All about Acceptability? Identifying Factors for the Adoption of Data Glasses

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ABSTRACT

Innovations often trigger objections before becoming widely accepted. This paper assesses whether a familiarisation over time can be expected for data glasses, too. While user attitudes towards those devices have been reported to be prevalently negative [14], it is still unclear, to what extent this initial, negative user attitude might impede adoption. However, in-depth understanding is crucial for reducing barriers early in order to gain access to potential benefits from the technology. With this paper we contribute to a better understanding of factors affecting data glasses adoption, as well as current trends and opinions. Our multiple-year case study (N=118) shows, against expectations, no significant change towards a more positive attitude between 2014 and 2016. We complement these findings with an expert survey (N=51) investigating prognoses, challenges and discussing the relevance of social acceptability. We elicit and contrast a controversial spectrum of expert opinions, and assess whether initial objections can be overwritten. Our analysis shows that while social acceptability is considered relevant for the time being, utility and usability are more valued for long-term adoption.

ACM Classification Keywords

K.4.0 Computers and Society: General

Author Keywords

Data Glasses; Augmented Reality; Technology Adoption; Social Acceptability; User Acceptance; Public Experiences;

INTRODUCTION

On their market entry, *data glasses*, light-weight head-worn computing devices (e.g., `Google Glass`, `Meta Pro` or the `Atheer one`), triggered a wave of criticisms. One cause for objections was their ability to unobtrusively record video imagery of their environment; seen as a threat to privacy [6].

Over the years, observations of technology adoption have shown that technical innovation often triggers fear, anxiety and objections [4]. However, it has also been noted that initial indignations often fade away and public opinion may change. Both Hosokawa's "Walkman Effect" [10] and the dissemination of consumer photography [2] show how users of a mobile gadget can attract criticism and be accused of rudeness and disrespect of other people's privacy. Albeit, the Walkman, which was predecessor to a whole line of portable music devices, including the iPod, and portable (digital) cameras have found their way into our daily life.

This paper investigates whether this effect also applies to data glasses, which we define according to [14] as class of mono- or binocular head-worn displays that resemble prescription glasses, not limited to a specific device type or brand[1]. Up to now the roles of familiarisation over time and social acceptability are not clear, as data glasses are different from earlier innovations. They differ in terms of form factor and display paradigm, but also in terms of (online) media coverage and exposure [19]: with only 1% of data glasses owners in the US[2], the majority of potential users did not come in contact with actual devices, before they became aware of the publicly hyped discussion. This paper looks at factors that are decelerating data glasses acceptance from both, a retrospective (user study-based) and a prospective (expert-based) point of view.

We retrospectively discuss the adoption of data glasses to date, based on a multiple-year case study (N=118) and investigate prognoses from a survey amongst 51 experts on data glasses, HCI and technology adoption from industry and academia. Our research questions are:

(A) *Can an alteration of user attitudes similar to the "Walkman Effect" be already observed for data glasses?*,

(B) *Do experts expect an alteration of user attitudes within the next ten[3] years?*, and

(C) *What factors impede an alteration in user attitudes?*

We contribute quantitative results of a multiple-year study on user attitudes towards data glasses, which is to the best of our knowledge, the first one reported. We surveyed at three distinct points in time, supplementing a study of 2014 (c.f. [14]) with

*Part of the data collection of the presented case study has been carried out by Marion Koelle as part of her doctoral studies at the University of Passau, Germany (2013-2016).

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[1] Examples of commercially available data glasses announced or launched between 2014 and 2016: https://www.wareable.com/headgear/the-best-smartglasses-google-glass-and-the-rest, accessed 15/12/2016

[2] c.f.: Vision Voice Newsletter. Google Glass Awareness in the US, http://east.visionexpo.com/Press/Vision-Voice-Newsletter/Google-Glass-Awareness-in-the-US/, accessed 15/12/16

[3] c.f. Years to mainstream adoption for **AR**, Gartner, http://www.gartner.com/newsroom/id/3412017, accessed 15/12/16

surveys in 2015, and 2016. Our user study's results are complemented with an expert survey identifying weak spots and eliciting a prioritisation of challenges for data glasses adoption. We highlight notions regarding social acceptance, spectator attitudes and (un)obtrusiveness of the device. With our work we contribute to a better understanding of factors that impede or support data glasses becoming habitual in real-life scenarios.

