Contact details (must contain all author' names, affiliations and contact details)

Smart-glasses: exposing and elucidating the ethical issues

Bjørn Hofmann[1,2], Dušan Haustein[3], and Laurens Landeweerd [4,5]

1. *Norwegian University of Science and Technology, Gjøvik*
2. *Centre for Medical Ethics, University of Oslo, Norway*
3. *New Technologies Research Centre, University of West Bohemia, Czech republic*
4. *Oslo and Akershus University College of Applied Sciences (HiOA), Norway*
5. *Radboud University, Nimegen, the Netherlands*

Corresponding author:

Bjørn Hofmann, b.m.hofmann@medisin.uio.no

Centre for Medical Ethics,

University of Oslo

PO Box 1130, Blindern

N-0318 Oslo

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Abstract:

Objective: To provide an overview over ethical issues relevant to the assessment, implementation, and use of smart-glasses. The purpose of the overview is to facilitate deliberation, decision making, and the formation of knowledge and norms for this emerging technology.

Method: An axiological question-based method for human cognitive enhancement including an extensive literature search on smart-glasses is used to identify relevant ethical issues. The search is supplemented with relevant ethical issues identified in the literature on human cognitive enhancement (in general) and in the study of technical aspects of smart-glasses. Identified papers were subject to traditional content analysis.

Results: 739 references were identified, 247 were identified to be relevant for full text examinations, and 155 were included in the study. A wide range of the ethical issues are identified. Amongst them are privacy, safety, justice, as well as change in human agency, accountability, responsibility, and social interaction. So were power- and ideology issues.

Conclusion: A wide variety of ethical issues with smart-glasses have been identified, such as issues related to privacy, safety, justice, change in human agency, accountability, responsibility, social interaction, power and ideology. Smart-glasses are envisioned to change individual human identity and behavior as well as social interaction. Taking these issues into account appears to be relevant when developing, deliberating, deciding on, implementing, and using smart-glasses.

Key words: Smart-glasses, autonomy, authenticity, agency, privacy, safety

Introduction

Smart-glasses promises “to be one of the latest and most ground-breaking technologies in current times” (Kumar and Sharma 2014). The process of combining actual and virtual reality creates augmented reality (Milgram et al. 2012). Because smart-glasses do not significantly distort vision for the wearer, an illusion of coalescence between actual and virtual elements is achieved, in contrast to virtual reality devices that tend to immerse the user more.

What are smart-glasses and how are they used?

"Smart-glasses,” "Digital Eye Glass," “eye glass display,” or "Personal Imaging Systems" are wearable devices that display images to the visual field of a user. They are designed to add visual elements to the visual experience of a person without significantly distorting or disturbing the person’s ordinary vision, qua use, interaction with the actual world and qua experience.

The devices involved vary but they do not merely display virtual elements that stand apart from the direct living environment. They often feature processing capacity that is similar to a smartphone or GPS. This shifts smart-glasses beyond the group of passive head-mounted displays. Moreover, devices like these do not only display information, but can also use the variety of sensors to track, analyse, distribute, and store data about the surrounding environment as well as the user. Among sensors and input devices are: accelerometers, magnetometers, GPS, microphones, touchpads, eye-tracking cameras etc. Data from these sensors can be utilized either by smart-glasses’ own processing unit itself or by a computer, usually a smartphone, connected to the glasses. These features allows utilizing smart-glasses in a variety of scenarios (Steve Mann 2014).

