Consent in the Age of AR: Investigating The Comfort With Displaying Personal Information in Augmented Reality

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ABSTRACT

Social Media (SM) has shown that we adapt our communication and disclosure behaviors to available technological opportunities. Head-mounted Augmented Reality (AR) will soon allow to effortlessly display the information we disclosed not isolated from our physical presence (e.g., on a smartphone) but visually attached to the human body. In this work, we explore how the medium (AR vs. Smartphone), our role (being augmented vs. augmenting), and characteristics of information types (e.g., level of intimacy, self-disclosed vs. non-self-disclosed) impact the users' comfort when displaying personal information. Conducting an online survey (N=148), we found that AR technology and being augmented negatively impacted this comfort. Additionally, we report that AR mitigated the effects of information characteristics compared to those they had on smartphones. In light of our results, we discuss that information augmentation should be built on consent and openness, focusing more on the comfort of the augmented rather than the technological possibilities.

CCS CONCEPTS

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

KEYWORDS

Data Glasses, Augmented Reality, Mixed Reality, Social Acceptability, User Acceptance, Public Experiences, Personal Information, Disclosure, Consent, Comfort

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1 INTRODUCTION

For humans, it's challenging to keep our thoughts to ourselves. Retaining secrets and not disclosing oneself can lead to pressure, preoccupation, and ultimately stress [38, 64]. Disclosing our thoughts, in turn, helps to relieve distress [60], and can even have therapeutic value [51]. Previous work has shown that humans have an intrinsic value associated with self-disclosure [61], which Jourard and Laswakow [27] define as "the process of making the self known to other persons" [27, p.1].

With the upcoming of social media or online forums, people started to "seize these opportunities to satisfy their instrumental needs" [9, p. 653] for self-disclosure. While more likely to share common information about themselves online [53], users nevertheless also self-disclose sensitive information [5]. However, this self-disclosure is only one possible information source in an online context. It was shown that information about a person could also be derived from other sources without the users themselves being involved in its disclosure. While other users or official sources could directly disclose information through, for example, posting it or making it accessible in open databases, a user's personal information (like age [2, 17, 33, 48, 52], gender [2, 33, 52, 62], or even political views [2, 41, 62, 67]) has also been shown to be disclosable through inference with machine learning. In the context of social media, a user's personal information (possibly coming from a variety of sources) is then often viewed [50] by other users without any form of interaction with or consent by its originator. In this way, users are scrolling through their news feeds – often only "socially browsing" [65] – over the information others provide.

With Augmented Reality (AR) on the horizon, a new possibility of self-disclosure is slowly emerging. Bazarova et al. [9] argue that when new technologies expand the opportunities for self-broadcasting, people will adapt accordingly. In a future world where AR glasses are omnipresent, it is, therefore, not difficult to imagine that personal information could also be displayed through this

new medium. Information could be found online and augmented to the physical appearance of people we perceive [1, 35] in our daily lives. We argue that walking through the streets and perceiving information augmented to people passing by has similarities to the above-mentioned scrolling through a news feed, perceiving information on passing posts.

Until now, researchers have, to the best of our knowledge, only explored the idea of augmenting personal information in a face-to-face context (as ice-breakers [25, 28, 36, 46] or to give (mutual) conversational topics [36, 49, 66]). However, information could not only be added to a context in which we (plan to) interact but, like on social media, consume without any form of interaction. While we know such interaction-less information consumption from other technologies, we argue that this augmentation and its unique attributes make it inherently different from the context in which we currently perceive personal information. We argue that one of the main factors that distinguishes displaying information in AR compared to, e.g., smartphones, is that the information's perceiver is not alone in it. The person the information refers to (from here on called information target or target) is also present. On the smartphone, the perceiver only looks at their digital representation. In AR, in turn, that person themselves enters the situation, making it a social situation including not one but two actors.

Therefore, we explored how different *kinds of information and their level of intimacy (information-type)* influence the *perceiver's or target's (role)* comfort when displayed in a non-conversational *AR glasses scenario compared to current-day digital self-disclosure displayed on a smartphone(medium)*. As discussed above, previous work has shown that personal information can not only be self-disclosed but obtained through other sources. As AR devices (depending on their implementation) might allow deducting non-self disclosed information from the situation [13, 42] or through other sources, we are also interested in how AR influences the perceived comfort when the displayed information is *self-disclosed or not (disclosure)*.

We conducted an online experiment (N=148) using a mixed factorial design to investigate these factors, having two between-subject (role and method) and two within-subject (information intimacy and disclosure-type) factors. Analogously to previous work on the social acceptability of future AR application areas [22, 31, 32, 55], we did not create an artificial scenario in the laboratory but presented the participants with an abstract but realistic scenario asking them to envision themselves in this situation.

Compared to displaying information on a smartphone, we found that the thought of being augmented through AR made our participants feel less comfortable. These findings were accompanied by AR, also showing a lowering the influence of characteristics of the information itself. While information's intimacy and origin were great predictors for comfort on a smartphone, it lost part of its predicting power in AR. While we found that both parties would feel more uncomfortable with non-consensual, non-self-disclosed information in AR, the range of information with which the parties would feel comfortable differs. With the information target generally feeling worse and participants also stating that they would want to first consent to every augmentation of information, we discuss how consent on the targets site and openness towards them will be vital for making people feel comfortable with AR head-mounted displays (*AR-HMDs*) and their possibility to augment information.

With our work, we make the following contributions:

- The quantitative and qualitative findings of an online survey, revealing that properties of information itself lose a part of their predictive power on comfort when viewed in AR. They also reveal differences in comfort with displaying (non-)consensual information between target and perceiver, as well as participants only feeling comfortable with the thought of basic personal information (first name, interests, age, or gender) being displayed.
- Discussion of the found results and its implications on how consent and a focus on the augmentation target are essential for developing information augmentation in a way all parts are comfortable with

2 RELATED WORK

With our work, we build on multiple fields of research which we will introduce in the following. First, we will lay out previous work on how researchers have used AR technology to add personal information into a social context. Secondly, we introduce previous work on how personal information can be acquired without the belonging person disclosing it themselves.

2.1 Social Information Augmentation

By interpreting the collected visual information provided by an *AR-HMD*'s sensors, previous work has shown that the technology can aid users by emulating a human's ability to detect emotion. For example, do Daniels et al.'s [13] "Superpower Glasses" aid children with autism spectrum disorder during social interactions by such detection. It first detects other persons' emotions and then displays it as social feedback to the child. Similarly, Emotion Game [42] analyses the expressed emotion of a social counterpart. It then uses this information to gamify learning to detect emotions by quizzing the user about which emotion the counterpart showed. Another approach was chosen by Iwamura et al. [24]. They aid users with memory problems by displaying pictures of prior meetings with the current interlocutor, helping them to remember the respective person.

Different researchers tried to initiate conversations by displaying personal information without using AR glasses. McCarthy et al. [46] tried to kickstart conversations by using RFID chips to identify bypassing persons at a scientific conference, displaying their name, affiliation, and picture on a public screen. Kao et al. [28] designed a Mug with an OLED display that could display differing information in private or social interactions. Jarusriboonchai et al. [25] used a similar but more targeted way by wearing a display around the neck that could break the conversational ice by analyzing their Twitter, and Facebook likes displaying a mutual topic for a two-person meeting.

