On Futuring Body Perception Transformation Technologies: Roles, Goals and Values

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ABSTRACT

Body perception transformation technologies augment or alter our own body perception outside of our usual bodily experience. As emerging technologies, research on these technologies is limited to proofs-of-concept and lab studies. Consequently, their potential impact on the way we perceive and experience our bodies in everyday contexts is not yet well understood. Through a speculative design inquiry, our multidisciplinary team envisioned utopian and dystopian technology visions. We surfaced potential roles, goals and values that current and future body perception transformation technologies could incorporate, including non-utilitarian purposes. We contribute insights on such roles, goals and values to inspire current and future work. We also present three provocations to stimulate discussions. Finally, we contribute methodologically with insights into the value of speculative design as a fruitful approach for articulating and bridging diverse perspectives in multidisciplinary teams.

CCS CONCEPTS

• **Human-centered computing → HCI theory, concepts and models**.

KEYWORDS

Body Perception, Body Transformation, Speculative Design, Fictional Scenarios, Futuring

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1 INTRODUCTION

The way we perceive and experience our bodies shapes our interactions with the surrounding environment, with others and with ourselves [30]. Technological advances in sensing and actuating capabilities, and the integration of body technologies in everyday contexts are revolutionizing how we humans perceive, relate to and engage with our body [37, 60, 89, 99]. This article concerns an emerging type of body technologies: *Body Perception Transformation* technologies. These technologies augment or alter the own body perception outside of our usual bodily experience through e.g. sensory augmentations [95], perceptual illusions of one's body changing [63, 64], or even direct manipulation [42]. These technologies include VR (e.g. [47]), wearables (e.g. [50], implants (e.g. [99]), and robotic devices (e.g. [76]) and bring the promise of having significant effects on humans in health, entertainment, sports, and arts [31, 50, 60, 79, 89]. Yet, as emerging technologies, most research on them is still confined to proofs-of-concept (e.g. [60]) or controlled experimental studies in lab settings (e.g. [71, 79, 84]), and there is a need to address numerous open questions concerning the potential impact of these technologies on everyday contexts. These include understanding the roles they will play in shaping our interactions with the world, ourselves, and others; the goals people will pursue with them and the values that these technologies will incorporate.

Our group, a multidisciplinary team researching body perception transformation technologies, engaged in a series of workshops and exercises to start thinking about these questions and inspire future research that addresses them. We employed a speculative design methodological approach [22] to articulate, surface and explore implications, potentials, hopes and concerns for the body

perception transformation technologies we are researching. Each one of us imagined and created our own utopian and dystopian technology visions, which we contrasted and discussed together towards surfacing commonalities and differences.

The speculative exercise yielded common themes regarding the roles (e.g. enhance human capabilities, empower humans, or control body experiences), goals (e.g. improve people's lives, connect with others, non-instrumental goals) and values (e.g. agency, reinforce or challenge status-quo) that we envision for these technologies. It also helped surface frictions and differences in approaches, values and goals among the team members. Both were helpful for us to better understand the diversity within our multidisciplinary team and to identify issues we might need to address.

The contribution of our work is twofold. First, we contribute to research on body perception transformation technologies (e.g. [31, 49, 50, 59, 60, 73, 76, 79, 84, 86, 89]) with a characterization of roles, goals and values that these technologies may incorporate (Section 5). Some of these can already be seen in current research, but in particular we contribute with others that can help open up new lines of research in which body perception transformation technologies are designed and used for non-utilitarian purposes (e.g., fostering connections beyond the individual, playfulness, joy and dissidence). We also provide three provocations to stimulate further discussions in the field (Section 6.1.2). Secondly, we contribute methodologically with insights on how speculative design can be a fruitful approach for multidisciplinary research teams to articulate and share individual technology visions, to identify similarities and differences among team members and to spark conversations towards shared roadmaps (Section 6.2). We believe that our work can help others in body perception transformation communities to critically examine their own technology visions, and inspire research that expands on the current state of the art.

2 THEORETICAL UNDERPINNINGS AND RELATED WORK

2.1 Body Perception and Body Perception Transformations

From a cognitive neuroscience perspective, own-body perceptions refer both to perceptions of one's own body appearance, including shape, size, and configuration, often referred to as body image [19, 51], as well as to perceptions of one's body motor capabilities, such as body part position and kinematics, often referred to as body schema [48, 54], which are used for reaching for objects, walking, and tool manipulation. These perceptions influence the way we move [46, 54], our emotional states [67, 68], and are key to self-awareness, self-identity [87, 93] and for social behaviour [52, 56]. Critically, despite the fact that a person's physical body may not generally change quickly, the perceptions people have about their own body are highly plastic [9]. The key to body perception transformations through technology is the alteration of multisensory or sensorimotor signals related to the body [9, 20, 51, 77, 90, 91]. For instance, visual feedback on one's moving body can be manipulated using immersive VR, to create illusions of having longer arms [47] or a shorter/taller or slimmer/wider body [66, 83, 97]. These transformations can be designed and supported by technology that exploits the mechanisms underlying such experiences, that is, altering the multisensory or sensorimotor signals related to the body and in turn alter motor and social behavior, emotional state and self-identity [13, 17, 55, 67, 68, 81, 82]. For example, altering the frequency of the own footstep sounds can influence perceived body weight and impact gait, emotional state, and feelings of being quicker and more feminine [17, 84, 86].

2.1.1 Technological Approaches to Transform Body Perception. In HCI, we find current approaches for body perception transformation that are relevant to our work and that we will use to ground and discuss our results.

Multisensory Body Illusions. In addition to investigating the connection between the mind and body, HCI researchers have expanded their focus to explore multisensory body illusions in the context of various applications. There is an emergence of social VR applications (e.g., [69], VRChat [1]) and VR games (commercial, e.g. Ready Player Me [2], or research games e.g. [65]) that build on embodiment research. The embodiment of virtual avatars is an effective approach to support motor learning and rehabilitation [38], or to change people's attitudes and social behavior (e.g. in relation to racial or age bias) [4, 52] (see review by Mottelson et al. [59]). Beyond the use of VR, an emerging approach (e.g. [31, 49, 50, 84, 86]) focuses specifically on developing wearable technology that induces multisensory body illusions as a way to transform body perception to tackle specific user needs in real-contexts of use through the use of sensory signals rather than visual ones. This approach builds on the principle of altering the multisensory or sensorimotor signals related to the body, for example, through sound [91]: altering footstep sounds [84] or sonifying people's movements through different metaphorical sounds (e.g. water, wind, metal gears) has been shown to transform how people perceive their body image (e.g. feeling bigger, or smaller) and capabilities (e.g. feeling more or less agile) [49, 50]. Recent studies have demonstrated the effectiveness of such an approach in motivating physical activity in physically inactive people, or in rehabilitation in people with chronic conditions [31, 49, 50, 84–86]. Haptic feedback has also been explored in this context, for instance, a force illusion that creates the illusion of limbs drifting and favours a movement reflex [73] or haptic metaphors combined with textiles to alter body perceptions [88]. Even olfactory cues have been shown to influence body perception both in VR ([70, 71]) and in combination with auditory cues ([11]).

