Accepted Manuscript

Title: Imagining futures: A collaborative policy/device design for wearable computing

Author: Maribeth Gandy Paul M.A. Baker Clint Zeagler

PII: S0016-3287(16)30008-8
DOI: http://dx.doi.org/doi:10.1016/j.futures.2016.11.004
Reference: JFTR 2174

To appear in:

Received date: 8-1-2016
Accepted date: 4-11-2016

Imagining Futures: Collaborative Policy/Device Design for Wearable Computing

Maribeth Gandy - Wearable Computing Center, Institute for People and Technology, Georgia Tech

Paul M.A. Baker - Wearable Computing Center, Center for Advanced Communications Policy, Georgia Tech

Clint Zeagler - Wearable Computing Center, Institute for People and Technology, Georgia Tech

Highlights

- The potential uses of, and markets for wearable computing devices is expanding rapidly
- Such devices can create barriers or opportunities for positive cultural and social impacts
- Design integration of accessibility, interoperability, and supportive policy will improve opportunities and usability
- Interdisciplinary collaboration in design, research and device development in social, technological and regulatory contexts is needed
- We propose the use of futures studies to craft and explore multidisciplinary images of the future

Abstract

The rapidly expanding market for wearable computing devices (wearables), driven by advances in information and communication technologies (ICT), wireless access, and public acceptance of a design aesthetic, is indicative of the near limitless potential for changing the relationship of users to information context(s). As the adoption of wearable devices spreads, there are cultural and social impacts that represent both barriers and opportunities, with subsequent policy ramifications. All too often designers, technologists, and policymakers operate independently developing products that are out of sync, lack interoperability, or are hindered by well meaning, but obstructive policy. This paper proposes a futures-based, iterative policy-informed design framework for developing wearable devices that guides interdisciplinary collaborators early in the process of designing a research & development plan. This approach allows for the development of "images of the future" through which various potential implications and effects of device design in social, technological, and regulatory contexts can be explored.

1. Introduction

The rapidly expanding market for wearable computing devices (wearables), driven by the confluence of information and communication technology, increasingly common availability of wireless access, and public acceptance of the "technology as fashion and representation of self" design aesthetic, suggests near limitless potential for changing the relationship of users to information context(s). The adoption of these devices can be affected cultural and social factors that represent both barriers and opportunities, with subsequent public policy ramifications. All too often designers, technologists, and policymakers operate independently of product development, with consequential products that are out of sync, lack interoperability, or are hindered by well-meaning, but obstructive policy. This paper proposes a framework for the design of wearable devices, provides information on the parameters of wearable systems that informs a formal and specific vision of future devices, and then uses this information to craft example future scenarios for wearable technology. We expand a typical political-economic future-based approach (e.g. Roth & Kaivo-oja, 2015) to encompass potential social, cultural, and regulatory considerations which could guide interdisciplinary teams early in the process of developing new research initiatives.

Too often wearable devices are designed around technological function with a less consideration given to the complex social, cultural and policy environment they operate within. The use-context of devices needs to be factored early on into device design, encompassing normative values and economic concerns. Consider, for example, how normative assumptions have changed over time about specific necessary technical skills, such as the ability to read and write in cursive handwriting, or the capability to perform complex mathematical operations without calculators.

We rarely can predict how society will respond to, and change, as the result of the availability of new technology (e.g. “The coming of the wireless era will make war impossible, because it will make war ridiculous.” (Marconi, 1912) and “There's no chance that the iPhone is going to get any significant market share” (Ballmer, 2007)); and wearable technology is no different, but we all must constantly strive to anticipate and respond to new innovations and the resulting societal impacts. As Dator observed, “what futurists do is not try to "predict" "the future" but to "forecast" "alternative futures" for study and evaluation, and then to help individuals, corporations, governments, and other groups to envision and to move towards their preferred futures--the best, possible, "real" world they can imagine [...] re-envisioning as new information, technologies, challenges, and opportunities, and the desires, hopes and fears of new people, emerge.” (Dator, 2011). Since its incarnation in the early 90’s (Thorpe, 1998) the focus of wearable computing research has been to 1) solve the weighty technological challenges of wearable computing (e.g. power, size, computing power, interface) to the extent that a consumer device could be manufactured and sold (Starner, 1996) and 2) explore how to make the device appealing to consumers by making devices physically (Dunne, 2010) and functionally (Rhodes & Starner, 1996) attractive (Zeagler, Gilliland, Profita, & Starner, 2012). Beyond these initial challenges, given the deployment of millions of wearable sensors and platforms, designers would benefit from being able to draw on a framework for thinking about the technology that guides development teams in exploring implications and effects across technological, psychological, stylistic, social, economic, and policy dimensions.