Others have shown that initiating and leading a conversation can be supported through AR glasses. Bace et al. [6], for instance, implemented a system where users can exchange information about themselves triggered by hand gestures. The exchanged information is then augmented around their originator. Another more potent way of receiving information about a person is to automatically

map existing information to the person the user is facing without exchanging them. Therefore, first, their identity has to be determined [35]. This could be done via face recognition [1]. Kunze et al. [35] have shown that it is possible to recognize a person by analyzing what the *AR-HMD* perceives and comparing the found faces to those of the user's contact list. Acquisti et al. [1] established a connection to the user's social media account to identify a surrounding person online. Afterward, the user's *AR-HMD* can display information the augmentation target supplied on their social media presence. Additionally, during a conversation, similar systems have been developed that can aid in finding conversation topics by displaying interests both parties share [49, 66] or engage further interest about topics that are not mutual [36]. Primed for the context of getting to know others, participants in different studies created digital self-representations [36, 37, 47]. The information they chose to represent themselves herein differed from that they had disclosed on their social media accounts. Our work explores if, in a non-conversational context, users show a differing comfort compared to how they would feel when the same information is displayed conventionally (e.g., on a Smartphone).

2.2 Information Acquisition for Displaying in Augmented Reality

Information displayed on AR devices can to be gathered from the situation itself, from distant sources like social media pages [1], or from databases belonging to the AR-Application [35]. This information can ordinate in two ways: it can either be disclosed by the information target themselves or through other means without the person directly disclosing it. In the following, we will build on related work to explain how such non-self-disclosed information can be gathered.

While work presented in Section 2.1 aimed at helping persons with impairments, it is also possibly to use current and future advances in machine learning in a similar way to advance human capabilities. Li et al. [40] present an artificial intelligence (AI) that outperforms humans at detecting facial micro-expressions, which are brief, involuntary facial movements that can unveil the true feelings of a person trying to put on a mask to hide their real feelings [18]. AI also has started to outperform humans in a multitude of other areas like estimating a person's age [19], sexual orientation, or race [20] through visual clues [63]. These current-day advances illustrate that in a future AR context, machine learning might disclose information that an augmented person did not consent to.

As Bermejo et al. argue, "AR and big data have a logical maturity that inevitably will converge" [10, p. 1]. Accessing big data analysis through *AR-HMDs* could also lead to further information becoming accessible that was either not self-disclosed or not self-disclosed in the same context it is being accessed in. In the context of such cross-context linkage, previous work has shown that it is possible to link different social media appearances, therefore deanonymizing single social media appearances deemed anonymous [7, 68]. With the collected data of (multiple) social media appearances, it is possible to predict undisclosed private information with high accuracy through so-called inference attacks [41]. One way to archive this is through analyzing a user's online behavior [21], so it's, e.g., possible to detect multiple classes of depression from the social activity online [14–16]. As people that share common attributes are more likely to interact [48], inference attacks can be executed by analyzing people the user is connected with online, unveiling new information about the initial person [67]. This holds especially true for minorities that gather in communities like, e.g., homosexual males [56]. Previous work on inference attacks has shown that it is possible to detect a multitude of attributes in this way including political views [2, 41, 62, 67], religious views [62], gender [2, 33, 52, 62], sexual orientation [26, 56], age [2, 17, 33, 48, 52], city of residence [21], high school [48], interests [62], relationship status [33], employer [21]. As AI only calculates possibilities, such predicted information can only be trusted to a certain degree. While they are already at a high level of accuracy, this level will increase over time as the technology itself evolves. Another source of information could be open databases. Knowing a person's name and information like their hometown also enables a system to query data from official sites like the open criminal records in the US [1] or the open tax returns in Norway [2].

We, therefore, argue that data displayed in a future AR scenario does not necessarily have to be self-disclosed but could also be derived from other sources without the user's consent. In the following, we will call such information non-self-disclosed information.

3 HYPOTHESES

In this work, we explored the augmentation of a person with personal information. Feelings toward Information Augmentation could be highly subjective, and each participant might have their own personal reasons for the way they feel. In the field of proxemics, Sorokwska et al. [59] determined the rather abstract feelings of people when entering their comfort zones by asking them if they would be comfortable with it. In the field of HCI, others also used the adjective "comfortable" to determine the participant's feelings towards being touched [22] or being visually altered in another persons *AR-HMD* [55]. Here, it was argued that comfort best captured the participants' multi-dimensional and personal feelings towards the respective concepts. In addition, Ma et al. [44] state that when they asked participants about the likelihood to disclose data, the participant's answers not only included self-disclosure risk and concerns but also their judgment of whether the data might be interesting or not. They argue that asking for comfort instead mitigates these limitations. We, therefore, argue that the metric *Comfort* could best capture "the multi-dimensional and highly personal" [22, p. 4] feelings participants had towards Information Augmentation and also mitigate limitations towards the explanatory power about willingness to share. For all the reasons above, we also decided to use comfort as a key metric for measuring how participants feel about information augmentation.

This paper aims to explore the impact of the augmentation of personal information generally. The following nine hypotheses summarize our aim. The first five (*H1a* to *H1e*) are related to how

[1] https://staterecords.org/criminal.php, ACCESSED: 8-SEPTEMBER-2021
[2] https://www.skatteetaten.no/en/forms/search-the-tax-lists/, ACCESSED: 21-JULY-2021

Medium (AR/Smartphone), *Role* (perceiver/target), and *felt intimacy of information* influence comfort with displayed personal information. The following four (*H2a* to *H2d*) incorporate that information might not only be consensually self-disclosed but derived through other sources.

3.1 Medium, Role, and Intimacy

In comparison to, for example, current information perception on smartphones, AR will have two actors that are part of the immediate situation. Instead of looking at the digital representation of an information target, the perceiver looks at their physical appearance, making them an active part of the situation. Hence, instead of perceiving or disclosing alone, the situation becomes more open, taking away part of the actor's anonymity. From previous work, we know that such anonymity increases our comfort with disclosing information [44]. Reducing anonymity should, therefore, impact the perceiver's comfort negatively. We also know that anonymity reduces the felt risks of social sanctions for our actions [8]. Such feelings could happen, in this case, with perceiving personal information about others without directly asking. In the context of toxic online behavior, participants were less disinhibited when they experienced anonymity, invisibility, and a lack of eye contact [39]. Being in the exact location as the augmentation target strictly reduces the chances of feeling invisibility and could even lead to eye contact between the two parties. Thus, we hypothesize:

> ***H1a:*** *Both parts (target and perceiver) generally feel less comfortable with the perception of information in AR than on a Smartphone*

Related work on visual augmentation has also shown that when visually altering a person through AR technology, the target will generally feel less comfortable with it [55]. While we know that comfort is influenced by the intimacy of information [44] (for hypotheses regarding intimacy, see below), we also hypothesize that the target, as a more passive non-acting part of the situation, will feel less comfortable with it. Hence:

> ***H1b:*** *The target of the information augmentation will feel less comfortable than its perceiver*

As discussed above, when the situation becomes less anonymous for the perceiver, they are now facing the information target instead of being alone with their smartphone. In addition to the same happening to the target, for them, additional factors change. While the target broadcasts information to an (anonymous) mass of people on the smartphone (SP), the context switches to a face-to-face context in AR. Instead of knowing that someone, some-when might see the information, the target is also confronted with knowing - and being in - the exact moment. This, in turn, could make the target feeling more judged and mitigating the Internet's effect of freeing us from the feelings of expectation [39]. Therefore, we hypothesize:

