Don't look at me that way! – Understanding User Attitudes Towards Data Glasses Usage

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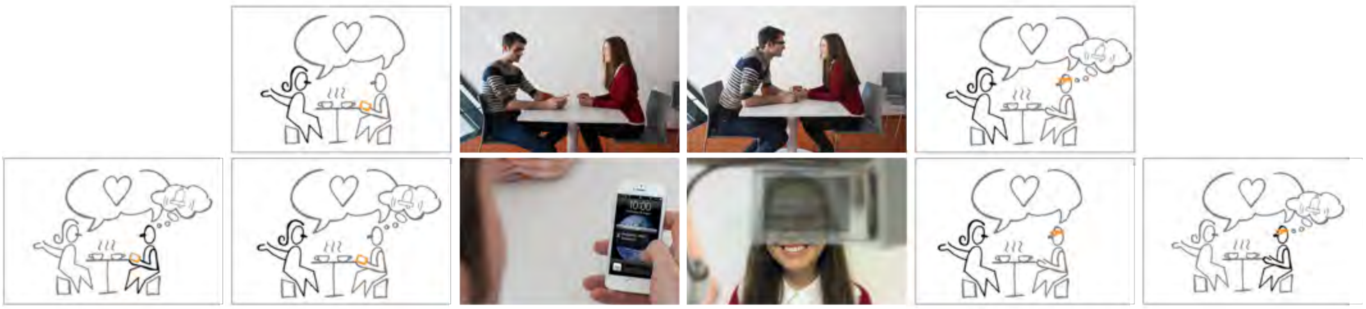

Figure 1: We investigate how data glasses usage is perceived by device users as well as by their peers based on abstract, sketched scenarios. In particular, we investigate how knowledge about usage intentions – indicates as "thinking bubbles" affects social acceptance. For presentation, the sketched depictions are shown along with possible "real-world" equivalents. However, the actual study only made use of the abstractions, to prevent e.g. cultural bias.

ABSTRACT

Data glasses do carry promising potential for hands-free interaction, but also raise various concerns amongst their potential users. In order to gain insights into the nature of those concerns, we investigate how potential usage scenarios are perceived by device users and their peers. We present results of a two-step approach: a focus group discussion with 7 participants, and a user study with 38 participants. In particular, we look into differences between the usage of data glasses and more established devices such as smart phones. We provide quantitative measures for scenario-related social acceptability and point out factors that can influence user attitudes. Based on our quantitative and qualitative results, we derive design implications that might support the development of head-worn devices and applications with an improved social acceptability.

Author Keywords

Data glasses; social acceptability; privacy; user attitudes;

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INTRODUCTION

In April 2013, the first few thousand test users of Google Glass[1], a light-weight head-mounted display, hit the streets. Though public attention has been mainly attracted by the rise of this particular device, the idea of so-called head-mounted displays (HMDs) dates back to 1968 [25]. Since then, HMDs have become more sophisticated and less obtrusive. Those kinds of head-worn devices are promising, as they allow for hands-free interaction as well as instant and direct information access. While the new generation of HMDs, which we refer to as *data glasses*, gained recognition for its innovative design, it also triggered a wave of critical reactions discussing public privacy concerns as well as its social acceptability.

This paper presents a two-step user study that investigates scenario-related social acceptability of data glasses and contrasts it with more established devices such as smart phones. Starting from a focus group discussion (7 participants) a scenario-based questionnaire has been designed and filled out in a user study with 38 participants. Our study design adds a novel approach to the body of related work, by using abstract pictograms instead of real-world footage which allows to better prevent cultural or gender bias as well as brand-specific effects. As an additional advantage this technique allows to aim for a high repeatability and reproducibility of the results in contrast to e.g. in-situ methods. Thus, future work can draw benefits from the presented results, as the measurements could be conveniently reproduced to map a development over time.

We first present qualitative results of the focus group discussion and highlight key findings. The quantitative results of the

[1] `http://www.google.com/glass/` retrieved on 2014/09/06

user study are presented and linked back to the key findings from the focus group. Informed by our results, we provide quantitative measures to substantiate our implications and point out factors that can influence user attitudes. Promising application areas for data glasses are highlighted. In particular, our research provides first indicators that the course towards professional use cases is promising. This finding aligns with Google's decision to discontinue Google Glass in its current form[2] and to focus on 'some specialized, even lucrative, uses in the workplace'[3]. We conclude with incentives for the development of design principles for HMDs with an improved social acceptability.

Motivation

As data glasses are a novelty to the mass-market audience, there is no general understanding of (non-)acceptance criteria for of their usage yet. It might seem at one's fingertips to relate those yet-to-define criteria to the collocated usage of other portable information and communication devices, as it has been researched by [12, 28]. However, the media's critical reactions suggest that user attitudes towards data glasses usage are different, thus featuring unique issues, that cannot be deduced from observations in recent history of technology. A first indicator is Google's decision to change perspectives, which might prove a landmark in the history of technology adoption. Above all, formerly introduced divisive technologies such as e.g. the Walkman in 1984 [9] did not reach comparable media coverage and far-reaching consequences.

Nevertheless, we claim that the strengths of head-worn devices substantiate the need for a better understanding of the concerns and anxiety they trigger. Our research thus aims to gather insights into the nature of general concerns related to data glasses. In particular, we focus on factors that might influence the users' attitude towards data glasses usage. By *quantitatively* measuring the factors' impact, we add novelty to the body of related work where mostly *qualitative* findings are reported. From our initial focus group discussion we learned, that one relevant factor is social context. Hence, we proceeded with an approach that not only considers the user but also takes into account the user's socioenvironment. We investigate how potential usage scenarios are perceived by device users, their conversational partners and by third-parties.

Terminology

Though public attention has been mainly attracted by the rise of Google Glass, the idea of so-called head-mounted displays (HMDs) is much older. A first bulky prototype was presented by Sutherland [25] in 1968. Since then, HMDs have become more sophisticated and less obtrusive. Due to the appearance of the current generation of light-weight HMDs, which start to resemble common off-the-shelf spectacles, we refer to them as *data glasses*.

