Understanding Perception of Human Augmentation: A Mixed-Method Study

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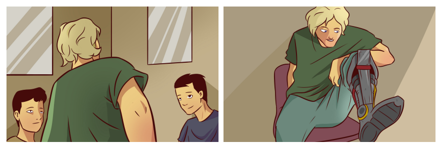
(a) Sensory augmentation vignette


(b) Motor augmentation vignette

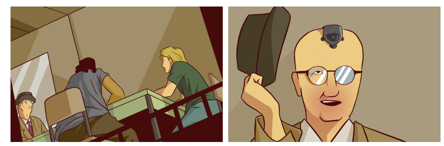

(c) Cognitive augmentation vignette

Figure 1: Visual representation of text-based scenario applied in this inquiry. A visual representation of vignettes is only used in this manuscript for reference and to improve clarity. In the two studies reported in this work, vignettes were text-based only to avoid potential biases.

ABSTRACT

Technologies that help users overcome their limitations and integrate with the human body are often termed "human augmentations". Such technologies are now available on the consumer market, potentially supporting people in their everyday activities. To date, there is no systematic understanding of the perception of human augmentations yet. To address this gap and build an understanding of how to design positive experiences with human augmentations, we conducted a mixed-method study of the perception of augmented humans (AHs). We conducted two scenario-based studies: interviews (n = 16) and an online study (n = 506) with participants from four countries. The scenarios include one out of three augmentation categories (sensory, motor, and cognitive) and specify if the augmented person has a disability or not. Overall, results show that the type of augmentation and disability impacted user attitudes towards AHs. We derive design dimensions for creating technological augmentations for a diverse and global audience.

CHI '23, April 23–28, 2023, Hamburg, Germany

ACM ISBN 978-1-4503-9421-5/23/04.
https://doi.org/10.1145/3544548.3581485

CCS CONCEPTS

• **Human-centered computing** → *User studies*; **Human computer interaction (HCI)**; **Empirical studies in HCI**; **HCI theory, concepts and models**.

KEYWORDS

human augmentation, augmented human, social attitudes

ACM Reference Format:
Steeven Villa, Jasmin Niess, Takuro Nakao, Jonathan Lazar, Albrecht Schmidt, and Tonja Machulla. 2023. Understanding Perception of Human Augmentation: A Mixed-Method Study. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (CHI '23), April 23–28, 2023, Hamburg, Germany*. ACM, New York, NY, USA, 16 pages. https://doi.org/10.1145/3544548.3581485

1 INTRODUCTION

Humans create tools and technologies to facilitate their lives [15]; this ability is crucial in human development as it opens up new opportunities for action and enables individuals to execute tasks faster and more effectively [15]. However, as technologies move ever closer to or become part of our bodies, not only is the relationship between humans and technology becoming more intimate [31] but also the boundary between man and machine becomes blurred.

A range of terms engages with the blurry boundary between man and machine. More precisely, augmented human, cyborg, cybernetic being, and bionic person are all terms that describe a similar phenomenon: a fusion between human and machine. We now live in a time when augmented humans are no longer just part of a vision presented in science fiction novels. Today, a number of augmentations for humans are already available on the consumer market. Correspondingly, augmented humans are regularly discussed in the media [1]. The coverage varies between highly critical and very enthusiastic articles. Consequently, as we have reached a time where human augmentations start becoming a part of our daily lives, there is a need to understand the factors that impact how humans perceive other humans that use technological augmentations. To that end, we conducted a mixed-method study to analyze the perceptions people have about human augmentations.

Human augmentations and assistive technologies can be situated on the same spectrum. They allow humans to overcome certain constraints. For example, assistive technologies such as hearing aids and cochlear implants can enhance hearing for people that are hard of hearing [23], thus enhancing their sense of hearing. Human augmentations can enhance senses too. For instance, Abdelrahman et al. [1] developed a prototype which enables users to see the infrared spectrum using video mixed reality and thermal cameras, thus enhancing their sense of vision. There is already a considerable amount of research on the perception of assistive technologies. Aspects such as stigma, fears, social acceptance and changes in the perception of assistive technologies over time have been discussed (e.g., [10, 40]. Despite the fact that assistive technology and human augmentations are on the same spectrum, recent research reveals that users perceived them differently [4, 29]. Now that we live in a time when human augmentations are becoming accessible to all people, it is high time to analyze how human augmentations are perceived by people around the augmented humans (observers) and consequently how positive experiences with human augmentations can be designed. This leads to the following research questions:

- **RQ1:** Which factors influence the perception of augmented humans?
- **RQ2:** How do the different augmentation types affect the perception of augmented humans?
- **RQ3:** How does it affect the perception of augmented humans whether the augmented human has a disability or not?

To address these open questions, we conducted semi-structured interviews and an online survey. We used scenarios to explore how various augmentations (sensory, motor, and cognitive) are perceived and if the assessment of such augmentations is affected by the augmented person's condition described in the scenarios.

In summary, this paper contributes the following:

- a qualitative study of how people perceive augmented humans based on 16 interviews with participants with diverse cultural backgrounds sharing their views and opinions;
- a survey derived from the interviews that consider six scenarios based on three augmentation types (sensory, motor, and cognitive) and the person's condition (disability, no disability);
- a between-subject vignette study (n = 506) exploring the perception of different human augmentations; and
- implications on how to design positive experiences and interaction with augmented humans for a diverse audience.

[1] https://www.sciencefocus.com/future-technology/cyborgs-transhumans/

Following the call to diversify participant samples in HCI by Linxen et al. [25], this study is to the best of our knowledge the first empirical inquiry into the perception of AHs working with a sample of participants with diverse cultural and geographical backgrounds.

2 RELATED WORK

Augmentation technologies are more than tools integrated with humans to execute a task more efficiently. Instead, they are about exploring human and biological limits, and overcoming them with the help of technology. In this section, we outline the concept of human augmentation as understood and discussed today. Next, we provide an overview of human augmentation technologies present in the HCI literature. Finally, we review the current knowledge of human augmentation and its impact on society inferred from similar paradigms.

2.1 Human Augmentation

The research field forming around the term "human augmentation" is comparably young and a shared understanding of its core concepts is still in development [16, 35]. As a result, definitions of human augmentation are often quite broad [16], which makes it challenging to identify what counts as human augmentation and what does not.

For example, a lab technician using an electron microscope fulfills various of the cited conditions (e.g. overcoming biological limits)—their vision is greatly enhanced and modern microscopes use AI for image processing. Still, most people would not consider this a prototypical example of an "augmented human."

Yet, as research around human augmentation aspires to form a field, there is some consensus on aspects of this new concept [6]. It is generally accepted that human augmentation involves a close relationship between humans and technology to achieve goals not reachable independently. Further, the task's agency is usually localized within the human, i.e., the technological appliance is (often implicitly) conceptualized as a subordinate, not as a partner [30, 37]. Concretely, the technology enhances the human but does not gain agency over the task, even if it incorporates some amount of intelligence.

Another strain of research focuses on the improvement of human skills under the term "human enhancement." However, human enhancement describes a different concept, namely, the general practice of enhancing human beings or human skills. The idea of improving natural human skills is not new; humankind has envisioned enhancing human beings for years; diverse practices, techniques, and technologies have been explored to achieve such a goal (see chemical cognitive enhancements [42, 46] or genetic alteration [43]). However, enhancing human abilities using digital technologies can be referred to as "human augmentation" [35].

Furthermore, depending on the type of technology used and the functions that the technology implements (input, output, processing), three main types of augmentation can be developed: sensory, motor, and cognitive [18, 35]. However, it has to be noted that in some definitions, social augmentation is considered an additional type of augmentation [16]). Under this rationale, the difference between human augmentation and human enhancement can be described as follows: a genetically enhanced human is not an augmented human, whereas a technologically enhanced human is. As a result of these considerations, the following will serve as a working definition of human augmentation in the context of this manuscript:

> Human augmentation is the discipline that seeks to enhance human performance and skills using near-body digital technologies that mediate the interaction of the individual with the self or the world. Such augmentation technologies do not assume control over the task that the augmented human performs, but instead serve as the user's subordinate.

2.2 Human Augmentations in HCI

Exploring a future where human capabilities are not dependent on evolutionary constraints but on technological advancements is an intriguing endeavor for HCI scholars [18, 39]. The boundaries between humans and machines are blurring with the new generation of on-body technologies [49]. Computations and measurements typically performed under the supervision of experts using specialized devices (for example, the traditional blood pressure meter) have been integrated into consumer devices (e.g., smartwatches, smart bands) [27]. Forthcoming steps in computational dynamics anticipate sensory fusion with the user, where information is communicated implicitly through the user's senses and without the need for conscious processing of the information [29].