RELATED WORK

We outline theories and models of two relevant research areas: the dissemination of a technology from niche applications into society and the adoption of technology by individuals.

Technology Diffusion into Society

Mensvoort's "Pyramid of Technology" [25] describes the different levels a technology attains from being envisioned (level 1) until becoming naturalised (level 7) and omnipresent. Characteristically, many technologies only climb the lower half of the pyramid, i.e. *applied* (level 3) or *accepted* (level 4), before they stabilise or are replaced by newer technologies. Innovation diffusion models [22] illustrate that initial judgements, though made without any prolonged use of the technology, serve as a filter and either result in non-appropriation or adoption of a new technology. In consequence, initial user attitudes, as we assessed in our case study, are crucial for the success or failure of a particular technology's adoption.

This work focuses on the transition (or "disruption") between an *applied* and an *accepted* technology, c.f. Cisco's Media Disruption Map[4]. Data glasses have attained the *applied* level by taking the step out out of the lab. Our work looks closely on the preconditions of an alternation to an *accepted* technology, i.e., to being "part of our daily life" [25], which we consider achieved if a society's majority has moved from being *excluded* on to being *core* or *peripheral* users [23].

Technology Adoption by Individuals

Davis' well-known Technology Acceptance Model (TAM) [5] defines the adoption of new technologies by individuals based on two main factors: usefulness and perceived ease-of-use. Derivate models add subjective norms and social influence [16, 26], and share the assumption that individuals tend to consult their social network in order to reduce anxiety towards an innovation [11]. Building upon this theoretical ground work, we investigate the characteristics of data glasses adoption, particularly looking into cross-relationships of different factors and provide a device-specific ranking of relevant factors.

An in-depth investigation of smart watch adoption in the context of TAM has been presented by Kim et al. [13]. They investigate "subcultural appeal", i.e. smart watches being a fashion statement, in addition to traditional TAM patterns. Buenaflor et al. [3] assess human factors, including social, physical and demographic aspects of the acceptance of wearable computing devices. A stream of research conducted by Rauschnabel et al. takes a managerial perspective on data glasses adoption. They look into social norms and functional benefits [18], fashion [19] as well as perceived usefulness, ease-of use and both user's and bystander's privacy [20]. While prior work determined factors that influence data glasses adoption, our work goes further and estimates the precedence of improvements based on expert opinions.

[4]Gottlieb Duttweiler Institute. From Innovation to Disruption, http://www.gdi.ch/i2d/index.html, accessed 15/12/16

MULTIPLE-YEAR CASE STUDY

We present a multiple-year observation of user attitudes towards data glasses, complementing a previously published survey [14]. Unlike in the preceding study, which focused on factors that influence user attitudes, the present study assesses changes in user attitudes over time using the original semantic differential and scenarios to assess the user attitude at *three distinct points in time*, i.e., 04/2014, 04/2015, and 04/2016.

Methodology

We conducted repeated measurements (2014, 2015, and 2016) following the study design and procedure described in [14]. Participants were asked to rate a set of 56 scenarios (28 involving data glasses, 28 smart phones) based on a semantic differential (c.f. Table 1). They indicated their subjective perception using a slider, comprising a range of -5 to +5 with a resolution of 1.0 (11-pt. Likert Scale). The questionnaire was filled out on a desktop computer in a quiet lab environment using a neutral survey platform.

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

Table 1. Semantic differential with pairs of adjectives.

All participants were recruited via a regional recruitment platform, which, in contrast to online recruitment, allowed to rule out sampling errors due to changes in popularity of social networks or fluctuation of mailing list subscriptions. Thus sampling stability and a more reliable and valid between-subjects comparison can be achieved. Repeated participation of an individual participant in multiple runs was ruled out during recruitment. Monetary compensation according to the platform's convention (€ 10 /h) was disbursed after the study in a separate room and by personnel different from the experimenter. We analysed the results based on the following hypothesis:

H_1: *There was a significant alternation in user attitudes towards data glasses between 2014 and 2016.*

Participant profile

Distributed over three distinct samples, 118 participants, aged between 18 and 58 ($\bar{x} = 23$, $\sigma = 4$), 47% female, participated in our study (c.f. demography in Table 3.2). Professional backgrounds/study subjects were diverse with their distribution corresponding to the faculty-wise distribution of study subjects at the whole university (i.e. no IT surplus).

