Exploring Eye Visibility and Mutual Gaze in Augmented Reality Glasses

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Fig. 1. A: Adaption of Pervasive AR would lead to a lack of mutual gaze amongst users due to the opacity of the AR devices. B: Participants evaluated Snap Spectacles (top-left), Microsoft Hololens 1 (top-right), Microsoft Hololens 2 (bottom-left) and Magic Leap 1 (bottom-right) for their social acceptability. C: The participant is wearing the apparatus without (top) and with (bottom) eye visibility adjusted.

As Pervasive Augmented Reality, a continuous and omnipresent augmentation of our environments, presents itself as the next evolution in wearable technology, we ought to explore how this addition to our day-to-day lives will change the way we interact with each other. Significantly, how the lack of mutual gaze (eye contact) due to the tinted nature of Augmented Reality glasses would affect our interpersonal relationships and behaviours. We conducted an empirical study with 20 participants who, in pairs, were exposed to a Pervasive AR technology probe that allowed them to make their eyes more or less visible based on their preferences. In this work, we report our findings related to the eye visibility levels the user expects for themselves and from others, as well as its effect on fellow users' trustworthiness and the social acceptability of Pervasive AR devices.

CCS Concepts: • **Human-centered computing → Empirical studies in HCI**.

Additional Key Words and Phrases: Augmented Reality, Mutual Gaze, Perception, Acceptability, Empirical Study, Technology Probe

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1 INTRODUCTION

The introduction of the Apple Vision Pro[1], especially the EyeSight feature, has drawn attention to the importance of device users' eye visibility. Recent studies have explored the concept of Pervasive Augmented Reality (Pervasive AR), suggesting it could be the next major advancement in wearable and omnipresent technology [9, 23, 27]. Pervasive AR is defined as a continuous interface that will overlay relevant information in a timely manner for the user as they move about their day [11]. Thus, Pervasive AR is context-aware and has the capability of adapting to suit situations.

Pervasive AR is envisioned to offer users a constant stream of information, unlike the sporadic interactions we have with mobile phones [11]. With our mobile phones, we take them out, seek out specific information, and return them to our pockets. Whereas Pervasive AR wearables will likely be an always-on system that anticipates the users' needs (context-aware) and delivers relevant information without the user having to actively seek it out [11, 23]. Thus, users will always wear Pervasive AR glasses regardless of the environment or the situation [11]. Recent studies have explored how Pervasive AR would affect users and non-users in social settings [2, 23, 28]. Many such studies have focused on the form factor of wearable glasses [8], and in our , research we address one specific aspect of wearable form factors that may affect how we interact with others in the same environment: eye visibility.

In social interactions, eye contact or mutual gaze is a basic and essential non-verbal cue for successful communication among people [3, 6, 7, 12, 13], mutual gaze is crucial for connecting with someone. It is a reflection of a person's qualities, especially the trustworthiness of a person [18]. And though the newest Augmented Reality (AR) devices in the market show potential for a Pervasive AR future with their functional capabilities, sensors, and form factor, one of the common factors about these devices is that they primarily have lenses that are tinted, which limits how much of the user's eyes others would be able to see. This creates a limitation of mutual gaze in social interactions when using Pervasive AR glasses.

Our study aims to explore the effect of lack of eye visibility when using Pervasive AR glasses in public and how it may influence our behaviours towards each other. Furthermore, we look into the personal preference of eye visibility for oneself and others they interact with. We hypothesised that participants would prefer to have their partner's eyes visible than to have them occluded behind tinted Pervasive AR wearables. Furthermore, we investigated how socially acceptable different Pervasive AR wearables would be and hypothesised that Snap Spectacles[2] will have higher social acceptability than other wearables.

2 RELATED WORK

Pervasive Augmented Reality remains a promising domain, and many have explored its potential [11, 23, 27]. Grubert et al. [11] defined Pervasive Augmented Reality (Pervasive AR) as,

> *. . . a continuous and pervasive user interface that augments the physical world with digital information registered in 3D, while being aware of and responsive to the users context.* [11, p.1]

However, with the potential adoption of Pervasive AR, it is important to look into how they will be adapted to society and the concerns that may arise from it. While the ethical implications of Pervasive AR have only been minimally explored

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[1] https://www.apple.com/apple-vision-pro/
[2] https://www.spectacles.com/new-spectacles/

[23, 27], there has been extensive research on its social acceptability. This research has focused on how device users perceive gestures and overlays, the impact on social interactions, and the effects on bystanders [9, 16, 17]. Additionally, studies have examined how social interactions between users and observers influence the social acceptability of AR devices [2, 28]. Given this focus on social interactions, we aim to explore the importance of mutual gaze, a key non-verbal cue in communication, in the context of Pervasive AR users.