This paper, then, examines the interplay of the design of wearables in terms of the social and cultural systems in which they are used, and potential policy and technological barriers and opportunities that could impact the design and deployment of wearable technologies in the future. Finally we identify key components of a collaborative policy design framework that could enhance the optimal adoption and diffusion of wearable computing devices.

1.1 A futures-based approach

An approach to developing “visions of the future” and which serves as the basis for actions in the present that inform strategic planning (Kreibich, Oertel, & Wolk, 2011) is well suited to be one of the outputs of our collaborative policy framework. Our future visions have three dimensions: persona (users), context (cultural/social), and technology (upcoming innovations). For our purposes, the persona and context components are primary. Technological advances are going to happen; devices are going to get smaller and yet more powerful, enjoy greater connectivity with other devices, and utilize more sophisticated input and output. However, we are interested in how these technologies will be applied to the infinite number of possible wearable uses, and the social construction of policy as facilitated by technology change.

We believe that technology, be it mainstream, “off the shelf”, assistive or augmentative, has the capacity to significantly inform upcoming wearable research and policy activities. People working with wearable technology often focus their research on the needs of users with disabilities because it allows them to solve fundamental technology problems with broader application, while leveraging a motivated participant pool, and creating truly impactful applications that can change users’ lives for the better. Working with users with disabilities and creating assistive technology based systems provide valuable test beds for producing research contributions with universal application. For example, Komor’s work on proprioceptive interfaces (Komor et al., 2009) includes initial work with vision-impaired users although the potential applications include the next generation of spacesuits. Even though his eventual system may not be assistive, there is considerable value in beginning his research with users that have the most experience using non-visual interfaces. We hypothesize that the concept of “assistive” technology will transform into “augmentative” technology as advanced wearable technology makes it possible for everyone to be improved/enhanced cognitively, physically, socially, and aesthetically. Will particular limitations continue to be viewed primarily as disabilities, or will it become standard to recognize that everyone has characteristics that they want to augment or alter?

In the future visions presented below, we focus on the concept of personal identity and how it could be changed via wearable advancements (see Fig. 1). This is of particular import to assistive technology; it is with the user at all the times and she may want to control to what degree others are aware of their impairment in social settings, at work, and in public. She may also wish to “alter” the level of assistance she is receiving as well as the degree to which the technology is perceptible by observers and manifests on her person. We believe that in one possible future (essentially) all people have ability to construct their identities and change them (both figuratively and literally) based on situation and context. In this paper we explore the potential transformative impact of constructed and situational IT.

Often, future visions may seem outlandish or “sci fi” upon first reading, but it is actually these unexpected scenarios that are more probable (Dator, et al., 2013) and they should not be dismissed because they read as fantastical in the context of present day (e.g. explorations of “Dark Tourism” (William & Wright, 2016)). We were inspired by the the use of plausible yet provocative stories ((Yeoman, 2012) as input (Lindgren & Bandhold, 2009) into a more formal method utilizing participatory design (PD) and action research design (AR) techniques from human-computer interaction (HCI) to create policy focused tool for foresight projects. PD for wearable computing is a collaborative process, often based around artifacts or lo-fi prototypes, where the group of researchers and target users create new concepts for systems through co-design. In this work we are exploring how an input into the PD process can come from our foresight activities, that like Delphi method (Kaplan, Skogstad, & Girshick, 1950) do not focus on consensus (as PD often does), but captures the convergence of opinions from a diverse set of experts/stakeholders (e.g. user, coworkers, caregivers, bystanders, policy makers, manufacturers etc.). What we present in our scenarios below is preparatory work for a PD activity and illustrates how this framework can be used to inform more traditional HCI design activities. This is an attempt to overcome a glaring problem with wearable computing systems (particularly for assistive technology), where the vast majority face unanticipated challenges with deployment, adoption, public acceptance, and adherence while using the technology, resulting in underuse by the populations for which they were designed.

In this paper we present a collaborative policy and device design framework that allows us to think formally about future visions and presents two provocative scenarios presenting future identity, disability, and assistive technology that illustrate the potential of an interdisciplinary futures-based framework for wearable computing research.

1.2 Future Studies, Participatory Design, and Public Policy

Much previous work in wearable computing and assistive technology research, due to technology limitations, took place in a laboratory; building prototypes and running scientific studies of their use with participants. While this can be effective from a narrowly technological perspective, use “in the wild” requires the overlay of a number of additional factors. For instance how do the devices interact (or interfere) with other devices? If there is wireless communication involved, issues of spectrum usage, bandwidth -- all regulatory issues -- come into play. The same device might be more or less regulated depending on intent (use) of the device. What kinds of information does the device use and what networks does it “talk” to. Here issues of privacy, security, and ownership of data are complicated, and best addressed during rather than after the design and development of the device. Finally, end user characteristics and desires affect uptake and adoption. While a device might have augmentative features, for instance, the end user might not want to signal publicly that they have functional limitations or disabilities and hence elements of design and fashion can be effectively applied to product design to conceal device use.