Year	N	Female	Mean Age	Age Range	σ
2014	38	16 (42%)	23	18–38	4
2015	41	18 (44%)	22	20–31	3
2016	39	22 (56%)	23	20–56	6
Overall	118	56 (47%)	23	18–56	4

Table 2. Demography; Age profile and gender distribution.

Analysis and Results

With our study we replicated the study presented in [14], and re-conducted it twice over a period of two years. For analysis participants were grouped according to their year of participation. We evaluated the questionnaires reliability based on Cronbach's Alpha ($\alpha \in [0.95; 0.98]$[5]), which accounts for a high consistency within individual measurements [15]. The answers to the semantic differential (11-pt., ordinal scale) were analysed for each scenario and each pair of adjectives individually. Medians were determined and analysed for significance (Kruskal-Wallis test, $df = 2$, adjusted for ties). With no statistically significant differences (all $p > .01$) found, the null hypothesis (H_0), stating that there is no significant alternation in user attitude between 2014 and 2016, has to be accepted.

Limitations

The case study's results confirm the (prevalently negative) user attitude towards data glasses and their influencing factors found in [14]. On top of this, the repeated study shows that there has been no significant change in user attitudes over the three years of investigation. While our findings are applicable to the student population in Passau, Lower Bavaria[6], Germany, our results might not be fully generalisable. Particularly, more progressive user groups (e.g., early adopters) or regions (e.g., silicon valley, metropolises) might already show first signs of an alteration in user attitudes, not captured by our study.

EXPERT SURVEY

Starting from those results we subsequently assess (based on expert opinions) whether those negative attitudes entail a lack of social acceptance and if benefits from data glasses usage are capable of overwriting initial objections. With our expert survey we assess prognoses for the adoption of data glasses, and identify open issues and disagreements.

Expert Profile	Count
UX/IxD Practitioner (min. 2 years experience*)	27 (53%)
Researcher (before PhD⋆)	11 (22%)
Researcher (Post-doc**, Professor**)	33 (65%)
Early Adopters (min. 1 month experience)	10 (20%)
Author, Journalist or Blogger†	7 (14%)
PR, Marketing, Sales (AR or HmDs)	3 (6%)
Developer (Data glasses HW/SW)	17 (33%)
Other	2 (4%)

* Areas of expertise: User Experience Design, Interaction Design, User-Centered Design or similar.
⋆ Areas of expertise: data glasses, head-worn displays, Augmented Reality, or similar.
** Areas of expertise: Human-Computer Interaction, Technology Adoption Research, Information Ethics, or similar.
† with at least one published article or blog entry covering wearable devices, data glasses, smart contact lenses or other future, head-worn technologies.

Table 3. Predefined expert profiles, participants were presented with brief descriptions (including level of expertise) and asked for self-assessment, multiple selections were possible.

Methodology

We deployed our expert survey online via a neutral survey platform (i.e., not associated with a brand or manufacturer) to prevent sponsor bias. Its main part consisted of 2 two-tiered questions (6-pt. Likert scale with free text explanatory statement: Q1, Q3) and one asking the participants to rank improvement criteria by relevance (Q2).

[5] Cronbach's α determined separately for each perspective (1st person, 2nd person) and device (smart phone, data glasses)

[6] Details on the regions demographics available from https://www.statistik.bayern.de/veroeffentlichungen/, accessed 15/12/16

Q1 Within the next 10 years: do you expect data glasses to be worn by people as a matter of routine?

Q2 What would have to be improved such that data glasses can become a tool used by people in their everyday lives? Please provide us with a ranking. (Options based on [27], c.f. figure 2)

Q3 To what extent do you think that social acceptance will be relevant for the success of data glasses?