2.1 Mutual Gaze and Its Importance in Social Interactions

Non-verbal cues, particularly eye contact, are crucial in empathetic communication [12]. Eye contact, or mutual gaze, has been a focus of social psychology for over six decades [7] and has been regarded as a key indicator of sincerity in social interactions [3]. Mutual gaze occurs when two people look at each other [3]. Argyle et al. [3] also note that strangers typically make eye contact about 25% of the time during social encounters. Highlighting the importance of eye contact, Heron [13] states that, aside from physical contact, mutual gaze is the only action that enables simultaneous reciprocal interactions. Bindemann et al. [6] report that gaze is processed before other facial expressions in encounters. In specific contexts, such as between a counsellor and client, eye contact signifies attention and enhances the client's connection with the counsellor [14].

Beyond the presence or absence of mutual gaze, people have learned to interpret gaze behaviour and direction as indicators of personal qualities. Kreysa et al. [18] note that individuals are more likely to trust and believe speakers who maintain a direct gaze compared to those who avert their gaze. Additionally, gaze behaviour is linked to emotions, with direct gaze associated with approach emotions (anger and joy) and averted gaze with avoidance emotions (fear and sadness) [1, 6]. Graham and Ritchie [10] found that wearing sunglasses decreases the wearer's perceived trustworthiness. Similarly, Viola [29] explored the impact of sunglasses on identity recognition and the sense of intimacy. While most research on mutual gaze originates from psychology and sociology, the HCI community has also shown interest in how mutual gaze affects communication across various mediums.

2.2 Mutual Gaze in Human-Computer Interaction

Regenbrecht et al. [25] in their early explorations of the importance of mutual gaze, investigate and report the strengths and drawbacks of different methods for implementing mutual gaze in videoconferencing. Similarly, Regenbrecht et al. [26] reports that mutual gaze in videoconferencing improves perceived trust between users. Expanding on their previous work Regenbrecht and Langlotz [24] review the importance of mutual gaze in videoconferencing, highlighting its role in providing feedback cues that enhance conversation quality. They discuss various camera positioning strategies to better simulate mutual gaze between participants. Furthermore, Lee et al. [19] investigated the role of gaze in collaborative videoconferencing, finding that it enhances communication by improving presence, facilitating clearer understanding, and making collaboration more effective.

In the domain of AR and Mixed Reality (MR), the importance of mutual gaze when performing collaborative tasks has been investigated [4, 5, 21]. These works report that there should be affordances that enable mutual gaze [5] and that domain warrants further exploration. In this study, we aim to investigate the importance of eye visibility for Pervasive AR devices in the context of social interactions.

3 METHOD

We conducted this study to investigate how the eye visibility of Pervasive AR glasses affects social interactions and its potential implications. We were further interested in exploring the effect eye visibility would have on device acceptability. While eye contact is a crucial non-verbal cue in social communication, gaze can be directed and received in different ways to convey specific messages [1, 6, 7, 18]; therefore we hypothesised that there are two dimensions to eye contact that are worthwhile exploring; how the receiver perceives their own eye contact and how they perceive their conversation partner's eye contact. Thus, with the aim of identifying the potential different expectations of eye contact, we focused on two categories of eye visibility: (1) Acceptable eye visibility for **self** and (2) Acceptable eye visibility for **others**.

We implemented a simple mechanism by fixing LED lights to Snap Spectacles (over both lenses) to make the lenses reflect light more or less, thereby making the user's eyes more or less visible to others. The study was conducted with two participants at a time in a controlled lab environment and consisted of the following five sessions. The procedures followed during each one of these sessions are defined in detail in section 3.3.