The idea of transferring information usually perceived by one sense to another has attracted health and interaction researchers' attention for years [45]. Another strain of research focuses on healthy individuals wanting to enhance their senses and, consequently, their perception of the environment. An example of this is the prototype developed by Abdelrahman et al. [1], which enables users to see the infrared spectrum using video mixed reality and thermal cameras. Moreover, exoskeletons have been widely used in motor augmentation to enhance strength [24] and support people with mobility restrictions [20]. Indeed, the use of prosthetics has already resulted in individuals with motor impairments outperforming individuals without impairments in competitive sports events [14]. Recently, prototypes were proposed to augment jumping [44]. Although these devices are still cumbersome due to their size, they evidence the growing interest in motor augmentations within the field of HCI. More recently, wearable technologies, such as Electrical Muscle Stimulation (EMS) or vibrotactile devices, have been explored to improve motor skills [33, 34]. Notably, Kasahara et al. [21] reported super-human reaction times by stimulating the participant's forearm. Human augmentation can be manifested in three ways: enhanced sensory capabilities, enhanced motor skills, and enhanced cognitive performance.

The examples above illustrate the growing interest in understanding and designing human augmentation in HCI. This paper contributes to this body of knowledge by building an understanding of the perception of AHs and their (perceived) social consequences by drawing on a diverse sample.

2.3 Society and Human Augmentation

Recent years have seen increased interest and research into the question of social acceptability's influence in shaping the evolution of technology [26, 28, 32]. Koelle et al. [22] posited that a human-machine interface is sociably acceptable if its existence or the user's interactions with it are congruent with the user's self-image and external image, or positively affect them. In general, society frowns upon interfaces that alter one's self or external appearance for the worst. In response to these demands, we intend to identify the aspects that influence the perception of human augmentation technology users. Social Psychology, Neuroscience, and Ethics research have identified a core group of dimensions relevant for the assessment of and experience with human enhancement, and that repeatedly feature in research. For example, Fitz et al. [13] reported that safety, pressure, fairness, and authenticity are the dimensions that modulate public attitudes toward human enhancement. In detail, they described *safety* as the analysis of risk and benefits of cognitive enhancement for the individual (this dimension is also addressed by Scheske et al. [38]). The *pressure* dimension is defined as the social pressure to have augmentations (similarly defined by Dubjevic et al. [11]). The *fairness* dimension is reported instead as the sentiment of distributed justice, balance, and feelings of cheating [9]. Finally, the *authenticity* dimension was expressed as the impact of the enhancement on the individual's character and worthiness of achievement [7]. In addition, Conrad et al. [8] demonstrated that people are more open to others using enhancements than using them themselves. Though these dimensions are consistently reported in the human enhancement field, it is not clear if they are transferable to human augmentation technologies. Therefore, an understanding of how people assess AHs from the HCI perspective is required. We aim to fill this gap by conducting the first study on perception of AHs across a diverse sample.

Moreover, how the enhancements are communicated to the public influences the attitudes toward human enhancement. Evidence shows that the terminology used in the discourse about human enhancement impacts the acceptance and attitudes of these technologies [8]. As an illustration, using the word "fuel" instead of "steroids" evokes less negative attitudes. Therefore, how augmentations are articulated can impact society's attitudes toward AHs. To take this aspect into account, we have worded both our survey and our interview protocol as neutrally as possible.

Recent work in HCI reported that the level of integration of augmentation in the body plays a role in its acceptance. Specifically, Rousi et al. [36] studied cognitive enhancement from the body's perspective; they refer to these levels of integration as Endo (in-body), Exo (wearable/embodied), and External (environment). Rousi et al.'s work addressed emotional attitudes toward human augmentation technologies, wearable devices, smart clothing, smart glasses, and what the authors refer as cognitive enhancement games. For example, they found that people are less willing to use a brain or eye implant than smart glasses or smart textiles, suggesting that the integration level impacts augmentation acceptance. In this regard, we used the same level of integration in each of the augmentations studied in this manuscript.

Work has been done to understand people's opinions toward enhancements. However, in-depth insights about attitudes toward humans enhanced using technology (human augmentation) are still needed. This work aims to address this gap using a mixed-method approach. We explored the factors influencing attitudes toward

AHs. Moreover, we explored the perception of different types of augmentation from the lens of these factors.

3 METHOD

We followed a two-stage approach to gain knowledge on the factors that influence attitudes toward AHs (Figure 2). First, we examined the dimensions influencing the population's judgments of AHs through 16 interviews. Second, we examined the perception and acceptance of the three different types of augmentations in a between-subject vignette study as described in Section 6. By running semi-structured interviews with a diverse sample (countries from the Americas, Europe, and Asia), we followed a call to diversify HCI participant samples by Linxen et al. [25]. We aimed to gather different perspectives and concerns regarding the judgment of AHs. Although it does not cover all the possible opinions that can emerge from other cultures (i.e., Slavic, African, and Middle Eastern among others), we consider this an initial approximation toward comprehensive mapping of human augmentation technologies and a first step toward building an understanding about how the world perceives AHs. Furthermore, for the between-subject study, we included participants from the same set of countries. The study was conducted during the months of June to September of 2021 in different academic institutions across the four included countries (USA, Germany, Japan, and Colombia).

This study has been approved by the Institutional Review Board of the University of Maryland (approval number 1645727-2).

4 WHICH FACTORS IMPACT THE PERCEPTION OF AUGMENTED HUMANS? AN INTERVIEW STUDY

We conducted 16 semi-structured interviews with participants from four countries to gain knowledge about attitudes and perceptions toward human augmentations. This constituted the first step of our inquiry and aimed to collect different perspectives of human augmentation technology users. All interviews were conducted in a one-on-one session with a single researcher and in the native language of the participant. All interviews were conducted using online video-conferencing software with audio-only recording upon receiving consent from participants (see Figure 3 for an overview).

Vignette Design A. We decided to use vignettes in both studies (in a vignette study participants are asked to see the world through the eyes of a hypothetical person in a specific scenario). Our decision is motivated by past work showing that vignette studies offer the means to balance the benefits of experimental research with high internal validity and the advantages of applied research with high external validity [2].

The choice of scenarios informed by Findler et al. [12] and Riasmo et al. [35] follows the rationale of covering human augmentation from three different standpoints: cognitive, motor, and sensory. Therefore, we developed three vignettes exhibiting the three types of augmentations [35]: *Sensory* augmentations represented by an eye augmentation, *motor* augmentations represented by augmented legs, and *cognitive* augmentations represented by a brain augmentation. We consciously decided not to describe the level of integration (implant, embodied, or environment) to learn more about participants' initial assumptions about this aspect. The augmentations used in the vignettes were brand-agnostic; this is, we did not prime the participants by mentioning any companies or form factors that can bias their answers. In the accessibility literature, it has been demonstrated that individuals have different judgments depending on the type of condition of the assessed individual (Fidler, 2007). Therefore, we wanted to individualize these three points of view to gain more detailed knowledge.

In each scenario, a man, named Michael, has a first-time encounter with another person during a social gathering. This person tells Michael that they have an augmentation and what the consequences of this augmentation are (see Figure 1 for visual reference). The vignettes differed regarding the type of augmentation—it either improved perception (artificial eye), cognitive abilities (brain implant), or motor skills (artificial legs). The following is an example vignette.

> Michael went out for lunch with some friends to a coffee shop. A man with improved sight, with whom Michael is not acquainted, enters the coffee shop and joins the group. Michael is introduced to this person. Shortly after that, everyone else leaves, with only Michael and the man with the improved senses remaining alone together at the table. Michael has 15 minutes to wait for his ride. Michael has heard that it is possible to see small details at long distances and even infrared with this augmentation. Try to put yourself in the described situation and see the world through Michael's eyes.

Interview Protocol. During the interview, we first obtained demographic data. This was followed by defining the concepts "augmentation" and "bionic person" to familiarize participants with the idea and to avoid confusing similar words in the different languages. We then presented one of the three vignettes to the participants and asked them to voice their thoughts. Based on what the participants voiced, we then inquired in more detail about aspects such as interest in, avoidance of, and other thoughts on human augmentations. In the final part of the interview, we gave the participants the opportunity to ask follow-up questions and thanked them for their participation in our study.

Translation and Transcription: The interview script was developed in English and subsequently translated to Japanese, German, and Spanish. The translations were executed by individuals knowledgeable in human augmentation. After the interview, we used a two-translator approach to translate and transcribe the interviews back into the English language: one translator transcribed the audio file while the second validated the accuracy of the transcription and translated it to English. After this, the first translator checked the document in English again. We repeated this process across the three non-English languages.