As social beings we live in community, thus the impact and factors that affect the use of wearable devices goes significantly beyond individual preferences - economic, cultural, social, perceptual - to name a few. The governance of society at large as well as the interests that are involved in the matters that affect society (the public) at large can generally be referred to as the public sector and the actions that affect the greater whole captured by the term public policy, or simply “policy.” Associated dimensions of public governance include the specific mechanisms by which policy impacts society - law and regulation. For the purposes of this paper we generally refer to the mechanisms by which the public sector regulates or influences the use of wearable devices as “policy. While many of cultural “soft-variables” are not typically the direct focus of policy, they do represent considerations which ultimately affect the development, implementation and efficacy of policy approaches. Hence the need to consider issues such as accessibility and affordability of technology when designing wearable technology.

Further, given recent advancements in technology, the marketplace, and our culture innovations from the lab are now entering the marketplace at a rapid pace. As Funk (2015) suggests, “New forms of computing, smart phones, mobile telecommunication systems, Internet of Things, wearable computing... are likely to become economically feasible and rapidly diffuse in the next 30 years" and "more likely to enable changes in higher level systems." The relationship between computing technology and humans is becoming increasing intimate, both literally and figuratively. The trajectory is from mainframes locked in machine rooms, to desktop computers in our homes, to laptops that travel with us, to mobile devices that are within feet of us twenty-four hours a day, to the next phase of computing which will be wearable technology and digital information that is seamlessly integrated into our bodies and minds. As a result " the very idea of what is the human body and what it means to be human is changing in ways seemingly beyond our control and capacity to comprehend the implications for what might lie ahead. " (Watson, 2010)

We came to realize the *mutative* power of wearable technology, exhibited in recent cultural phenomena such as the debate over body-worn cameras on law enforcement, the societal pushback on Google Glass, and the growing concern that mobile devices are distracting us from the world and each other. As Dator et al. observe, our current emerging technologies are "harbingers of new, even more intimate and profoundly mutative levels of technology...we are in greatest social and environmental mutation ever" (Dator, Sweeney, & Yee, 2015). We decided that new techniques were needed in our field that allow researchers to acknowledge the "fundamental ethical ambiguity of these mutations" (Dator, Sweeney, & Yee, 2015) and to proactively consider potential futures as a method of informing research initiatives early on.

Our research is inspired by work such as Warnke & Schirrmeister (2016) that urges foresight practitioners to "complement their well developed set of technology oriented methods with equally sophisticated approaches tackling societal aspects of innovation" and particularly by examining the fringes of the innovation system and the "disregarded signals:" members of the society who are marginalized or who have special needs. This is one motivation for focusing much of wearable computing research on the disability community and it motivates our story-based approach for this work. We recognize the importance of the value of an anecdotal "n of 1" to inform research, in addition to the large numbers and statistical significance that is typically the keystone for much of the science in our fields. In this paper we are inspired to think of how the future wearable devices will impact convention, public policy, and regulation by looking to fringe voices and issues of the present such as transgendered persons' access to public restrooms, conflict over "open carry" of firearms, body modification, and augmentation of athletes via performance enhancing drugs that might not seem, at first, relevant to wearable computing. To this end, the insights emerging in futures studies are especially valuable for technology policy development, an area that under-applies this type of innovative thinking (Miles, 2010; Feige & Vonortas, 2016; Van der Steen & van Twist, 2013).

1.2.1 Connections to Participatory Design

While specificity is critical to assistive technology design, additionally a participatory design (PD) approach is needed (Wu, et al., 2005; Wolf, 2014; Williams, 2015; Kuber, 2007). Much like (DiSalvo, 2008), the form of PD we utilized is highly focused on the use of a specific type of technology (non-visual modality wearable interface) and designing with universal design and assistive technology guidelines we and others have previously created (Gandy, Baker, & Zeagler, 2015).

Policy researchers have increasingly directed attention toward issues associated with the development of technology, particularly when emerging technologies are applied to health, disability, aging, and assistive technology (Baker, 2008; Shinohara, 2011; Harte, 2014). Public policy is all too frequently seen as a barrier to development, but a more nuanced take is that that it provides an opportunity to highlight the factors that can influence, and increase the accessibility of the design of technology. However, the influence is bidirectional; not only does policy influence technology development, conversely, technological innovations also have significant influence on policy and regulatory development (NCD, 2011). As the potential of technologies, be they biomedical (Berg, 2009) or wearable (Bostrom, 2009), to truly augment human capabilities is realized, collaborative, interdisciplinary approaches are needed to address ethical, social, and public policy implications. The intentional inclusion of multiple stakeholders both in the design process (e.g. participatory design) as well as in the policy and regulatory processes increases the probability that the end products are both technologically functional and usable to a wide range of end-users. The technology/policy design framework (Gandy, Baker, & Zeagler, 2015) (see Fig. 2) is an initial step toward formally including that perspective into advancing wearable computing research.