Human-Computer Integration. Another approach includes those body-based user interfaces that integrate interactive devices directly into the human body, e.g. by utilizing implanted haptic stimulation or touch interfaces, so that the body becomes the interface. This approach often builds on altering body perception by altering the very physical body through technology. Recent advances in the field suggest that such human-computer integration interfaces may be used to alter people's body's morphology and abilities to act, providing additional skills or limbs to accomplish complex tasks; their perceptions, such as experiencing non-existent stimuli; and even the experience of having a body, as they may affect the user's sense of body ownership, location, or agency [79, 99]. For example, electrical muscle stimulation or mechanical actuators can be used to move the user and perform tasks [45]. Its latest conceptualizations emphasize the importance of understanding the user's physiological and mental state in influencing the sense of

agency when integrating computers with the human body, leading to symbiosis and fusion outcomes [60]. Symbiosis involves collaboration between humans and digital technology, sharing agency (i.e. sense of ownership over actions), particularly in collaborative and creative tasks. Fusion extends the human body through devices, such as a limb, or a sense, and can vary in terms of agency. Fusion may present varying degrees of agency [60], e.g.: an artificial arm that feels like a natural extension of the body grants the user nearly complete agency, whereas a device controlling body movements through muscle stimulation may reduce human agency significantly.

Robotics. Similar reflections are recently found within robotics [76]. in particular in scenarios with tight physical human-robot sensorimotor interactions (e.g. assistive robotic devices). In those, bridging cognitive models of sensorimotor integration and an understanding of body experience into the robotics development can facilitate a seamless integration of these devices into the user's body schema, promoting a sense of embodiment, agency and control.

Works within these approaches aim to "enhance" physical, cognitive, and emotional abilities using technology, which aligns with transhumanist perspectives on the relationship between humans and technology [7, 8, 58, 75, 92]. These share a positive belief in progress and technology that by leveraging technological advancements, humans can surpass their natural abilities, bodily limitations and vulnerabilities [98]. Often, such perspectives fall short in considering the material and subjective nature of bodies and the self, elevating dualistic ideals of mind-body and anthropocentric progress [98]. These yield a gap in body perception transformation technologies research: the research and use of these technologies to foster experiences beyond enhancement, for non-instrumental goals, and considering the human body not as generalizable and isolated but rather as a living, interconnected and interdependent with others. There exist HCI approaches that offer alternative technology visions that can help address this gap in body perception transformation research.

Soma Design. Rooted in somaesthetics [78], soma design emphasizes the living body in design and use [37, 41]. Avoiding generalization goals of previous approaches and renouncing dualistic views on body experience [40], soma design addresses individuals' body perception in their situated contexts and favours subjective, vulnerable, first-person accounts of somatic experiences. As a design program, it aims to develop and train one's aesthetic ability, that is, the capacity to bodily appreciate what one experiences in everyday contexts [37, 41, 80]. As such, the body perception transformations of its designs promote meliorative cultivation of how we experience our body as a site of sensory appreciation towards ourselves, others, and the world [78, 80].

More-than-human Perspectives. Another alternative approach to technology for body experiences consists in more-than-human perspectives, which reframe the "*human*" from an independent actor that manipulates the world to a constitutive aspect of a complex set of more-than-human *entanglements* [25, 36]. Such perspectives embrace ambiguity and blurry boundaries, transcending dualist views of e.g. nature and culture, human and nonhuman, organic and technological, mind and body, animal and machine [10, 25, 35, 98]. They "*offer starting points for ethical approaches and analytical abilities to engage with contingent entanglements and multiple others*" [98] that, by moving the *human* away from the centre, could shed light on current predicaments such as climate and ecological collapse, global-scale pandemics, and late-stage capitalism [25, 35]. In these perspectives, approaches that foreground the use of low-tech [18] and already-existing hardware [53] aim to minimise the energy consumption of computational endeavours (ibid.) and challenge a narrative of "*technological solutionism, planned obsolescence and consumer capitalism*" [18]. Others in unconventional computing research have suggested exploring the use of living materials, like slime mould [3], fungi [21] and bacteria [16], to develop computing systems that are responsive, adaptable, sustainable, and biocompatible.

In this work, we speculated possible utopias and dystopias for future body perception transformation technologies, several of which build on current approaches and others that yield novel perspectives regarding the type of experiences that body perception transformation technologies can foster.

3 METHODOLOGY AND METHODS

We employed a speculative design approach [22] to articulate, surface and explore implications, potentials and concerns of the body perception transformation technologies we are researching. Speculative approaches involve imagining alternate realities and possibilities, and envisioning different worlds and circumstances (ibid.). In our work, we focused on hypothetical future technologies for body perception transformation and scenarios of use. Our futuring inquiry centred around the year 2053, which we collectively chose to allow for plausible but significant technological advancements while maintaining some resemblance to our current society to avoid complete science-fiction speculations.

Our speculative exercise involved 3 workshops and 2 home exercises, which we describe below. The exercise was organized internally by the first author of this paper within a multidisciplinary research team at the Computer Science and Engineering Department of Universidad Carlos III de Madrid. As a team, we are working on an European Research Council-funded project focused on engineering body perception transformation technologies. Us researchers participating in the speculative exercise consisted of the project's PI, 3 post-docs, 2 PhD students, and a research technician (3 women, 4 men). Our team members bring about expertise from various fields, including cognitive neuroscience, computer science, engineering, HCI, interaction design, artificial intelligence, and interactive arts. Most of us perform positivist, experimental and quantitative research in our work, with only some of us having more extensive knowledge of qualitative approaches such as e.g. soma design. For some of us, this marked our first exposure not only to speculative design as a research approach but also to a more critical inquiry into computer science research.