Participants. First, we had a local researcher in every sampled country, thus ensuring that every sampled country had a representative in the research team. Then, we recruited participants for the interview using the snowball strategy. Although some of the

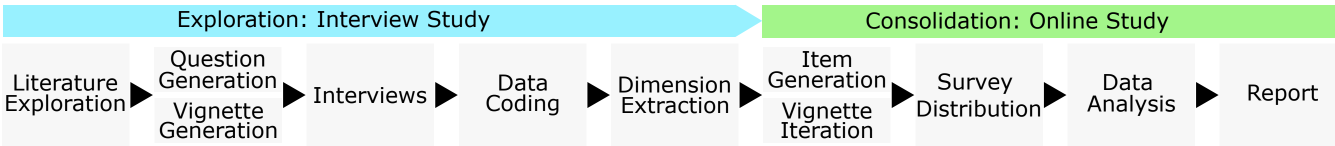


Figure 2: Study diagram: In the Exploration phase, we addressed RQ1: Which factors influence the perception of augmented humans? and RQ2: How do the different augmentation types affect the perception of augmented humans?

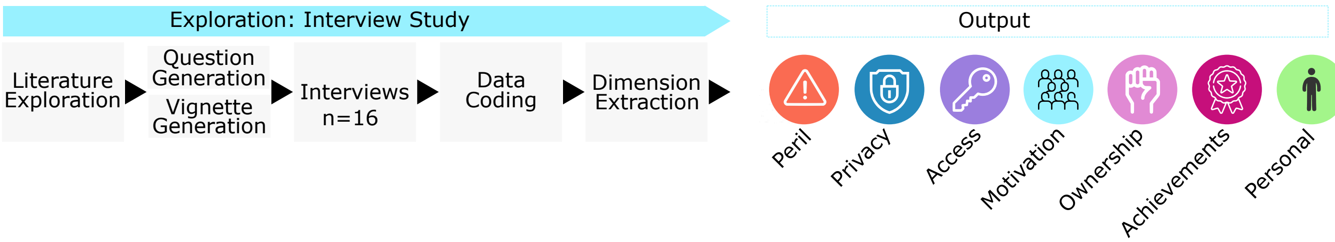


Figure 3: Exploration phase: we addressed RQ1: Which factors influence the perception of augmented humans?

participants could also have had the interview in the English language, we opted to have all the interviews in the participant's native language and led by a researcher from the same nationality. We invited 16 participants using snowball sampling. All participants were compensated for their participation according to the average income of the respective countries. We searched for participants with heterogeneous age ranges and individuals from industry and academia from diverse subject areas. Table 1 presents demographics of the participants.

Analysis. All translated and transcribed interviews were imported into the qualitative data analysis software Atlas.ti. We conducted a thematic analysis as follows: In the first step, two researchers coded a representative sample of 25% of the material using open coding in line with Blandford et al. [5]. Then, we conducted an iterative discussion to establish an initial coding tree. The remaining transcripts were split between the two researchers and coded individually. Finally, we conducted a concluding discussion session to finalize the coding tree. This was followed by a thematic analysis to identify emerging dimensions from the material as described by Blandford et al. [5].

5 INTERVIEWS: RESULTS

Here, we present the findings of our qualitative inquiry. Based on our analysis, we conceptualized six dimensions: Peril, Privacy, Access, Motivation, Ownership, and Achievement, plus an overarching topic consistently found in the interviews, which is the Personal preference to have an augmentation. Our findings are described below and illustrated with excerpts from the interviews. Each excerpt is marked with the respective participant ID.

5.1 Peril & Privacy

The first theme focused on the potential danger emanating from human augmentations, encompassing aspects such as human augmentations as weapons or invisible threats, privacy issues, and defense strategies. Interestingly, participants considered the potential risks of human augmentation from different perspectives. Risks caused by AHs as well as risks caused by the actual augmentation were discussed. The fact that it was unclear who or what was the source of risk in human augmentations (e.g., the human or the technology) and who could possibly be harmed by the augmentation (e.g., the augmented human or a non-augmented human) illustrates the complexity of the issue. The need to assess the risks posed to the AHs by the augmentation was emphasized by many participants. The following statement highlights this consideration:

> For public use, the legal side of it should be checked (...) that person that is going to be using it, is this [i.e., the augmentation] going to pose any kind of threat to their body or physiology. I would like to check all this first, then I'll go for that. (U4)

All participants discussed the potential threat to individuals or society caused by different augmentations. For example, they often either explicitly or implicitly compared them to weapons. This is highlighted by a statement of one participant discussing the potential danger of bionic vision compared with a motor augmentation:

> When it comes to bionic vision, yes, it could interfere, but in this case (motor augmentation), it shouldn't unless this person does, I don't know, some sort of martial art. Their legs would allow this person to give a faster kick or a better punch. They would be stronger and hurt the person they're fighting against. It could also be dangerous because having such strong legs could lead you to kill someone by simply kicking them. (C1)

Another aspect that emerged from the interview data was that participants often expressed their worry about potential privacy issues related to human augmentation. Controlling other people or being controlled by other people with the means of the augmentation was a recurring topic in our interviews. On the other hand, participants who discussed the potential privacy issues of

Table 1: Overview of the interview participants

ID	Country	Gender	Age	ID	Country	Gender	Age	ID	Country	Gender	Age	ID	Country	Gender	Age
C1	Colombia	Male	27	**J1**	Japan	Male	26	**G1**	Germany	Male	36	**U1**	USA	Female	50
C2	Colombia	Female	26	**J2**	Japan	Male	30	**G2**	Germany	Male	25	**U2**	USA	Female	23
C3	Colombia	Female	25	**J3**	Japan	Male	65	**G3**	Germany	Female	62	**U3**	USA	Female	23
C4	Colombia	Male	40	**J4**	Japan	Female	27	**G4**	Germany	Female	33	**U4**	USA	Male	31

augmentations also considered potential positive aspects of human augmentations such as understanding emotions.

The need to develop a strategy to react to potential threats caused by augmentations or AHs was a recurring topic. One participant reflected on strategies to mitigate the potential threat of AHs. The scenario he described could almost be compared to an augmented human arms race:

> Often with things like this, if there is an attack vector, a defensive strategy is developed in return. I don't know. Other people would start bionically changing themselves too, to ensure you can't see anything, that they hide their sweat or something or cool themselves in some other way or somehow stop the stress reaction or something. (G2)

5.2 Access

Many participants reflected on the prerequisites of accessing human augmentations. Their opinions ranged from the need for all people to *have* access to human augmentations, to all people *must have* human augmentations, to people with special needs should have priority access to human augmentations:

> No, I don't think it's ethical if only some people have it [i.e., the augmentation]. I believe everyone should have it. One could say: "Okay, let's give it to the engineers and scientists since they are the ones who are technically in charge of the world's progress and are working with all those things." But what about psychologists, philosophers, and teachers? Why shouldn't they have it as well? Or why can't I have it? If I'm an employee at a company, why can't I have it if that would increase everyone's overall performance? Ethically, I don't think it's okay to limit this knowledge to a select group of people; we should all have it. It should even be mandatory. It is something everyone should have from day one. (C1)

Many participants discussed the need to provide access to human augmentations for everyone. Concurrently, almost all participants agreed that it would be completely acceptable if only people with special needs would have access to a specific augmentation to improve their quality of life (illustrated by the next quote). This is an interesting contradiction as both principles cannot be implemented at the same time. Consequently, based on the statements of the participants, some kind of eligibility analysis may be necessary to award human augmentations.

> If there is a certain kind of regulation that requires people to be selected, those who need it the most should come first. Naturally, if it can be used to bring people with low abilities to the level of ordinary people, I suppose those people should be given priority. (J3)

Some participants commented on the price of the augmentation. Most participants critically reflected on the potential issue that only wealthy individuals would have access to augmentation, which in turn could potentially lead to a larger socio-economic divide. However, some participants considered potential solutions, such as regulating the price of Human Augmentations:

> [Similar to] anything else someone wants really badly. The price must be within a feasible, affordable range. For example, every fool can afford a car. So that's exactly the price range that this [i.e. Human Augmentation] should be in. But I think that tough legal regulations are needed [to ensure that augmentations stay within that affordable price range], and that worldwide. (G3)

5.3 Motivation

The motivation to have an augmentation was discussed by the participants from two different dimensions. First, they reflected on the users' core values (e.g., socially altruistic or egoistically motivated). Second, the participants reflected on whether they would like to have a human augmentation themselves. It was particularly valuable to learn that despite general caution, some participants even expressed certain jealousy toward AHs. Better understanding of the perceptions and assumptions regarding users' motivations in this context is essential. These insights can then be considered in the design of future human augmentations. The augmentations that most participants assessed most positively were cognitive and motor augmentations.