Smart-glasses can connect to the Internet and can access a wide range of data sources, e.g., maps, news, messages, and emails. They can track eye-movements and present marketers with a heat-map of goods the costumers look at the most. They can recognize places and faces and display information and social media profiles of people the smart glasses user is looking at. Smart-glasses are already applied in medicine, and are envisioned to have a wide range of applications in this field (Singh et al. ; Moshtaghi et al. 2015; Hetterich et al. 2014; Mentler et al. 2015; Klein et al. 2015; S. Mitrasinovic et al. 2015; Maas et al. 2015; Rankin et al. 2015), education (Ikonen and Knutas ; Labus et al. 2015; Freina and Ott 2015), tourism (Harasymowicz 2015), social science research (Paterson and Glass 2015), navigation (Ostendorp et al. 2015; Higuchi et al. 2015), crowd steering (Borean et al. 2015), activity recognition (Zhan 2014; Betancourt et al. 2015) including diet recognition and food behavior control (Gemming et al. 2013; Farinella et al. 2014), mood (engagement) measurement (Kunze et al. 2015), forensics (Karabiyik 2015), promoting cultural sustainability (Irving and Hoffman 2014), promoting teamwork and safety (Moshtaghi et al. 2015) and they can also be used for military purposes. Prototypes and applications exist in several of these fields. E.g., within health care, a wide range of applications have been identified, such as hands-free photo and video documentation, telemedicine, Electronic Health Record retrieval and input, rapid diagnostic test analysis, education, and live broadcasting (Stefan Mitrasinovic et al. 2015), as well as health promotion (Edington et al. 2015).

These are only a fraction of possible scenarios for smart-glass applications. And it is clear that each brings a series of ethical questions that need to be answered.

Which group is involved in the use of the technology?

Smart-glasses have a broad range of potential users. Similar to smartphones, they are designed to be versatile. They are a multipurpose platform with multiple applications. Smart-glass users can be divided into two main groups: regular consumers or professional consumers. Common to both groups is that smart-glasses provide extended capabilities.

Regular consumers are envisioned to use smart-glasses mainly for entertainment and experience enhancing purposes. A regular user may wish to stay connected to other users, browse the Internet, and consume digital content. As opposed to smartphones, smart-glasses are deliberately designed for continuous use and for multi-tasking, e.g., consuming media and using social networks while simultaneously doing something else. This approach was taken by a number of smart-glasses such as Google Glass, Recon Jet, Microsoft HoloLens, or CastAR.

The other main group is professional consumers, who are envisioned to benefit from the technology's 'hands-free' features. There are numerous attempts to bring the smart-glasses technology to logistics, automotive, retail, and many other industries and services. What makes smart-glasses useful in these fields is the potential to display, filter, and interact with the data generated by the actions taking place on the workplace, while, again, freeing the user's hands, e.g., making a fire fighter able to navigate even if visibility is low because the device can display the position and the route to a given target. Smart-glasses systems that are being developed for the professional group of users are, for example, the Epson Moverio series, Vuzix M100, Kopin Golden-i, or ODG R7.

Why do we need to assess smart-glasses?

The objective of this article is to expose and elucidate the ethical issues relevant to the research, development, assessment, deliberation, decision making, implementation, and use of smart-glasses, as an example of a technology used for human cognitive enhancement. The purpose of the overview is to support and facilitate an open and transparent deliberation with regard to this emerging technology.

Methods

We followed an axiological question-based approach to identify ethical issues relevant for decision-makers, which is used in health technology assessment (HTA)(B. Hofmann et al. 2014), and has been developed for use in the field of human cognitive enhancement (B. Hofmann Submitted 2016). Question-based methods are well known in the literature on ethical issues of human enhancement (Allhoff et al. 2009). Although the approach may be used as a checklist, it may also be used as an input for and as a guide for processual forms of technology assessment, e.g., ethical-constructive technology assessment (Kiran et al. 2015).

As part of the axiological question-based approach, we performed a literature search on smart-glasses in order to identify ethical issues relevant for assessing the technology. An initial search on PubMed did not result in any relevant references. A search in Google Scholar was performed with the search string ("smart glasses" OR "smart glasses" OR "digital eye glass" OR "personal imaging system" OR “eyeglass display”) AND (ethics OR ethical OR moral OR benefit OR therapy OR harm OR hazard OR distortion OR privacy OR authenticity OR integrity OR “selfhood"). All identified references were investigated with respect to relevance to the various questions of the approach (Cross reference to methods paper). Conventional qualitative content analysis (Hsieh and Shannon 2005) of the identified papers in full text was performed to identify ethical issues. Identified ethical issues were grouped in accordance with the questions. Issues not addressed by any questions were highlighted