> ***H1c:*** *The gap in comfort between AR and Smartphone will be be enlarged when being the target, compared to being the perceiver.*

Previous work on the intimacy of personal information has shown that intimacy is a strong factor influencing how comfortable we are with this information being shown in a smartphone context [44]. We hypothesize that the lost anonymity and the social factors coming with AR technology will in turn act as catalysts for those feelings. Making us more open to judgment as we have a physical person seeing our intimate information. Hence:

> ***H1d:*** *AR will increase the impact of information intimacy on our feelings of comfort*

We also suspect that the role will influence how the intimacy of information affects us. While disclosing more intimate information makes us more uncomfortable, it might also get more interesting for perceivers. Therefore, balancing out the influence of the information's intimacy. We hypothesize:

> ***H1e*** *Intimacy will have a stronger impact on comfort levels of Target than Perceiver*

3.2 Disclosure

We, like described above, argue that information might also be disclosed without the information targets cooperation. We, therefore, also look at the influences of the two possible disclosure types: Either the information is disclosed by the person themselves (self-disclosed) or through other means (non-self-disclosed). Generally, we argue that both perceiver and target will feel less comfortable with the information that was non-self-disclosed. For the target, they lose control over their information and what others can perceive. Loss of control, in turn, is associated with negative feelings like stress, anxiety, and depression [11, 29, 57]. For the perceiver, knowing that the information was derived without explicit consent could pose a moral conflict creating moral dissonance [43]. As some people might not be able to find self-justifications [23] why they watch information without the other person's consent, they will subsequently feel bad. Hence:

> ***H2a:*** *Overall the actors will be less comfortable with Non-self-disclosed information than self-disclosed ones.*

As discussed above, we suspect that in the case of non-self-disclosed information, both parties will have a reason to feel bad about the information presentation. For self-disclosed data in turn, the perceiver is freed of their moral burden. However, the target still is the passive part of the information presentation and therefore still is having less control over the information in this specific moment. Hence:

> ***H2b*** *There will be a greater difference between target and perceiver for self-disclosed data*

In AR, with the creation of a social situation and the loss of anonymity, we argue that the relieve of knowing that information was given with consent and the stress with knowing that it was not should be amplified. This should lead to an enlarged difference in comfort, between self and non-self disclosed in AR compared to on the smartphone. Therefore:

> ***H2c*** *In AR the comfort gap between Self and non-self-disclosed will be enlarged*

While intimacy is a main factor on self-disclosed data [44], we think that this factor will be less important when the data is not self-disclosed. As we hypothesized above, we believe that both parties will feel less comfortable in general through either loss of control or moral dissonance. While making us feel worse for intimate information it will especially influence non-intimate information that we would feel comfortable with otherwise. Changing

the positive into a negative feeling brings the comfort towards high and low intimacy information further together. Hence:

> ***H2d*** *Intimacy has more influence on self-disclosure then on non-self-disclosure*

3.3 Exploratory Part

In addition to this hypothesis-focused part, we also wanted to explore what information should be displayed in AR and what information participants feel comfortable with depending on their *Role* and the information *Intimacy* level.

> ***RQ:*** *What (non-)-self-disclosed information can be displayed that makes neither Perceiver nor Taget uncomfortable?*

3.4 Study Context: Future AR Social Media

Just presenting the abstract concept of augmented information to participants in a study would make it difficult to understand and evaluate. Only describing that information is displayed would raise questions about its purpose and, e.g., the legal grounding, which was a significant problem with previous hardware like Google Glass [34]. We, therefore, needed a story as the carrier to convey the rather abstract concept of non-conversational information augmentation. We found this in social media, a context in which we are already used to self-disclose [5, 9, 53] and perceive information about others. It is also known that social media is often used in a non-conversational context [50, 65]. We argue that scrolling through a newsfeed and perceiving information on posts passing by has similarities to, e.g., walking through the streets and perceiving augmented information about people passing by. By introducing the concept embedded into a social media story, we can also introduce both parties as users of this application and, therefore, omit legal issues the participants could see in this augmentation.

4 EVALUATION OF THE AUGMENTATION OF PERSONAL INFORMATION

To evaluate our hypotheses, we conducted a questionnaire-based online survey, exploring how AR technology and the accompanying visual proximity of augmenting personal information influences participants' reported levels of comfort in a non-conversational context. Inspired by Ma et al. [44], we used a mixed factorial design, including two between-subject and two within-subject factors. Therefore, we had four between-subject conditions build upon the factors *Role* and *Medium*. In each condition, we asked the participants to imagine themselves in the *Role* of one of two persons included in the scenario: The person the personal information is shown about (*target*) or the person perceiving it (*perceiver*). Depending on the condition, the *perceiver* encounters the information either by scrolling through their social media news feed displayed on their smartphone (*Smartp.*) or by using a future AR social media application, which augments other users encounter in real-life (*AR*). Figure 2 depicts all four resulting conditions: Using *AR* and being the *perceiver*, using *AR* and being the *target*, using a *Smartp.* and being the *perceiver* or using a *Smartp.* and being the *target*.

The two within-subject factors were the felt *Intimacy* of different data types and the procedure for acquiring this data (*Disclosure*). As described in Section 2.2, we see two methods of *Disclosure* for the augmentation of personal data: either the information is *self-disclosure* or *non-self-disclosure*. The survey overall consisted of five steps: (1) information intimacy rating, (2) introduction to either *Smartp.* or *AR*, (3) information comfort rating, (4) single item-questions, and as the last step (5) the querying of demographic information. Below, these are described in detail.

Survey vs. Lab Study

Following Rixen et al. [55] (building on the work by Kölle et al. [32]), we chose the approach of letting participants imagine themselves in specific situations to avoid an artificial lab study, thereby, ruling out potential accompanying biases. For example, conducting a lab study with bulky state-of-the-art AR glasses covering only a part of the user's field-of-view could induce a severe hardware bias. Furthermore, by not having actual other people in the study but only showing an androgynous representation, we can eliminate gender bias and other biases a natural person would have entailed. As we recruited our participants via Prolific[3], we were able to reach a broader audience and were not reliant on technophile students, as might have been the case in a typical lab study.

4.1 Procedure

We structured the study into five parts. After registering with our study and accepting the consent form, we presented the participants with parts in the following order.

Part 1: Data Intimacy Rating

Following Ma et al. [44], in the first part of the study, participants had to rate how intimate they thought different kinds of presented information to be. As we wanted to explore how comfort is influenced whether the information is acquired through *self-disclosure* or *non-self-disclosure*, we took data items, which were shown to be acquirable through *non-self-disclosure* or could be otherwise accessible online. We arrived at the presented information by taking 13 items from related work on inference attacks, two from open sources, and two name-related items. The participants rated the perceived intimacy on a 7-Point-Likert scale from 1 (Not intimate at all) to 7 (Extremely intimate). We later recentered the scale to make 0 the neutral answer. All 17 can be seen in Table 1 ordered by their average intimacy ratings. Querying these intimacy ratings, we were able to not only directly compare *information types* but also how participants stood towards them as this could be highly subjective. While a person's age, for example, could have low intimacy for one person, it could be highly intimate for another, which could lead to a differing sharing behavior. Participants were presented with the items in random order.