> I would love such a technology. If that's something that can be done, I would be jealous of that person to be honest. [chuckles] That's the thing with me, probably I would want it too. (U3)

In contrast, some participants questioned the motives of people who would be interested in augmentations. Hence, interviewees contemplated potential reasons why someone would get an augmentation. In this context, egoistic motives and criminal intentions were discussed:

> I think there needs to be a social reason. (...) I think it's a very small minority of people who are interested in the latest technology, like 1% of all people, and most of them are people who came up with something bad. Like criminals. (J2)

There was no agreement among participants about the value of egoistic versus social motivations to get an augmentation, meaning that some participants emphasized the importance of doing something positive for society (as highlighted above). In contrast, others focused on the potential benefits for individuals. Interestingly, some participants critically questioned having an augmentation for egoistic motives. However, for most participants, the main justification for having an augmentation would be a specific need to address. For instance, many participants expressed that it would be self-evident to get a motor augmentation to mitigate the after-effects of an accident or an injury:

> That's fine. A prosthetic leg means you've lost a leg. If you can supplement what you've lost and get a higher ability [than other people], that's fine. (J4)

5.4 Ownership & Achievement

Another theme conceptualized based on our analysis describes AHs' perception on a spectrum from humans to artificial beings. Aspects such as responsibility for and ownership of augmentations (e.g., (dis)advantages in competitions), stigmatization due to augmentations, and the need to hide or disclose augmentations based on the social context were discussed. Many participants reflected on the essence of human beings and whether one or many augmentations could change this essence. Further, fear related to losing agency was mentioned by some participants. It is essential to emphasize that this dimension only takes into consideration the apparent ownership that an observed augmented human possesses, and not necessarily the actual ownership or agency that an augmented human possesses over their augmentation.

Many participants of the Colombian user group and some participants of the Japanese user group discussed social consequences such as stigma due to augmentations. Interestingly, this aspect was not mentioned by any German participant. One participant envisioned a situation where stigma would lead to a situation where a doctor would mistreat a patient that has an augmentation:

> If that stigma is extended to, for example, healthcare, it will be necessary to educate doctors who are going to see patients who have augmentations because there might be opinions that– For example, if they are people who are not included in a healthcare system because doctors don't have good opinions on that. "Doctor, listen, I don't know. It seems like this part of the joint in my augmentation is causing me a rash on my hip". "Oh, and who told you getting an augmentation was a good idea?". The stigma can be generalized through all different areas and I think it will be important to prepare the person who is going to have something that is different. (C3)

On a similar note, participants discussed making augmentations invisible to avoid stigmatization. In contrast, many participants emphasized the need to make augmentations visible for disclosure reasons and that it would be an ethical issue if the augmentation would be hidden.

One aspect that can be associated with both specific stigmatization of AHs and wondering about the agency is the attribution of success or achievements:

> It's strange to say congratulations. If a person transforms like that, I can't say he is great because it's just an ability of the prosthesis, right? (J2)

In the first step of our study, four dimensions were identified. These dimensions will now be explored quantitatively in the next step. For a detailed quantitative analysis, two of the identified dimensions are subdivided again so that we now have seven dimensions for the second study: PERIL: How dangerous or safe is an augmented human perceived to be? PRIVACY: Does human augmentation hinder privacy? ACCESS: Should everyone have access to augmentations or should access to augmentations be regulated? MOTIVATION: What is the motivation of the augmented human to acquire the augmentation: personal benefit or social benefit? OWNERSHIP: Are AHs the owners of their augmentations or do the augmentations control the AH? ACHIEVEMENTS: Are the achievements of AHs legit? PERSONAL: Do I want to acquire an augmentation? In the following section, we analyze these dimensions in more detail.

6 IMPACT OF TYPE OF AUGMENTATION AND DISABILITY CONDITION ON PEOPLE'S PERCEPTION OF AUGMENTED HUMANS: AN ONLINE SURVEY

The online study builds on the findings of the interview study and examines how the TYPE OF AUGMENTATION and CONDITION of the augmented human impacts people's perceptions (Between-factors TYPE OF AUGMENTATION and CONDITION). We conducted a between-subject online study using six vignettes that included one out of three TYPES OF AUGMENTATION (Levels: COGNITIVE, MOTOR, and SENSORY) and the CONDITION of the augmented human (Levels: DISABILITY, NO DISABILITY). The vignettes were informed by the work of Findler et al. [12], Riasmo et al. [35], and the findings of the interview study. See Figure 4 for an overview.

Participants. We collected data from 751 participants; after filtering, we ended up with 506 respondents (50.5% female, 48.6% male, and 0.9 % non-binary) from Colombia (n = 149), Germany (n = 205), Japan (n = 65), and the USA (n = 87) (see Table 2). Participants' average age was 36.87 years (SD = 5.36).

We refrained from using survey platforms such as Mturk and Prolific to facilitate consistency of the sampling given that such platforms have different payment systems (incentives) and are mostly Western-oriented, the pool of participants does not cover South American or Asian countries [2] [3] and using a different platform per country could induce confounding factors into the data. Therefore, we applied the snowball strategy. We did this by contacting multiple university faculties, explaining the study's purpose, and distributing the surveys to students after contact was established. Although we know this can potentially end up sampling a specific population inside the country of origin, this is consistent across countries and is, to the best of the research team's knowledge, the most ecological way to guarantee data integrity while sampling from diverse sources. We also filtered respondents who reported a country of origin diverging from the target samples.

[2]https://www.mturk.com/help
[3]https://participant-help.prolific.co/hc/en-gb/articles/360021985613-Who-can-participate-in-studies-on-Prolific-

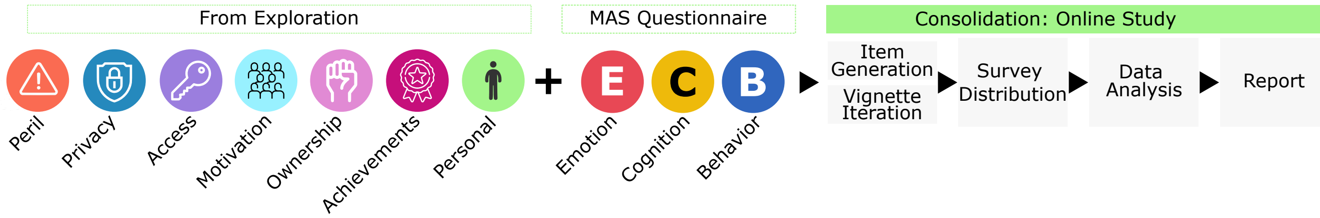


Figure 4: Consolidation phase: we addressed RQ2: How do the different augmentation types affect the perception of augmented humans? and RQ3: How does it affect the perception of augmented humans whether the augmented human has a disability or not?

We filtered the data based on the following criteria to remove random answers and bot responses:

(1) Exclude responses with unrealistically short completion time.
(2) Exclude responses from countries not belonging to the selected countries.
(3) Exclude responses with poor open-ended questions coherence.
(4) Exclude incomplete responses.

Table 2: Demographic distribution of the survey participants (506 responses collected via snowball sampling and survey platforms)

	Age		Gender			
	M	**SD**	**Female**	**Male**	**Non-binary**	**Total**
USA	43.65	17.12	45	42	0	87
Japan	37.2	11.2	30	35	0	65
Germany	38.0	15.7	112	92	1	205
Colombia	28.6	9.3	69	77	3	149
Total	36.8	5.36	256	246	4	506

Vignette Design B. Each participant was presented randomly with one of the six vignettes presenting a fictitious scenario based on the interview results and *The Multidimensional Attitudes Scale Toward Persons With Disabilities (MAS)* [12]. The story behind the fictitious scenario is similar to the one presented in section Vignette Design A. In each scenario, a man, named Michael, has a first-time encounter with another person during a social gathering. This person tells Michael that they have an augmentation and what the consequences of this augmentation are (see Figure 1 for visual reference). The vignettes differed in two aspects: i) the Type of augmentation—it either improved perception (artificial eye), cognitive abilities (brain implant), or motor skills (artificial legs), and ii) the Condition of the augmented human—the person either wanted to improve their abilities because he had a disability condition or he wanted to extend their abilities beyond the normal human range. The following is an example vignette for the combination of improved perception × non-disability condition:

> Michael went out for lunch with some friends to a coffee shop. A man with an artificial eye, with whom Michael is not acquainted, enters the coffee shop and joins the group. Michael is introduced to this person. During the chat, the man tells them that he replaced his healthy eye with an artificial eye to augment his vision beyond the normal range. Shortly after that, everyone else leaves, with only Michael and the man with the artificial eye remaining alone together at the table. Michael has 15 minutes to wait for his ride. Michael has heard that it is possible to see small details at long distances and even infrared with this augmentation. Try to put yourself in the described situation and see the world through Michael's eyes.

In addition, we include participants' Country of Origin (country where respondent was raised) as a third factor of interest in our analysis. Thus, the survey was designed as a quasi-experiment with three independent variables (type of augmentation, Condition, and Country of origin).

Measures. As dependent variables, we constructed 46 Likert-type items inspired by the seven dimensions that we derived from the interview study: peril, access motivation ownership achievements, privacy and personal. Additionally, we included the *The Multidimensional Attitudes Scale Toward Persons With Disabilities (MAS)* [12] scales (emotion, cognition, behavior).