Beyond Google Glass, there have been several commercialization attempts of this concept[4,5] that are referred to as "glasses-style augmented reality (AR) devices" in [7]. However, our survey neither confined by a specific brand or manufacturer nor bound to the Augmented Reality display paradigm [2].

As we aim to investigate the key concepts from a user-centered perspective, we decided to use the term *data glasses* during our studies and within the scope of this work. We claim that, by making use of this broad definition, we abstract the discussion about general usage scenarios from the capabilities of a specific device. This is further motivated, as many potential users do not yet have personal experiences with this kind of devices. Nevertheless, they have their own mental model of what can or cannot be done with data glasses. As mental models can be based on individual experience, this is not necessarily congruent with the actual capabilities of an existing, marketable device. A more in-depth description of what is comprised by the term data glasses, as we understand it, is summarized in Table 1.

> **Data Glasses** are a class of 'head-mounted displays' (HMDs) which can be either monocular or binocular. They are characterized by their
>
> 1. *mobility*: the device is mobile, i.e. it is not constraint by its size or weight or by being attached to an extra peripheral device, e.g. a desktop computer.
> 2. *embeddedness*: the device is non-immersive and embedded in the real world, i.e. it serves as an optical combiner by providing either an optical see-through or video-see through perspective on the environment.
> 3. *connectivity*: the device is interconnected with other devices and data sources.
> 4. *availability*: the device is either available on the mass market or for a large target group (i.e. professionals in a specific field, e.g. surgery).

Table 1: Characteristics of the term *data glasses* as it is used by this work. Our definition comprises both, monocular and binocular devices. We further do not restrict the term to devices with a specific sensor set (e.g. an optical camera).

RELATED WORK

Social implications of data glasses might relate to acceptability criteria of other portable and wearable information and communication devices. In this section, we thus discuss related work in the field of mobile personal devices without limiting our review to HMDs or data glasses in particular.

Mobile device usage in social context

Social implications of human-computer interaction (HCI) and interaction styles that are visible to the public have been particularly investigated within the context of gesture-based interaction with mobile interfaces. Researchers addressed this

[2]BBC News, **http://www.bbc.com/news/technology\-30831128**, retrieved on 2015/01/15

[3]Reuters, **http://www.reuters.com/article/2014/11/14/us-google-glass-insight-idUSKCN0IY18E20141114**, retrieved on 2015/01/15

[4]VuzixM100,**http://www.vuzix.com/consumer/products_m100/**, retrieved on 2014/09/06

[5]Epson BT-200, **http://www.epson.com/cgi-bin/Store/jsp/Landing/moverio-bt-200-smart-glasses.do**, retrieved on 2014/09/06

topic aiming to determine the borderline between acceptable and unacceptable gestural interaction. Ronkainen et al. [22] investigated the user's willingness to utilize a "tap-gesture" for interaction in different situations. They presented video scenarios to their participants and asked them to imagine themselves in the videos. For our study design, however, we decided for *sketched* still images instead of videos to reduce distortion effects (e.g. gender bias) caused by the depicted actors.

The social acceptance of gestural interaction with data glasses has been comprised but not elaborated by a more comprehensive evaluation on hand-to-face input by Serrano et al. [24]. With our work, we contribute to the understanding of social acceptability of HMDs in public and thus extend prior work.

Rico et al. [21] conducted a comprehensive evaluation of a body- and device-based gesture vocabulary. They were able to relate the acceptability of the used gestures to a combination of audience and location. Device perception from an observer's point of view has also been tackled by Profita et al. [20], who explore non-traditional ways of on-body input. They present a survey of third-party perceptions of user interactions with a wrist-worn interface. We present results of first- and second-person perspectives, extending available knowledge. We additionally provide *qualitative* and *quantitative* data, complementing existing research. In our user study we take into account that the two influencing factors presented by Rico et al. are relevant to social acceptability. We thus follow a scenario-based approach, where the choice and description of scenarios comprises both place and social context.

However, we do not particularly focus on gestural interaction or other input modalities. Though input styles are one important nuance of data glasses usage in public, we decided in favor of a deductive approach to allow for a broader, more general overview. In contrast to existing work we do not limit our evaluation to the interaction with the device but also investigate effects caused by its presence.

Device usage in professional environments

Our expectations with regard to confidentiality are particularly high in situations where we need to unveil personal information to others that are neither family nor friends. This might, for example, include a visit to the doctor or lawyer.

DeBlasio et al. [6] compare traditional (analog) and technology-supported documenting methods in physician-patient interaction. They evaluate the quality of care (QoC) based on a series of questionnaires that was filled out by the participants after they had watched a video. Video-based studys allow to vividly depict realistic scenarios, including e.g. non-verbal communication. Nevertheless they also might be more prone to bias from e.g. gender, ethnical group or sympathy that might interfere with mere effects from the used technology. For this reason, we consciously decided against imagery showing real persons and for androgynous sketched still imagery.

In a more recent study, Ziefle et al. [31] in 2010 investigate acceptance patterns of different concepts for e-health care systems, incl. smart mobile devices, smart clothes as well as smart environments. In [29], a focus group based evaluation of the perceived privacy and security of e-health systems is presented. For a study presented by McNaney et al. [15], 4 Parkinson's patients took part in a 5-days field trial and used Google Glass during their everyday life. The authors note that patients requested full control over detailed privacy settings as well as the opportunity to create user-defined rules. They further present experiences of the participants in several public situations, such as shopping, driving and meetings with friends. While they focus on Parkinson's patients as a specific target group, the study presented here investigates the acceptability of data glasses on a more general basis. Moreover, we consider both users and their social environment, such as e.g. friends or colleagues. In order to more closely represent a larger group, we also decided for a gender-balanced sample.

User-centered aspects of HMDs

Albeit the major gain in public attention is very recent, effects of HMDs on user behavior have already been studied for several years. Costanza et al. [5] presented eye-q, a peripheral notification display embedded into the frame of consumer glasses. They evaluated the effectiveness of data glasses under real-world conditions. While focussing on ecological validity and realism, they were able to show that data glasses have the potential to be used during everyday activities, even when mobile. However, at this time (2006) the authors did not incorporate privacy or acceptability aspects into their study.