Part 2: Introduction to AR and Disclosure-types

Firstly, participants had to understand the underlying concepts of *AR-HMDs* and different *disclosure types*. Therefore, for *AR* conditions, we first introduced the concept behind *AR-HMDs* in the form of textual information. To make it more understandable, we also

[3] https://www.prolific.co/, Accessed: 26-AUGUST-2021

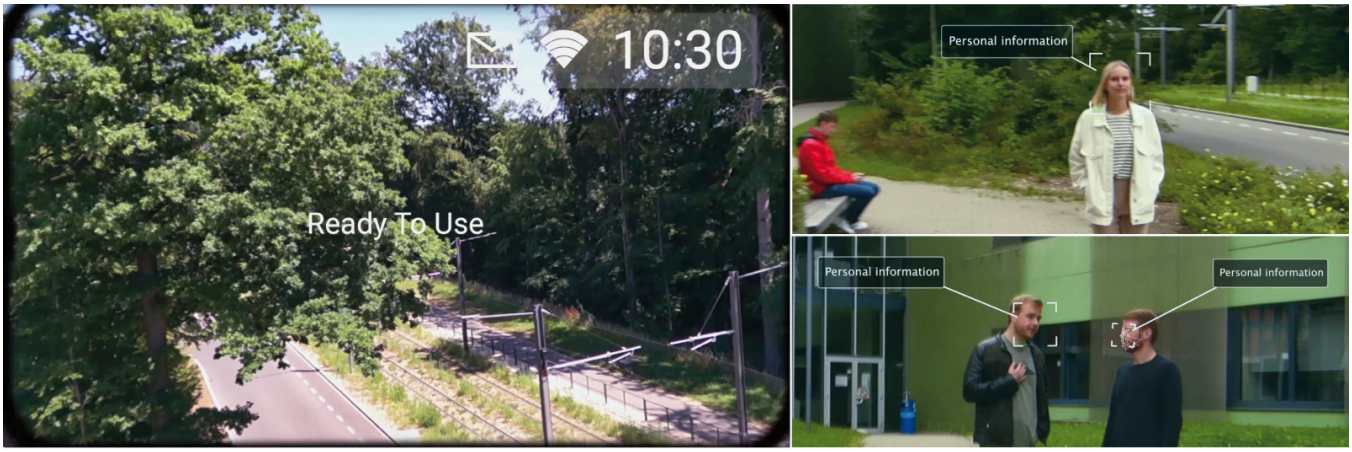

Figure 1: Screenshots from the explanation videos shown to the participants. The left picture shows a full screenshot from the first video introducing AR. The right shows parts of the person augmentation video. On top, a person walking towards the FOV, on the bottom, two persons talking, while the right person's face shows a face scanning animation.

Table 1: Intimacy Ratings on a scale form -3 (not intimate at all) to 3 (extremely intimate)

Datatype	Source	Avg.	Std. Dev.
first name	name related	-0.9	2.02
gender	[2, 33, 52, 62]	-0.8	2.00
age	[2, 17, 33, 48, 52]	-0.7	1.78
occupation	[21]	-0.6	1.62
high school	[48]	-0.5	1.70
interests	[62]	-0.3	1.78
last name	name related	-0.2	1.90
city of residence	[21]	-0.1	1.78
employer	[21]	0.1	1.78
relationship status	[33]	0.2	1.80
date of birth	[4]	0.3	1.83
political views	[2, 41, 62, 67]	0.6	1.60
religious views	[62]	0.6	1.69
sexual orientation	[26, 56]	0.8	1.74
criminal history	open sources	1.3	1.71
tax history	open sources	1.4	1.71
mental health status	[14–16]	1.9	1.31

showed a mock-up video of how an *information source* device could look and display information. Analogous to Rixen et al. [55] we showed User Interface elements like time and notifications inspired by existing devices like Google Glass (see Figure 1 on the left). After laying this groundwork, we introduced the participants to the displaying of personal information. In this context, we showed another mock-up video to participants depicting how passersby are augmented (see Figure 1 (right)). To not bias the participant in having already seen, e.g., a name augmented to a person, we used "personal information" as a placeholder for all types of information.

While the prior described part was only shown to participants in the *AR* conditions, the following part concerning *disclosure types* was shown to all participants. Here we first textually explained how people *self-disclosure* on social media. Then we introduced the participants to the concept of *non-self-disclosure* information. Added up, participants of the *AR* took ≈ 5 min to finish this introduction section, while participants in the *Smartp.* condition took ≈ 2 min. By asking comprehension questions, we ensured that participants were attentive, understood the topic, and could build a mental model of the situation[55]. The mock-up-videos shown to the participants are provided in the supplemental materials to this work.

Part 3: Information Comfort Rating

The following section explored how feelings towards sharing different *information types* changed depending on seeing it in the roll of *perceiver* or *target* and how it is influenced by the *Medium* and *Disclosure*. Here the participants first were confronted with a situation regarding the displaying of personal information requested to imagine themselves in it. Participants had to imagine they would be either using a future AR social media application or current day social media on their smartphone. They were then told that either a stranger is perceiving information about them or vise versa. We clarified the missing interaction for the *AR* conditions by telling the participants this person was a few yards away. While using a smartphone implies it in the *Smartp.* conditions, we explicitly stated that the two actors did not share the same location.

To illustrate the situation and make it easier for the participant to imagine it, we showed an abstract illustration of each of the four resulting conditions. We based the persons appearing in those on the *Humaaans design library* by Pablo Stanley[4] and removed their head hair to minimize gender bias by making them look more androgynous [55]. The pictures shown to the participants are the same we earlier used to illustrate the conditions. They can be seen in Figure 2.