We also included a section on *Value conflicts*, contrasting three aspects: 1) Purpose of the augmentation (Individual vs. Social), Disclosure of the augmentation (Aesthetics vs. Disclosure), and Access (Augmentations should be Regulated vs. Open Access). We asked participants to indicate on binary scales which of the two values regarding augmentation they considered more important. The survey ended with the question, "What would you ask this person?" and an open text field to provide any additional comments or considerations. The survey was developed in English and subsequently translated by professional translators to the remaining languages. Afterward, authors who were native speakers of the target language double-checked the translation's consistency with the English original.

Participants filled in their demographic data and were then debriefed about their rights and the purpose of the study right after opening the survey. Afterward, they read one of the vignettes. They were then asked to take the perspective of the protagonist of the vignette to rate their agreement to statements on Likert-type items. Participants took part of the experiment voluntarily without receiving any compensation. The average survey completion time was 32 minutes.

7 ONLINE SURVEY: RESULTS

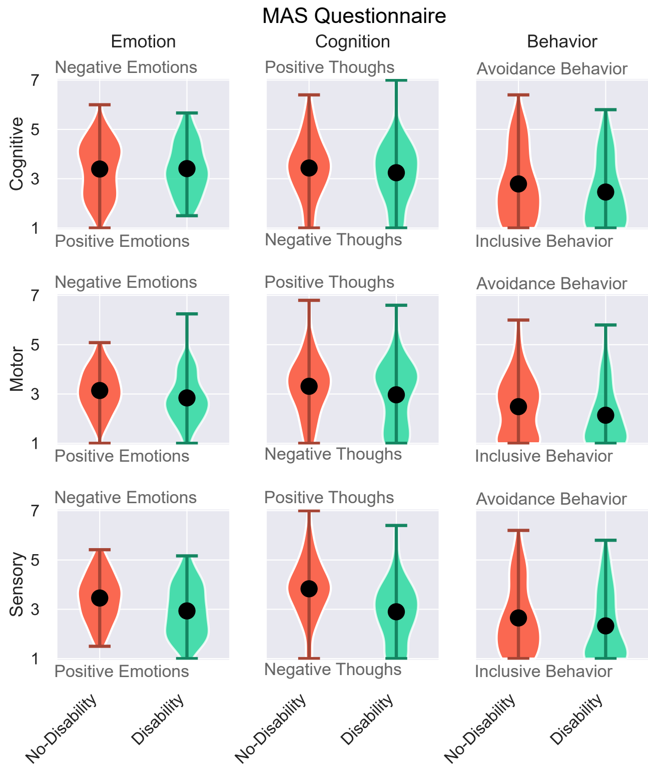


Figure 5: Perception toward augmented humans (MAS questionnaire dimensions): Emotion (1. Positive emotions toward augmented humans, 7. Negative emotions toward augmented humans), Cognition (1. Negative thoughts toward augmented humans, 7. Positive thoughts toward augmented humans), Behavior (1. Inclusive behavior toward augmented humans, 7. Avoidance behavior toward augmented humans).

We applied the Aligned-Rank Transform procedure [47] to analyze whether average ratings differed across conditions. We applied this to the data before performing analyses of variance with the between-subject factors TYPE OF AUGMENTATION (Levels: SENSORY, COGNITIVE, MOTOR). The summary of ratings for the latter can be found in Table 3 and Table 5 and the distribution can be observed in Figure 6 and Figure 5. On the other hand, we also analyzed respondents' COUNTRY OF ORIGIN (Levels: USA, JAPAN, GERMANY, COLOMBIA) influence in the perception of AHs . A summary of ratings for the latter is shown in Table 4 and Table 6. We further explored significant main effects using within-factor post-hoc pairwise comparisons.

All the p-values were adjusted for the number of comparisons. Due to the high number of possible comparisons and the limited space of this paper format, we focus on the main effects and leave out interaction effects. This section also provides descriptive statistics such as the ratings' arithmetic mean (M) and the associated standard error (SE).

7.1 General Assessment

Value conflicts and the subscales of the MAS scale describe in a broad sense the interaction with an augmented human but also enforce the respondent with a set of fundamental questions: Should the use of augmentation devices be regulated or free? What emotions, thoughts, and behaviors would someone experience or execute when interacting with a human augmentation user? We address these questions in this subsection.

Value conflicts. We presented participants with three value conflicts. Each time, they had to choose which of two values they considered more important. Regarding the first conflict—using augmentations for personal improvement vs. augmentation for improving society—more participants chose the latter option (61.8%). Colombia and Germany, in contrast with Japan and the USA, gave priority to the social role of augmentation devices ($\tilde{\chi}^2(3) = 17.69$, $p < 0.001$). Regarding the second conflict—aesthetic appearance (Augmentation not explicitly visible) of the user vs. disclosure (augmentations should be visible)—more participants indicated to prefer an aesthetic appearance (63%). No significant difference was found between countries. Lastly, participants were asked to choose between regulating access to augmentations vs. providing access to all. There was a slight majority in favor of regulation (52.7%).

Emotion. The EMOTION subscale of the MAS questionnaire analyzes the tendency of an individual to elicit positive or negative emotions on the respondent. A lower value represents a tendency toward positive emotion. The condition of the augmented human significantly impacted the emotions towards the augmented humans.

In this sense, the pair COGNITIVE-MOTOR augmentation was the only pair with significant contrast, in which COGNITIVE augmentation (M = 3.397, SE = 0.082) tended to elicit more negative emotions than the MOTOR augmentation (M = 2.997, SE = 0.073; $t(482) = 3.228$ $p < 0.01$). Seen from the COUNTRY OF ORIGIN lens, COLOMBIA (M = 2.936, SE = 0.087) had the most positive emotions. We found significant differences in the pairs COLOMBIA-GERMANY ($t(482) = 3.516$ $p < 0.001$) and COLOMBIA-JAPAN ($t(482) = 3.608$ $p < 0.001$).

Cognition. The COGNITION subscale of the MAS QUESTIONNAIRE analyzes the tendency of the observer to have negative or positive thoughts regarding an individual. The tests applied on the data failed to find a main effect in terms of type of augmentation or country of origin of the respondent.

Behavior. The BEHAVIOR subscale of the MAS QUESTIONNAIRE analyzes the inclusive or avoidance behavior of the observer regarding an individual. No effect was observed on the TYPE OF AUGMENTATION regarding the respondent COUNTRY OF ORIGIN; only the pair COLOMBIA-JAPAN was significant ($t(482) = 2.657$, $p < 0.05$), with COLOMBIA being the country with the most inclusive behavior (M = 2.274, SE = 0.097). However, all countries leaned toward inclusive behavior.

7.2 Dimensions

In this section, we report the results for the set of dimensions extracted from section 4 (see Figure 3 for reference). These dimensions answer questions such as: How dangerous is an augmented human

Table 3: Summary of the main effects for the the MAS questionnaire in terms of Condition and Type of Augmentation, C = Cognitive, M = Motor, S = Sensory

	Disability						Type of Augmentation											
	Yes		No		Yes vs No		Cognitive		Motor		Sensory		C vs M		C vs S		M vs S	
	M	*SE*	*M*	*SE*	*t(482)*	*p*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*t(482)*	*p*	*t(482)*	*p*	*t(482)*	*p*
Emotion	3.072	0.067	3.317	0.062	2.582	**0.010**	3.397	0.082	2.997	0.073	3.181	0.079	3.228	**0.004**	1.688	0.211	-1.561	0.264
Cognition	3.041	0.082	3.535	0.078	4.115	**<0.001**	3.352	0.097	3.174	0.102	3.342	0.101	0.967	0.598	-0.060	0.998	-1.031	0.558
Behavior	2.316	0.084	2.641	0.086	2.624	**0.009**	2.633	0.107	2.322	0.098	2.478	0.108	1.446	0.318	1.092	0.520	-0.364	0.929

Table 4: Summary of the main effects for the MAS questionnaire in terms of Respondent's Country of Origin, Emo = Emotion, Cog = Cognition, Beh= Behavior

	CO		DE		JP		US		CO vs DE		CO vs JP		CO vs US		DE vs JP		DE vs US		JP vs US	
	M	SE	M	SE	M	SE	M	SE	t(482)	p	t(482)	p	t(482)	p	t(482)	p	t(482)	p	t(482)	p
Emo	2.936	0.087	3.309	0.069	3.418	0.126	3.211	0.107	-3.516	**0.003**	-3.608	**0.002**	-1.911	0.225	-1.112	0.683	0.936	0.786	1.694	0.328
Cog	3.183	0.120	3.358	0.085	3.452	0.149	3.202	0.130	-0.826	0.842	-1.302	0.562	0.113	0.999	-0.735	0.883	0.813	0.848	1.272	0.581
Beh	2.274	0.097	2.444	0.099	2.763	0.160	2.715	0.164	-0.886	0.812	-2.657	**0.040**	-2.339	0.091	-2.106	0.153	-1.724	0.312	0.481	0.963