There are many examples of PD in the wearable space. Klann worked with firefighters to design a wearable solution and, germane to this paper, they studied the socio-technical system of interdependent factors critical to an effective wearable computing solution (Klann, 2007). Unsurprisingly, they found it is hard to predict the cascading impact of changes on such ecologies. There are many PD ranging from navigation aids for the visually impaired (Williams, 2015; Kuber, 2007) and amnesiacs (Wu, et al., 2005) and to tactile (Wolf, 2014) and point-light displays (Fortmann, 2014). Most of the projects did not address how their systems would need to adapt to different contexts, potential community reaction, policy etc. For example Wu found that ambient noise in the shopping mall interfered with audio prompts. And the point-light display was rated as disturbing by participants in a dimly lit environment or in the presence of strangers (Fortmann, 2014). These PD activities produced valuable research results and artifacts, but we believe that initial PD involving stakeholders and researchers using the futures-based process we are presenting here could anticipate some of these issues and allow the team to consider them in the design from the beginning.

In this work, we are not focusing on what “is” in terms of socio-technical context but what “might be”. The aforementioned projects successfully utilize the prototyping, participatory design, testing cycle. We are proposing our framework be applied even earlier. Why design before you probe the realities of deployment? To be blunt what happens when you take this technology into a public restroom, the LSAT, a playground, airport security, a movie premier, or a courtroom? What are needed are more “Social Wearability” research techniques that support the analysis of the wearer's emotional and social comfort (Dunne, 2014). We argue that initially focusing only on the relationship between the user and the technology, can result in wearable computers that are unwelcome in the real world (Honan, 2013).

2.0 A Proposed Framework for Policy Informed Wearable Design

Our wearables policy/device design framework (Fig.2 below) integrates design thinking and policy development approaches to generate more flexible, responsive technology outcomes (Baker, et al., 2015). In the initial stage of the process typical design components such as appearance, behavioral considerations, technology and social-cultural factors are mapped. This provides an "object" that can be used to assess contextual factors. The second stage provides a comparable policy analytic approach: conducting a policy and contextual baseline assessment to determine what conditions currently exist; a barrier and opportunity analysis, which building on the baseline assessment articulates potential barriers to wearable device development and distribution, and complementary opportunities which might be used to facilitate device development. This primarily is focused on the technological and regulatory dimensions of the devices, rather than the use context of the device, mapped in the first stage. Subsequently stakeholder input is solicited, and at this point the process merges with a design thinking approach, considering user needs. A key component of policy-driven device design process, as we propose, is articulation of conditions, mechanisms and outcomes to help stakeholders identify, or at least be sensitized to the potentials of devices and software.

The expansion here is to consider that "users" in a policy context which includes policymakers and regulators, industry representatives, and standard setting bodies. The standard approaches to development of policy can be organic (naturally emerging), or by design (intentional), and driven by a range of stakeholders, public, or private, or individual. In general, it is a distinct process not always involving those impacted, such as end-users or developers, although U.S. federal agencies are increasingly making concerted efforts to open the regulatory process to be more inclusive (Torfing & Ansell, 2016). As a more inclusive approach, the third stage of the framework focuses on policy as well as technological device design and initial articulation of objectives, outputs and anticipated outcomes. Drawing on the design input components to help craft policy scenarios, using baseline policy assessment, participants explore team based development possibilities using parallel processes focused on searching for new and creative possibilities, while policy specialists address regulatory and legislative constraints. The outcomes, can expected to be 1) technology that more closely reflects user, environmental and stakeholder interests rather than having to be adapted for use after the fact, and 2) a function of the collaborative design process, techno-centric insights that can be fed back into the policy and regulatory process reflecting real world, evidence based input.

Early indicators of the social acceptance of more advanced wearable technologies is somewhat mixed. A pertinent recent example of this has been the rapid interest and equally rapid pushback against use of Google Glass in public places, and possibly serves as a warning shot in a much larger culture "war" over public and private use of wearable technologies. An interesting aspect of this conversation, what social and cultural norms and expectations apply to the public use of these technologies, comes into play in respect to the expectations of privacy an individual has.

Other social and cultural conventions will play a part in wearable technology's acceptance. For instance, as we design technology to be worn on the body, we also have to design ways to interact with and control this technology. The functionality of on-body interfaces and applications has been studied extensively (Lyons et al., 2004; Gilliland, Komor, Starner, & Zeagler, 2010; Komor et al., 2009; Zeagler, Gilliland, Profita, & Starner, 2012; Harrison, Tan, & Morris, 2010; Drugge, Witt, Parnes, & Synnes, 2012; Rhodes & Starner, 1996), however very few studies have focused on researching social acceptability and adoption of wearable devices. An important takeaway from these studies is that these interactions and preferences can be explored, and designing with this knowledge can make for more rewarding and socially acceptable experiences.