3.1 Speculative Exercise: Process and Methods

The whole exercise involved three collective workshop sessions (WS), each lasting approximately one and a half hours, plus two individual home exercises (HE). The goal of the exercise was to imagine and articulate individual utopian and dystopian visions regarding body perception transformation technologies and collectively discuss them, as a way to foster a reflection within the

group on e.g. the implications they carried for our present work, underlying values, perspectives and individual technology visions, and so forth.

WS1: *Future*storming. The first workshop aimed to foster a future-oriented and idea-generation mindset. It involved a brainstorming session focused on a hypothetical 2053 future (i.e. a futurestorming), facilitated by two of us authors. The futurestorming covered various aspects of the relationship between the self and the body, the body and other bodies, the body and practices, the body and the environment, and the body and organisms of power. These were selected by the first and sixth authors (the workshops' facilitators) as potentially interesting, framing, areas to ideate upon, from a tight connection with one's own body to other aspects that shape our body experience in a variety of ways. We considered one by one each of these aspects in a thinking round. For each round, we had a minute to write down ideas on sticky notes, first envisioning a utopian future and then a dystopian future. Inspirational images from sources such as [22] were used to stimulate imaginative thinking related to technology, body shapes, and futuristic scenarios. The futurestorming helped us trigger our imagination and get comfortable with placing our inquiry in the future, which paved the way and offered inspiration for the creation of our utopias and dystopias.

HE1: Imagining Utopias and Dystopias. Individually, we engaged in an imaginative exercise to envision future utopias and dystopias body perception transformation technologies based on our knowledge, research experiences, values, desires, and personal backgrounds. Thinking in terms of utopias and dystopias was intended to help surface explicitly both hopes and concerns for the technologies—an approach also found in other works [62, 92]. The first author provided a structured sheet with different sections and questions to guide our ideas, facilitating the creation of utopian and dystopian technologies and scenarios. The sheet included prompts about our vision of the future in 2053, a description of the imagined technology, the people impacted by it (beneficiaries or those experiencing challenges), potential contexts of use and effects, and how the technology would influence the body's relationship with other bodies, practices, the environment, or power structures. We also had access to materials from the first workshop, such as inspirational images and sticky notes, to inspire our thinking.

WS2: Moving Towards Design. The second workshop had two parts, aiming to create captivating and thought-provoking artefacts that would provoke discussions and open questions. In the first part, in couples, we shared and refined the utopian and dystopian ideas we had captured in the sheets, e.g. by checking the level of detail and plausibility of our speculations. In the second part, the first author introduced the rest to different types of artefacts they could create to illustrate such utopias and dystopias (e.g. audiovisuals, tangible prototypes, narratives, fanzines/comics, collages, drawings or sketches and illustrations). We aimed at being savvy in terms of our own creative abilities and resources to put content and media together. We also started to design each individual illustrative artefact in WS2.

HE2 and WS3: Creating, Sharing and Discussing Utopias and Dystopias. We completed our artefact designs at home. In the third workshop, we shared our artefacts and narratives, engaging in discussions. We started with the utopias and due to the number of questions, the workshop had to be extended into a second 1h session, to present and discuss the dystopias. After each presentation, we discussed insights and implications. Finally, we reflected on the speculative exercise methodologically. WS3 was video-recorded and two of us authors also took live notes during discussions.

3.1.1 Data Analysis. We analyzed the created artefacts in conjunction with 1) the sheets that participants created in HE1, which provided greater detail into the envisioned utopia and dystopia; and 2) the written notes and videos from WS3, which captured our discussion points and reflections. Our analytical approach was inspired by thematic analysis [33] and focused on identifying recurring themes in our data sources that would represent recurring ideas. The first author performed an initial inductive, open coding of the data focusing on the content and type of considerations present in each utopia and dystopia, and constructed initial groupings of the codes, in a manner resembling affinity diagrams. Both the coding and the groupings were discussed and polished with the second and last authors of the paper, who collectively derived a final set of shared themes and subthemes across the utopias and dystopias, which we present in Section 5.

4 UTOPIAS AND DYSTOPIAS OF FUTURE BODY PERCEPTION TRANSFORMATION TECHNOLOGIES

We present five utopias and dystopias created by five participants in the speculative exercise. Two participants' contributions were excluded from the results due to one participant's inability to finish the exercise due to time constraints and another contribution's lack of relevance to body perception transformation. Here, we provide a concise description of each utopia and dystopia, while a more detailed version with a table relating scenarios and participants is available in the supplementary material.

4.1 Utopias (Figure 1)

4.1.1 MindHarmony. MindHarmony, a neuroimplant with direct connections to the nervous system, aims to enhance reality perception. It can be turned on and off as desired. By altering sensorimotor perception, such as body sensations, sounds, or smells, MindHarmony profoundly impacts emotional states. It can positively influence movement perception, such as creating a sense of fluidity, and evoke a soothing sense of freedom through customized soundtracks or body sounds. With its widespread use, MindHarmony enhances everyday activities, work, leisure, and artistic experiences.

4.1.2 SoundBody. SoundBody is an affordable and accessible app that uses phone sensors to understand individuals' body perceptions. It updates a real-time "body image blueprint" based on data like motion, heart rate, and breathing. Through manipulating sensorimotor loops, the app provides customized sound feedback to alter body image. It helps users, for example, young individuals concerned about appearance, transform their perception both when alone or in social situations. The app helps them to increase body satisfaction, experience and save "favourite" body images and body ideals, which could be rooted in individuals', groups' or societal body standards, allowing them to feel e.g. lighter, more elegant, and ultimately more confident.

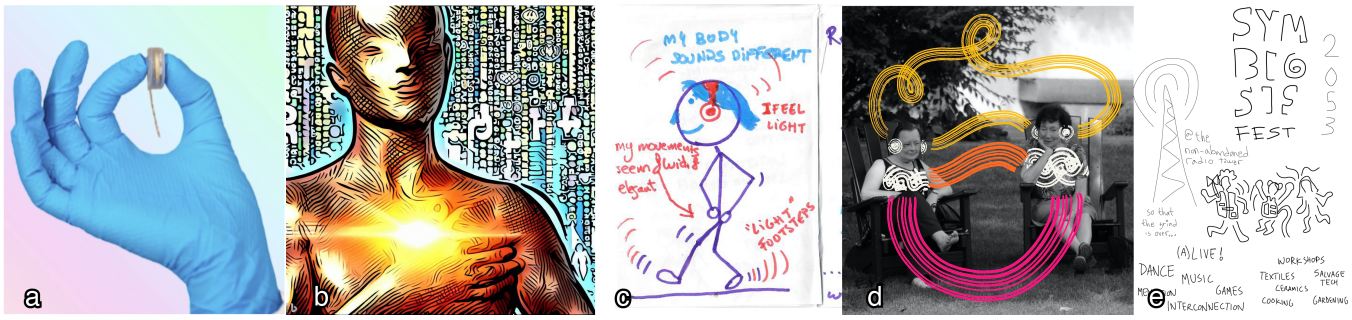

Figure 1: Illustrative snapshots from the different artefacts created to illustrate each utopia. In order: a) MindHarmony; b) EpiSense; c) SoundBody; d) ConnectingBodies; e) Symbiosis. The supplementary material includes the full artefacts created, with longer and richer descriptions of the utopias.