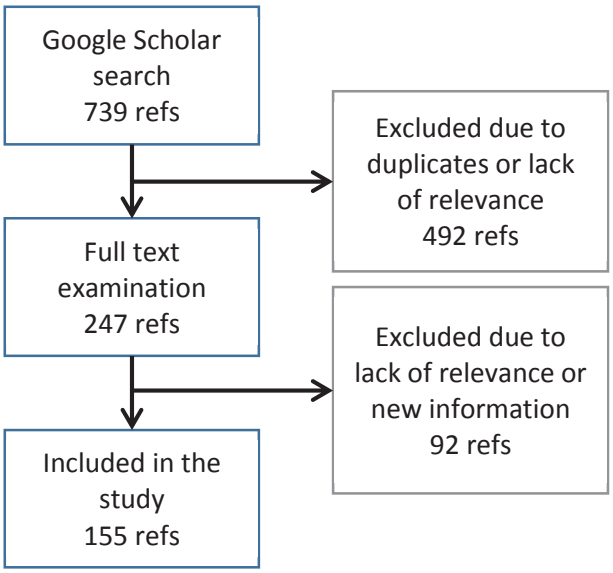
and questions not covered by any identified issues were analyzed on basis of the content of the articles to see if there are ethical issues that have not been identified by the literature.

While the method aims at comprehensiveness in covering all ethical issues, it does not aim at being exhaustive in identifying all references addressing the same issue. When a certain issue is identified in a significant number of references and including more references for the same issue does not add new information, further references are not included. The number of times an issue is mentioned in the literature does not add value, as some references only mention that there are ethical issues without providing any analysis and as controversial statements may generate a lot of responses without added value (i.e., "noise").

Results

The literature search identified 739 references. 247 references were found relevant for identifying ethical issues with smart-glasses and were examined full text. 155 of these references were included for content analysis of the full-text items. The results of the search strategy are shown in Figure 1.

Figure 1 Search strategy results



A wide range of ethical issues were identified. Organized by the questions of the axiological approach they will be presented below grouped under suitable headings to increase readability and avoid fragmentation.

Benefits and harms

Experiences and reports on benefits and harms vary amongst users and types of smart-glasses (Koelle et al.). Some important issues highlighted in the literature are summarized in Table 1.

Table 1 Overview of potential benefits and harms identified in the literature

Potential benefits	Potential harms
Smart-glasses may become an extensions of human body and mind (Huang 2013) and enhance our interaction with the environment (Benessia and Pereira 2015)	Make people feel uncomfortable (Wolf et al. 2014) and result in "cyber sickness" (see text below)
Alter (improve) health behavior (Doherty et	May make people dependent (Bendel 2014)

al. 2013).	
Block unpleasant experiences and avoid anxiety (in a hospital setting)(Tse et al. 2002) and to support patients with specific needs (of care) (Hetterich et al. 2014)	Psychological and health risks with smart-glasses have been pointed out (Jacquemard et al. 2014)
Making learning more efficient or create new learning modes(Koper 2014). However, the outcomes of learning with smart-glasses are mixed (Sapargaliyev 2015)	Safety aspects are also identified in the use of smart-glasses, e.g., in (pervasive) gaming (Valente et al. 2015) or navigation (Jones 2014)
Provide safety and security, e.g., for persons with various forms of impairment, such as detecting hazards for persons with visual impairment (He et al. 2015), or in the industry (Neira Millan 2013)	Smart-glasses are envisioned to threaten security (Boissier and Castelfranchi 2015) as information about a person and his or her behavior may become accessible by others (Nyang et al. 2014).
Smart-glasses may increase situational awareness (Ackerman 2012), multitasking abilities (Nikolov 2013), and orientation (Muschiol 2015)	May make people dependent (Bendel 2014)
Assist recognizing and remembering (Iwamura et al. 2014) as well as impede forgetting (Jacquemard et al. 2014)	Psychological and health risks with smart-glasses have been pointed out (Jacquemard et al. 2014)
Be a valuable extension of the human brain (Bendel 2014) and predicting cognitive states (Henderson et al. 2013)	Safety aspects are also identified in the use of smart-glasses, e.g., in (pervasive) gaming (Valente et al. 2015) or navigation (Jones 2014)
Increase power through the aggregation of data, e.g., images (Bendel 2014).	Distraction and information overload (Ranck 2012)
Smart-glasses are envisioned to improve security (Sehgal et al. 2015), e.g., of elderly by preventing crimes (by saving events in the could)	Potential exploitation and steering (Borean et al. 2015), leak of sensitive information (Shen et al. 2015)
Compensate for impaired functions, such as landmark identification for persons with reduced visual ability (Ugulino and Fuks 2015) increasing their quality of life (He et al. 2015)	Breach of privacy (See section below)
User empowerment, self-sufficiency and inclusion in decision making, and new business models through open hardware, open software, and open data (Romano and Cangiano 2015)	Uncomfortable to wear (Page 2015; Ajmi and Robak 2015) (physically and socially)
Opens for multidisciplinary collaboration (Ranck 2012)	Potential non-sustainable augmentation or enhancement
Facilitate communication across language and culture barriers (Kaeri et al. 2015)	Negative reactions (verbally or physical) by people in public spaces (Wolf et al. 2014).
Provide evidence and facilitate litigation (Bergman 2013)	May reduce some cognitive capacities as they are “outsourced” to technology, e.g., navigation skills, or delegate crucial tasks to less skilled personnel.