Assuming that the adoption of wearable devices is a socially desired or beneficial outcome (and hence, broadly, in the public policy domain), a range of options exist to drive uptake. Given that at least some of the concerns related to technology adoption are driven by unfamiliarity with or (mis)perceptions, one method would be to develop industry sponsored outreach and awareness campaigns devised to help wearable users develop understanding of the impacts of technology use, and ways of maintain control of the technology. An effective, non-regulatory approach, in this case users providing input into the device design process, can be seen as participants in the broader deployment process rather than simply being subject to technological change.

By mapping unconstrained design scenarios to the constraints imposed by (current) regulatory considerations it is possible to articulate alternatives that both creatively address the potentials of new technologies while avoiding pitfalls that could derail the process if not recognized until later in the design process. While this part of the framework is focused specifically on wearable (policy) design process, an expansion of the model focuses outward at continued engagement with users to help anticipate potential objectives. By coupling design thinking with a futures based generation of alternative scenarios, potential objections, concerns, and even expectations of end-users can be anticipated and explored more fully.

The final stage of the proposed model is the evaluation and feedback process. As feedback comes from users, as well as other stakeholders in the policy/device design framework, developers as well as other members of the design team reconvene to review the initial assumptions and scenarios. The design team then makes changes to the devices as appropriate, or employs other policy driven engagement and outreach approaches to address concerns of users, or respond to regulatory bodies.

2.1 Futures Contexts: Trend forecasting, fashion design and technology

Trend forecasting is, to say the least, a complex endeavor, and futures thinking is at the heart of the trending. *"A trend is not, as some people think, a term exclusively associated with fashion. Nor is it a term that simply refers to processes which affect the physical or aesthetic changes in our culture. A trend can be emotional, intellectual, and even spiritual. At its most basic, a trend can be defined as a direction in which something (and that something can be anything) tends to move and which has a consequential impact on the culture, society, or business sector through* *which it moves."* (Raymond, 2010) Because we are concerned with envisioning the future(s) of wearable technology it becomes interesting to look at how these two industries currently trend forecast.

First, trend forecasting in fashion is closely tied to popular culture. Because of the product life cycle of fashion garments and fabrics, it is important to understand what will be "in style" two years out. Trend forecasters look to known cultural shifters, such as movies and museum exhibitions which are all scheduled at least two years out. These cultural beacons can easily have an affect on themes and silhouettes for fashion lines. Fashion designers look to the arts to feed their curiosities just as the rest of us. The fashion industry has overcome the hard task of forecasting color by creating sets of color trend books. These trend books in all practicality set or narrow trends because they are tools all design houses use, thereby mitigating the risk of picking a color scheme that is out of alignment. General color ways are however also influenced by popular culture and attitude. This, however, suggests that anticipating fashion change is a near term rather than mid- or long term endeavor.

Trend analysis for technology has historically been much more straightforward. Within the last couple of decades, technology has trended towards stronger / faster / lighter / smaller design. So within technology development, trends for products tend to move in this direction. Ideas for new products have come from science fiction and the dreams of children, as much as from experts. In the 1950s holding a cordless phone and talking to an image of another person was science fiction. Researchers and engineers are used to short term and long term trends, which is why futures is such a strong method for narrowing and considering trends in technology.

In parallel to advancements specific to wearable technology we are starting to see the technology industry, in general, take into consideration "fashion think". Large companies such as Apple, Google and HP, have hired executives from design and fashion. The most likely explanation for this is that these executives know how to run companies which operate within trending models dependent upon popular culture. Both fashion and technology now depend upon the heterophilous nature of our complex popular culture -- how we use technology is a trend in and of itself. How we dress, and what we decide to portray can be done through our clothing, or through digital avatars. Perhaps, through futures visioning, both will become one, all of them are impacted by the culture in which they are created. Culture is both formed, charted, and navigated by trends, and conversely trends, arise out of socio/cultural contexts.

3. Future Scenarios of Wearable computing

'*any useful idea about the future should appear to be ridiculous*' (Dator, Sweeney, & Yee, 2015)

A not unfamiliar maxim of design is that it is hard to design for that which you can not conceive. Typically a linear design process might make assumptions about anticipatable change. "*The future is like the present but more so*." One of the most powerful contributions of futures thinking is the ability to jump outside of a linear change process, to attempt to envision possibilities which are not yet currently technologically possible. By taking away the idea of “you can’t do that” - designers sidestep extant restraints. So by envisioning the fantastic, the range of that “which can be conceived” expands.