(1) **Session 1:** Evaluating the perceived social acceptability of Snap Spectacles, Microsoft Hololens 1, Microsoft Hololens 2 and Magic Leap 1 (Figure 1 image B).
(2) **Session 2:** Establishing eye visibility levels on the Snap Spectacle apparatus.
(3) **Session 3:** Evaluating the perceived trustworthiness of partners and social acceptability of eye visibility adjusted Snap Spectacle apparatus in four conditions.
(4) **Session 4:** Re-calibrating eye visibility levels post task.
(5) **Session 5:** Post-study semi-structured interview.

The formulated hypotheses for this study are as follows:

Hypotheses

(1) H1: Due to its form factor, we assumed Snap Spectacles would have a higher social acceptability rating than other devices.
(2) H2: Due to better eye visibility, we assumed the trust ratings of participants would be higher when the eye visibility of their partner is set to their optimal than when the glasses are at their original state.
(3) H3: We assumed that the social acceptability of the glasses would be higher when they are eye visibility adjusted than when it is at their original eye visibility level due to the importance of mutual gaze in interactions, as suggested by related work.
(4) H4: Due to conditioning and familiarity following the tasks and the higher perceived importance of eye visibility before the tasks, we assumed eye visibility levels set before the task would be higher than the eye visibility levels set post-task.
(5) H5: Due to pre-established relationships, we assumed that the optimum eye visibility levels set for partners when the partner is unknown will be higher than when the partner is a friend.

Ethics approval for this study was obtained from the University of Otago's Ethics Committee prior to the conducting of the study (reference number: 24/0658).

3.1 Materials

3.1.1 Apparatus. We used Snap Spectacles as the technology probe for this study. LED lights were fixed over each lens to adjust lens opacity, controlled by a variable resistor. This setup allowed participants to regulate eye visibility during the study. Each lens had three individual lights powered by an external 10,000 mAh battery pack. Due to the limited 45-minute battery life of the Snap Spectacles, they were also connected to the battery pack. Additionally, two 47R resistors limited the LED brightness, and a 10KR potentiometer enabled brightness adjustment within a range of 1-16.

3.1.2 Augmented Reality System. Three applications were developed for this study using Lens Studio. The first application served as a tutorial to help participants familiarize themselves with the device. The second application was used during Session 2 (establishing the eye visibility levels), displaying definitions for each eye visibility level participants needed to set. It also allowed participants to balance content legibility with eye visibility.

For the main task, a simple application was developed to display conversation topics in a non-intrusive manner. Topics were selected from Cambridge IELTS Preparation Textbooks (e.g., *"The roles of men and women are changing. How has this impacted how people view marriage in your culture?," "How has the internet changed the way people have relationships with each other?"*). The goal was to minimize distraction. To determine the optimal content placement, we referenced Rzayev et al. [28], who suggested displaying non-critical notifications aligned with the conversation partner's face (termed "*observer-locked alignment*"). However, due to limitations in face tracking with Snap Spectacles when the partner's face was obstructed, we opted for screen space content display instead.

3.1.3 Quantitative Measures. We recorded the eye visibility levels defined by the participants (1-16 potentiometer scale). Additionally, the following questionnaires were answered.

All participants completed a demographic questionnaire about their gender, age, profession, ethnicity and prior experience with AR. In addition to the standard demographics information, we collected the skin colour and eye colour of participants as it was revealed during pilot testing that skin colour and eye colour affect the level of eye visibility. Our observations suggested that the lighter the skin colour, the more visible a person's eyes would be through the glasses at different eye visibility levels. To collect skin colour from participants, we referred to the findings and categorisations of Reeder et al. [22]. Similarly, the lighter the eyes, the more visible they were through glasses.

Participants answered three other questionnaires during the study. In Session 1, participants answered the WEAR Scale [15] on a 6-point Likert-like scale (1 - *Strongly Disagree* to 6 - *Strongly Agree*). This questionnaire was used to evaluate the social acceptability of the aforementioned four AR devices (Figure 1 image B).

During the main task, the participants answered, firstly, the Individualised Trust Scale (ITS) [30]. In our revision of the questionnaire, we only included items that had an unrotated primary loading of above 0.75. Secondly, to evaluate the suitability of Pervasive AR devices during interactions, participants completed a social acceptability questionnaire adapted from Profita et al. [20] by Regenbrecht et al. [23] after each condition. This questionnaire assessed users' perceptions of their partners while wearing Pervasive AR glasses, focusing on how participants viewed the other person.