McAtamney et al. [14] describe the effects of an HMD on informal face-to-face communication. They present a between-subjects experiment, comparing a "wearer-condition" with a "non-wearer condition". The perceived impact of an HMD on a conversation between two participants, one of each group, is measured based on formal and informal feedback. In particular, they considered how the users' attentiveness, concentration, eye contact during conversation, and the naturalness in their behavior was perceived by themselves (as "wearer") respectively by their counterpart (as "non-wearer"). Our study design builds upon their work in terms of the comparison between the first-person view, where the interviewee is wearing the device, and the second-person view, where she is colocated with another person using the device.

In contrast to the previous work, we do not set up an artificial scenario in the lab, but present the users with a range of abstract, but realistic scenarios. By asking the users to imagine themselves in the depicted situations, we aim to rule out potential bias from the artificial situation. However, we have to acknowledge that our interviews, in the style of [22], also have their limitations which we discuss at the end of this work.

A more recent study (2013) on the design space for data glasses [13] addresses general issues such as optics, technology, social implications and form factors and collect initial user feedback. Nevertheless, the paper lacks detailed feedback on user attitudes and social aspects. With our work presented here, we aim at closing this gap.

Social implications of video recordings

One particularity of data glasses is that some them possess the ability to record video and/or audio. To novices it is often unclear if a device is able to record, if it is recording and what is captured. The way data glasses are worn does not inherently communicate if data is captured. By contrast, users of mobile hand-held devices, such as cameras or smart phones, convey the action of recording to spectators by holding their device differently. Bohn et al. [3] note how the perception of privacy borders is influenced by our reliance on *borders due to ephemeral or transitory effects*. It is characteristic for human information processing that a large amount of small details passes away unnoticed, or is forgotten after a short period of time. They assume that technologies being able to capture and prevail this kind of detailed information are potentially affecting our interpersonal relationships. It is further noted that the pure (potential) existance of imagery, video or audio recordings, even if not disclosed to third-parties, makes many people feel uncomfortable and thus affects the social acceptability of such capturing devices.

More recently, these aspects have been reconsidered within the topic of *lifelogging*. Hoyle et al. [10] evaluate dedicated lifelogging devices, such as the Narrative Clip[6], the Autographer[7], and data glasses with lifelogging functionality with regard to application scenarios, usage and sharing of the collected data as well as privacy perception. Benefits, risks, as well as legal aspects of lifelogging are discussed by Wolf et al. [30].

Denning et al. [7] conduced "Paratyping"-style interviews with bystanders of data glasses in cafés. They investigated in which way the interviewees expected the presence of the device to change the bystander experience. They further analysed the factors contributing to the participants objections to being recorded and collected their ideas on imposing restrictions on recording. As one of the influencing factors the "place as a social construct" was identified. Their results add to implications obtained from previous research [18] on CCTV that found the acceptance of being recorded varying by location. With our study, we built upon these results and aim to provide a deeper understanding of space- and context-based perception of data glasses usage in public.

FOCUS GROUP

We conducted an initial focus group discussion to better understand in which occasions, situations and locations the usage of data glasses is (in-)appropriate or discussed controversially. In particular, we aimed to identify reasons for positive and negative reactions to data glasses.

Seven participants, aged between 25 to 37 (mean age $\overline{x} = 32$, standard deviation $\sigma = 4$), took part in a 40 min. focus group discussion. The participants, 3 male, 4 female, were researchers with different areas of expertise. None of them had a background in computing science or HCI. They were recruited from two universities, unequal to the authors' affiliation. Two of them were experienced with data glasses in a broad sense, i.e. they had tried HMDs once to a few times. They did not consider themselves as regular users. The remaining 5 had never used or tried such devices.

[6]Narrative Clip, `http://www.getnarrative.com`, retrieved on 2015/02/06

[7]Autographer, `http://www.autographer.com`, retrieved on 2015/02/06

Methodology of the Focus Group

The focus group discussion took place in a seminar room at TU Munich. At first, the participants were asked to note down situations, in which data glasses are already used or in which they could imagine that data glasses will be used in the future. The participants had 15 min. time to reflect and note each item on a separate card. In a second step, they were asked to group these situations into 3 categories using 3 separate pin boards based on an open discussion of 25 min.

- *Inappropriate*: the participants agreed concordantly that in these situations the usage of data glasses is not acceptable or should be restricted. (**I**nappropriate **S**cenario, **IS**)
- *Controversial*: the participants were indecisive or disagreed on whether data glasses usage is socially acceptable or unacceptable in these situations. (**C**ontroversial **S**cenario, **CS**)
- *Appropriate*: the participants agreed concordantly that in these situations the usage of data glasses is both reasonable and acceptable. (**A**ppropriate **S**cenario, **AS**)

The participants were served with beverages and sweet buns. They did not receive monetary compensation.

Discussed Items of the Focus Group

The items named by the focus group indicate that the usage of data glasses in social contexts is perceived as highly debatable. Participants discussed a variety of items, including potential usage situations as well as roughly defined applications on data glasses. For analysis, dublicates were removed and items were summarized.

In summary, 26 different items were identified, of which 9 situations and 5 applications (cf. Table 2) were rated as *controversial* and in parts discussed emotionally. In 7 of the discussed situations data glasses usage was rated as *inappropriate*. On the one hand these included occasions where technology use is prohibited or restricted per se, such as "courtrooms" (IS1), "sauna/pool" (IS2), "church/synagogue" (IS3) as well as descriptions such as "on a date/rendez-vous" (IS4) or "during confidential meetings" (IS5), where social norms apply. While we assume these not to be very surprising, on the other hand also statements such as "record s/o without consent" (IS6), "anywhere before everyone viewed agreed" (IS7) were documented. These nominations reflect our initial impressions that data glasses usage is perceived as a serious threat to privacy. Though legislation varies between regions (described in detail in [30]), the discussion on data glasses indicates that there might be a wish for more comprehensive regulations for public video and audio recordings. The flag *appropriate* was assigned to a range of prevalent non-public occupations such as "cooking" (AS1) or "relaxing at home" (AS2) as well as (semi-)professional activities such as "training observation" (AS3), "skiing-/biking goggles" (AS4) and "surgery/medical applications" (AS5).