Previously we have applied our policy-first approach to the early planning of our research projects including the design of a wearable device for situational awareness by users with vision impairment and to create the research, development, and training plans as part of a project under the Rehabilitation Engineering Research Center for Wireless Technologies (Wireless RERC). We see our policy framework as prior input into the participatory design process and we also believe it is complementary to a Futures-based approach. This allows us to explore more “fringe” scenarios that could drive long-term wearable initiatives. We also see our policy framework as a bookend to evaluation approaches that later allow the team to reflect post-hoc upon the value of futures techniques to a project (Kim, 2016)

The following sections detail two future scenarios that represent promising directions for wearable device research. We use these two scenarios to explore the Collaborative Policy and Device Design Framework by working through the three stages of the process to illustrate how it could enhance an interdisciplinary research initiative and product design.

3.1 Future Visions: Assistive becomes Augmentative

Assistive technology is generally defined as "any item, piece of equipment, or product system, whether acquired commercially, modified, or customized, that is used to increase, maintain, or improve functional capabilities of individuals with disabilities" (Assistive Technology Act, 1998). And, as a design objective, assistive technologies augment a user’s natural abilities, regardless of the baseline. This is important given the characteristics of people with disabilities, defined in the U.S. by the American with Disabilities Act (ADA) as “a person with a disability as a person who has a physical or mental impairment that substantially limits one or more major life activity. This includes people who have a record of such an impairment, even if they do not currently have a disability.” But thought of more broadly, assistive technology serves to bridge a gap between capacity and desire. All too often overlooked, or worse, disregarded, in the design process (Baker & Moon, 2010), people with disabilities represent a sizable population in the U.S., and for whom such devices facilitate great social inclusion. This is non-trivial, the World Health Organization (WHO) estimates that about 15% of the world's population, or approximately 1 billion people, live with disabilities; as such they are considered to be the world's largest minority (WHO, 2014).

While not specifically designated as “assistive technology” wearable devices can nevertheless facilitate the social inclusion and participation of people with disabilities. Widespread acceptance of mass-market mobile technology has been a boon for people with disabilities, from not only cost perspectives, but also in terms of social (and to an extent, fashion) acceptance of capacity enhancing devices. Hearing-impaired users who would traditionally used a TTY machine (an analogue telecommunications device that lets people who are deaf, hard of hearing communicate over standard telephone times) can now text each other using equipment designed for the general public. Video chat over mobile devices allows use of American Sign Language (ASL) to communicate.

However, in this exercise we imagine a scenario where *assistive* technology has evolved into ubiquitous *augmentative* technology used by everyone. As the distinction between disability and augmentation of ability becomes unclear, how do we reconceptualize the idea of "persons with disabilities", and hence, regulation such as ADA, as well as the use of enhancement technology in settings such as school, work, and sports settings?

Imagine wearable devices, sophisticated, ubiquitous, a nd inconspicuous technology, providing "normal" persons with the opportunity to become *augmented*. It is these innovations that offer tremendous potential to transform our quality of life and our culture (in positive and negative ways), but will also pose a considerable challenge to designers and policymakers. What are the parameters of "normal" when they are significantly mutable by technology?

What social policy, legislation, and even entirely new conventions will be required in response to the changes flowing from adoption of augmentative technology? Will wearable technology be allowed during standardized tests in school, during an Olympic race, or during a professional occupational practice? This is not an entirely new question, for example, one of the pioneers of wearable computing, Thad Starner, was allowed by his Ph.D. committee to use his wearable computer, the focus of his thesis research, during his qualifying exam (Boran, 2011). After deliberation, the committee decided that it had become an assistive device and that its continuous use was the point of Starner's research. They also considered awarding the subsequent degree to Starner and his wearable computer. This is an early example where society had to contemplate at what point technological augmentation was considered "cheating" and inequitable.

We already recognize assistive technologies commonplace in the lives of a person with disability. Hearing aids, crutches, and eyeglasses, are all used by the general population, and are allowed as an accommodation used while working at a job or taking a test. These are generally assistive (i.e. aiding the individual to function at a typical level) but technological enhancements will be able to make wearable users above average, or even outside of the (currently) normal range of capacities. While augmentation that assists a user to offset disability is routine, technologies (from pharmaceuticals to mobile devices) that allow someone to exceed their "natural" abilities can cause concern. Significant number of questions may arise as we approach a transhuman future (Bernal, 1969): should an augmentative device be required to be conspicuous such that people will be aware you are using it; what if an employer decides to only hire people who are willing and able to augment themselves with technology that makes them more effective at their job; could wearable technology be used in reverse -- to reduce capabilities of those who are more gifted in order to "even the playing field" (as imagined in Vonnegut's (1961) short story "Harrison Bergeron."

A futures approach to the adoption of wearable technologies shifts from a focus on technology, per se, to identity construction, where users of augmentative wearable technologies choose an image, persona, or even environment to project to viewers, virtual or in person. Social norms and regulation balance privacy, desires, fashion and accessibility in a way that allow maximum freedom and self expression while protecting vulnerable populations and preventing fraudulent activities.