[4]https://www.humaaans.com/; Accessed: 25-JUNE-2021

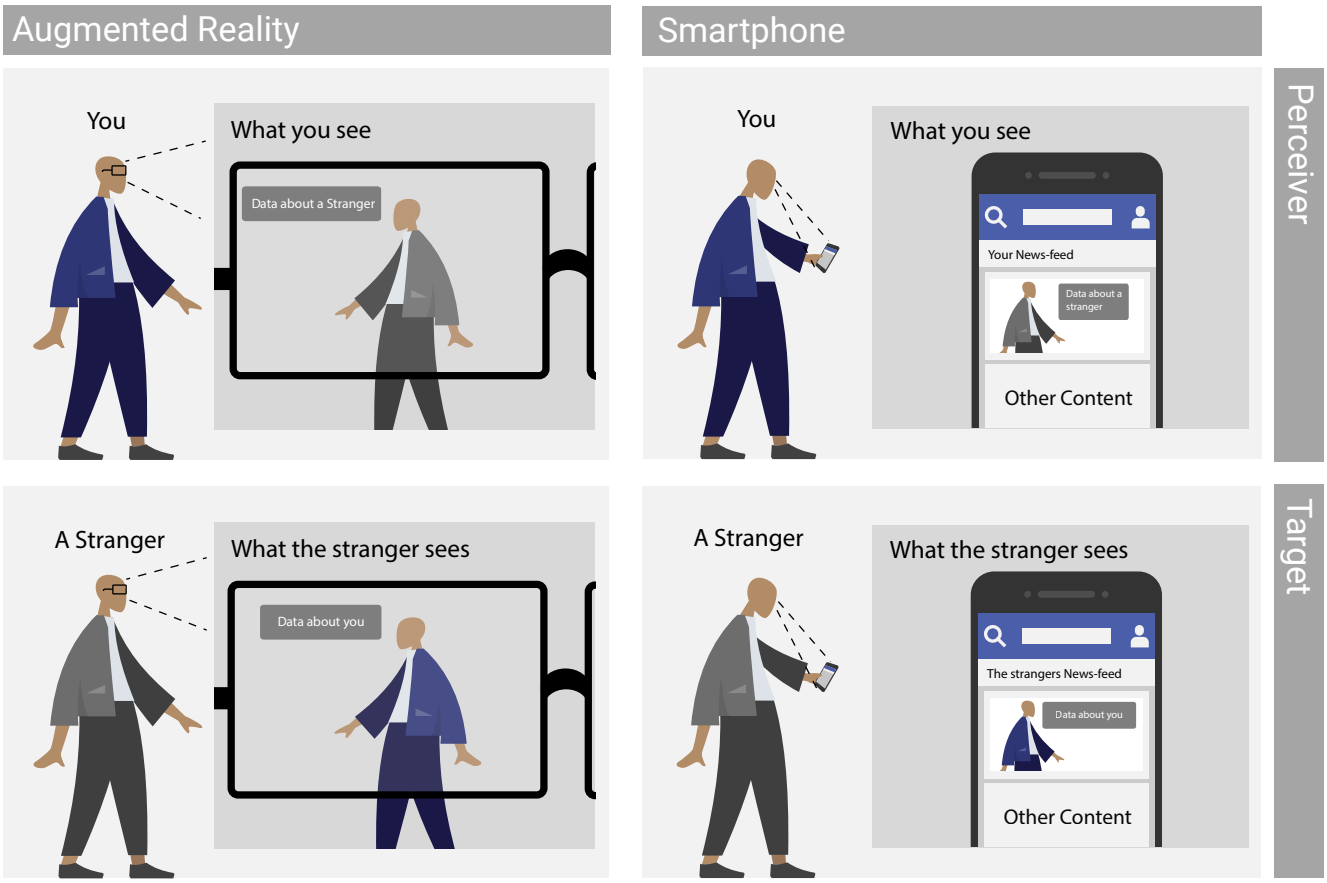

Figure 2: Pictures showing an abstract situation the participants should imagine themselves in for each condition ordered in a grid. The columns define the Medium (AR/Smartphone), and the rows the participant's Role (Perceiver/Target). The person the participants were asked to imagine themselves being is wearing blue.

Imagining themselves in this situation, as either perceiver or target of information in either *AR* or *Smartp.* participants, they had to rate how comfortable they felt when each of the *information types* (see Table 1) would be displayed. The items were queried in a randomized order. The participants were asked to rate the items two times. Once, they had to imagine that the information was acquired through *self-disclosure* once through *non-self-disclosure*. We also randomized which type of disclosure they had to rate first.

Part 4: Single Items
After finishing the main conditions, we asked the participants for additional single items. In both *AR* or *Smartp.* we asked how much they would agree to wanting to be informed if somebody would like to perceive information about them on (depending on the condition) *AR* or *Smartp.*. We also asked them whether they would agree to wanting to consent to each displaying. In the *AR* conditions, we also asked them to imagine owning a *AR-HMD* and then if they would activate/deactivate/use a feature that would augment information about the people around them.

Part 5: Demographics and Open Comments
In the end, we queried the participants' demographics. We placed it at the end to not prime the participants for stereotype biases [58]. Participants in *AR* conditions, could also leave comments about fears they have and chances they see with the technology.

4.2 Measurement

As we argued in Section 3, we found that in multiple social acceptability studies, the concept of comfort was used as it "best captured the multi-dimensional and highly personal nature" [22] of, e.g., visually altering a person through AR technology [55], entering their comfort zone [59], or touching them [22]. In accordance to Rixen et al. [55] we measured it on a 7-Point Likert Scale ranging from 1 (very uncomfortable) to 7 (very Comfortable) [55].

Table 2: Participants sorted by gender and condition

Condition	Male	Female	Non-Binary	N
AR / Target	13	23	1	37
AR / Perceiver	16	20	1	37
Smartphone / Target	16	20	1	37
Smartphone / Perceiver	14	21	2	37
Total	59	84	5	148

4.3 Participants

For our study we recruited participants on Prolific [5]. Here we recruited US citizens only, avoiding confounding variables such as culture [54]. We paid a wage of £8 per hour for their efforts. This resulted in a payment of £1.20 for ≈ 9 min in the *Smartp.* conditions. In the *AR* conditions participants received £1.73 for ≈ 13 min.

Data Preparation

Initially, we received 232 responses to our study. Each Prolific worker was only allowed to submit one response. Therefore, we had to exclude 23 duplicate responses from the same Prolific worker identifiable by their Prolific ID. After comparing crowdsourced study data and laboratory data, Alallah et al. see "crowdsourcing platforms as viable options for conducting social acceptability research" [3, p. 1]. We nevertheless included attention- and comprehension checks to ensure that participants were attentive and understood the described, non-trivial concepts. We had to exclude 3 responses failing our attention checks (which were designed in accordance to the Prolifics guide on fair attention checks [6]). We further excluded 61 participants for failing our comprehension test. This process lead to 148 responses evenly distributed between the four conditions (37 each). This distribution can be seen in Table 2. The participants were aged between 18 and 50 (M=28.62, SD=8.50).

5 RESULTS

The two main objectives in our study were: First, test the hypotheses about *Medium*, *Role*, *Disclosure*, and *Intimacy*. Secondly, we had an explorative approach on finding what *information types* participants felt comfortable with depending on their *Role* and how the information was disclosed. In the following, we report the results on those topics individually.

5.1 Hypotheses

Beginning our study, first participants each had to rate how intimate they thought each of the *information types* to be. Then, mapping those ratings to the later ratings for comfort, we generated 17 *Intimacy*/*Comfort* pairs for information acquired through each *self-disclosure* and *non-self-disclosure*. Therefore we arrive at 34 (=17x2) observations per participant. Overall we, therefore, base our analysis on 5032 single observations.

From previous work done by Ma et al. [44], we know that comfort with the content being displayed and its intimacy is linear. We, therefore, analyze the data by fitting linear mixed models to predict *Comfort*. To accord for differing tendencies to disclose, our models included the participants as a random effect. The models were run using the lme4 package in R (estimated via restricted maximum likelihood (REML)). Results of our two models are depicted in Table 3. We will discuss these in detail below.