4.1.3 EpiSense. *EpiSense*, an artificial second-skin made of biomaterials, acts as an interface between individuals and the external world. It has advanced sensing capabilities to detect physiological states like respiration, movement, arousal, sweat, and heart rate. *EpiSense* offers real-time brain stimulation, sensory feedback, and actuation to optimize health and decision-making. It can monitor stress, anxiety, and depression indicators, informing individuals in real time for self-awareness and appropriate actions. Furthermore, *EpiSense* can enforce beneficial perceptions and actions, such as aiding smoking cessation, to enhance individual well-being.

4.1.4 ConnectingBodies. *ConnectingBodies* is a wearable toolkit of sensors and actuators, powered by an open-source platform. It enables multiple individuals to share bodily sensations and perceptions with each other. Users can configure and embed specific body experiences into multisensory actuators like clothing and accessories. This allows others to feel and share these sensations, creating a shared experience. People utilize *ConnectingBodies* for various purposes, such as play, pleasure, or emotional connections, such as reliving past experiences or enhancing intimate relationships. The very creation of technology becomes a shared act between people and communities that connects them.

4.1.5 Symbiosis. *Symbiosis* is a festival set in a dystopian 2053, featuring community workshops for various crafts like textiles, cooking, and gardening. In it, people in salvaging technology workshops produce *Symbiosis Vests*, which enable their wearers to experience sensory inputs from diverse elements and scales: inner workings, bacterial and fungal activity, other people, water levels, tides, electromagnetic spectrum, moon cycles, planetary motion, etc. Made with reused electronics and analogue technologies, these low-tech vests serve as a means for individuals to reconnect with themselves, the natural world, and their communities. They offer a sense of purpose and a reminder of the value of life.

4.2 Dystopias (Figure 2)

4.2.1 MindHarmony. *MindHarmony*'s dystopia features the same neuroimplant, which now controls the type of body experiences that people are allowed to experience, as it can hack thoughts, emotions, and sensations towards capitalist values of production. For example, increasing productivity through hacking people's experience of time. Creativity and self-identity became nonexistent. The device is found in everyone and cannot be turned off.

4.2.2 SoundBody. *SoundBody*'s dystopia features the same wearable technology, but it is programmed to impose specific types of body experiences deemed "desired" by an external organization. Users are forced to conform to these standards, and the control of body perceptions affects motor behaviour, self-perception, identity, emotions, and social interactions. Everyone is forced to use this technology in various contexts, eroding individuality and controlling body perceptions as a way to control behaviours and emotions, as a way to "perform" better (i.e. work more efficiently, exercise more, socialize more). As a result, this technology impacts work efficiency, leisure activities, and the relationship between the body and the environment.

4.2.3 EpiSense. In *EpiSense*'s dystopia, the same artificial second skins, but its all-encompassing nature captures and processes vast amounts of data, resulting in the misuse of personal information and privacy breaches. Technology skews the relationship between individuals and their bodies, diminishing personal autonomy and enabling manipulation. Society becomes heavily surveilled, blurring the line between public and private realms. Marginalized groups suffer from discrimination and exclusion due to unequal access to and utilization of these technologies. Moreover, ethical concerns arise regarding biomaterials and the treatment of sentient species. This dystopian reality raises questions about data access, purpose, and impact on end-users.

4.2.4 Transform.Me. *Transform.Me* is a collection of designer accessories that, through sensory feedback illusions, aim to change people's perception of their body appearance and abilities to align with societal ideals and stereotypes. It is popular among young individuals and those who struggle with body concerns. Marketed heavily through social media and influencer culture, it is presented as a self-help intervention for mental health, empowering individuals to manage body-related stress and negativity. However, the use of *Transform.Me* discourages critical thinking and awareness of the sociopolitical factors that contribute to body ideals, standards, and stereotypes.

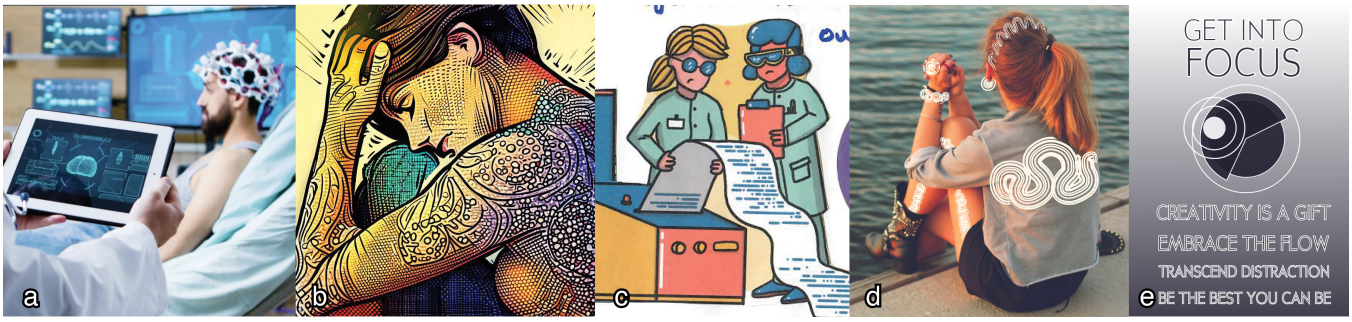

Figure 2: Illustrative snapshots from the different artefacts created to illustrate each dystopia. In order: a) MindHarmony; b) EpiSense; c) SoundBody; d) Transform.Me; e) Focus. The supplementary material includes the full artefacts created, with longer and richer descriptions of the dystopias.

4.2.5 Focus. *Focus* offers a solution to the problem of tiredness, in the form of a neuroimplant that inhibits the perception of fatigue and stimulates individualism. People use it during work, all the time, during large stretches of time, because with it they are able to keep working regardless of inhumane conditions. People forget their sense of embodiment, self and self-care, and they lose the need for community. Focus is marketed positively as a way to develop one's creativity and avoid distraction, becoming the best version that one can be.