It is important to notice that the same effect may have both positive and negative implications. E.g., distraction can be negative for attentiveness but positive for pain distraction (Triberti et al. 2014).

Health effects

More specifically a series of health effects are discussed in the literature, such as various eye effects (B. L. Due 2014). None of the studies present high quality evidence, as smart-glass use is not yet so frequent. However, as informed by the precautionary principle, absence of evidence is not evidence of absence of a health effect. Therefore, initial findings are reported.

Smart-glasses use wireless technologies to transmit data. This poses a risk of exposure to potentially harmful levels of electro-magnetic radiation (Organization 2011), especially so when these devices are to be worn on one's head for prolonged periods of time (Markov 2015).

The display of the smart-glasses is located very close to the users' eyes. This forces them to direct their gaze towards a small and bright spot in a potentially uncomfortable space of their visual field. This strains the eyes and may cause asthenopia (an ophthalmological condition characterized by nonspecific symptoms such as fatigue, pain in or around the eyes) (Behar-Cohen et al. 2011; Pan et al. 2012).

The blue-rich LED-based displays of the majority of smart-glasses can hasten macular degeneration. Although there is no evidence this is the case for humans, animal experiments with LED light discovered greatly hastened macular degeneration (Sliney 1984; Shang et al. 2014). Additionally, blue-rich displays are also known to influence the circadian rhythms of their users by suppressing the hormone melatonin levels which aids sleep (Cajochen et al. 2011).

Moreover, users may feel nausea and motion-sickness while using smart-glasses that obstruct their field of view. This is more likely to happen with fully immersive head-mounted displays, as they cover the entire field of view, but users sensitive to the disconnect between the moving virtual information and their stationary body may experience blurred vision, disorientation, or nausea (Chang et al. 2012; Falahee et al. 2000).

Challenging privacy

Data security and privacy are without doubt the issues that were mentioned and discussed most widely in the identified literature (M. J. Egenhofer and Kuhn 1998; M. Egenhofer 1999; Thiel and Thiel 2014; Lerch 2014; Koren and Klamma 2015; Boissier and Castelfranchi 2015; Ling et al. 2014; Jacquemard et al. 2014; Yoon et al. 2015; Satyanarayanan et al. 2015; Kumar and Sharma 2014; Arnold et al. 2015; Haris et al. 2014; Kotsios 2015; Speed et al. 2013; S. I. Friedland 2015; Chalfen 2014). The filming and recording function of smart glasses makes it possible to "broadcast," identify, and follow persons and events, making people constantly followed (Tunçalp and Fagan 2014). Smart-glass systems can be eavesdropped, seen, or recorded by unauthorized parties (Forte et al. 2014). Smart-glass use makes it impossible to know whether you are recorded (Dainow 2014). Face recognition functions with smart-glasses challenges individuals' ability to remain anonymous in public places (Welinder 2013). Although identification is acknowledged to have a range of beneficial uses, it may also reduce people's ability to "go under the radar" and it is argued that it calls for regulatory reflection and responses (Welinder 2013). Some manufacturers address these issues by adding a 'privacy indicator' light to their smart-glasses, like the latest M300 model from the company Vuzix. Negative reactions (even physical assault) towards people wearing smart-glasses in public places have been reported (Wolf et al. 2014), and such reactions may depend on cultural context, place and time.