Under this scenario, technology is sufficiently concealable that social convention has become to reveal the use of such devices, and adjust presentation to context (e.g. driving a car, presenting in a business meeting, playing a game of soccer, dancing at a nightclub, or sitting at a group meal, etc.) This future vision provides contextual input into nascent research plans as well as the design of policy approaches that are anticipatory rather than reactive. In next section, we work through the types of questions and decisions that the framework leads us through, and see how this process could be used to develop a focused research plan for an education focused wearble agent.

3.1.1 Application of Policy/Device Design Framework

The always on - always connected device networked envisioned in the Internet of Things (IoT) framework reached maturity, but faster than anyone intended. Early versions of this advising/informing information overlay (text/notification over handheld devices), pointed the way for the arrival of ubiquitous information connectivity, allowing people to offload the requirements of memory recall to this external network. As is the case with many kinds of technological innovations it wasn't the scientists and engineering experts that had the most significant impact but the informal teams of stakeholders working together collaboratively to come up with soft ideas about what the ways the technology could be used, social situations that might arise, how fashion, style and culture adopted and shaped the technology.

Years ago an important strand of research started with the idea of a Remembrance Agent (RA) (Rhodes & Starner, 1996) -- an "always on" wearable that based on conversation happening around the wearer, displayed relevant content (e.g. articles, personal notes, news etc.). The implementation, more than twenty years ago, was limited by hardware, lack of mobile broadband connectivity, and the early state of the World Wide Web. The prototypic system proved very useful as a cognitive prosthetic, but was unwieldy, conspicuous and required significant amount of onerous inputs from the user. The system was not ready for large-scale deployment. Now, envision continuing this work with modern hardware, connectivity, online resources, and user-friendly wearable input and output (I/O). This is a good example of a wearable system that would first be designed as an assistive technology for those with cognitive impairments, but could prove extremely useful to non-impaired users.

It is also possible to imagine that such a service, becoming ubiquitous, allows people to offload the requirements of memory recall to this external system. We must endeavor to envision all aspects of development and deployment at the formative design stage: How would this system be perceived by society and what effects would it have in environments such as the workplace and school? The team would want to ensure that design decisions could be made early on in the process to help produce a "future" that is acceptable and equitable, and consistent with conventional use and regulation.

Develop Use Case: Secondary Education and Augmented Learning Environments; Wearable Tutors and Remembrance Agents support young learners with cognitive impairments.

Technology has allowed the shift from delivery of information -- “teaching” to a focus instead on contextualized enhanced learning solutions that matches resources to the needs and desire of the learner. While “schools” still exist they are almost unrecognizable to an observer transported from the late 20th century. Rather than learning in lockstep classes at set times and places, students are free to come and go as they please, within the space of the safe school environment. Artificial Intelligence (AI) enhanced Wearable Tutors (WT) patiently guide and remind learners of where they are supposed to be and what they should be focusing on. As side benefit of the use of these virtual tutors, the School Proctors (what used to be administrators), are able to monitor and ensure the safety of the learners. Many of the policy concerns of the late 20th century were no longer as important, having been addressed proactively through innovative collaborative design approaches that developed comprehensive, rather than piecemeal solutions to various aspects of education and learning. A specialized version of the Wearable Tutor, the Remembrance Agent (RA) is tailored to meet the needs of learners with cognitive disabilities.

Baseline Assessment: Long gone are the paper, pencil and observation based assessment protocols. Application of basic design phases of the, now standard, collaborative policy design approach identified key components that could be modified and used in new ways to enhance the learning process. Application of fixed, contextual, virtual and of course, wearable technology allowed capture of the students actual way of interacting with material and environments. Student limitations were assessed and measured, and matched to algorithmically developed programs, students placed in contexts best suited to their physical, cognitive and emotional characteristics.

The Design Components (see Baker, et al. 2015) for more exhaustive discussion of design parameters)

- *Technological Considerations (form factor of the device, battery life, amount of computing power, network speed and ubiquity)*: The technology choices made by those designing and deploying the RA had significant implications for how long the device could run unpowered during the day, how small/discreet it is, and whether the information the RA provides would be low enough latency to rely on. The team considered issues of user needs such as environments where connectivity might be unreliable and how robust the speech recognition would be in various environments due to ambient noise, crafting a final product that provided adaptive presentation and interface modes depending on the context of the physical space/technology access and that could be packaged in various form factors that allow the user personal choice over the body placement and conspicuousness of the device and its functionality.
- *Social (the experience the community has with the user and the system)*: The designers also had to consider early on, how would other students react if one or more of their cohort was using this during class? Or a test? Initially, there were community concerns about privacy (e.g. are the students or teacher being recorded?) that were ameliorated via

educational campaigns and instructional materials that made it clear what information is collected, transmitted, and stored. The physical interface of the RA was also redesigned to include obvious cues via lights, sounds, and interactions from the user that convey when the device is in use and what data it may be collecting. Ultimately, the RA was more readily accepted in communities where it was presented as an assistive device required for students with disabilities. However, many parents see the RA as giving an “unfair” advantage and attempt to have their child diagnosed with a learning disability so they are allowed to use the RA during placement tests.