A summary of discussed *controversial* situations (CS) and applications (CA) is listed in Table 2. To allow for an in-depth evaluation of the named situations and applications, we conducted a further user study which we describe in the subsequent chapter.

Controversial Situations	
CS1:	during personal interactions
CS2:	business meetings
CS3:	walking in urban areas
CS4:	when children are involved
CS5:	walking outside of urban areas
CS6:	teaching situations
CS7:	cultural events
CS8:	working environments
CS9:	while driving
Controversial Applications	
CA1:	recording of images, video, audio
CA1:	navigation
CA2:	reading news, messages
CA3:	sightseeing
CA4:	gaming

Table 2: Distinct 9 situations and 5 applications named and classified as *controversial* during the focus group discussion. Duplicates were removed and items were summarized.

Focus Group Findings

We now present key insights of the focus group in more detail.

Social context matters.

The suggested situations were discussed more critically by the participants if they involved interpersonal communication. Situations where only or prevalently the device user was involved, e.g. home entertainment applications or professional occupations such as surgery and manufacturing, were rated less severe. Those were assigned to the "appropriate" category in most cases. Data glasses usage during personal conversations was considered "rude". However, participants also claimed that the usage of data glasses during interpersonal interactions was not perceived differently than smart phone or other device usage.

Freedom of choice versus privacy protection is controversial.

As a general tendency, we noted that the participants' attitudes towards a usage situation changed depending on whether they imagined themselves as the person using a device, their conversation partners, or third-parties. On the one hand, the participants claimed the freedom to use whatever device they want, as long as they do not interfere with anyone else. Some participants even felt the neccessity to advocate their free choice of device usage: *"You are trying to forbid me my freedom of holding my mobile phone like this. I don't interfere with you at all. If you don't like me sitting like this, that's your problem. Not mine." (P1)* On the other hand, they also expressed that they are likely to feel intimidated when others in their proximity use devices such as data glasses. Some participants requested to forbid the usage of data glasses in public spaces.

More established devices are perceived differently.

The participants were more sensitive to privacy violations by data glasses than to the same inappropriate behaviors using established devices. However, P1 noted, "*[...] it's forbidden to record certain stuff, and it's forbidden with [data glasses] in the same way as with other UIs [user interfaces]*". Denning et al. [7] investigated the reasons behind that effect by asking "Do you think recording with those glasses is similar or different to recording with a cell phone? Why?". A similar effect has been reported as the so-called *status quo bias* [23].

Knowledge about performed actions is relevant.

The participants expressed the desire to know what the person facing them is using her device for. Often, the inherent form factor of devices such as smart phones already communicates a type of action. Actions such as e.g. "taking a video" or "reading" could be inferred from the device posture or from the gaze direction of its owner. However, data glasses do have different affordances. In this case, the participants were unsure how the type of action performed by the owner can be deduced. We assume that this is both due to the fact that the participants were not experienced with others using data glasses and as a consequence of the characteristic form factor of these devices.

It is preconceived that data glasses are always recording.

Similarly, we observed that some of our participants assumed that data glasses are inherently recording. P2 stated *"If you wear [data glasses] that is similar to that you are recording. I think, you must not use them. You must ask everyone before."* The participants also stated that LED lights indicating whether a device is recording, were either not perceived at all or did not entirely eliminate their concerns.

Summary of the Focus Group

During the focus group, we gathered a list of 9 situations and 5 applications that were identified as controversial. The focus group indicated that user attitudes towards data glasses usage are more critical than towards the usage of other portable devices. We noted that data glasses usage might be perceived differently from a first-person (the user's) point of view than from a second-person perspective. This finding aligns with the effect described by Palen et al. [19], where they found a notable discrepancy in their participants' perception of the social appropriateness of mobile phone usage, when comparing their initial attitudes to their opinions in the first 6 weeks after they became active mobile phone users. Moreover, we found that knowledge about actions or intentions of device usage affects its acceptance. Following a two-step approach, those aspects were reconsidered during the user study.

USER STUDY

Under consideration of the focus group's feedback we conducted a quantitative user study. In contrast to the initial focus group discussion, we decided to base the design of our second study on predefined, but roughly sketched scenarios that leave room for individual associations (cf. Figure 1). We base our choice of scenarios upon one of the focus group's essences – "social context matters" – and expand our focus to social acceptability. We therefore give some notes on the definition and evaluation of social acceptability in HCI. We go into detail on the choice of scenarios and the design of the questionnaire. Finally, selected results and key findings are highlighted.

Evaluating Social Acceptability

Social context motivates us to constantly evaluate how we are perceived by others and to adjust the way we act accordingly. To evaluate the social acceptability of human-computer interactions, it has been suggested by Brewster et al. [4] to consider both an internal and an external view. They consider how an individual using a device perceives this experience, as well as how this user's actions with the device are perceived by others nearby. Montero et al. [17] formalize a measure for social acceptability that incorporates two dimensions:

- The *user's social acceptance* is defined by [17] as the internal effect the device usage has on her: How comfortable or relaxed did she feel interacting with it? How natural or awkward felt the task in the respective environment?
- In contrast, the *spectator's social acceptance* evaluates the external effect of the user's interactions with the device: Does it appear 'normal' or does she stand out?

This definition aligns with our findings from the initial focus group discussion, where we found a discrepancy between internal and external view. To comprehensively evaluate social acceptability by taking both dimensions into account, our study design evaluates scenarios shown from an ego perspective as well as from a second-person view. We furthermore utilize a semantic differential that matches both sides. This allows us to assess and compare those two contrary perspectives.