3.1.4 Qualitative Measures. A semi-structured interview was conducted in Session 5, post-task, to gain a better understanding of the participants' opinions; (1) on the importance of eye contact in social interactions while using AR glasses, (2) on potential behavioral changes due to lack of eye contact and (3) the ethical concerns resulting from such effects. They were also given the opportunity to elaborate on their reasoning behind the answers to the questionnaires and their opinions on whether they see themselves in the future using similar devices.

3.2 Participants

Participants were recruited by directly approaching them in public settings and advertisements on social media. Participants were either recruited as pairs, where they signed up together or were recruited individually and paired up depending on their availability. All participants were compensated for their time with a $20 supermarket voucher as a token of appreciation. 20 participants (8m, 12f) took part in the study. The participants had an average age of 27.55 years. None of the participants recognized themselves to have considerable prior experience with AR, 45% of the participants

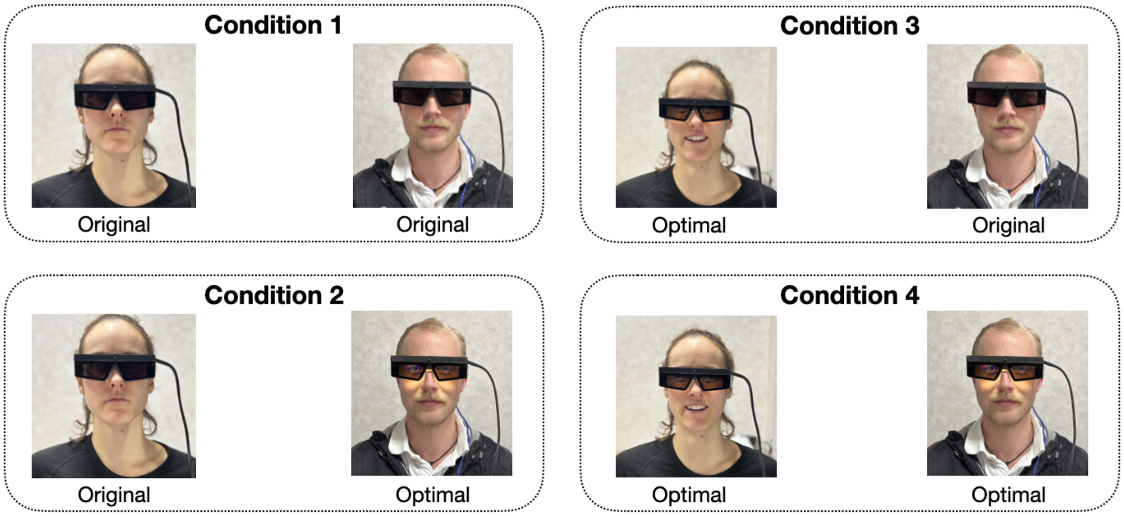

Fig. 2. Session 3 conditions: Participants had the eye visibility set to either the original state of the Spectacles (LED lights switched off) or to the optimum-self level of eye visibility they established in Session 2

reported that they had no experience with AR at all, with 55% noting that they had some prior experience with AR. 90% of the participants were students, with 1 lecturer and 1 research assistant. Furthermore, 45% of the participants reported fair skin, 25% medium skin, 20% very fair skin, and 1 participant each reported having olive skin and dark skin, respectively. 55% of the participants reported brown eyes, 35% reported blue eyes, and 1 participant each reported green eyes and grey eyes.

3.3 Study Design and Procedure

Upon arrival, participants received an information sheet detailing the study and signed consent forms. Before starting, they completed a demographic questionnaire. The researcher then introduced Pervasive AR and showed a concept video for Google Project Glasses[3] to help envision a future with Pervasive AR. Once participants understood the concept, **Session 1** began, where they evaluated the four AR devices (Figure 1 image B). The researcher explained that all devices were functionally similar and demonstrated each device on the researcher by putting them on. After each demonstration, participants completed the WEAR scale for the respective device.