Smart-glasses can be used to monitor a person's level of attention (Lee and Balan 2014) and they are envisioned to provide unprecedented surveillance of everyday life (Steve Mann and Ferenbok 2013; Noble and Roberts 2016) on the one hand. Employee location monitoring is identified as one potential challenge. On the other hand, sousveilance ('undersight', computationally mediated veillances) is identified as a beneficial potential (McKenna et al. ; Sebastian Mann 2013; Steve Mann and Ferenbok 2013), foreseen to protect the wearer of smart-glasses and to balance the harms from surveillance (Steve Mann 2012).

As smart-glasses are envisioned to be a useful tool for health monitoring, such uses strongly enforce the issues of privacy and authenticity (Takei et al. 2015). When elaborating and enforcing regulations, it was recommended to differentiate between self-monitoring and the capturing or monitoring of others (Thiel and Thiel 2014).

Issues such as intrusiveness, transparency, and challenges with obtaining informed consent were highlighted (Doherty et al. 2013). Solutions to some of these issues were also suggested, e.g., assuring limited resolution in public spaces (Satyanarayanan et al. 2015) and the development of various protocols (Zhang et al. 2014b).

Changing the human condition(s)

It was pointed out that smart-glasses can distort our perception (Jacquemard et al. 2014), "modify our perception and the world," or more directly "modify our world and ourselves" (Liberati and Nagataki 2015). According to a postphenomenological perspective (Ihde et al. 2015; Rosenberger and Verbeek 2015), smart-glasses can change the way we perceive and act in the world (Harg 2014). Moreover, it is argued that they merge the physical and digital world (Bailey 2014). Smart-glasses can also change our way of learning, e.g., by promoting our learning by being ("Praxistemology") (Sebastian Mann and Hrelja 2013)

The glasses become part of the person (Bendel 2014) and they shape human actions and experiences (Verbeek) and augment the real world with a virtual aspect, in so called "reality shifting"(Pedersen 2013). Smart-glasses can also be seen as part of a fragmented human enhancement (being a specific part of cognitive enhancement) enhancing the fragmentation of human abilities (Lucivero and Vedder 2013). Smart-glasses can be used to focus attention and intention (Zhang et al. 2014a) potentially changing human interaction. Accordingly, altering behavior and sociality has been identified as one potential challenge (Valente et al. 2015). Moreover, reality-altering effects may also induce ethical challenges (Valente et al. 2015), e.g., detachment from reality (Sultan 2015) or blurring the phantasy-reality distinction (Wassom 2014). Social care and health care are foreseen to merge (Michael 2013). Use at home, and in smart-houses (Dauber et al. 2014) may change people's conception of home.

More generally, smart-glasses were identified as threats to human values (Naydler 2013), the responsibility for our actions (Ricci et al. 2015; Pejovic et al. 2015; Wassom 2014), as well as our accountability (Tunçalp and Fagan 2014). E.g., they may extend our responsibility according to extended abilities, e.g. by recording our wrongdoings (Steve Mann 2013). The environmental burden of smart-glasses and related technologies was also discussed (Teehan 2014; Moghaddam et al. 2014).

More fundamentally, smart-glasses are identified to move the boundaries between people (B. L. Due 2014) and may also come to change the conception of the self (Pedersen 2013), as well as human agency (Ricci et al. 2015; Pereira et al. 2013), dignity (Tunçalp and Fagan 2014), and authenticity (Pejovic et al. 2015). They may strongly influence the human mind and body, human capabilities, and the good life (Tunçalp and Fagan 2014).

Where systems analyze people's desires based on their previous behavior, and assist in fulfilling or enhancing these desires, it may also raise the question of respect for autonomy (Kruijsen 2008).

It has also been pointed out that smart-glasses can change ethics. E.g., action-guiding applications may ensure that our actions are morally acceptable, on the one hand, but reduce our independent ethical reflection, on the other hand (Wassom 2014).