Table 3: Linear Mixed Models Predicting *Comfort*

Variables	Model 1	Model 2
(Intercept)	-0.53^{**} (0.18)	-0.62^{**} (0.22)
Main Effects		
Medium (Ref: *AR*)	0.68^{**} (0.21)	0.44 (0.31)
Role (Ref: *perceiver*)	-0.98^{***} (0.21)	-0.68^{*} (0.31)
Disc (Ref: *non-self-disclosure*)	1.37^{***} (0.04)	1.66^{***} (0.08)
Intimacy	-0.31^{***} (0.01)	-0.19^{***} (0.03)
Interactions - Medium		
Medium x *Role*		0.27 (0.44)
Medium x *Intimacy*		-0.12^{*} (0.05)
Role x *Intimacy*		0.01 (0.05)
Interactions - Disclosure		
Medium x Disc		0.30^{*} (0.12)
Role x Disc		-0.79^{***} (0.12)
Disc x *Intimacy*		-0.18^{***} (0.05)
$R^2 conditional$	0.55	0.57
$R^2 marginal$	0.23	0.24
Significance Codes:	*p<0.05; **p<0.01; ***p<0.001	

Main Effects

We start with discussing Model 1 and the main effects of *Medium*, *Role*, *Disclosure*, and *Intimacy* on *Comfort*. To simplify the discussion, we re-centered the measured intimacy of information, making 0 the neutral option. *Intimacy* is therefore now ranked from -2 ("not intimate at all") to 2 ("extremely intimate"). As we hypothesized, we found a significant impact of all factors on *Comfort*. We first found a significant positive effect of *Medium* (Ref: *AR*) on comfort, meaning that participants felt more comfortable with the thought of information being displayed on a *Smartp.* rather than in *AR*, therefore, supporting *H1a*. There also was a significant negative effect of *Role* (Ref: *perceiver*) on comfort, indicating that participants in the *perceiver* conditions felt more comfortable with the thought of displayed information. Hence, we also found support for *H1b*. We additionally found a statistically significant positive effect of *Disclosure* (Ref: *non-self-disclosure*) on comfort, meaning that participants felt more comfortable with the thought of self-disclosed information, supporting *H2a*. In accordance with findings by Ma et al. [44] we found a statistically significant and negative effect of *Intimacy* of information on comfort, meaning that participants felt less comfortable with the information they found to be highly

[5] https://www.prolific.co/, Accessed: 26-AUGUST-2021

[6] https://researcher-help.prolific.co/hc/en-gb/articles/360009223553-Using-attentionchecks-as-a-measure-of-data-quality, Accessed: 26-AUGUST-2021

intimate.

Interaction Effects
By adding the interaction variables, we can now use Model 2 (see Table 3) to examine whether there are effects moderating the found regulation effects. We found no moderating effect of *Role* on *Medium*'s regulation effect and hence no indices that support *H1c*. The same is true for *Role* and *Intimacy*, which lead us to reject *H1e*. In turn, we found a negative interaction between *Medium* (Ref: *AR*) and *Intimacy*, suggesting that, in the *Smartp.* condition, the regulation effect of *Intimacy* is stronger. This, in turn, means that the felt *Intimacy* of information has less impact on how comfortable we feel when information is displayed on a *AR* compared to *Smartp.*. We, therefore, reject *H1d* and report reversed findings.

We found three interactions, including *Disclosure*. First, we found a positive interaction between *Medium* (Ref: *AR*) and *Disclosure* (Ref: *non-self-disclosure*), suggesting that *AR* has a negative influence on *self-disclosure* information, which means that we feel less comfortable with *self-disclosure* data in AR than in SP. In turn, this suggests that the difference of felt *Comfort* between *self-disclosure* and *non-self-disclosure* is smaller in *AR* than on *Smartp.* (see Figure 3). We, therefore, reject *H2c* and report reversed findings. Second, we also found a negative interaction between *Role* (Ref: *perceiver*) and *Disclosure* (Ref: *non-self-disclosure*), suggesting that being the *perceiver* positively influences felt comfort concerning *self-disclosure* information. Meaning that *self-disclosure* leads to a greater difference in how comfortable *perceiver* and *target* feel with displayed information with *perceiver* feeling more comfortable (see Figure 3). We, therefore, found support for *H2b*. Last, we found a negative interaction between *Disclosure* (Ref: *non-self-disclosure*) and *Intimacy*, suggesting that, in the *self-disclosure* condition, the regulation effect of intimacy is stronger. Meaning, intimacy has a higher impact on how we feel when the data is *self-disclosure* than when it is *non-self-disclosure*. We, therefore, found support for *H2d*. A summary of supported and rejected hypothesizes can be found in Table 4.

Table 4: Summary of Hypotheses

H	Hypothesis Summary	Support?
H1a	Less comfortable in *AR* vs. *Smartp.*	Yes
H1b	Less comfortable for *target* vs. *perceiver*	Yes
H1c	Ar will have a increased impact on *target* compared to on *Smartp.*	No
H1d	AR will increase the impact of information intimacy	No^{rev}
H1e	Intimacy stronger impact on comfort levels of Target than Perceiver	No
H2a	Less Comfortable with non-self-disclosed vs. self-disclosed	Yes
H2c	In AR bigger gap between self- and non-self-disclosed	No^{rev}
H2b	Greater difference between target and perceiver for self-disclosed info.	Yes
H2d	Intimacy has more influence on *self-disclosure* vs. *non-self-disclosure*	Yes

No^{rev}: Reversed effect was found

5.2 Single Item Questions

We also asked the participants single item questions. Two were asked in both *AR* and *Smartp.* conditions, while participants could only answer the addition three in *AR* conditions. All were answered on a scale from 1 (Completely Disagree) to 7 (Completely Agree). To analyze the questions appearing in all conditions, we each executed a ANOVA and used Tukey multiple comparisons tests for the post-hoc analysis. The first question was asking if the participants would like to be informed every time another person would like to view information about them on their AR glasses or smartphone (depending on condition). We found a significant and large ($F(1, 144) = 28.95$, $p < .001$) effect of *Medium*, with participants wanting to be informed about displaying on *AR* (M=6.36, SD=1.14) more then on *Smartp.* (M=5 , SD=1.88). The second question was asking the participants would like to explicitly give their permission every time anther person would like to view information about them on their AR glasses or smartphone (depending on condition). Here we found a significant and medium ($F(1, 144) = 18.80$, $p < .001$) main effect of *Medium*, with participants in the *AR* (M=6.5, SD=1.04) showing a higher agreement to the statement than in *Smartp.* (M=5.46, SD=1.77).

In the *AR* conditions only, we further asked if when owning AR-glasses, the participants would activate/deactivate/use a feature that would display information about the persons around them. We found no significant influence of *Role* and report a tendency that the answers all center around the neutral answer-option. Statistics for this questions can be seen in Table 5.

Table 5: Single item questions answered in the *AR* conditions

Would you...	Mean	SD	Distribution
Use Feature	4.1	1.8	
Activate Feature	4.0	1.8	
Deactivate Feature	4.3	1.9	

5.3 Datatype

We now come to our research question on what information is suitable for displaying in *AR* by making neither *perceiver* nor *target* uncomfortable. We try to find indices on this question by looking at the means for *information types* for each *perceiver* and *target* as well as *self-disclosure* and *non-self-disclosure* information.

With *H1b* being confirmed, we know that the *perceiver* was generally more comfortable with displayed information than the *target*. We can see this trend depicted in Figure 4, visualizing the means for each *information types* ordered by overall stated comfort from low to high. Looking at this data, we can also see that participants in the *self-disclosure AR* conditions only felt comfortable with a view *self-disclosure information types*. Namely, *gender*, *first name*, *interests*, *age*, and *sexual orientation*. For *non-self-disclosure* information, they only averagely felt comfortable with their *gender* being displayed.