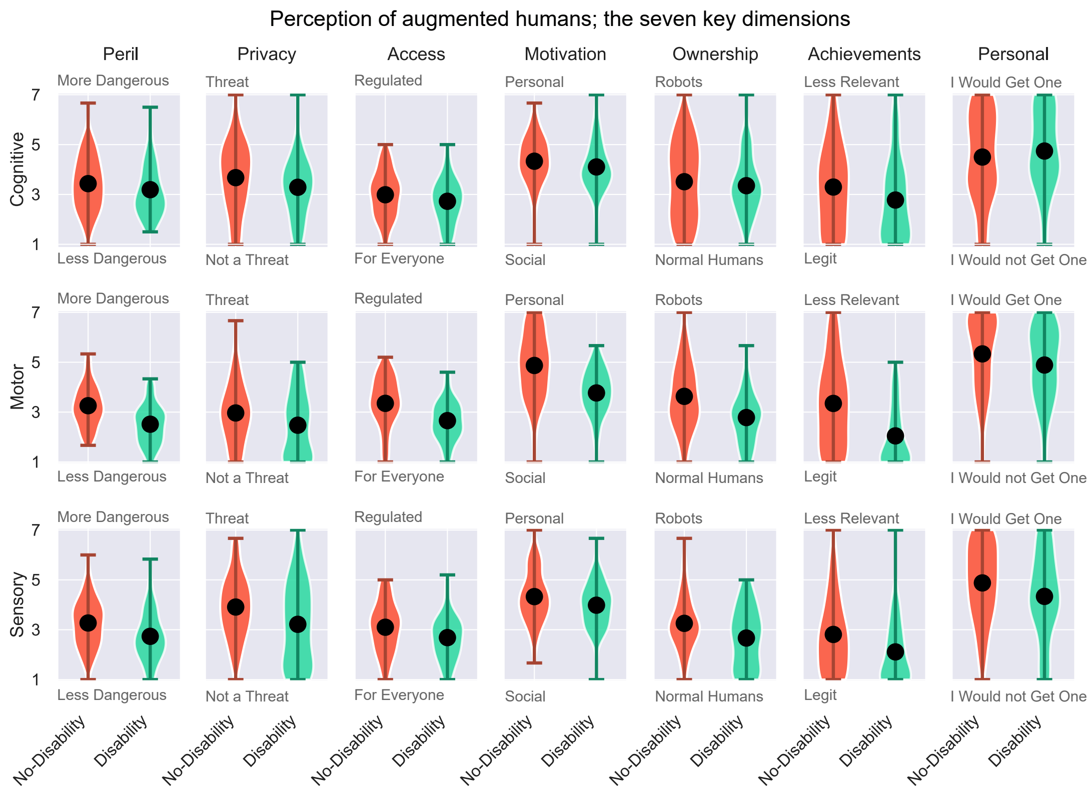


Figure 6: Perception toward augmented humans: Perilous perception (1. Less dangerous, 7. More Dangerous); Privacy (1. Augmented humans are not a threat for privacy, 7. Augmented humans are a threat for privacy); Access (1. Augmentations should be available for everyone, 7. Augmentations should be regulated); Motivation (1. Individuals use augmentation for social benefit, 7. Individuals use augmentations for personal benefit); Ownership (1. Augmented humans are normal humans, 7. Augmented humans are robots); Achievements (1. Augmented humans' achievements are legit, 7. Augmented humans' achievements are less relevant); Personal (1. I would not like to have an augmentation, 7. I would like to have an augmentation). The black circle in the graphs indicates the distribution's mean value.

perceived to be? Should everyone have access to augmentations? Should augmentations have a social or individual purpose? Does human augmentation hinder privacy? Are AHs the owners of their augmentations or do the augmentations turn them into robots? Are the achievements of AHs legit? Would the observer want to have an augmentation?. **The collected data yielded that the previous CONDITION (Disability, No-disability) of the augmented human (observed human) impacted all the dimensions presented below with the exception of the personal preference** for acquiring an augmentation (see Table 5 for a summary). This behavior is coherent with the formulation of the dimension given that it does not reference the observed human but the observer. In the following, we report the results for every dimensions in terms of type of augmentation and country of origin of the observer. In our analysis, we also accounted for technological preference, but no significant changes occurred.

Peril. The PERIL dimension analyzes how much an observed augmented human is perceived to be dangerous, with higher values representing a higher perception of threat. Our sample yielded that the perceived threat posed by an augmented human is modulated by the TYPE OF AUGMENTATION and COUNTRY OF ORIGIN. COGNITIVE augmented individuals were considered more dangerous (M = 3.310, SE = 0.088) than MOTOR (M = 2.910, SE = 0.071; t(482) = 3.161, $p < 0.01$) and SENSORY augmented humans (M = 2.984, SE = 0.079; t(482) = 2.462, $p < 0.05$). Country-wise, only the pair COLOMBIA-GERMANY was significantly different (t(482) = 2.595, $p < 0.05$) with COLOMBIA considering AHs as less dangerous (M = 2.926, SE = 0.088).

Privacy. The PRIVACY dimension analyzes the extent to which AHs are a threat for the observer's privacy, where a lower value means a lower perception of threat for the respondent's privacy. The sampled data show an influence of the TYPE OF AUGMENTATION and the respondent's *country of origin*. Participants rated SENSORY (M = 3.557, SE = 0.116) and COGNITIVE (M = 3.477, SE = 0.103) AHs as a greater threat to their privacy than MOTOR augmented humans (M = 2.722, SE = 0.102), with values of (t(482) = 3.828, $p < 0.001$) for the pair COGNITIVE-MOTOR and (t(482) = 5.125, $p < 0.001$) for the pair SENSORY-MOTOR.

Respondents from GERMANY consistently rated AHs as a threat for their privacy in comparison with the rest of the sample (see Table 6).

Access. The ACCESS dimension analyzes the observer's opinions about regulations of human augmentations, where a lower value means a preference toward universal availability of augmentations. The sampled data did not show any influence of the TYPE OF AUGMENTATION in the respondent judgment of openness or regulation of human augmentation. The COUNTRY OF ORIGIN of the respondent only yielded a significant difference in the pair JAPAN-USA (t(482) = 2.854, $p < 0.05$), with USA respondents leaning toward universal availability of augmentations (M = 2.703, SE = 0.117) and Japan being more conservative than the rest of the sample (M=3.169, SE=0.083) . However, all the countries remain on the universal availability side.

Achievement. The ACHIEVEMENT dimension analyzes the respondent's perception of the achievements of an augmented human, where a lower value represents a higher validation of the augmented human achievements.

The respondent's *country of origin* and the *Type of Augmentation* had an influence on respondents' perception of achievements of the augmented human. In detail, a SENSORY augmented individual's achievements were regarded as the more legit among the three types of augmentation. Respondents from GERMANY were the most skeptical about achievements attained with the help of augmentations (M = 2.954, SE = 0.114), followed by those from the USA (M = 2.891, SE = 0.117), COLOMBIA (M = 2.651, SE = 0.137), and JAPAN (M = 2.062, SE = 0.114). Respondents from JAPAN particularly, seemed to validate more augmented human's achievement than the rest of the sample (for more detail, see Table 6).

Motivation. The MOTIVATION dimension analyzes the respondent's perspective on the motivation that an augmented human had to acquire a given augmentation. It does so in a continuum from social focus (1 in the scale) to individual focus (7 in the scale). How strongly a user of augmentation is perceived to act with an individual or social intention was impacted by the participants' COUNTRY OF ORIGIN but not significantly by the TYPE OF AUGMENTATION. In this dimension, a clear difference was noted from the respondents from JAPAN regarding the rest of the sample, with social motivation as the perceived motivation. The rest of the sample interpreted a personal motivation (refer to Table 6 for details).

Ownership. The OWNERSHIP dimension analyzes the extent to which an augmented human is still perceived as having agency over the augmentation (Owning the augmentation) or the augmentation having agency over the human (being a computer, robot, machine). Lower scores represent that the augmented human preserves the agency. In this dimension, our sample yielded that the TYPE OF AUGMENTATION and COUNTRY OF ORIGIN of the respondent impacted the perception of ownership over the augmentation. In detail, COGNITIVE augmentation had the highest impact on ownership perception (M = 3.429, SE = 0.105). Although respondents of all countries leaned toward AHs being the owners of the augmentation, GERMAN respondents were significantly more conservative (M = 3.750, SE = 0.093) (please refer to Table 6 for details on the contrasts).