Social interaction

Social and cultural aspects are identified and discussed (Renzi and de Freitas 2015). Smart-glasses may disturb, disrupt, alter (B. Due 2015), or impair social interaction (Jacquemard et al. 2014) and they may thus call for new social etiquette (B. L. Due 2014). The ability to record every interaction may violate the guarded settings most of social interactions occur in (Ling et al. 2014). Smart-glasses may also find activist applications for social change, e.g., in terms of so-called Maktivism (Steven Mann et al. 2014). Smart-glasses may also result in communicative abundance, which can come to alter the basis of democracies (Keane 2013).

It was also pointed out that technologies such as smart-glasses may get embodied (Verbeek 2015) and change basic conceptions such as "interface," "mediation," and "interaction."(Gill 2015) They may re-configure our self-conception and make its "users reenchant their lives through the spectacular wonder of consumerism and the modern moral narratives of science and technology."(Gallitano 2015) Others are more careful, and argue that you are not what you wear (Marken 2015).

Smart-glasses are also envisioned to change education as students have a significantly different access to information (Chalfen 2014), and Q&A will be publicly and instantaneously available (Bieber et al. 2015). It may also change social science, as it gives power to the research subject (Chalfen 2014).

Justice

The issue of justice in the availability and access to the technology has been brought up in the literature (Garcia and Sandler 2008), e.g. in increasing the digital divide (Weber and Zink 2014) in general, or in sports where smart-glasses and other smart-devices can create an unfair advantage for those, who have access to the technology and thus can train more effectively (Bozyer 2015), in particular. Smart-glasses have also been addressed in the perspectives of race, class, and gender (Noble and Roberts 2016). On the other hand, it has been pointed out how smart-glasses may contribute to level the playground (Bendel 2014).

Ideology and power

The question whether smart-glasses are launched (partly) to increase the data, information, and power of companies such as Google has also been raised (Hedegaard Hansen et al. 2014) and discussed (Noble and Roberts 2016). Others have pointed to the potential to use the technology to nudge or direct people's attention (Morozov 2014) calling for awareness of threats of undue influence, to autonomy, and to democracy. Smart-glasses are also analyzed in terms of commodification of emotions, the "unbridled exploration and intrusion into the physical and emotional space of others," and the "expansion of the surveillance state" (Noble and Roberts 2016).

New technology, such as smart-glasses, combined with Big Data analytics are also identified to point towards pre-crime punishment or the pre-emption of inferred criminal intent (Hildebrandt 2014). Correspondingly, nudging, directing, or ordering people may be possible via smart-glasses.

It was also often argued that smart-glasses is one example of a technology in a grand movement of *solutionism*, i.e., a movement where technology is not only a "quick fix" or nails "to the man with the hammer," but more radically, where what is presumed to be pressing problems to be solved are not problems at all (Morozov 2013). Accordingly, the importance addressing the transcendent authority that lies in the expert systems that create the technology has been highlighted (Gallitano 2015).

Smart-glasses are intrinsically biased towards focusing on things and selling products (Benessia and Pereira 2015; Pereira et al. 2013). They contribute to a trend of formatization (Gehmann et al. 2015), i.e., under the guise of promoting liberty, they format our perceptions, conceptions and rationality (Gehmann et al. 2014).

As indicated, informational autonomy and informational justice (fair access to information and ICT) have also been pointed to as important issues to address (Bendel 2014). Another identified issue is that effective use of smart-glasses presupposes trust and can undermine trust and effective use if misused or if they malfunction (Pejovic et al. 2015).

Other rights and legal aspects

Beyond privacy, regulatory issues mentioned in the literature include image rights (Bendel 2014), as well as data obtained from 'smart' devices used as evidence in court, while the data are obtained without warrant (S. Friedland 2013). In the book *Augmented Reality Law, Privacy, and Ethics: Law, Society, and Emerging AR Technologies* Brian Wassom discusses a wide range of legal aspects with augmented reality in general, which also are relevant to smart-glasses. Among these are, privacy, litigation procedure, tort and personal injury, property rights, and intellectual property, as well as advertising, marketing, and commerce (Wassom 2014). Smart-glasses may also influence civil rights (Wassom 2014) and become relevant for free speech and discrimination (Roesner et al. 2014).