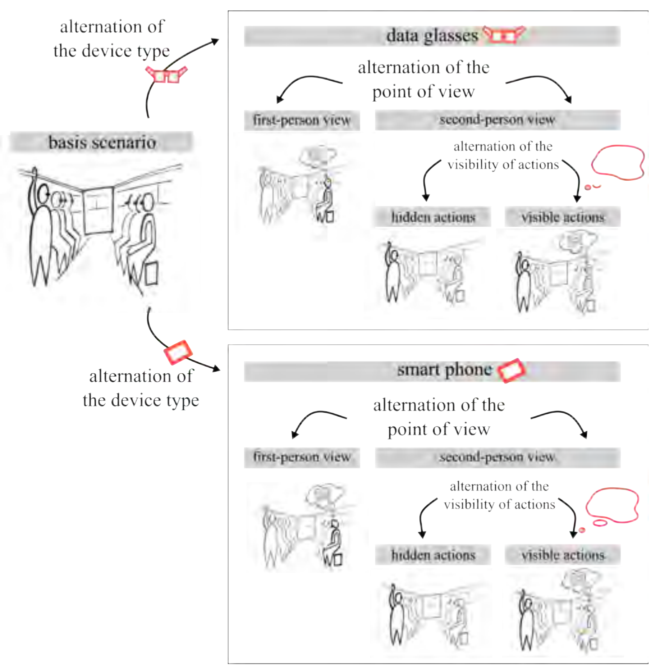


Figure 2: Alternation scheme for one example scenario out of the *public spaces* category. Starting from a basis scenario, 6 variants are derived of which 4 are evaluated by each participant. [best viewed in color]

Methodology

We evaluated the designed scenarios with 38 participants, of which 16 (42%) were female. The participants were aged 18 to 38 ($\overline{x} = 23$, $\sigma = 4$). They were recruited via a local recruitment platform based on a random selection of a gender-balanced subsample of the platform's database ($N = 1471$). 2 of the participants had experiences with data glasses; all other participants stated to have no such experiences. The study was conducted in a controlled lab environment at our institute. Participants registered for individual time slots of 1 hour each. In order to minimize effects of social desirability or social approval, the questionnaire was filled in by each participant in private using a desktop computer located in a separate polling booth. In order to gather unbiased and spontaneous reactions, the participants where not informed about the study's topic during the registration process. They were briefed on the purpose of the study in the beginning of their lab session. During the study, the participants were shown different sketched illustrations of usage scenarios, one at a time. Each scenario was represented by an illustration and two to three neutral descriptive sentences. An overview of all scenarios (for brevity in second-person perspective) is shown by Figure 6. Following a between-subjects design, the participants were assigned to two different groups by lottery draw. Half of the participants were told what purpose the depicted person was using a device for, i.e. they were allowed to "read the thoughts" of the person using the device. In contrast, the other half did not receive any additional information, i.e. they had to rely on the way the device was held by the person depicted in the scenario and guess the action. They were served with cold beverages and sweets and received an appropriate monetary compensation following the recruitment platform's convention, i.e. 10€/hour. The compensation was disbursed after the study in a separate room and by personnel different from the experimentator.

Choice of Scenarios and Study Design

Based on the situations that were rated as *controversial* during the focus group discussion we created a catalogue of illustrations of 14 different scenarios (in total 84 different variations). A summary of all scenarios is shown in Figure 6. To allow for a detailed evaluation, the scenarios were altered in two ways. From each basis scenario, several illustrations were derived, by alternating the kind of device (data glasses or smart phone) and the person using the device (*first-person* condition, *second-person* condition). The derivation of 6 variants based on one example scenario is illustrated in Figure 2. The first-person view is not subdivided as it always includes an indicator for the performed actions. This was decided, as in a realistic scenario the device user usually is aware of the intention of her actions. The scenarios were assigned to 3 main categories:

1. *interpersonal conversations:* conversational situations where two or more actors are involved, different topics of conversation are depicted using symbols. **[4 scenarios, 24 variations]**
2. *(semi-)public spaces:* situations in public where strangers are encountered as well as characteristic situations while driving. **[5 scenarios, 30 variations]**
3. *working environments:* professional situations that involve a spectator (e.g. as patient, customer or an audience). Scenarios only involving a professional user and a device were not considered. Illustrations including a notebook were added for baseline comparison. **[5 scenarios, 30 variations]**

All in all, we created 84 different illustrations, of which 18 are shown from a first person's view. Two-times 38 illustrations are shown from a second person's view, either with or without depictions of the intention of device usage. Each participant rated *all first-person perspectives*, and one of the aforementioned sets-of-38, according to her assignment to the "thought-reader" or "non-thought-reader" condition in the between-groups design. Overall, 56 illustrations were rated by each participant in randomized order, taking approx. 30min.

To ensure that the used picture vocabulary is clear and comprehensible for a general audience, we based the sketches on the *bikablo visual dictionary*[8]. Persons are depicted androgynous, i.e. they are not explicitly male or female. This aims to support the interviewee in putting herself in the position of the shown actor.

Design of the Questionnaire

The questionnaire started with a brief section assessing the technology affinity of the interviewee on a 5-point Likert Scale. The eight items were chosen from the standardised and verified questionnaire TA-EG [11]. Comprising 4 subscales, namely enthusiasm for technology, positive and negative consequences as well as expertise, we found the TA-EG suitable to provide a baseline for user attitudes towards technology.
The scenarios were rated based on a semantic differential, in order to compare the effect of the scenarios' alternations on a numerical basis. Semantic differentials are a well-understood and established method to measure emotional responses in psychology and in HCI [1, 8]. The adjectives used for our investigation were justified by related work and deliberately chosen based on recent research. Our choice is based on work of Walter et al. [27], who explicitly focus on scenarios involving human-machine interactions and human-human interactions. Table 3 lists the pairs of opposites comprised by the semantic differential.

negative connotation	positive connotation
tense	serene
threatened	safe
unsure	self-confident
observed	unobserved
skeptic	outgoing

Table 3: Pairs of opposites used to create the semantic differential. Positive connotations are listed on the right, negative connotations on the left.

The participants were asked to indicate their subjective perception of the scenario based on pairs of opposites using a slider on the screen below the illustration. The slider range comprises -5 to +5 (resolution of 1.0) and corresponds to a 11-point Likert Scale (resulting in ordinal scaled data [16]).

Results

In the following, selected results of the user study are discussed and linked back to the initial hypotheses obtained from the focus group discussion and related work.

More established devices are perceived differently.