Following the AR device evaluation and prior to beginning Session 2, the researcher demonstrated how to use the Snap Spectacles, which included browsing through applications, opening and closing applications, and, most importantly, interacting with the device by tapping on the device's touch panel by following a tutorial on the glasses. Finally, the researcher turned on the LED panels and demonstrated how to control the brightness of the LED panels to increase or reduce their eye visibility.

Session 2 began with participants setting their preferred eye visibility levels for themselves and their partners. Participants opened an application displaying definitions for the three eye visibility levels:

(1) *Minimum eye visibility*: Just enough eye visibility for eyes to be seen, but not clearly enough to track gaze.

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[3] https://www.youtube.com/watch?v=5R1snVxGNVs

Fig. 3. Participants in Session 2 (left) and Session 3 (right)

(2) *Maximal eye visibility*: Maximum eye visibility before it appears unnaturally illuminated.
(3) *Optimum eye visibility*: Ideally, between the Minimum and Maximal eye visibility levels previously set.

Pilot testing revealed that using a mirror did not accurately reflect the visibility due to our eyes adjusting to the LED light; therefore, the participants were asked to set eye visibility levels using their partners as reference, first for themselves: *Levels set for self*, then for their partner: *Levels set for partner*. Before proceeding, the researcher adjusted each participant's glasses to the Self-Optimum level to ensure content legibility.

Session 3 followed by participants engaging in four conditions (Figure 2). The four conditions were defined based on, (1) eye visibility at the original state of the glasses (with LED lights turned off) and (2) eye visibility set to at *Optimum* as set for self (Figure 3).

During each condition, participants sat across from each other and engaged in a conversation for about 10 minutes. Following the approach of Rzayev et al. [28], the researcher initially instructed participants to introduce themselves. Subsequently, participants switched to new conversation topics as needed, with topics displayed on their devices. The topics were drawn from Cambridge IELTS Preparation textbooks' speaking test prompts. After each conversation, participants removed their devices and completed the ITS and social acceptability questionnaires.

Following the conclusion of Session 3, Session 4 commenced. **Session 4** was conducted the same way as Session 2, where participants, if necessary, made revisions to their previously established *Optimum* eye visibility levels both set for themselves and their partner. This session of the study was carried out to investigate whether the perceived importance of eye visibility levels had changed since having used them during a social interaction in Session 3.

The final session, **Session 5,** was a semi-structured interview carried out by the researcher with both participants at the same time. Following that, the participants were thanked for their time and presented with a supermarket voucher.

4 RESULTS

The quantitative data of this study was analyzed using R Studio and SPSS. Shapiro-Wilk tests were performed to assess normality by testing against the null hypothesis.

Table 1. Descriptive statistics of WEAR scores for each evaluated AR device

Device	**N**	**Mean**	**SD**
Snap Spectacles	20	3.56	0.87
Hololens 1	20	3.24	0.74
Hololens 2	20	3.13	0.67
Magic Leap 1	20	2.77	0.73

4.1 H1 results: No significant difference was found between Snap Spectacles in comparison to the other three devices.

The responses collected during the AR device evaluations (Session 1) were analyzed as described in Kelly and Gilbert [15] to derive the social acceptability rating of each device ranging from 1 to 6 (1 - *Very socially unacceptable* and 6 - *Very socially acceptable*). A one-way ANOVA test was carried out, which reported statistically significant differences between groups, $F(3, 76) = 3.77$, $p < 0.05$. To explore further if social acceptability scores for Snap Spectacles were significantly different from other devices, we performed post-hoc Tukey evaluations, identifying that the Snap Spectacles only reported statistically significant differences in comparison to Magic Leap 1 but not the Hololens 1 or Hololens 2. Hence, this disproves the hypothesis that the Snap Spectacles would have a higher social acceptability than the other three devices evaluated. The mean values and standard deviations computed for social acceptability scores of each device can be seen in Table 1. Furthermore, elaborating on these scores in Session 5, participants noted that they preferred the Snap Spectacles due to its form factor, which was similar to high-end sunglasses and light-weight and that the Magic Leap 1 reminded them of devices from science fiction movies, that they would not prefer to wear on a daily basis in public settings.

4.2 H2 Results: No significant difference was found between the trust scores for the Optimal-Optimal condition and the Original-Original condition.