Other issues not covered by the questions in the axiological approach

Some related ethical issues are not explicitly covered by the questions of the axiological approach, but identified by the literature search. Technological and cultural obstacles for the uptake of smart-glasses is one example of this (Ranck 2012), although this is partly covered by question 14 in the axiological approach. Socio-cultural barriers may bar beneficial (or harmful) implementation and use of a technology. On the other hand, various forms of technological imperatives (B Hofmann 2002), may facilitate such implementation and use.

Questions from the axiological approach, not covered by findings in the literature

Conversely, some questions induced by the axiological approach are not covered by literature identified in the search. These are:

- *Does this technology contribute to solving important societal problems, tasks, or challenges?* (Q6) Although a wide range of (potential) benefits are highlighted in the literature, none of these are presented as "a problem in need for solution," but rather "a technology looking for problems."(Huff and Munro 1985)
- *Can the implementation and use of the technology alter human morality or responsibility?* (Q9) Although these issues have been touched upon, they have not been dealt with in great length. The question of what responsibility a person has when acting on information or "advice" presented via smart-glasses appears to need more elaboration than given in the literature.

- *Is it clear how risks arising from the implementation, use or withdrawal of the technology should be handled?* (Q17) Although risk and safety issues have been handled, the issue of technology withdrawal has not been mentioned or addressed in the identified literature.
- *Are there good existing alternatives to this application?* (Q19) This issue has not been discussed.
- *Does the technology have potential alternative or dual use?* (Q24) Although warfare is mentioned in several articles, this issue has not been extensively addressed in the identified literature.

Methodologies and frameworks identified

During the literature search and the conjoint conventional content analysis various methods and approaches for addressing ethical issues in cognitive enhancement technologies were identified:

- Agential realist perspective (Barad 2007)(Tunçalp and Fagan 2014).
- Anticipatory technology ethics (Brey 2012)(Tunçalp and Fagan 2014).
- Ethical Constructive Technology Assessment (eCTA, or more precisely, technology accompaniment) (Kiran et al. 2015).
- Ethical Technology Assessment (eTA) (Palm and Hansson 2006).
- Specific framework: An ethical framework for automated, wearable cameras in health behavior research (Kelly et al. 2013).
- Bateson's idea of "total circuits to understand the interrelationship between persons, the social world, and technology (Gillespie and O'Neill 2014).

Discussion

This article has identified a variety of ethical issues with respect to smart-glasses. Most often mentioned and addressed were privacy issues, but safety, justice, change in human agency, accountability, responsibility, and social interaction were also mentioned or addressed. So were power and ideology issues. Some relevant issues were not mentioned or addressed in the scholarly literature, but were identified by the axiological method. The literature is diverse, and there is no general agreement on the ethical issues or the ranking between them. The literature also covers a lot of contextual ground with respect to types of smart-glasses, applications, users, and settings.

The point here has not been to conclude whether smart-glasses are "good" or "bad." The article does not extend to giving arguments for specific decisions on particular applications, as it is restricted to providing input to the deliberative policy processes. As such, we aimed to provide funders, developers, decision makers, implementers, ethicists, and social scientist with an overview of ethical issues relevant for the development, deliberation, implementation, use, and formation of knowledge and norms with respect to smart-glasses. Not all the identified issues may be relevant for all applications and implementations of smart-glasses. Specific implementation contexts may only actualize certain ethical issues (or none). Moreover, there is a heterogeneity of ethical issues, as there is a heterogeneity of (and use of) smart-glasses. Therefore, it is important to make specific assessments in specific contexts of smart-glasses development, implementation, and use. Although specific context dependent assessments are beyond the scope of this article, we hope that the presented overview will be of value for such specific context dependent assessments.

There are obviously several limitations to the present approach. One of them is that all the arguments regarding the ethical issues identified have not been included or addressed in this study,

e.g., there are a wide range of specific arguments concerning health hazards with specific smart-glasses that have not been explicitly addressed. However, this is not a systematic review of arguments or reasons (Strech and Sofaer 2012), and it is not an full-blown assessment of a specific type of smart-glasses.