The survey explicitly targeted participants that had prior experience with data glasses (e.g., as developer, researcher or early adopter) or expert knowledge in the field of HCI/ICT. For recruitment we used snowball sampling in addition to purposive sampling via email and social networks based on pre-defined expert criteria (c.f. Table 3). Out of 90, 51 experts (15 female), aged 24 to 54 ($\bar{x} = 35$, $\sigma = 7$) submitted completely filled out questionnaires. The majority of participants live and work in Europe (39, 76%) and the US/Canada (10, 20%), followed by Middle East/North Africa (1, 2%) and Asia (1, 2%). There was no compensation paid for participation.

Results and Discussion

The participants' qualitative statements were analysed independently by two coders with regard to re-occurring themes and arguments. Following the procedure of inductive category development [17] results were categorised and summed up (occurrences denoted as n). In the following we highlight the key findings and relate them to prior work.

Prognoses The majority of participants estimate data glasses to be worn as a matter of routine within the next 10 years (Median=3, σ=1.3); also shown in Figure 1. While participants value the advantage of hands-free interaction (n=5), situated information access (n=7), as well as natural interaction (n=4) they also name both technological and societal issues that would have to be solved before wide adoption becomes possible. Particularly, opinions diverge regarding the pervasiveness of adoption and prerequisites that would have to be met. Participants expect data glasses to be successful in specialised application areas (n=18), such as the work place (n=15) or sports (n=4). Opinions were divided whether adoption by consumers for casual usage is likely (n=6) or unlikely (n=7).

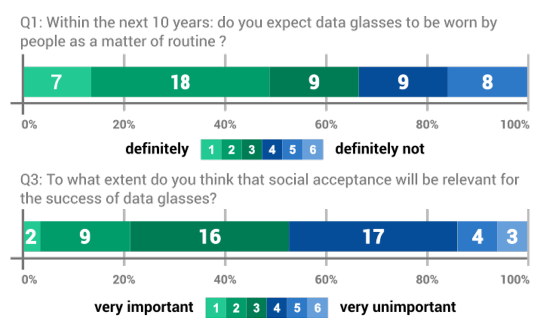

Figure 1. Answers to Q1 (top, Median=3, σ=1.3) and Q3 (bottom, Median=3, σ=1.2), measured on 6-pt. Likert Scales.

Prerequisites for Adoption Subsequently, we highlight the most frequently named factors that impede the adoption of data glasses. Overall, a lack of suitable use cases and useful applications (*Utility*, n=12) was discerned. Participants agreed that overcoming the current lack of utility is crucial for adoption: *"So given we come up with suited application scenarios,* *data glasses will become ubiquitous."* (P71) Furthermore, participants criticised a lack of wearing comfort and named *Ergonomic Issues* (n=13) as hindrance for adoption. P40 states *"Form Factors are too cumbersome and do not outweigh the provided utility."* This critique is also backed by previous results by Motti et al. [9] who note a lack of "Wearablity" of current devices. Moreover, *Pricing* will have to decrease (n=4) for data glasses to become more affordable. In addition, *Usability* (n=3) has been raised as issue: *"They do not yet present a superior means of communicating information to a user, because the interface is not nimble to manipulate."* (P24) Perceived awkwardness and social shaming (*Social Image*, n=18), as well as *Privacy* (n=7), and *Ethical Issues* (n=9) have been also noted to impede the adoption of data glasses.

Need for Improvements Q2 asked the participants to rank given areas of improvements according to their relevance for the adoption of data glasses. Figure 2 illustrates the overall ranking (middle, dark blue, N=51) along with rankings by subsamples that rated social acceptability either more important (N=27), i.e. below the median or less important (N=24) , i.e. above the median. Rankings were determined based on aggregated scores (Borda count). Differences between sub-groups are significant (χ^2(48, N=421) = 148.17, $p < .001$, V = 0.45). Usefulness, functionality, and usability, along with compatibility with daily routines have been concordantly identified as most important areas for improvement, as also reflected by the qualitative statements outlined above. Those results are further backed by Shackel's acceptability equation [24].