The analysis of the focus group discussion indicated that more established devices, such as smart phones, and data glasses are perceived differently. The results of the user study support those initial findings. We computed average scores from the mean values of the semantic differential. Scenarios where data glasses were used, achieved lower average scores (min. avg. score: -3.1, max. avg. score: 0.4, $\overline{x} = -0.99$, $\sigma = 1.63$) than scenarios where smart phones usage was depicted (min. avg. score: -1.4, max. avg. score: 3.8, $\overline{x} = 2.68$, $\sigma = 2.86$). The differences were significant[9] for all scenarios.

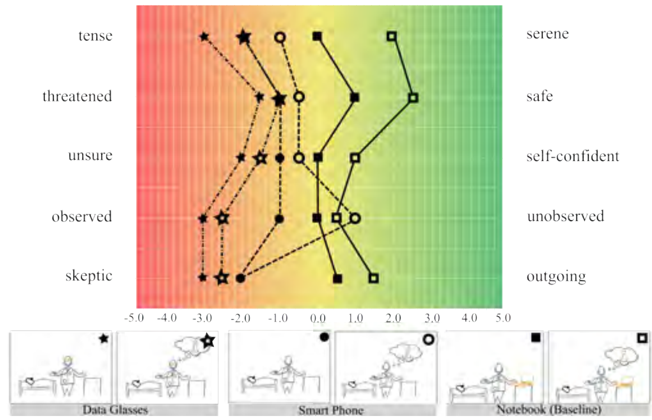


Figure 3: Detailed results of the semantic differential for a medical scenario (left). Data glasses and smart phone conditions are depicted along with the notebook condition, which is used as baseline comparison. [best viewed in color]

The largest differences were found for conversational scenarios. Figure 4 visualizes the median values ($\overline{x}$) obtained from the semantic differential for each of the conversational scenarios and for each pair of opposites. The derived scenarios are grouped based on their basis scenario. The *Pearson product-moment correlation coefficient* (r) (cf. Figure 4, middle column) indicates a moderate positive correlation ($0.20 < r(188) < 0.39$, $p < 0.001$, marked by *), respectively a strong positive correlation ($0.40 < r(188)$, $p < 0.001$, marked by **) between the measured perception of scenarios involving data glasses and smart phones ($r(188) > 0.0$, $p < 0.001$). One scenario (conversational scenario 2, C2) shows a negligible relationship ($0.0 < r(188) < 0.19$, $p < 0.001$).

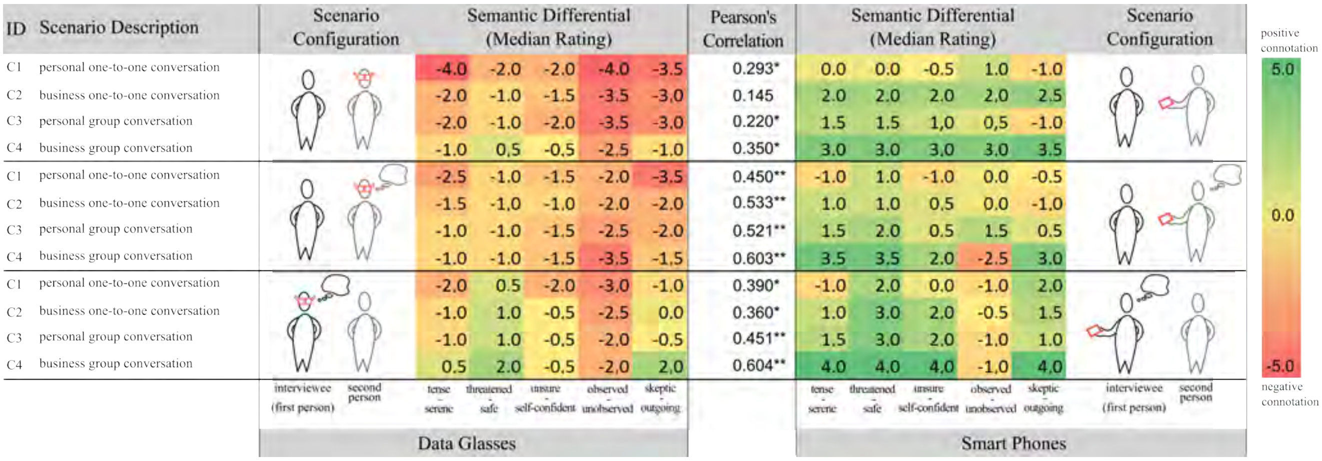
In Figure 3 detailed results of the semantic differential are shown for a medical (work) scenario. Data glasses and smart phone conditions are depicted along with the notebook condition, which is used as baseline comparison. Both notebook ($p < 0.001$) and smart phone ($p < 0.001$) condition achieve significantly higher scores than the data glasses condition. Thus we cannot confirm the results in [6], where a desktop computer condition was rated significantly worse than wearable conditions.

Females are more likely to express negative feelings

We found significant differences between male and female participants for 18 of the 22 evaluated scenario variations with data glasses. 16 of the 22 evaluated scenarios, were rated significantly (all $p < 0.05$, $p \in [0.0001, 0.03]$) more negative by female participants. In contrast, the two second-person scenarios involving data glasses usage during driving, were judged significantly more negative by our male participants.

[8]Bikablo Visual Dictionary. `http://www.bikablo.com`, retrieved on 2015/02/06

[9]The p-values for the within-subjects comparisons were obtained from the *Wilcoxon Signed Rank Test* resp. the *Friedmann Test*