Our approach may also be criticized for being eclectic, "impure," and divergent if the aim is to inform deliberations and decisions. This is a highly relevant critique as the approach that we applied addresses a wide range of topics and includes existing (H)TA methodology, e.g., ethical Technology Assessment (eTA) particularly preoccupied with quantifiable risk (Palm and Hansson 2006), "hard impact" (T. Swierstra 2015) and "soft impact" approaches (van der Burg 2009; T. Swierstra and te Molder 2012; T. Swierstra et al. 2009), technological mediations (Verbeek 2011), as well as other approaches (Sollie and Düwell 2009).[1] Hence, it may generate tension between these methodological elements if the goal is a specific decision. However, the approach is warranted when the aim is to establish a broad, open, and transparent assessment, deliberation, and implementation process.

The applied approach should not be read as a checklist. It is far from obvious that "the moral assessment of new technologies is narrowed down to evaluating a list of pre-defined ethical issues" or that it is principled based (Kiran et al. 2015) in this case. Moreover, the ethical issues identified by this approach are not an end-point for ethical deliberation on smart glasses, but as a starting point for deliberations, decisions, and implementations as well as modifications, negotiations, formation of knowledge, and constitution of moral and social norms and values. Any evolution, constitution, or construction of norms and values (Geels 2005; Boenink et al. 2010; Oudshoorn and Pinch 2003) needs to take as a point of departure the present realm of norms and values.

The literature search performed for this study was also limited to Google Scholar, and it may be argued that searches in the Philosophers Index, Web of Science, EMBASE, ISTPB + ISTP/ISSHP, HTA databases would have added significantly to the identified issues. However, there are very few relevant studies to be identified in these databases, and, as stated in the methods section, the aim of the search was to identify the ethical issues, and not how many times they were mentioned. As the analysis quickly became saturated with the found references, we think that we have been able to identify the most and the important ethical issues with the search strategy. However, we welcome colleagues to perform more extended searches.

This study has some interesting implications. First, it indicates that the scholarly literature may not be sufficient to identify all relevant and/or interesting ethical issues. The questions of the axiological method may identify important ethical issues not yet addressed. Second, the issues identified in this article may be of relevance to (the assessment of) other types of human cognitive enhancement technologies.

It is also important to notice that there has not been a strict quality assessment of the included literature (beyond ordinary scholarly publishing criteria) and the occurrence of the ethical arguments listed. E.g., the studies of smart-glasses' impact on health are not based on rigorous studies (e.g., Randomized Controlled Trials). Many of the other impacts are also quite speculative. There are of course several reasons for including such studies. First, no high quality empirical studies on the outcome of long term smart-glass use are (yet) available. Second, although quite speculative, the foresights can provide relevant scenarios and spur fruitful discussions for the development and implementation of smart-glasses.

[1] Although it is beyond the scope of this article to scrutinize to what extent the question-based axiological approach applied here is compatible with other established methods for assessing emerging technologies, this study indicates that there is substantial overlap.

Some readers may find that there is an imbalance in table 1, finding the benefits more significant than the potential harms. However, it should be noted that this imbalance may as well indicate that smart-glasses are hyped (Ajmi and Robak 2015). It may also stem from the fact that they are developed and promoted by engineers who focus on the technical aspects (Page 2015).

Contextual in-depth ethical analysis of specific smart-glasses is beyond the scope of this study. Our study is limited to providing an overview. Nevertheless, we hope that our systematic synopsis can be a resource for such context-dependent in-depth analysis and inspire contextual in-depth ethical analysis of all the various types and applications of smart-glasses.

Conclusion

A wide variety of ethical issues with smart-glasses have been identified. Privacy issues were mentioned and addressed most frequently. Safety, justice, change in human agency, accountability, responsibility, social interaction, power and ideology were also identified. Smart-glasses are envisioned to change individual human identity and behavior as well as social interaction. Taking these issues into account appears to be crucial for fruitful development, assessment, decision making, implementation, use, and formation of knowledge and norms with respect to smart-glasses.

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Contributions

BH designed the study and performed the literature search. BH, DH, and LL performed the screening and the analysis of the literature. BH wrote the first draft of the paper. All authors have contributed to the revision of the paper and have approved the final version.

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