The performed paired t-test of the Optimum-Optimum trust scores and the Original-Original trust scores revealed that the mean difference between trust scores for the two conditions was statistically non-significant, $p - value = 0.09$. Cohen's effect size value ($d = -0.33$) indicates a small effect size for this finding, thus disproving the hypothesis of higher trust ratings when eye visibility is set to Optimal as opposed to the glasses' original state.

4.3 H3 Results: No significant difference found in social acceptability scores between conditions, Optimum-Optimum and Original-Original

For this evaluation, we focused on the perceived *Awkwardness, Appropriateness, Rudeness* and *Uncomfortability* of the device. For each of these items' scores, paired t-tests or Wilcoxon signed rank evaluations between the Optimum-Optimum and Original-Original conditions were performed.

Awkwardness score for the two conditions reported a $p - value$ of 0.29. This indicates that the median awkwardness of the devices during the optimal eye visibility state is not significantly different from the median original state. Similarly, the findings indicate a small effect size of $d = -0.21$. *Appropriateness* scores for the Optimum-Optimum condition and the Original-Original scores were deemed statistically non-significant based on the reported $p - value$ of 1. And the findings suggested a negligibile practical significance of $d = 0$. *Rudeness* scores between the Optimum-Optimum condition and the Original-Original condition were identified to be statistically non-significant with a $p - value$ of 0.07.

Table 2. Descriptive statistics of eye visibility levels set for self and partner prior to the task and following the task

Eye visibility for	Device	N	Mean	SD
Self	Pre-task	20	13.7	1.38
	Post-task	20	12.1	4.32
Partner	Pre-task	20	13.9	1.21
	Post-task	20	13.25	3.35

And the practical significance of the findings were small ($d = -0.42$). Finally, the *uncomfortability* scores for the two conditions were also identified as statistically non-significant, $p - value = 0.15$. And the findings reported a small effect size, $d = -0.27$.

Hence, the hypothesis of social acceptability scores being higher when eye visibility is adjusted as opposed to when it is not, was disproven.

4.4 H4 Results: No significant difference found between the eye visibility levels set before the task and the eye visibility levels set post task.

The Wilcoxon signed ranks test reported a $p - value$ of 0.24 for Optimum eye visibility levels defined for self prior to and after the conversation task, indicating that the differences between the levels set before the session and after the session are statistically non-significant. The effect size for the findings suggests a medium practical significance of $d = 0.5$. There is a mean change of 1.6 for Optimum eye visibility levels set pre-task and post-task. Similarly, the eye visibility levels set for partners show a mean change of 0.65 following the task (refer to Table 2 for the reported mean values). Even though the Wilcoxon signed rank suggests that the findings are statistically non-significant ($p - value = 0.82$) and the effect size for these findings is small with a d value of 0.26.

4.5 H5 Results: No significant differences were found between the levels set for partners who were unknown and known prior to the study.

To evaluate whether the eye visibility optimums set by participants vary if they knew the partner before participating in the study or not, we used a one-way ANOVA test followed by a post-hoc Tukey test. The ANOVA results were, $F(3, 16) = 1.69$, $p > 0.05$. The Tukey test did not report any significant findings for either group (based on familiarity categorised as Not at all, A little, Well, Very well). This indicates that the differences between the eye visibility levels set for partners who were unknown were statistically non-significant from the levels set for partners that the participants already knew prior to the study.

4.6 Observations

A notable observation during the study was that, during the Session 2 and Session 4 where the participants established eye visibility levels for both themselves and their partners, the values set were often influenced by facial indications of discomfort by the partner when exploring the eye visibility range. When the participant is using their partner as reference and is adjusting the eye visibility (by changing the brightness of the LED panels of the partner's Spectacles), the partners often either verbally or facially indicated their discomfort towards the lights, and this factor may have influenced how accurately the participants defined the levels during Session 2 and Session 4.

4.7 Interview

The interview data was transcribed and analysed by identifying patterns in the data set. The main findings concerned whether the participants would want to wear Pervasive AR devices themselves in the future and the importance of eye visibility when using such devices.

