration is necessary to design an interaction which invokes a need for distance while also conveying intimacy.

A sense of interpersonal proximity while maintaining distance could be generated by providing multimodal stimulus. As mentioned by P6, for example, intervention in audio to make the wearer's sound come from the mask may have improved the sense of proximity. Other candidate modalities include the sense of touch and heat, both of which can be strong indicators of proximity, as they typically require contact to be conveyed.

Finally, adding a user-controllable element to the system may accelerate both design and acceptance into society. In terms of design, allowing users to choose interactions and appearances can give the designers references as to what is considered desirable. In terms of acceptance, the ability to personalize things associated with oneself (i.e., having a degree of choice) has been shown to result in greater degrees of acceptance [24]. These will all be considered in future work as we continue to explore the vision of a masked future supported by augmented reality technologies. Overall, while our study has shown that our concept of using AR technologies to overcome the impediments generated by masks under the COVID-19 pandemic, there is much technical and design work necessary before it can be used effectively and for widespread commercial use.

5.3 Revised Speculations on the Vision

Our focus at the beginning of this research was on exploring interactions in a society where AR had already become commonplace. The data obtained from our study served to fill in the details of our vague image, such as unique troubles which could occur while using AR, and our proposed system, in daily life. Responses from P4 and P5, for example, enlightened us to the fact that reactive movement of the mask (independent of the wearer's motion) could result in misinterpreted intentions. While such occurrences exist even in typical face-to-face communication (e.g., misinterpreting a wave which was meant for someone else), they would certainly become more commonplace if the motion of virtual objects was a complex combination of both the wearer and observer's motion. Similarly, a comment by P6 highlighted the need to consider many people interacting at once and the combined effect of many virtual masks approaching an observer. Furthermore, it highlighted the need to consider the impact such a future could have on crowd psychology and not just on interpersonal interactions.

Our study additionally allowed us to elucidate some of the ethical concerns which might result from common use of such a system. These ethical concerns include common ones associated with the widespread use of AR technology, such as security and privacy, but also included ones which are concerned with the use of avatars to represent oneself. The degree of anonymity afforded using avatars, the potential for identity theft, and the possibility of malicious interventions into sight are a few examples of topics which were touched upon in the interviews. The former two have been widely discussed in literature discussing identity in the computer age, especially in the context of the internet and virtual reality [1, 10, 23]. The last has parallels in discussions on security around the internet of things (i.e., the idea that a malicious agent could gain access to your home and physical environment) [4]. However, in this case, it is not the physical environment that surrounds the user, which is in jeopardy, but the user's perception of it. One can imagine, for example, a driver's view being obstructed by a virtual object as they round a turn. Secure use of the technology while still allowing casual and widespread use will, therefore, be a major topic which must be addressed as AR gains common use. As a whole, our speculation on our vision of the future would benefit from a closer examination of the errors and exploits which become possible due to the introduction of ubiquitous AR into society.

6 CONCLUSION

In this paper, we presented our vision of a new normal under COVID-19. In this new normal, people live everyday life outside their home in a mixed reality generated through augmented vision where both virtual and physical objects coexist to facilitate safe and effective interpersonal interactions. To explore this future, we took a speculative design approach and developed a prototype system which allows users to gain first-hand experience of the future we envision. Specifically, we developed an AR system and novel interaction designed to facilitate natural distancing between interacting parties. The system consists of commercially available AR hardware arranged in the form of a full-face mask, and the interaction consisted of a virtual mask which moves towards an observer if they approach too closely to the wearer. We used this prototype in an explorative study to obtain feedback regarding our implementation as well as our vision of the future. Through the user study, we were able to verify that the prototype can invoke naturally distanced communication. At the same time, user feedback brought to light the many technical and ethical concerns which must be addressed as AR technologies become ubiquitous and are employed by the general population to support daily activities under COVID-19. Finally, we believe this study will serve as a seed for discussion about how we may define a new normal where various technologies ubiquitously support life under COVID-19.

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