5 SHARED THEMES ACROSS THE IMAGINED BODY PERCEPTION TRANSFORMATION TECHNOLOGIES

We identified recurring themes from the analysis of dystopias and utopias and notes from our group's discussions. They revolve around the roles of our imagined body perception transformation technologies (i.e. the functions assumed by the technology), the goals (i.e. the objective of using such technology, the aim or desired use's outcome), and values (i.e. the principles, beliefs or accepted standards in the technology's design or use). These capture our visions and concerns regarding these aspects for future technologies.

Different types of technologies emerged, building on different approaches to body transformations by altering sensory perception. High-level technologies like *MindHarmony* and *Focus* proposed direct brain stimulation through neuro implants and stimulators. *EpiSense* introduced an all-encompassing second skin made of biomaterials for sensing and actuation. Others imagined wearable and *stick*able technologies that would provide sensory illusions to alter body perception, including apps and headphones in *SoundBody*, reactive vests in *Symbiosis*, Arduino-like toolkits in *ConnectingBodies*, and interactive jewels and stickables in *Transform.Me*. It's worth noting that within the speculations that emerged, we remained stuck to our known senses — even if we did envision mappings from other spectra into our own range of sensations (as we will elaborate below). The umwelt or perceptual bubble through which we experience the world allows us to exclusively interface with species existing in the same perceptual range [96].

5.1 Technology Roles

Three recurring roles for body transformation technologies were identified in our utopias and dystopias, which were not mutually exclusive in our scenarios.

5.1.1 Enhance Human Capabilities and Psychological Well-Being. In both utopias and dystopias, most of our scenarios proposed technology to enhance and transform people's perception and sensorimotor capabilities. This role in our empirics mostly encompassed physical augmentations (in comparison to e.g. fewer emotional interventions), which reveals how our group envisioned these technologies to enhance capabilities and well-being. Physical enhancements were often in focus, with variations in emphasis. *SoundBody* and *Transform.Me* aimed to transform sensory abilities through body illusions, altering body perception and increasing satisfaction. *ConnectingBodies* and *Symbiosis* also prioritized sensory augmentations, but with a focus on sensing and connecting with the other. Emotional well-being was highlighted in all scenarios, although it was not the principal focus. *EpiSense* and *MindHarmony* envisioned holistic transformations, integrating physical, cognitive, and emotional enhancements through second skin and brain implants, respectively. This role aligns with a transhumanist view on surpassing our perceptual abilities through technological advancements [7, 8, 75, 92], which is evident in current approaches to body perception transformations [60, 79, 99]. This role prompted discussions within the group, as some members aimed to steer away from common transhumanist pitfalls, e.g. overlooking the material and subjective aspects of bodies and the self, elevating anthropocentric progress ideals [98]. Towards that, we discussed the need to consider more explicitly in our research other approaches such as soma design [37] and more-than-human perspectives [10, 25, 35, 36, 98], yet a roadmap to do so was out of scope.

5.1.2 Empower Humans. In some of our scenarios, technology was envisioned as an agent that explicitly would empower the people using it, although the exact way how encompassed a variety of considerations, e.g. from concrete experiential aspects that, if addressed, could empower humans (i.e. fostering human creativity, enacting dissidence) to technological approaches (i.e. through

open-source technologies to allow people to build their own experiences). In *ConnectingBodies* and *Symbiosis*, technology was envisioned as an empowering element in people's lives, specifically related to creativity and the ability to live desired body experiences. Both scenarios presented a utopic vision, emphasizing accessibility, user-friendliness, and open-source hardware and software. *ConnectingBodies* enabled individuals, of different technical expertise, to explore and create their own body illusions. *Symbiosis* went further, empowering humans to resist their dystopic society by creating and inhabiting their own alternative experiences. The role of technology in these utopias aligns with the concept of *conviviality* [43] as used within HCI [24, 44]. Conviviality emphasizes autonomous and creative relationships between people and their environments through empowering, simple, and locally accessible tools [18, 24, 43, 44]. Within the group, discussing this role led to two coexisting views on the role of us researchers. One view saw us technology researchers as problem-solvers, focused on providing functional solutions to others, which is evident in body perception transformation and human-computer integration communities (e.g., [45, 60, 79, 99]). The other view saw us researchers as creators of tools that empower others to discover their own problems and solutions, as seen in soma design projects (e.g., [94, 95]).

5.1.3 Control Body Experiences. Several dystopian scenarios depicted technology as a controlling and restrictive force in people's body experiences. *MindHarmony* and *Focus* portrayed brain implants as means of controlling cognitive and sensorimotor functions. *SoundBody*'s dystopia enforced a limited set of "desirable" body experiences through sound feedback manipulation. In these, technology control was justified in the name of power entities (e.g. companies or states), driven by underlying goals of capitalist production and growth. However, in the utopia of *EpiSense*, controlled body experiences were presented as desirable for health reasons, with the second skin intervening in sensorimotor functions if deemed harmful to the individual's well-being. This role is closely related to the value of agency discussed in Section 5.3.2. Within our group, our scenarios and discussions afterwards revealed that we often viewed this role in quite simplistic terms, as either positive or negative to humans. Yet, ongoing discussions in human-computer integration communities [60, 99] highlight considering together agency and control, upon which we later elaborate.

5.2 Technology Goals

We identified recurring goals that justified the use of body transformation technologies. These were not mutually exclusive. Most scenarios featured an instrumental use of technology [23], employing it to achieve specific goals. However, some scenarios also highlighted the intrinsic value of the technology encounters themselves.

5.2.1 Improving People's Everyday Bodily Experience. In utopias, body transformation technologies played a recurring role in improving people's everyday bodily experience. This broad, and overarching goal manifested in many different ways in the utopias, addressing varied aspects of daily life, from e.g. feeling happy to rehabilitation - revealing a wide interpretation of how these technologies could improve bodily experiences. This goal was prominent in scenarios that envisioned widespread use of technology (*EpiSense*, *MindHarmony*'s and *SoundBody*'s utopias). *EpiSense*'s second skin would enhance self-understanding by detecting elusive aspects of the body experience, leading to better decision-making. *MindHarmony*'s brain implant would assist with everyday tasks, promoting happiness and efficiency. *SoundBody*'s sound-based body illusions would cater to different needs, such as enhancing confidence and supporting physical activity or rehabilitation. These scenarios emphasized the positive impact of technology across various aspects of daily life, including work, health, and family. This goal is also seen in current technologies for body perception transformation, such as sensory body illusions in health and well-being contexts [14, 32, 72, 74], and human-computer integration scenarios (e.g. providing additional skills or limbs to accomplish complex tasks [60]). However, we found that this goal often incorporates a technosolutionist perspective, using technology to solve complex problems and improve lives. It was suggested within the group that it would be valuable for body perception transformation communities to explore how people's lives can be enriched beyond technosolutionism, e.g. bringing beauty, aesthetic appreciation, or fun, as proposed in soma design [37, 80].