ID	Scenario Description	Data Glasses: Scenario Configuration	Data Glasses: Semantic Differential (Median Rating) tense - serene	threatened - safe	unsure - self-confident	observed - unobserved	skeptic - outgoing	Pearson's Correlation	Smart Phones: Semantic Differential (Median Rating) tense - serene	threatened - safe	unsure - self-confident	observed - unobserved	skeptic - outgoing	Smart Phones: Scenario Configuration
C1	personal one-to-one conversation		-4.0	-2.0	-2.0	-4.0	-3.5	0.293*	0.0	0.0	-0.5	1.0	-1.0	
C2	business one-to-one conversation		-2.0	-1.0	-1.5	-3.5	-3.0	0.145	2.0	2.0	2.0	2.0	2.5	
C3	personal group conversation		-2.0	-1.0	-2.0	-3.5	-3.0	0.220*	1.5	1.5	1,0	0,5	-1.0	
C4	business group conversation		-1.0	0.5	-0.5	-2.5	-1.0	0.350*	3.0	3.0	3.0	3.0	3.5	
C1	personal one-to-one conversation		-2.5	-1.0	-1.5	-2.0	-3.5	0.450**	-1.0	1.0	-1.0	0.0	-0.5	
C2	business one-to-one conversation		-1.5	-1.0	-1.0	-2.0	-2.0	0.533**	1.0	1.0	0.5	0.0	-1.0	
C3	personal group conversation		-1.0	-1.0	-1.5	-2.5	-2.0	0.521**	1.5	2.0	0.5	1.5	0.5	
C4	business group conversation		-1.0	-1.0	-1.5	-3.5	-1.5	0.603**	3.5	3.5	2.0	-2.5	3.0	
C1	personal one-to-one conversation		-2.0	0.5	-2.0	-3.0	-1.0	0.390*	-1.0	2.0	0.0	-1.0	2.0	
C2	business one-to-one conversation		-1.0	1.0	-0.5	-2.5	0.0	0.360*	1.0	3.0	2.0	-0.5	1.5	
C3	personal group conversation		-1.0	1.0	-0.5	-2.0	-0.5	0.451**	1.5	3.0	2.0	-1.0	1.0	
C4	business group conversation		0.5	2.0	-0.5	-2.0	2.0	0.604**	4.0	4.0	4.0	-1.0	4.0	
		interviewee (first person) / second person												interviewee (first person) / second person

Figure 4: Detailed results for all conversational scenarios. Scenarios are alternated, as depicted above, in terms of a) the type of device (left: data glasses, right: smart phone), b) the device user (black: the interviewee and greyed out: a second person) and c) the visibility of actions performed with the device (indicated by "thinking bubbles"). The mean rating of each pair of opposites is color coded from 5.0 (green) to -5.0 (red). Pearson correlations for $r(188), p < 0.001$ are given in the middle column. [best viewed in color]

Despite this exception, we find in summary that female participants were more likely to express negative feelings towards scenarios with data glasses than male participants. A colloquial explanation for similar effects in the past has been to assume that women are less enthusiastic about technology and less likely to be early-adopters. This is also reflected by the TA-EG, where our female participants were significantly more likely to approve the items of the *enthusiasm for technology*. However, the TA-EG questionnaire did not yield significant (all $p > 0.1$) differences between male and female participants regarding *positive and negative consequences of technology usage*. We think that the latter explanation is only covering one aspect of the described effect: In contrast to the scenarios involving data glasses, only 8 out of 22 depictions with smart phones show significant differences between male and female participants. Despite the lower enthusiasm for technology, also a second effect might be relevant: we earlier noted that it is preconceived that data glasses are always recording. If future work would be able to show, that the fear of beeing spied on varies between genders this might add up to that conclusion.

Freedom of choice versus privacy protection is controversial.

The focus group discussion implicated that the usage of data glasses is perceived more positively from a first-person perspective than when the device is used by a second person. The findings from the user study support this hypothesis partially. We found significant[10] differences for all conversational scenarios. The one-to-one business conversation was rated with a score of -0.6 from the first-person perspective and a score of -2.2 from a second-person point of view ($p < 0.001$). However, for scenarios involving random encounters in public environments, e.g. in the subway or on the street, no significant differences were found. A possible explanation might be the desire for social approval. To humans it is more important to receive positive feedback and appreciation from a person that he/she is personally connected with (such as e.g. a conversational partner) than e.g. from random passers-by. Nevertheless, from the *Pearson product-moment correlation coefficient* (r), an at least moderate positive correlation ($0.20 < r(188) < 0.39$,$p < 0.01$) between the rating of the *first-person* condition and the *second-person* condition, can be reported for all scenarios. A strong correlation ($r(188) > 0.4$, $p < 0.001$) was found for 8 of the 18 pairs of scenarios.This means that participants that rated others wearing data glasses more harshly, were also indicating more negative feelings in scenarios where they were using the device themselves.

Knowledge about performed actions is relevant.

The focus group's participants considered it relevant to have a rough idea of someone else's actions with a mobile device. To provide further evidence for this claim, we performed a between-subject test with two groups in this user study. Symbolic and textual cues indicating the usage goal were given to one group. In contrast, the other group was only told which device was used in which situation. Significant differences between those two groups were found for 3 of 4 conversational scenarios and 2 of 5 scenarios in public spaces.

We found no significant differences (*Mann-Whitney Rank Test*, all $p > 0.05$, $p \in [0.1, 0.4]$) for work environments. It could be concluded that data glasses that are used in work environments are inherently perceived as professional tools. Hence, additional markers indicating the purpose of their usage are not necessarily required. On the other hand, these findings also implicate that for applications that are designed to be used in private social contexts, indicators of their purpose of use can be one way to improve their acceptability. Putative knowledge about the purpose of device usage allows the observer to feel more secure. This assumption is also concordant with research on cognitive bias such as for example the *illusion of control* [26]. As data glasses are perceived as a threat to privacy, this aspect might be one key towards improving their acceptance.

[10] The p-values were determined using a *Mann-Whitney Rank Test* for the between-subjects comparison.

DISCUSSION

This section names and discusses implications and limitations of the presented research. We critically address several aspects of methodology and results. Concluding from the discussed aspects we then develop strategies for future work in this area. We provide examples for follow-up studies and possibilities for technology improvements.

Design Implications and Future Directions

This section revisits some of the results of our studies and highlights selected potentials that might motivate future design decisions. Based on qualitative and quantitative results of our study, we highlight initial indicators for best practices in data glasses design. We found that, to increase the prospects of head-worn devices to become part of our everyday lives, they would need to match the following characteristics.

Be task focused.