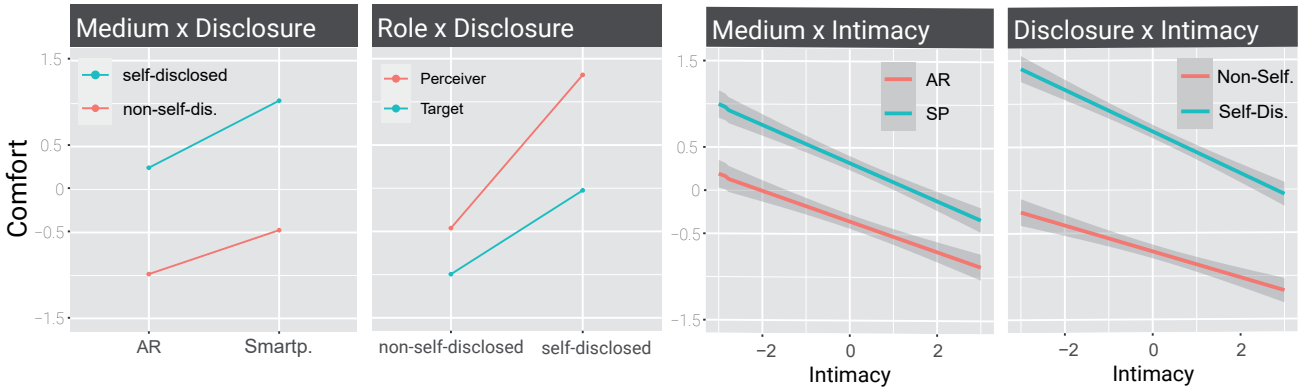

Figure 3: Visualizations of the interaction effects described in Section 5.1

6 DISCUSSION

In the following, we will discuss the results of our study and try to draw conclusions on the influences of displaying personal information in Augmented Reality compared to displaying it on a Smartphone.

6.1 Augmented Reality vs. Smartphone-Based Personal Information Displaying

On a smartphone, fewer factors influence how we feel about information. Here, the perceiver is alone with their smartphone and can, therefore, mainly be affected by the properties of the information itself and the way it is displayed. Information augmentation using an *AR-HMD* instead adds multiple additional factors. We found that these influence us to feel less comfortable with the information being displayed. We argue that one of the main factors that distinguish displaying information in AR is that the information's perceiver is not alone in the perceiving situation. The person the information belongs to is also present, changing the situation for both parties. The perceiver is now in physical proximity of their information target. For the target itself, while on the smartphone, they would broadcast to an anonymous mass online that can read the information at any given moment. In AR, they are now confronted with the person perceiving their data and experiencing it in real-time. For both parties, possible eye contact, and generally not being alone with their smartphone, might, therefore, introduce a lowered feeling of anonymity, which disinhibits oneself [39] and opens us to the feelings of social judgment [8]. That the situation itself becomes more important is also shown by the intimacy of the information losing a part of its power predicting our comfort certain information compared to displaying on a smartphone.

Therefore, we argue that when displaying information in AR instead of the Smartphone, we have to be careful as the metrics we use on information, e.g., social media, today might not be applicable to AR technology. While, e.g., intimacy is a strong predictor of the users' comfort on a Smartphone, the new situation arising from the augmentation includes other factors (like physical proximity and sharing the moment of perception) that lower the importance of today's key factors.

6.2 Effects of Self-Disclosed vs. Non-Self-Disclosed Data

We found that on Smartphones and in AR, participants generally felt less comfortable with the information not being self-disclosed but acquired through other means. Therefore, as hypothesized, taking away a person's autonomy and consent about their information makes us uncomfortable with it being displayed. Contrary to what we hypothesized, we found that in AR, the positive impact of knowing that information was given with consent was weaker than on Smartphones. Like the lowered influence of intimacy, it seems that also this attribute of the information loses part of its influence through the introduction of AR and the following emerging social situation.

As we hypothesized, looking at AR and Smartphones combined, we also found an interaction between the type of disclosure and the intimacy of information. We found that the lower the intimacy, the more the negative impact of missing consent weights. We argue that while intimate information already makes us feel uncomfortable, forcing information can only amplify this feeling. In turn, as we would feel comfortable with less intimate self-disclosed information, this feeling is turned around into discomfort, having a higher potential for a strong decrease.

In line with previous work on visual alterations in AR [55], we found that the perceiver of information is more comfortable than the target. We also found that knowing that displayed information was self-disclosed had a higher positive impact on the comfort of the perceiver than on the information target. We argue that while knowing that the information was self-disclosed brings relief from moral considerations for the perceiver, the perceiver must have other factors than knowing they self-disclosed the information that still inhibits them from feeling comfortable.

We also found that in AR conditions, participants showed significantly higher agreeing to (1) being informed of information about them was displayed and also (2) strongly wanted to explicitly

	PR	SD	TA	SD	PR	SD	TA	SD
tax history	0.0	2.3	-1.4	2.0	-1.7	1.8	-2.2	1.7
criminal history	0.1	2.0	-1.2	2.1	-1.6	1.8	-1.9	1.8
mental health status	-0.1	2.0	-1.5	2.0	-1.4	2.0	-2	1.8
employer	1.1	1.6	-0.9	2.0	-0.9	1.8	-1.5	2.0
date of birth	0.9	1.9	-1	2.1	-0.7	1.8	-1.8	1.8
city of residence	1.0	1.8	-0.9	2.1	-0.6	1.9	-1.6	1.9
political views	0.6	2.0	-0.5	1.9	-1.1	1.7	-1.4	2.0
religious views	0.7	1.9	-0.2	2.1	-1.0	1.7	-1.2	2.2
last name	1.1	1.8	-0.6	2.1	-0.7	1.9	-1.7	1.9
high school	0.8	1.8	-0.4	2.0	-0.7	1.8	-1.2	2.2
sexual orientation	0.6	2.0	0.1	2.1	-1.1	1.9	-1.2	2.2
relationship status	0.9	1.7	-0.4	1.9	-0.7	1.9	-1.4	1.9
occupation	1.3	1.7	-0.4	2.0	-0.4	1.9	-1.3	1.9
age	1.6	1.6	0	1.9	0.4	2.0	-1.1	1.9
interests	1.6	1.6	0.3	2.1	0.0	1.9	-0.6	2.2
first name	2.0	1.2	0.4	2.1	0.6	1.9	-0.6	2.2
gender	1.6	1.4	1.3	1.7	0.2	2.2	0.7	2.1