5.2.2 Connections Beyond the Individual. In some utopias, body transformation technologies were seen as a means to facilitate intersubjective experiences and enhance connections between individuals and other species. *ConnectingBodies* allowed people to create shared body experiences, fostering empathy, compassion, and a deeper understanding of others' emotions and sensations. *EpiSense* and *MindHarmony* enabled the sharing of feelings and emotions, with *MindHarmony* utilizing neural connections and *EpiSense* utilizing second skins for more nuanced and rich communication beyond verbal cues. Additionally, *Symbiosis*'s vests provided a means to connect with other beings and phenomena by connecting with various bodily, environmental, and cosmic aspects. This goal provided a different focus to the current body perception transformation communities and also soma design, which overwhelmingly centre on individuals' perceptions and experiences (e.g. [9, 13, 17, 20, 31, 41, 49, 50, 55, 66, 68, 79, 82, 84, 97]. These connections beyond the human species are elaborated further down in Section 5.3.3, and within the group, some members expressed a desire to integrate such perspectives more explicitly in their research.

5.2.3 Productivity Increase. In several dystopias, technology was used to increase and enforce productivity in different ways. For example, *Focus* centred on cognitive labour, such as creative and entertainment industries, using a neural implant to improve focus, reduce fatigue, and extend work periods. *MindHarmony*'s dystopia took a more insidious approach, altering people's perception of time with a neural implant to make work hours feel shorter and off-work hours feel longer, ultimately leading to longer work hours. Interestingly, within the group, our scenarios viewed productivity increase and work efficiency as dystopic goals, contrasting with some current goals for body perception transformation technologies (e.g. [60]). This connection may stem from the fact that in our dystopias, this goal was linked to technology controlling body experiences, resulting in a reduction of agency.

5.2.4 Conform to Social and Cultural Body Standards. In both *SoundBody*'s utopia and *Transform.Me*, technologies aimed to alter individuals' perceptions of their body image and capabilities to conform to societal ideals. However, the scenarios differed in their interpretations. *SoundBody* viewed it as a utopia, presenting it as an individual solution to address feelings of body inadequacy in regards to the own body and make them feel better with it—an approach paralleling nowadays's existing practices, like diet culture and plastic surgery. In contrast, *Transform.Me* criticized the approach of having to alter people's body perception to make them feel better about themselves, suggesting that the focus should instead be on questioning and challenging the societal body ideals that contribute to these feelings and marginalize non-normative bodies and experiences.

Within the group, this sparked a discussion on how we viewed the same goal in contradictory ways, based on our backgrounds, theoretical foundations, and visions for the technologies we design. It also raised questions about how these divergent views can coexist or be reconciled within the same research group, where one person's utopia may be another's dystopia. While finding a definitive answer was beyond of our scope (as it would involve a wider reflection on e.g. project goals, power relations within the group, etc.), we recognized the value in having articulated and acknowledged these diverse perspectives as an initial step to future actions.

5.2.5 Pleasure, Play, and Other Non-Instrumental Goals. *ConnectingBodies* and *Symbiosis* envisioned encounters with technologies that went beyond instrumental goals, focusing on pleasure and play. *ConnectingBodies* allowed people to create shared sensory experiences for playful interaction, such as experiencing each other's movements and sensations. It also explored pleasure in relationships, like a couple transforming their intimate interactions to dissolve physical boundaries. On the other hand, *Symbiosis*'s vests were designed for non-productive activities like parties and meditation rituals, encouraging curiosity, contemplation, and fun through experimenting with perception and engaging in leisurely experiences. The goal aligns with soma design approaches that prioritize aesthetic and sensory appreciation of body experiences [37, 41, 80] over instrumental goals. While the group does not currently explicitly pursue these non-instrumental goals in our research, it helped us become aware of it and several of us expressed interest in designing technologies for such goals in the future.

5.3 Technology Values

We refer to technology values as the principles or beliefs that shape the design, use, and impact of body perception transformation technologies in our utopias and dystopias.

5.3.1 Access. Most utopias emphasized democratic access to technology and imagined technologies that would have become widely used and inexpensive, with significant portions of the population having access to them. Yet, several of our high-tech utopias (e.g. *MindHarmony*'s neural implant, *EpiSense*'s second skin) did not consider in concrete terms how such widespread access would come to be realized. In contrast, other utopias explicitly foregrounded low and re-purposable technology as a means to achieve widespread technology access. *ConnectingBodies*, *SoundBody* and *Symbiosis* aligned with *low-tech* premises [18], imagining technologies that considered their environmental and social impacts, and that aimed at maximising the life of already-existing hardware [18, 53]. These either considered using already existing technology (e.g. smartphones and headphones in *SoundBody*) or reflected a making-attitude that would allow for repurposing (toolkit in *ConnectingBodies*, components in *Symbiosis*). In the latter two, community support was central to facilitating access to the technology, through e.g. dedicated workshops.

5.3.2 Agency. Agency in our scenarios referred to the experience of initiating and having ownership over actions, as opposed to something doing the actions for you, and was negotiated between the human individual and the technology. In dystopias such as *Focus*, *MindHarmony*, and *SoundBody*, technology had the most agency over the type of experienced body perceptions (e.g. emotions, perceptions and cognition), limiting human autonomy and serving capitalist agendas. Conversely, utopias like *ConnectingBodies* and *Symbiosis* saw technology as enhancing personal agency, empowering individuals to shape their own experiences in a convivial way [24, 43, 44]. In some cases, the integration of technology and the human body was almost inseparable, such as *EpiSense*'s second skins and *MindHarmony*'s neural implant, where human and technology acted as a joint entity for most of the time. However, agency remained fluid and subject to change in those, with options to turn off the implant (*MindHarmony*) or enforce actions based on health concerns (*EpiSense*).

