Predicting Inclusive Futures: Wearables, Automation, and Design Speculation

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Abstract. For the past 15 years wearable technology, Artificial Intelligence (A.I.), and the Internet of Things (IoT) have been gaining in popularity adoption in our everyday lives and in industrial design courses. In years past, there was an excitement around the seemingly limitless potential of these advances in technology to change lives and to usher humanity into the future. As many things ahead of their time, there have been a few bumps in the road, and it has taken use several decades to see where these innovations have landed in the marketplace. A.I. and machine learning are understood for their success in targeted advertising and route optimization as well as their inherent biases and lack of inclusion. IoT has paved the way for digital realities of paperless ticketing and smart toasters. Wearable technology, once so poised to push society into the world science reality, has not moved far beyond the wristwatch or earbuds, and seems to be advancing fastest in the gaming and health industries. In our everyday lives "wearables" has become synonymous with fitness trackers, health monitors, and VR headsets. Why has the creative promise of wearable technology seemed to slow down? In this paper, the authors will discuss university community-based and speculative project case studies that place wearable technology in critical contexts that center new and diverse voices, societal and embodied complexities, and raise ethical critiques on the role wearables might play in shaping a more inclusive society.

Keywords: Wearable technology · Inclusive design · Co-creation · Speculative design · Design bias · Algorithm bias · Embodied technology · Somatics

1 Introduction

The advancements we have made in wearable technology has the potential to inspire, heal, entertain, monitor, beautify, and alter our experiences in the day-to-day. However, the ubiquity of connected on-body technology that was promised in the science fiction visions of yesteryear is missing. This future vision of innovation in the wearables space has been limited by market-driven applications and the commodification of data—design drivers that have long fed conspicuous consumption and capitalism. While we have been locked in this market-centric cycle, accessibility, sustainability, ethical and cultural implications, the needs of diverse wearers and radical possibilities have been left out of

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the mainstream conversation. The wearables' field inspires designers and technologists to imagine new futures around materials, manufacturing, technology, and health. It is time to turn attention to fashion, ethics, sustainability, embodied interaction, data security, inclusion.

How has wearable technology shown up in the conversation on diversity, equity, and inclusion? How might wearable technology help to bring about more inclusivity and engage more diverse wearers? We should be inspiring future designers to consider a wide range of potential applications, impacts, and pitfalls of wearables by teaching our students to imagine new futures around on-body technology that is both thoughtful and radical.

Inclusive design is often considered through the lens of diverse physical and cognitive abilities [1]. While these needs are critical design constraints, we must also consider the expanded needs of our intersectional society that is inclusive of gender, class, race, education as well as ability across global socio-political and economic landscapes. Future wearable technologists and designers need to be cognizant of who benefits from and who is missing in the conversation around wearable technology. How can our approach to designing for the body expand to encapsulate a wider range of human experiences, interactions, and needs while also considering the benefits, detriments, and biases inherent in the design? Can an inclusive design approach help to reimagine these devices beyond assistive and adaptive into something integrative and embodied?

2 Wearables and Exclusion

Consumer wearables track our steps, monitor our sleep, determine our whereabouts, detect our emotions, and promote health living. The data collected and displayed to wearers and their healthcare providers has led to increased fitness and the real-time remote detection of crucial health information like heartrate irregularities and other high-risk concerns. Perhaps more than anything these days, data the MVP of wearable technology. And if we look to the ways in which this data is collected and used, we can see that not all wearables are equal or equitable.

Who Benefits, and Who is Left Out? From a health standpoint, smart wearable devices – powered by the algorithms of A.I.—have led to improved fitness and wellbeing [2], but is this benefit is not equitability distributed. Specifically, it has been shown that the sensors used in wearable devices fall short when used by people with dark skin tones [3], women, people with higher-than-average body fat percentages, when used in a variety of contexts, and by people certain disabilities [4].