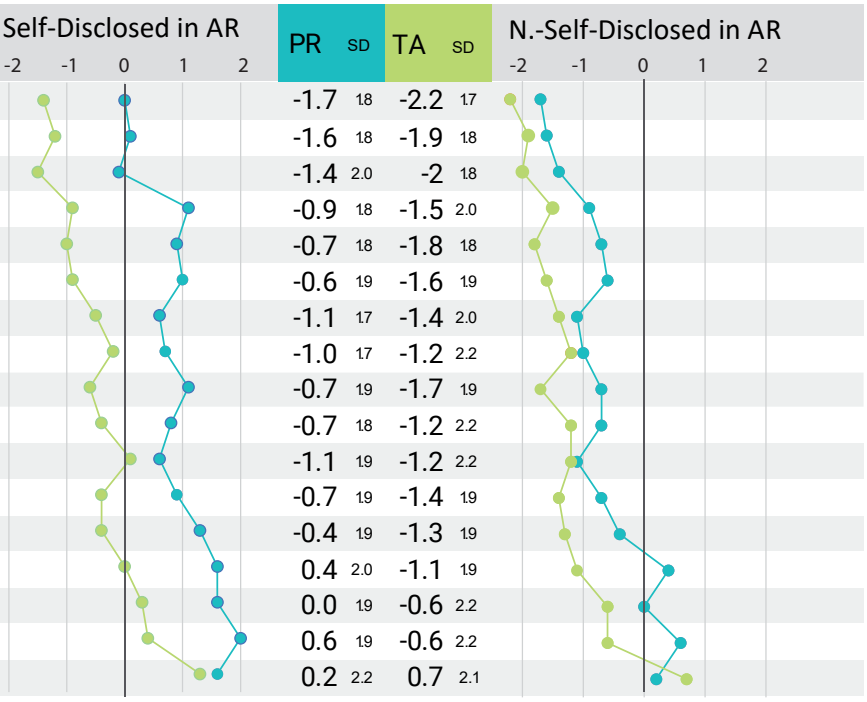

Figure 4: Average comfort ratings for the single information-types in self-disclosed in AR (left) and non-self-disclosed in AR (right). For each, averages for the perceiver (PR) and target (TA) are displayed. The information types are ascendingly ordered by comfort.

approve each request to do so. This demonstrates that while, in AR, the information itself and its origin lose influence on our comfort, targets still wished for a higher level of control over the displaying of information and consent to it.

6.3 Shaping Information Augmentation in Augmented Reality: Practical Implications

Overall, we found that people feel less comfortable in the situation in which they view information emerging through AR technology while also lowering the influence of characteristics of the information itself. Instead of having only one active actor in the act of viewing information, the new situation now actively incorporates the target. With them being the part which is less comfortable, it makes it even more important to induce both parties in the equation on how information augmentation should look. Designing systems for usability and matching the shown content to the interests of the perceiver becomes a less impactful way to design when optimizing for how users feel in future AR systems. Instead, developers should strongly invest in making the technology comfortable for the potential others that become part of augmentations their applications create, as they too will be influenced by it. All roles part of the applications need to be added to potential testing processes to ensure that the arising applications are socially acceptable and comfortable for anyone involved.

Focusing on the target also applies to the possibilities of acquiring information without their explicit consent. We found that while both parties would feel more uncomfortable with non-self-disclosed information in AR, the range of information with which the parties would feel comfortable differs. With participants also agreeing that they would want to first consent to every augmentation of information, we argue that consent on the targets site will be vital, making people feel comfortable with *AR-HMDs* and their possibilities. Developers, therefore, need to ensure that everyone involved in their application indeed consented to their involvement and the way it is executed.

While still having the possibility to shape if and how augmentation should be used in social situations, we argue that if so, consent and openness should be an essential property on which its development should focus on. In our study, we see that participants were indecisive if they would activate or deactivate such a function if owning an AR headset. Many participants in open comments on the study stated that they would imagine such a device in the hands of information agencies and not in private ones. The emerging physical proximity of the actors makes them feel vulnerable and worried, about it being used for criminal activities. A participant stated:

> *"My first fear that came to mind were stalkers or people who intend to harm, like rapists or kidnappers. By providing personal information, it makes us more vulnerable, especially if without our knowledge or permission. Literally supporting creeps and providing information to them with easy access."*

In spite of all the fears and in-comfort stated about the concept, there is still information that both perceiver and target feel comfortable with and that could be used to benefit our social coexistence. When disclosed with consent, both parties were, e.g., comfortable with displaying the target's first name, interests, age, or gender. Especially in the context of gender, participants repeatedly commented that they would like to use such a technology to display a person's pronouns. Showing that when implemented in a way in which we have agency and consent to it, information augmentation could be a comfortable space in which we e.g. express ourselves through exhibiting our interests or help people approaching us by letting them know how we want to be addressed. While it might become technologically possible to develop and deploy systems that go beyond and display further information, developers need to reflect if such information is vital to the purpose of their application. As going against what the people around, getting drawn into the context are feeling comfortable with could obstruct the newly emerging technology from becoming a safe, comfortable space for all.

6.4 Limitations

While being an established method of social acceptability research [30], we did not measure reactions to the technology itself but only to the abstract concept. This, in combination with the novelty factor of the AR-HMD technology, might have had an impact on our findings.

Previous work has also shown that when others are more accepting towards *AR-HMD* knowing what the person is displaying on it [32]. To investigate the concept, we had to explain it and what was happening in the situation to the participants in the conditions they were the information target. This in turn could in turn have also influenced the comfort ratings our participants and therefore were only able to research a situation in which both parts know what is displayed.

While presenting the participants with both, information that is self-disclosed and non-self-disclosed, we still had to introduce the participants to the concept of non-self-disclosed information. The introduction to this topic and the context it sets on the study could have biased the participants negatively towards *AR-HMDs* and smartphones, which in turn might have also influenced the answers on self-disclosed information.

6.5 Future Work

In our work, we found that the situation and context in which the information is presented are gaining relevance. Therefore, future work should address how different contextual factors influence our comfort with personal information augmentation. Here the context could differ on multiple factors, like being in a business or leisure time situation or augmenting in a one-to-one or one-to-many context. In our work, we also focused on information augmentation between strangers. As we know from previous work (e.g.[55]), the relationship the two actors share can impact how comfortable we feel with augmentations. Therefore, to get a more detailed view of information augmentation, future work should also investigate the relationship between the two actors and how it impacts their feelings when either one is augmented. From work on personalized privacy assistance (e.g. [12, 45]) , we know that the willingness to approve each sharing of information is dependent on the number of requests. In our study, participants strongly agreed with wanting to authorize each inquiry to display information about them. Future work should determine if this wish holds up to a real-life application context where multiple notifications could occur in a short frame of time.

7 CONCLUSION

With AR, we might soon be able to use its capability to identify the people around us and effortlessly display their personal information visually attached to their physical bodies. Hence, creating a new possibility of broadcasting ourselves and simultaneously consuming the information of our fellows. Previous work already shows that we as humans adapt our communication and disclosure behaviors to available technological opportunities [9]. With it not being a daily reality yet, we still have the possibility to shape this new way of information disclosure and perception in a way that focuses not on what is technologically possible but on what the involved persons feel comfortable with. To accomplish this, we need to know how the new situation influences emerging through AR make us feel compared to the traditional way of viewing information, e.g., a smartphone. Through a conducted online experiment (N=148), we provide empirical insights into how augmentation of personal information in AR influences our comfort and how it interacts with being perceiver or target of the information and the information's attributes. In our case, we looked at the information's intimacy level and whether it was consensually self-disclosed or not. Our results reveal a significant negative impact of perceiving personal information AR on our comfort compared to a smartphone. These findings were accompanied by AR also showing a decreased influence of characteristics of the information itself. While information's intimacy and type of disclosure were great predictors for comfort on a smartphone, it lost part of its predicting power in AR. We also found that while both the information perceiver and their augmented target would feel more uncomfortable with non-consensual, non-self-disclosed information in AR, the range of information with which the parties would feel comfortable differs. We found that the target generally felt less comfort when augmented and was significantly more likely to state that they would want to first consent to every augmentation of information than those on a smartphone. Therefore, our work discusses and sheds light on how consent on the targets site and openness towards them will be vital for making people feel comfortable with *AR-HMDs* and their possibility to augment information.

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