In multisensory body illusions approaches (e.g. [31, 49, 50, 84, 86]), maintaining a sense of agency is essential for the sensory-induced bodily illusions to emerge [6, 57, 84]. Yet, other approaches within body perception transformation communities, such as Human-Computer Integration [60], propose a more fluid view of human and technology agency and control, as it can be beneficial in some scenarios to leave a minimal agency to the human. These approaches view control in terms of the subjective experience of determining the outcome of the actions—the outcome matches the intentions. They propose that in some cases, users may desire to disengage and allow the system to take control, reducing their agency, e.g. in rehabilitation scenarios. Conversely, providing more control to users may align well with their sense of agency, but could limit the technology's effectiveness in truly extending body experiences [60]. Within the group, our perspectives of agency were rather individualist, i.e., not speculating in regards to other forms of communal or inter-species forms of agency, or even illusory agency, i.e., a false sense of capacity to impact the surrounding. We concluded that it is necessary for us to address explicitly and in more nuanced ways control and agency in our research.

5.3.3 More-than-Human Perspectives. Some utopias engaged with non-human relationships and sustainability. *Symbiosis*' vests and *EpiSense* incorporated a more posthumanist perspective [25, 34–36, 98], allowing people to connect with non-human phenomena and consider their placement in the world. *EpiSense* also raised ethical concerns about using non-human organisms as biosensors in a surveillance state, reflecting a kind of anti-speciesist perspective that can be seen as rooted in posthumanism perspectives too.

Similarly, the low-tech and salvage technology [18] approach in *SoundBody* and *Symbiosis* was partially informed by environmental costs (e.g. electronics manufacture, energy consumption), recognizing the intricate relationships that constitute the web of life, which aligns with current perspectives that call for maximise the life of already-existing hardware and minimise the energy consumption of computational endeavours [18, 53, 61]. Within the group, we realized that generally we maintained a very human-centred perspective, not only within our current research but in our imagined futures. Some of us expressed interest in exploring and incorporating more-than-human perspectives [25, 28, 35, 36, 98] and sustainability issues [53, 61].

5.3.4 Reinforce or Challenge the Status Quo. The technology's values were often related to the status quo of an imagined 2053, that is, the imagined and prevailing existing state of affairs in social, political, or economic contexts. Dystopias like *Focus* and *MindHarmony* used technology to enhance capitalist agendas of productivity and serve ruling state-companies. *SoundBody*'s dystopia enforced body perception alterations as a means of social control. Some potential technology uses in *SoundBody*'s utopia and in *Transform.Me* may end up reinforcing body ideals and stereotypes that can harm marginalized and non-normative bodies. Within our group, despite a general positive belief in progress and technology, most scenarios considering technology's relation to the status quo did so from a negative perspective of technology as enforcing it. Only *Symbiosis* stood out as its technology challenged power structures and enabled resistance in community-organized activist events. This made some of us reflect on how, in our own research, we may fall short in considering technology as a challenging agent to the current state of affairs, but a more thorough political discussion did not take place at that time.

6 DISCUSSION

We discuss the implications of our contributions to current body perception transformation research and discuss the value that a speculative design approach brought to our multidisciplinary team.

6.1 Implications for the Present

We identified various technology roles, goals, and values. While not exhaustive, these reflections represent our current considerations as a group. As we have pinpointed in the previous section, some of them align closely with the current state-of-the-art in communities working with similar technologies, such as the role of enhancing human capabilities, or the goal of improving people's lives – which resonate with the transhumanist perspective evident in work (e.g. [50, 60, 79, 86, 99]). Yet, our insights also reveal untapped roles and goals for these technologies, such as pursuing non-instrumental goals or taking an empowering role in people's lives. These contribute with novel perspectives regarding the type of experiences that body perception transformation technologies can foster. Similarly, while some values, such as agency, are currently under thorough discussion in these approaches (e.g. [60]); others have not yet received explicit attention. Our insights contribute to current work in body perception transformation technologies by mapping different aspects that can inspire, provoke, and serve as reflection points. They can also help others identify research gaps and possibilities.

6.1.1 Limitations and Future Work. We mapped technology roles, goals, and values, but with a focus on breadth rather than depth, as each of these aspects could be the sole focus of inquiry in future research. Similarly, creating individual utopias and dystopias led to diverse visions and contrasting perspectives, albeit at the expense of a unified and in-depth speculative scenario. It should be noted that our work explicitly required imagining future technologies and may thus have biased participants in creating speculations in terms of devices and apparatuses. This might have been detrimental to e.g. a nuanced discussion on the exact groups of people that would be impacted, benefited and excluded from each imagined technology, or more rich descriptions of the technology as a sociopolitical and cultural artefact. Our work initiated conversations on these themes, but further research is necessary to gain deeper insights.

6.1.2 Provocations. We provide three provocations to stimulate further discussions in the field of body perception transformation technologies.

Contesting Self-Determinism. A tacit agreement across some themes and individual perspectives is *self-determinism*, underlying it as an almost unquestionable value in our group when it comes to body perception transformations. This might not be surprising as it is one of the pillars of Western culture and ethics and liberal democracies [29] in which our group is arguably embedded. This is exemplified by the general perspective regarding loss of control and agency of one's own decisions as explicitly dystopian. Looking more in detail, however, section 5.2.4 regarding goals of conforming to sociocultural body standards touches on an interesting dissonance. While for some conforming to such standards is dystopian, for others the capacity to adapt on command to certain social expectations seems to be desired. Or in *EpiSense*'s case, the potential of a digital entity intervening in personal health was also deemed utopian. In this dissonance, while there seems to be an explicit assumption that anything other than self-determined ideas and thoughts about one's own body are negative, in practice this seems to be more complex. The notion of full self-determination might be at least partially incompatible with the notion of an embedded, situated, and socially complex dialogue with the world through which meaning is co-created. This dissonance is often unaddressed when discussing own-body perception, as ideas regarding external determination might immediately be neglected but may still be relevant. Yet, one might argue that they necessarily take place. In fact, the very notion of an own body may embody values of individual ownership that are frequently overlooked. Exploring alternatives with shared agency and forms of communitarian (including more-than-human) determinism (e.g. section 5.3.3)) might in turn depict more radically different scenarios. This could be an interesting exercise for future work with a similarly multidisciplinary group.

Moving Beyond Speculations. Engaging in this speculative exercise unarguably had a positive impact on our group (see Section 6.2), yet it also raised questions on how to move beyond the exercise itself and address some of the issues, frictions and opportunities that it revealed. We contend that embarking on this type of research inquiry requires a firm compromise within the multidisciplinary group to see the insights through to concrete actions.