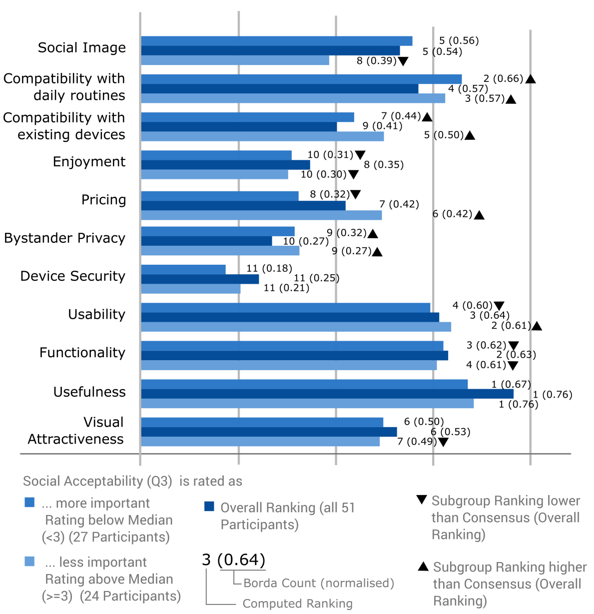

Figure 2. Ranking of required improvements for long-term adoption based on aggregated scores (normalised Borda count, in brackets), changes in ranks indicated by arrows.

How Relevant is Social Acceptance? Along with the improvement of the *Social Image* that was subordinated in Q2 (c.f. Figure 2), only a small majority indicates social acceptance to be slightly important (3) or important (2, Median=3, σ=1.2, c.f. Figure 1) for the adoption of data glasses. Interestingly, participants were in disagreement whether social acceptance is a matter of time (n=5) and exposure (n=2) or if it results from weighing benefits (n=4). Participants also stated that social acceptance comes naturally (n=2), and one participant challenged whether social acceptance can be supported by design: "After all, how can you design for social acceptability?" (P12); Also addressed by Kim et al. [12], who propose Acceptability Engineering as an extended research discipline.

Which Level of (Un)obtrusiveness? While appealing design (n=17), along with the *"Coolness Factor"* (n=4) was frequently named as prerequisite for adoption (Q1), multiple participants consider the resemblance to prescription glasses as crucial. They believe that miniaturisation and unobtrusiveness (n=7) will result in a higher social acceptability. P71 states *"Once we hit the point where data glasses are looking just like normal glasses [...] adoption will increase drastically."*. However, increasing the unobtrusiveness of data glasses might intensify a different set of problems. While the user becomes less prone to objections and social shaming, issues of (bystander) privacy (n=7) arise: it is unclear whether a device with camera is present and/or recording. The question whether interactions with a mobile device shall be unobtrusive [1, 7] or candidly communicated [8] has been adressed in earlier research (e.g., by Reeves at al. [21]) and also raised by P26: *"There is also the issue that the manipulations are highly visible, but the effects are not [...]"*. Finding the "right" level of (un)obtrusiveness challenge for future research; a tightrope walk, requiring to balance a trade-off between being unsuspicious and straightforward: they require *"[s]ubtle design that allows them to stand out, but not so obviously different"* (P76)

CONCLUSION

In this paper we investigated factors impeding and supporting data glasses adoption. Based on a 2014 to 2016 case study, we demonstrated that user attitudes have been stable and prevalently negative over the last three years. However, our survey amongst 51 experts shows that an alteration in user attitudes as well as an adoption of data glasses is expected until 2026. While social acceptability is considered relevant for the time being, experts expect it to be overwritten by more fundamental factors on the long run. They identify **(1) Usefulness**, **(2) Functionality** and **(3) Usability** as most crucial to long-term adoption. Moreover, the unobtrusive design (**Unobtrusiveness**) is named as a key strategy for improving the social image and acceptability.

Our present work demonstrates that data glasses, though already launched to public and widely discussed, still pose manifold challenges to (HCI) research and will not be accepted without efforts. In order to create utile applications (**Usefulness**) we require more user research, involving in-depth requirements analysis, and deep understanding of specialised (professional) use cases. Novel or improved hardware capabilities, powerful tracking methods, will be prerequisite to providing the needed services and functions (**Functionality**). Current usability issues (**Usability**) will be a challenge not only to usability research but particularly to those looking into novel, advanced interaction methods and visualisation techniques. Finally, design disciplines, e.g., interaction design, will be challenged to determine the the "right" level of unobtrusiveness for data glasses devices and interactions.

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