Personal preference. The PERSONAL PREFERENCE subscale addresses a respondent's willingness to acquire a given augmentation; higher values mean higher inclination toward acquiring the augmentation. Based on our data, participants stated a higher interest in obtaining a SENSORY (M = 4.635, SE = 0.133, t(482) = 2.839, $p < 0.05$) or COGNITIVE (M = 4.576, SE = 0.132; t(482) = 2.444, $p < 0.05$) augmentation compared to a MOTOR augmentation (M = 5.136, SE = 0.125). Country-wise, JAPANESE respondents reported a higher willingness to acquire an augmentation (M = 4.208, SE = 0.181) in contrast to GERMAN respondents that were the less interested on acquiring one for themselves (M = 5.268, SE = 0.109; t(482) = 4.773, $p < 0.001$); in this regard also, USA (M = 4.736 SE = 0.179;t(482) = 2.718, $p < 0.05$) and COLOMBIAN participants (M = 4.369 SE = 0.151; t(482) = 4.684, $p < 0.001$) followed the trend of JAPAN, being positive toward acquiring an augmentation.

Table 5: Summary of the main effects for all the explored dimensions in terms of Condition and Type of Augmentation, C = Cognitive, M = Motor, S = Sensory

	Disability						**Type of Augmentation**											
	Yes		**No**		**Yes** vs **No**		**Cognitive**		**Motor**		**Sensory**		**C** vs **M**		**C** vs **S**		**M** vs **S**	
	M	***SE***	***M***	***SE***	***t(482)***	***p***	***M***	***SE***	***M***	***SE***	***M***	***SE***	***t(482)***	***p***	***t(482)***	***p***	***t(482)***	***p***
Perilous	2.827	0.065	3.311	0.061	5.401	**<0.001**	3.310	0.084	2.910	0.071	2.984	0.079	3.161	**0.005**	2.462	**0.038**	-0.722	0.751
Access	2.691	0.056	3.125	0.064	4.912	**<0.001**	2.853	0.072	3.019	0.079	2.868	0.077	-1.700	0.206	-0.139	0.989	1.569	0.260
Motivation	3.960	0.063	4.520	0.075	5.686	**<0.001**	4.211	0.079	4.362	0.105	4.167	0.079	-1.537	0.275	0.340	0.938	1.883	0.145
Privacy	3.015	0.092	3.502	0.087	3.774	**<0.001**	3.477	0.103	2.722	0.102	3.557	0.116	4.838	**<0.001**	-0.265	0.962	-5.125	**<0.001**
Ownership	2.941	0.075	3.450	0.086	3.856	**<0.001**	3.429	0.105	3.230	0.102	2.935	0.092	1.443	0.320	3.419	**0.002**	1.957	0.124
Achievement	2.323	0.092	3.142	0.106	5.659	**<0.001**	3.023	0.129	2.753	0.132	2.435	0.112	0.889	0.648	3.148	**0.005**	2.244	0.065
Personal	4.647	0.108	4.901	0.107	1.613	0.107	4.635	0.133	5.136	0.125	4.576	0.132	-2.444	**0.039**	0.385	0.922	2.839	**0.013**

Table 6: Summary of the main effects for all the explored dimensions in terms of the Respondent's Country of Origin, Per = Perilous, Acc = Access, Mot = Motivation, Priv = Privacy, Own = Ownership, Ach = Achievements, Pers = Personal Preference

	CO		**DE**		**JP**		**US**		**CO** vs **DE**		**CO** vs **JP**		**CO** vs **US**		**DE** vs **JP**		**DE** vs **US**		**JP** vs **US**	
	M	**SE**	**M**	**SE**	**M**	**SE**	**M**	**SE**	**t(482)**	**p**	**t(482)**	**p**	**t(482)**	**p**	**t(482)**	**p**	**t(482)**	**p**	**t(482)**	**p**
Per	2.926	0.088	3.161	0.071	3.156	0.132	3.054	0.099	-2.595	**0.048**	-1.907	0.226	-1.294	0.567	-0.031	1.000	0.814	0.848	0.662	0.911
Acc	2.842	0.083	2.968	0.068	3.169	0.083	2.703	0.117	-1.218	0.616	-2.465	0.067	0.755	0.875	-1.654	0.349	1.819	0.266	2.854	**0.023**
Mot	4.246	0.094	4.437	0.080	3.544	0.118	4.310	0.113	-1.855	0.249	4.839	**<0.001**	-0.309	0.990	6.456	**<0.001**	1.231	0.607	-4.637	**<0.001**
Priv	2.978	0.115	3.750	0.093	3.051	0.175	2.759	0.157	-5.862	**<0.001**	-0.518	0.955	0.987	0.757	3.890	**<0.001**	5.962	**<0.001**	1.281	0.575
Own	2.978	0.115	3.750	0.093	3.051	0.175	2.759	0.157	-5.862	**<0.001**	-0.518	0.955	0.987	0.757	3.890	**<0.001**	5.962	**<0.001**	1.281	0.575
Ach	2.651	0.137	2.954	0.114	2.062	0.141	2.891	0.187	-1.775	0.287	2.665	**0.040**	-0.944	0.781	4.125	**<0.001**	0.494	0.960	-3.191	**0.008**
Pers	4.369	0.151	5.268	0.109	4.208	0.181	4.736	0.179	-4.684	**<0.001**	1.180	0.640	-1.152	0.658	4.773	**<0.001**	2.718	**0.034**	-2.017	0.183

8 DISCUSSION

In this section, we first provide answers to our research questions, then we discuss the general perception of AHs based on the analysis of our interviews and the results of the online study. We then outline insights following the structure of the dimensions identified. We adapted the MAS questionnaire [12] to measure attitudes toward AHs. The questionnaire focuses on three aspects: behaviors, cognition, and affects. The questions concerning behavior focus primarily on avoidance behaviors such as leaving the room the augmented human is in or moving to another space. Cognition mainly focuses on aspects concerning interest in and the first impression of people. This subscale includes questions such as if someone looks interesting or if the participant would like to get to know the AH more. Affects focus on affective experiences such as fear, depression, relaxation, or shame.

This study set out to identify factors relevant for the assessment of AHs (RQ1). In addition, we analyzed how the type of augmentation and user's disability condition impact the perception of AHs (RQ2). With regards to the question *Which factors influence the perception of augmented humans?* (RQ1), our results show that the following six dimensions modulate the perception of augmented humans: peril, privacy, access, motivation, ownership, and achievement . Furthermore, for the question *How do the different augmentation types affect the perception of augmented humans?*, we found that the type of augmentation had an impact on the perception of all dimensions apart from access and motivation (RQ2). Finally for the question *How does it affect the perception of augmented humans whether the augmented human has a disability or not?*, we found that the previous disability Condition of the augmented human was the most decisive factor across all our samples; nearly every dimension was impacted depending on whether the individual in question had a disability before acquiring the augmentation (RQ3).

8.1 What is The Current Perception of Augmented Humans?

Our analysis, based on multiple data-sources, showcases some interesting tensions. While being generally optimistic about augmentations, respondents reported not wanting an augmentation for themselves. This opinion was shared across every sampled Country of origin with participants from Germany being most skeptical. Based on the adapted MAS questionnaire results (subsections Behavior and Emotion), we observed that our sample was mainly positive about the augmented human described in the vignettes regardless of their Condition, the Type of augmentation, and the Country of Origin of the participants. However, the cognition dimension of the MAS Questionnaire showed that our sample tended to have negative thoughts toward AHs. Cognitive augmentations were the most controversial augmentation type. Cognitive AHs, which elicited the least positive emotions, were seen as the most perilous and the ones reduced the perception of ownership and achievement the most. Further, cognitive augmentation was seen as more dangerous than, for example, motor augmentations, where the augmentation itself could be used to induce physical damage to someone else. Notably, motor augmentations were seen as the least dangerous in terms of privacy and peril, but also the least wanted of the three augmentations. At the same time, motor augmentations elicited the least negative emotions and behaviors. This result could be explained with the high correlation of motor augmentation devices and assistive devices for people with mobility restrictions, and the bias against assistive device adoption [48].

Finally, sensory augmentations seemed to only be perceived less positively when it comes to privacy.

8.2 Cross-cultural Aspects

Following a call from Linxen et al. [25], we contribute a study with a geographically diverse sample. The attitude of responses of participants from Japan were significantly different from German ones in five out of seven dimensions, making their opinions the most contrasted, whereas participants from Colombia and the USA did not present any significant difference.