Algorithm Bias. If wearables do not work for everyone, that means these benefits "*cannot be fully enjoyed until and unless the reliability of a complete system is ensured"* (*Saleem,* 2017) [5]. Specifically, the failure of fitness trackers to accurately read biometric data on dark skin tones is due to technological limitations of photoplethysmographic (gPPG) green light signaling—a widely used health tracking signal used in wrist-worn smart watches and health trackers. While this health tracking technology works well for people with lighter skin tones, it has not been studied extensively with darker skin tones [3]. The lack of both inclusive models and diversity in research is

evidence of inherent biases in wearable devices and design research that does not stop at skin color. As data is obtained on mass from wearable devices the machine learning algorithms feed this data into a system that perpetuates the bias that lighter skin tones and individuals of a higher economic class are more important because they own more wearables.

Disabled wearers are also unable to fully benefit from the use of mainstream wrist-worn tracking devices which comprise most of the field. The problems range from unusable sensor data to poor body fit. This ableist lens on technology development requires those with physical and cognitive disabilities to adapt to the technology, instead of pushing the technology to "be designed to 'fit' diverse bodies" [6] of all shapes, sizes, genders, and abilities at rest and in motion. If wearables are economic goods, data is the market's most valuable commodity. In the pursuit of quantifying ourselves, we must also be prepared to hand over data access to those who not only use our information to improve the services of their products, but who make money and decisions that serve to benefit systems that are not always secure, egalitarian, or ethical. This leads to increased concerns over data privacy [5]. The sharing of this personal and private data raises questions of autonomy, power, and surveillance.

The bias for lighter skin tones, able bodies, and the reliance on private personal data are pervasive in the fields of design and wearable technology [7, 8]. This raises trust concerns. Too often, critical improvements in research and development practices comes well after a device is released on the consumer market which means those left on the sidelines have to fight to be heard and are often ignored rather than having their needs addressed in the beginning.

How Can Wearables be More Inclusive? Design and technology can be more inclusive by changing the way we design, shifting who is in power and who is empowered in the process of developing new ideas. We need to bring diverse perspectives to the table to share in the co-creation of ideas. To mitigate the inherent biases that seep into our work, designers must strive to meet the needs and listen to the voices of those at the margins and underrepresented from a variety of intersectional lived experiences (across age, race, gender, socioeconomic status, and ability) to the benefit of all [9].

3 Futures: Pushing Wearables Forward

As we reflect on the shortfalls and biases inherent in wearable technology, it is just as important to consider the early spirit of wearables as this promise of the future. Inspired by and inspiring the genre of science fiction in both costuming and plot, wearables were poised to become ubiquitous in a near future not only in ability to read and record data from the body through its integration into fashion and dress, interface with the body, and the interaction with external devices and spaces. It is time to translate these fictional ideas into products that integrate with our reality.

There are several paths that might inspire further innovation: fashion [10] and performance art. Susan Ryan's (2014) work to connect the concept of dress with the futuring of digital interfaces and devices through smart garments stimulated discourse on both technological development and challenged traditional notions of what is fashionable [11].

By rooting ourselves in wearable technology's relationship with embodied interaction, we open the door to design speculations that can prioritizes materiality, technology, embodied experiences while simultaneously challenging normative modes of designing that constrain us and have led to bias in the field. By centering the somatic experiences of the diverse wearers and choosing a speculative path, we create novel needs for new innovation and ways of understanding the context of use and the wearer's cultural, political, environmental, and historical world-view.

3.1 Somatic Expression Through Wearables

The relationship between somatic and performance has been demonstrated by performance artists Onyx Ashanti and dancer and academic Thecla Schiphorst, who have both pushed the needle on wearable technology through visualization and sonification. Ashanti is a self-described cyborg musician who creates improvised "beatjazz" through a full-body prosthesis he calls the *Sonocyb*—turning himself into a full-body electronic instrument playable with hands, arms and mouth [12–14]. Schiphorst explores new approaches to the design of wearable technologies as "an interface into ourselves" and suggests that performance methodologies, based on knowledge "constructed through experimental and embodied practice" of dance [15] can be used to create new models of gesture-based interactions.