Results of our user study provide indicators that data glasses in working scenarios are already perceived as professional tools. Future designs could make use of this by focusing on clear, task-oriented usages. During our focus group discussion, "surgery" and "skiing/biking" were named as possible task-specific use cases, and also as *appropriate* use cases. In consequence, a key to improving acceptance might be to design them as dedicated aid to specific professional (e.g. manufacturing or surgery) or semi-professional tasks (e.g. skiing[11] or biking[12]) instead of designing all-purpose data glasses.

Communicate the intention of use.

Many of our current devices, such as smart phones, do have an inherent form factor that already communicates a type of action. Actions such as "taking a video" or "reading" could be inferred from the device posture or from the gaze direction of its owner. However, data glasses do have different affordances. Our studies' results were able to *quantitatively* demonstrate that knowledge about the intention of device usage can significantly affect user attitudes. This complements and extends *qualitative* findings currently available in literature. P2 of our focus group noted, *"[...] If you go around with Google Glasses, there should be a rule to indicate whether the system is working"*. Our user study confirmed, that knowledge about the actions performed with a device are particularly relevant to reduce objections. We already find humorous examples of self-made or 3D-printed solutions, such as "Glass Privacy Cover"[13]. Future work hence might aim to find more appropriate and intuitive ways to communicate usage intentions to third-parties.

Follow a least capabilities principle.

From the focus group we learned that bystanders are likely to assume that data glasses are always recording, which negatively affects their social acceptance. We thus propose a simple least capabilities principle: If the use case does not require a camera/microphone/display, just do not add one. This could be supported by a modular design approach, such as Project Ara for smart phones[14]. One could even imagine to design interchangeable modules that could be attached and detached depending on the current use case.

[11] Recon Snow2, **http://www.reconinstruments.com/products/snow2/**, retrieved on 2015/02/06

[12] Recon Jet, **http://www.reconinstruments.com/products/jet/**, retrieved on 2015/02/06

[13] Glass Privacy Cover, **http://www.thingiverse.com/thing:96237**, retrieved on 2015/02/06

Limitations

To substantiate our conclusions, this section points out to which scope they are applicable and highlights their limitations. Designing a practicable survey requires to limit the overall time spent by a participant to complete the questionnaire to a reasonable amount. For this reason, we had to confine the scope of scenarios, first to social contexts, secondly to those that emerged as particular *controversial* during the focus group discussion.

Thus, our results might not be applicable to other contexts, where specific factors, such as e.g. productivity or safety, might be more relevant. The relationship between the user and other present people (e.g. instructor-scholar) was tackled, but not evaluated in detail. We acknowledge that - due to the finite amount of scenarios - there are many other situations with and without social context that have not been evaluated. We further acknowledge that the evaluated selection of scenarios is rather typical for Europe or the US and will most probably not be representative e.g. for MEA or APAC countries.

Our findings are congruent with what an experts eye might intuitively conclude from observation. Though, the motivation of our study is the need for the provision of hard numbers and facts, allowing quantitative arguments, instead of predictions from qualitative feelings. The novelty of data glasses themselves might currently have a significant effect on the results. However, we expect a shift in the future, comparable to mobile phones, whose perception also changed over time.

Conclusion

In this paper we presented *qualitative and quantitative* results of a scenario-based evaluation of data glasses usage. Starting from a two-step approach, including a focus group discussion and a user study, we identified factors that positively and negatively influence user attitudes. We found, that data glasses usage is perceived critically, but more positively from a first-person perspective (the user herself) than from a second-person perspective. However, one might argue that the negative attitude towards data glasses is related to the unfamiliarity of the device. Similar to the so-called "Walkman Effect" of 1984 [9], this negative attitude might diminish over time. Interesting developments could be discovered by repeating this study at regular intervals or in different regions. Therefore, the depictions used for the presented evaluation are publicly available at **http://www.eislab.net/dataglasses**. Up to now, to the best of our knowledge, only qualitative results are available. By publishing our *quantitative* results, we enable other researchers to compare their data against ours and, as suggested by our conclusion, investigate e.g. cultural or structural differences. Moreover, design implications for future head-worn devices were derived. Our research provides initial indicators for best practices in data glasses design. We found that, to evolve into a product that clicks with users, head-worn devices would need to *be task focused*, *communicate the intention of use*, and *follow a least capabilities principle.*

[14] **http://www.projectara.com/**,retrieved on 2015/02/06

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Appendix

C1) You are meeting in a caf. Your date is using data glasses (in order to receive a reminder for something important).

C2) You are meeting a business partner. S/he is using data glasses (in order to access additional information where necessary).

C3) You are attending a business meeting. The attendee just across from you is using data glasses (in order to access additional information).

C4) You are celebrating with the extended family. One of your family members is using data glasses (in order to take pictures and videos).

P1) You are walking the pedestrian area. A passer-by is using data glasses (in order to view navigational hints).

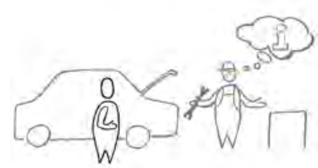
P2) You are walking the pedestrian area. A passer-by is using data glasses (in order to make a phone call).

P3) You are sharing a car. The driver is using data glasses (in order to view navigational hints).

P4) You are sharing a car. The driver is using data glasses (in order to make a phone call).

P5) You are taking the subway. The passenger just across from you is using data glasses (to read a news feed).

W1) You fell ill. The doctor is using data glasses (in order to access information on your course of disease).



W2) You are picking up your car at the repair shop. The mechanic is using data glasses (in order to access information on the vehicle's specific model).

W3) You are attending an in-house training. The presenter is using data glasses (in order to access supplementary information).

W4) You are customer at a store for electronic equipment. The sales assistant is using data glasses (in order to access product information and available stock).

W5) You are customer at a clothes store. The sales assistant is using data glasses (in order to access product information and available stock).

Figure 6: Overview of scenarios that were obained from the alternation scheme described in Figure 2. For brevity, we are depicting the second-person view with visible usage intentions for the data glasses condition. Other conditions are analogue. The illustrations follow the subsequent conventions:

- black: interviewee
- greyed out: third persons and surroundings
- orange: the device itself (here: data glasses)

"Thinking bubbles" indicate the visibility of actions performed with the device. Descriptions are provided. The subclause in brackets was only displayed under the visible actions condition. [best viewed in color]