Although there was a general agreement across all the sample, the extent to which respondents from every country scored AHs was significantly different, for example, in the case of privacy, the four countries sampled leaned towards AHs not being a threat for privacy, however Germany respondents were significantly less inclined to this judgment (refer to Table 6), this behavior also occurred in the Ownership dimension for Germany, in the Achievements dimension for Japan where respondents from Japan were the ones that validated the most augmented human's achievements, and, in the Personal dimension with Germany, where German respondents were the most reluctant to acquire an augmentation for themselves. Interestingly, the only dimension where there was a disagreement is the Motivation to acquire an augmentation; Japanese respondents leaned significantly towards the social use of augmentations while the rest of the sample did it for the personal use. This aligns with the opinions reported in the interview study where an interviewee from Japan mentioned that he cannot imagine human augmentations not being used for social benefit.

It is plausible that elements inherent to the country of origin, which were not accounted for in the main set of control variables, can have an effect. This is particularly intriguing in the case of the education level of participants or the level of exposure to emerging technologies. These things can affect how a person understands the scenarios they are given and, in turn, how they reported their opinions in the survey study.

8.3 Design Recommendations

In this section, we assess our findings through the lens of interaction design and give a list of design recommendations, highlighted in bold, along with evidence to support each recommendation.

Our results extend human enhancement literature [19, 41]. Our findings show that safety concerns regarding human augmentations concern two aspects. While previous work showed that the main concerns lie in the safety of the person undergoing an enhancement or intervention, our participants were concerned about the risk associated with getting an augmentation. Furthermore, the augmented human is also regarded as a potential threat to the individuals in their environment. Some participants even suggested that augmentations should be regulated in the same way as guns or weapons. Across all four countries, respondents were more restrictive about the adoption of augmentations by persons without disabilities. In addition, participants reflected on the potential threat of different augmentation types as illustrated by the artificial eye example. Participants speculated that augmented vision could enable individuals to identify physiological reactions that are not evident without the use of technology and, thus, have more information about the people in their environment. While our qualitative analysis revealed ways in which AHs can be perceived as a threat to one's safety, our quantitative results showed that in the case of privacy, the four countries sampled leaned toward AHs not being a threat for privacy; however, German respondents were significantly less inclined to this judgment (refer to Table 6). In general, participants emphasized the need to communicate the purpose of the human augmentation in a clear manner. This is in line with previous work [1]. Uncertainty about the purpose of human augmentations can lead to speculation and fear. **Consequently, communicating the application area or the purpose of augmentation through a clear and unambiguous design could help mitigate the population's concerns about human augmentations.**

The population sampled in this study converged in that augmentations should be available for everyone and not regulated. However, in case access to augmentations is restricted, participants favored prioritizing access to augmentations for people with disabilities, particularly if augmentations extended sensory and motor abilities related to body strength and endurance. The motivation to acquire an augmentation was a recurrent topic. Participants had strong opinions regarding the motivation to get an augmentation; one participant even suggested that people using augmentations for egoistic purposes have criminal intentions. Participants from Japan and Colombia assumed that augmentations are used for a social rather than individual benefit. Moreover, our results showed that the condition and the motivation for getting an augmentation strongly influenced people's attitudes toward human augmentation. Consequently, based on previous work and our analysis, assistive systems seem to be perceived as more acceptable than human augmentations designed for people without previous disability conditions. Therefore, an approachable human augmentation should offer flexible design solutions that can be adapted and used by individuals with different abilities and needs. This is in line with the vision of "assistive augmentations" introduced by Huber et al. [17]. The benefit of this approach could be twofold. People with impairments often reject using assistive technologies to avoid appearing "different." **We propose to design augmented systems that can potentially be used to address a variety of different user needs,. In other words, the design of hybrid augmentations (augmentations that are also built for assistive functions) can be used to address the challenge of making human augmentations acceptable and more inclusive by designing for a spectrum of abilities.**

Moreover, several participants addressed the topic of achievements in the interview study. Perceptions about the weakening of the importance of accomplishments because of the usage of augmentations were extensively discussed in the interviews. Yet, the quantitative data show that respondents tended to judge AHs as regular humans and saw their ACHIEVEMENTS as legit regardless of their augmentations. Participants from Japan valued the achievements of augmented humans the most. Participants from Germany valued the achievements of augmented humans the least. Another factor present in the discussion was losing agency after assimilating an augmentation. This recalls Anderson's [3] suggestion that *"Some augmentations may have profound effects on a person's sense of self."* This factor plays a role in the perception of the achievements of the user of the augmentation. There seemed to be a continuum between the joy of having augmented skills, perceiving an AH as human (including their achievements), and the need only to receive recognition when one deserves it. While participants expressed interest in experiencing an augmentation, our results indicate that achievements would be worth less if they were achieved while having an augmentation. Participants commented that AHs' accomplishments could not be considered their own but instead as the augmentation system achievements. This exposes a trade-off between the system's performance and the level of effort invested by the user. **We recommend paying special attention to navigating effort and effortlessness when designing human augmentations. Reducing the user's effort to the minimum would lead to lowering agency in the user and reducing the importance of accomplishments achieved while using the augmentation.**

8.4 Human Enhancement From the HCI Lens: Multifold Dimensions

In contrast with human enhancement literature [19, 41], the threat perception of the intervention (Augmentation, or Enhancement) does not only include the integrity of the individual receiving the intervention but also the individuals in the surroundings. This phenomenon holds for two of our seven dimensions, namely Perilous and privacy; During the interviews, our interviewees mentioned the associated of getting an augmentation. For example, in the case of implants, the risk of a wrong intervention, issues with bio-compatibility, or related would indeed impact the individual integrity. However, it unfolded another perspective, which is the threat that a person with augmented skills can pose if these skills are misused, it can be depicted with the case of motor augmentations, where an individual can increase their strength and use it against their peers. Such a situation was mentioned by one interviewee, who even suggested that motor augmentations should be regulated in the same way as weapons, given their potential. This also applies to the Privacy dimension; participants were worried about augmentation manufacturers having access to their data on a more intimate level, given that augmentations would integrate more closely with their bodies and, in a far too futuristic scenario, with their brains, therefore it is at least a reasonable concern. However, what is more interesting is the perceived privacy threat derived of the use of an augmentation; Participants also reported that an augmented human could potentially violate their privacy by making use of, for example, sensory augmentations that can reveal physiological reactions that are not evident without the use of technology.

8.5 Limitations

We recognize that our study is prone to certain limitations. Our study includes a sample with diverse geographical backgrounds as suggested by Linxen et al. [25]. However, it is necessary to broaden the boundaries of understanding of AHs beyond the countries sampled in this manuscript. Therefore, future work should also consider exploring different countries from the ones typically sampled even though it brings challenges (e.g., regarding data collection given the limited coverage of online survey platforms).

Furthermore, there may be additional factors influencing perceptions about AHs that we did not analyze in depth such as gender and religious opinions.

The impact of the interviewees' backgrounds on the questions they were asked and the answers they gave was not analyzed in this study. In the future, researchers may want to look at whether or not viewers' socioeconomic status and level of education affect their perceptions of augmented humans.

In this manuscript, we focused on the case of users with a single augmentation; however, the more general issue of augmented humans with multiple augmentations may require additional considerations beyond those we are able to address here. Yet, this is an intriguing potential direction for investigation.

Additionally, interacting with augmented people encompasses a number of perspectives that were not addressed in this publication and require inquiry in order to provide a more comprehensive understanding of this phenomenon, such as bystanders and users [22]. We were concerned with the observer perspective in this work.

Finally, this is a cross-sectional study and, therefore, cannot predict or analyze the evolution of the opinions about AHs. However, it can serve as a reference point for future work focusing on understanding the evolution and dynamics of perception of AHs.

9 CONCLUSION

This paper investigated perceptions toward augmented humans (AHs) with a diverse sample of participants from Japan, Germany, the USA, and Colombia. We conducted two studies: a qualitative interview study with 16 participants and a between-subject online study with 506 participants. We analyzed the interest in acquiring an augmentation and identified six dimensions involved in the attitudes toward augmented humans: peril, privacy, access, motivation, ownership, and achievement. Our results showed a strong impact of disability conditions in the opinions about augmented humans, meaning that respondents were more positive about augmented humans if the reason for acquiring the augmentation was grounded in compensation for a missed skill. Also, we discovered that different types of augmentations elicit different types and levels of concerns, i.e., cognitive augmentations were less well-received than motor augmentations; in addition, sensory augmentations were seen as a higher threat to privacy. Results also showed that the sampled countries have similar perception of augmented humans; however respondents from Germany were the least interested in acquiring an augmentation and participants from Japan perceived augmented humans to use augmentations for social reasons, which diverged from the rest of the sample. We hope that our results will inspire further research into the perception of human augmentations and how to design positive interactions between humans and augmented humans.

10 OPEN SCIENCE

In order to establish a thorough understanding and interpretation of this manuscript, we believe that it is essential for other researchers to examine and reproduce these results. For this reason, we actually recommend the reader to take a look at our compiled dataset and analysis scripts at: https://osf.io/83fc4/.

ACKNOWLEDGMENTS

This work was partly funded by the European Research Council (ERC AMPLIFY, no. 683008).

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