A common response by the participants was that the form factor of the devices needed to improve and evolve more to resemble regular spectacles with transparent lenses and be much lighter-weight to be acceptable. The majority of the participants had concerns about the device potentially making them feel too detached and "disengaged" from reality and others around them, reporting that the constant feed of data would be too "distracting" and "overwhelming". One participant suggested that "people will be distant and cold" by always relying on the devices. Another interesting response was that people might get too used to the device that the reality itself would feel disorienting. However, one participant noted that Pervasive AR might help connect with people by learning more about them and using that information to carry out conversations. Another concern was security, especially in public spaces with being recorded and issues regarding personal data and privacy. Few participants noted that they would eventually start wearing them as a result of "peer pressure and seeing others wear it", but some preferred to only occasionally use the devices but not continuously.

Regarding the importance of eye visibility, some participants noted that eye visibility is a sign of respect and makes a conversation feel more relaxed. With eye visibility, it's easier to form a trusting connection. One participant noted that if they could not see the eyes of the other person, it would be harder to focus on that person. Another common response was that eye visibility would be important during interactions to ensure that the other person is paying attention to them and not engaging in other activities at the same time. When asked about the symmetry of eye visibility—whether they preferred that everyone's eyes were visible or only some people's were visible, most preferred to have everyone's eye visible, with some saying they would let the users decide. Furthermore, most participants noted that eye visibility is only critical when you are getting to know someone for the first time, as it helps form your impression of them. Some participants reported that eye contact is important in specific situations, such as in sincere, emotional interactions, regardless of whether you already know the other person or not.

5 DISCUSSION AND CONCLUSION

The work presented here is our initial exploration in this research space and aims to inform the next steps. The purpose was to explore the significance of eye visibility for users and for future Pervasive AR applications. This importance, to a certain extent, has been confirmed by the *EyeSight* feature of the newly introduced Apple Vision Pro[4] mixed reality device. The device was introduced after the study was conducted. Hence, we were unable to probe the participants in particular about that feature. Although the statistical analysis did not highlight the importance of eye visibility in social interactions involving Pervasive AR devices, interviews revealed that eye visibility is crucial for forming meaningful connections. It ensures that our conversation partner is paying attention, even when they are receiving a constant stream of tailored information. In terms of engagement and the influence of eye visibility on engagement, we hypothesized that participants would set higher eye visibility levels for their partners whom they did not know prior to the study than for those whom they were already friends with. This hypothesis was not reflected by the analysis of the eye visibility levels set, even though the majority of the partners agreed in the interview that eye visibility is

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[4] https://www.apple.com/apple-vision-pro/

most crucial when you are meeting someone for the first time to form a trusting relationship with them as opposed to someone you already knew.

Several studies have previously explored the importance of eye contact in collaborative tasks [4, 5, 21]. Billinghurst and Kato [4], Billinghurst et al. [5] reported that affordances must be provided to ensure mutual gaze via Mixed Reality devices for effective collaboration. Although Prytz et al. [21] found that the lack of mutual gaze does not negatively impact collaboration, they suggest that mutual gaze should be explored in other contexts. Therefore, further research is needed to investigate the effects of the lack of mutual gaze in social interactions where non-verbal cues are crucial for bonding [3, 6, 7, 12, 13]. Moreover, the participants raised concerns related to the general use of Pervasive AR that were previously discussed in the works of Regenbrecht et al. [23] such as their theme, *the great divide*, which stated that participants believed the technology will create a barrier between the haves and the have-nots and that the constant feed of information will make the users uncertain about what is real and what is virtual. Thus, our work revealed that these concerns are omnipresent and warrant addressing through design, creating more opportunities for further research in the domain of Pervasive AR.

In conclusion, the study does reveal the importance of eye visibility in Pervasive AR social interactions but requires further investigation with suitable measures that would reflect our findings in a more statistically sound manner, along with eye visibility adjustment mechanisms that would not influence the participants' choices negatively or cause discomfort. Additionally, a larger and more diverse sample has the potential to reveal more interesting dimensions related to the importance of eye visibility for Pervasive AR users in social interactions.

AUTHOR CONTRIBUTIONS

Kushani Perera performed writing - original draft, conceptualisation, methodology, software, formal analysis, investigation and data curation; Tobias Langlotz performed writing - review & editing, conceptualisation, methodology, visualisation and supervision; Nadia Pantidi performed writing - review & editing, and supervision; Holger Regenbrecht performed writing - review & editing, conceptualisation, methodology, investigation, funding acquisition, and supervision.

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