We discussed the potential danger of our insights and discussions being relegated to a mere interesting, self-serving exercise, where one makes acknowledgements to critical issues that arise but then does not take deliberate, continuous and material action. This is, of course, not only a matter of individual or even group predisposition, but a challenge deeply rooted in the already-existing goals of the projects that fund our jobs, the hierarchical power structures in research teams, and sociopolitical intricacies in academia and funding entities. While all of us were deeply moved by particular insights or takeaways from our speculative exercise, some of us were left wondering to what extent we would have the flexibility to address them in reality. At large, such a discussion and articulation of the tensions intrinsic in our work is important in terms of fostering a more nuanced take on thinking about and designing new technologies that might, in the best case, turn into material, actionable changes (potentially including a turn into inaction). This is particularly important within Computer Science and Engineering Departments such as the one in which we are located, as there is an implicit approach corresponding to the technosolutionist norm within the industry and technoscientific academia.

More than Technosolutionism: Non-Instrumental Goals and Meaningful Technology Encounters. Our speculative exercise surfaced a tacit technosolutionist position [12] that permeated not only several of our utopias and dystopias but our general group's approach. Technosolutionism incorporates the belief that technology alone can solve complex social problems and address complex situations [12]. Our scenarios presented an idealistic view of technology that often oversimplified problems. While technology can be valuable in addressing challenges, technosolutionsim as an approach risks shifting responsibility from individuals, groups and institutions to technology itself, overlooking the social, political, and cultural factors that contribute to the issues being addressed [12]. Technosolutionism often leads to a positivist and instrumental technology perspective, as a means of achieving particular goals instead of designing meaningful encounters with the technology for their own sake. While this may be well known in critical approaches in HCI (e.g. [5, 27, 37]), we in body perception transformation research communities often tacitly and pre-reflexively incorporate such technosolutionist positions and instrumental goals (albeit notable VR exceptions, e.g. [1, 2, 65, 69]). We are not unaware of the professional world in which we are embedded, in which often technology research is rhetorically made relevant in terms of its potential solutions and potential economic gain. Yet, for us engaged in this exercise, there was freedom to explore other perspectives beyond technosolutionism and other goals beyond instrumental ones. We believe in the potential of these technologies to not only solve problems, but to bring beauty, pleasure, fun, connection, and creativity to people's experiences. We conclude with a call for action for research on body perception transformation technologies that explicitly explore that as a worthwhile, important, and potentially necessary endeavor.

6.2 Methodological Reflections on Speculative Design as Research Approach

The speculative exercise enabled our multidisciplinary team to explore and discuss roles, goals and values of future technologies and scenarios, unburdened by concerns about immediate feasibility, cost, or deployment constraints. It provided a platform for us to imagine and articulate our hopes and concerns related to our research and design endeavors. We reflect on the ways the exercise helped our group, to show the potential of a speculative approach to help a multidisciplinary team to articulate, share and contrast dystopian and utopian technology visions.

Future thinking. The exercise helped our group consider the future as a space that can be actively addressed in our research, emphasizing our role in actively shaping it. It prompted reflection on the desired futures we each aimed to create. Additionally, it revealed potential dystopic consequences of our work that some members had not previously considered, fostering a greater awareness of the broader implications and long-term effects of our research.

Interpersonal understandings. The exercise enhanced our understanding of our technology visions, hopes, and concerns. It provided a panoramic view of the different aspects being explored, fostering a deeper appreciation for each individual's perspectives, which connects with prior work [39] that has surfaced the importance of considering a plurality of perspectives in design futuring exercises, to engage imaginations of diverse potential futures. In our group, the exercise allowed colleagues to see the others' lived experiences reflected in their utopias and dystopias, for example, *EpiSense* addressed a self-concern regarding interpersonal communication, and *ConnectingBodies* and *Symbiosis* highlighted the value of leisure and non-productivity favoured by those of us who proposed them—which all became evident for the others in the group. Some considered this to be a beautiful exercise in understanding individual perspectives and brought about to some a heightened sense of connection and familiarity with others in the team.

Shape research approach within the team. The exercise provided a foundation to further shape the research approach within the team. It brought to light the need to both acknowledge but also expand beyond the transhumanist undertones of our research and incorporate soma design [37, 80] and more-than-human perspectives [28, 36, 98] to consider subjective experiences and acknowledge the entanglement between humans and the broader world. The exercise also highlighted the necessity of addressing the interplay between agency and control in a more nuanced manner within our group. Moreover, it initiated a discussion on proactive measures to prevent dystopias, resulting in initial suggestions such as technology manifestos, critical examination of project pitfalls, intellectual property registration, educational initiatives, and workshops to engage target users and inform policymakers. While the team remained uncertain about the implementation of these suggestions, the exercise surfaced these considerations and opened up avenues for further exploration.

Surface frictions. The exercise highlighted frictions within the research team, as despite working together on the same project, it became evident that there was a lack of a unified vision among team members, which aligns with findings in prior work on design fiction helping surface frictions [26] or conflicts [15] within research groups. The exploration of utopian and dystopian futures revealed differences in technology visions, values and approaches. As a simple example, some people anticipated neuroimplants as part of their utopias, while others found them repulsive. Differences also arose at a higher level, regarding the team's role in technology creation

and research, with some emphasizing problem-solving and others advocating for empowering individuals. Immediate agreements or roadmaps were not reached within the scope of the exercise, but it was valuable to identify tensions and initiate discussions.

Shape individual research. Some of us found the exercise helpful in shaping individual research agendas. The exercise provided some team members with the space to reflect on their desired research directions and explore new avenues aligned with their personal ideals. It also reminded some of them of their individual perspectives and values in future research, e.g. some realized they wanted to steer away from what they saw as problematic implications of transhumanism or technosolutionism. The discussion on technology roles and values increased awareness for some team members, making them consider these factors more explicitly throughout their research process.

7 CONCLUSION

In this paper, we have employed a speculative design approach to articulate utopian and dystopian visions of body perception transformation technologies. We contribute to advancing current research on such technologies by mapping out existing and potential technology roles, goals and values, which can help others critically examine their own technology visions and inspire research that expands on the current state of the art. Further, we contribute three provocations to foster discussions on the limits and possibilities of speculative exercises and in regard to the tacit techno-solutionist and self-determination values that often permeate our research in the body perception transformation communities. Finally, we also contribute methodologically with insights into how speculative design can be a fruitful approach for multidisciplinary teams to articulate and share individual technology visions, to identify commonalities and differences among team members, as well as to spark conversations towards shared roadmaps.

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