3.2 Futuring Wearables: Speculative Design and Transdisciplinary Co-creation

With the concepts of inclusion, speculation, performance, and embodiment in mind, let us look to design education. How might we push past the boundary between market-driven data collection and technical details towards the exploration of diverse needs and experiences? Experiences that can be expanded and augmented through embodied technology that inspires the development of new materials, new contexts of use? Experiences that are inclusive of all bodies and contexts of use. How do we reinvigorate a design practice that centers new and diverse and intersectional voices as experts, acknowledge societal complexities, and encourages critical discourse on the role wearables might play in shaping a more inclusive and ethical society?

When we teach wearables, we should work to develop novel approaches to technology development that is culturally responsive and based on embodied interaction and experiences through the technology instead of emphasizing data collection. In the two University projects highlighted in this paper, we will show two approaches to wearable design in the classroom—one based on play and speculation inspired by the Japanese art of Chindogu. The other project is rooted in co-creation with diverse community stakeholders who are performance artists. Our hypothesis is that by combining speculative, transdisciplinary, and collaborative design approaches with notions dress and somatic expression, students will learn to work alongside community collaborators with whom they might not have otherwise engaged to generate innovative and inclusive ideas.

Chindogu, Polar Pajamas and Listen & Learn. This *Chindogu* or "unuselessness" wearable project was inspired by the book *The Big Bento Box of Unuseless Japanese Inventions: The Art of Chindogu* [16]. This assignment was created to push design and

engineering students out of their comfort zones, to raise questions of social acceptability of on-body technology, and to inspire students to imagine novel sensors and technologies to improve the overall experience of wearables. As James Dator says, 'any useful idea about the future should appear to be ridiculous' (Dator, 2015) [17].

The project examples highlighted in this paper were created during the first week of the Wearable for Healthcare course created for GA Tech's Biomedical Engineering Study Abroad Program at the National University of Ireland Galway. Students paired up to design Chindogu-inspired wearable devices for each other that incorporated LittleBits [18] electronic prototyping components, the LittleBits CloudBit, and up to $5 of additional prototyping material. Students had to interview and observe their partners to better understand an everyday ambition that an on-body device might solve. Throughout the process, students worked to validate these design ideas and prototypes with their partners through sketches, testing prototypes, and conversations.

Polar Pajamas is a concept for a cooling shirt that uses cloud-based temperature data to activate a fan to cool the wearer. Future iterations might instead use on-body temperature to control a smart thermostat. *Listen & Learn* is a wearable auditory behavior correction device intended to deter the use of filler words when speaking (Fig. 1).

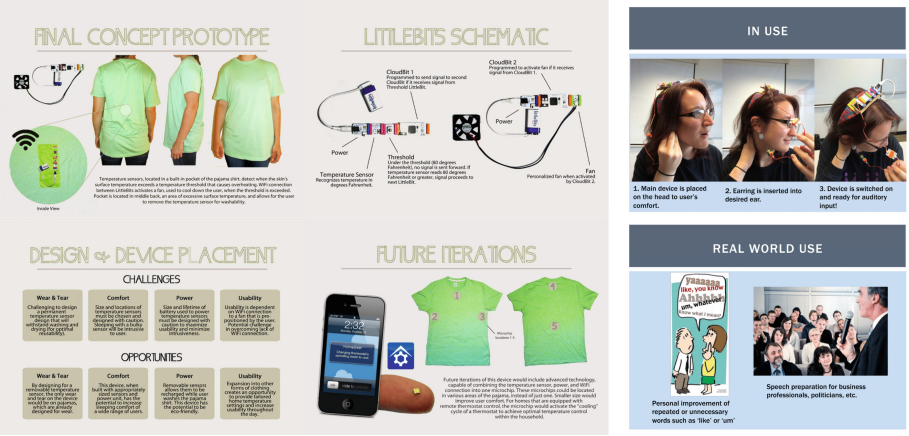

Fig. 1. *Polar Pajamas*, Alexandra Ricard, 2015 and *Listen & Learn*, Madison Lewis, 2015

In response to this assignment, students reflected on the challenges and opportunities inherent in their ideas and speculated on future real-world iterations. They also considered the technology and materials that would be needed as well as themes of discretion, celebration, intimacy, and wearability. These insights led directly into the development of research-based project for the *Wearables for Good* competition [19] that expanded on these critiques and pushed the students to consider a range of extreme needs and to preemptively consider issues of bias, comfort, size, care and maintenance, technology access, accessibility, sustainability, and cost.

Transdisciplinary Design, Drag Duality. The second project comes from Wearable Technology and Design [20], a course taught at GA Tech to computational media students. The course was designed to introduce wearable technology and teach the students to make a wearable technology prototype. The students worked in groups throughout the course.

For this project, student teams worked through a transdisciplinary design process with performance artists as collaborators and co-creators to develop "Boundary Objects" [21, 22]. All groups were supplied with SparkFun RedBoards programmed with Arduino for prototyping and smaller SparkFun Thing boards, sensors and other hardware as requested. Students were encouraged to make and draw as a to communicate ideas and were given tools such as an electronic textile swatch book [23] to spark discussions and ideation. Project materials were given to the groups and the final project garments were given to the performance artist collaborators.

In a break from the traditional participatory design process, we did not want a facilitator and participant role. The term "collaborator" was used deliberately throughout the course. It was important to establish this dynamic with the performance artist collaborators, so that the students would not view the collaborators as mentors or "clients," but rather as co-creators [24]. The students were also encouraged to leverage the diverse expertise, and perspectives of each team member (including the collaborators), as the goal of this course was not just to develop (and then assess) their technical skills, but also to provide valuable training in transdisciplinary collaboration.

Drag Duality is a dress and headpiece that puts on a light show. The audience gets to decide which song and performance (and thus which light display) they see (Fig. 2).

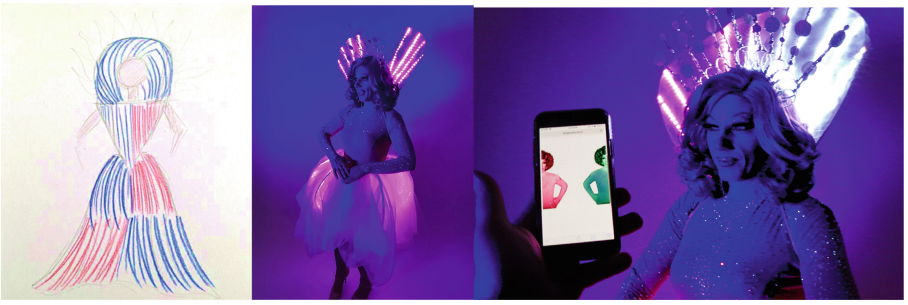

Fig. 2. Sketch by students and Drag Queen collaborator wearing the *Drag Duality* performance garment created by student group, controlled through a crowd voting web application.

4 Conclusion

Designers should work to minimize bias in wearable technology by pushing the field outside of the mainstream into something more exciting that engages diverse groups of people through their lived experiences. We can address the inherent biases in wearables if we start nurturing design students who are comfortable with critical discourse on inclusion, diversity, and equity. We can inspire changes in the field that will result in more thoughtful and critically responsive designs and designers.

As we push wearable technology education into a more inclusive arena, we must rely on both a futures-based approach [25]. While doing so, we must also ask students to reflect on the implications of design decisions from the standpoint of diversity and equity though social, cultural, and ethical lenses that carefully consider the impact of design on those marginalized by innovation due to their race, abilities, gender, geographic location, or socio-economic status. It is imperative that the design of wearables involves transdisciplinary teams and collaboration.

Through the combination of speculation, co-creation, and interdisciplinarity, we can continue to open dialogue that keeps us questioning current norms and looks to a future for wearable technology that is more diverse, imaginative, and inclusive.

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