- *Appearance (the look of the system and its level of integration with the user’s clothes and accessories)*: RA designers had to consider how appropriate the device was for various social and legal contexts (the playground, public transportation, the classroom). Original designs made the wearable look like an assistive device with a clinical look (e.g. hearing aids or wheelchairs) but as it became more ubiquitous new designs emerged that were more playful and personalized. The RA device is relatively inconspicuous but the user can signal device use so that others are not taken by surprise when the user begins interacting with it and to ameliorate some of the early paranoia about privacy. New motifs, and silhouettes of the RA device are now released seasonally, many younger users want to be seen with the newest model in the trendiest color.
- *Behavioral (the user’s actions when using the system and in response to its functionality)*: The designers also considered how the user behaved with the RA. Initial user interfaces were designed “in a vacuum” with little input from the children that were the target users (and their peers). These early interfaces ignored how the user would be perceived when interacting the RA around others. Some of the voice commands were disruptive to the environment and embarrassing for the user, while certain gestural inputs were too close to movements considered crude and funny by the children. If the interface was too discreet the user had the appearance of “super human” perfect memory recall, which was off-putting to her peers. Over time the interfaces were tuned based on this field-based data, and the users (and their community) slowly adopted new social norms for RA interactions (e.g. overtly turning it off/removing it before a private conversation with a friend and purposely exaggerating interactions with the device so as to cue others that the RA is in use). Certain interactions which at first seemed awkward in public became part of the social lexicon, and now everyone knows the gestures and touch interactions are of someone controlling an RA.
- *Legal (the current and future legal implications of the device)*: There are situations where RA use (e.g. the courtroom) or even the presence of the device on the user’s body (e.g. airport security) are more highly scrutinized and the regulatory landscape regarding this continues to evolve. As use of the RA became ubiquitous new issues arose, such as. For example, there is a case still moving through the courts where an employer was requiring its use by adults since it increased worker productivity. Conversely, there are citizens that have sought to ban its use in certain public locations such as bathrooms citing privacy concerns. Ultimately, the RA has led to a reexamination of the traditional delineation between disability, “normal”, an “assistive” and “augmentative” and redefined what is and is not under purview of the regulation such as the ADA.

Policy Components

Application of the policy components of wearable design is complicated a bit by the iterative nature of policy. It is both an input (specifically, in terms of the regulatory requirements governing aspects of the wearable ecosystem -- radio waves), as well as an output, where stakeholders in the regulatory system provide feedback to regulators and policymakers.

Drawing on the elements of the policy subsystem:

- *Opportunity*: Education is key to effective operation of societies, and learning -- the ongoing application to individuals -- has become a lifelong endeavor. The large number and variation in techniques occurring in secondary schools makes these especially interesting substrates for innovative experimentation. Devices such as Wearable Tutors make contextually information and guidance available just in time. Increasing number of options for secondary education, made possible by technological and educational policy innovation expands opportunity for Wearable Tutor and similar devices.
- *Barrier Analysis*: A number of factors which can be barriers to development and subsequent adoption broadly fall into these categories: 1) awareness, 2) technological, 3) economic, 4) policy/regulatory, and 5) social. These tend to operate together so isolating the impact of these variables is high context dependent. Significant barriers to RA adoption/access, but which are addressable by the collaborative design/policy framework include: *technological/design* - It is challenging to design a device that is usable, safe, and of the proper form factor for a children; and would be sufficiently fashionable to be appealing. There are undoubtedly rules in different school systems that would limit students from using, or even having the WT device with them, at school; *price* both for the system and due to the need for ubiquitous wireless broadband connectivity; *policy/regulatory*: at the individual level - privacy, data protection, safety/security; at the institutional level - data management and access, disciplinary and content management; device tracking and security; and final at the technology level, regulation of devices, regulation of wireless connectivity; if medical data involved, HIPAA (Health Insurance Portability and Accountability Act); educational reporting requirements, state and federal.
- *Stakeholder Objectives, Expectations, Concerns*: input would be solicited from parent, students, school and system administrators, and potentially device and network providers. Certain concerns from school administrators might include a worry that there would be an expectation for teachers to help the student learn and/or fix the device during school hours, that the device's presence could be distracting to classmates, or that there could be health risks associated with long term use. While parents could have concerns that the cost will be too high, that the child will become too reliant on the technology and miss out on developing traditional strategies for coping with her cognitive impairment, or that the child may break and/or lose the device.
- *Objectives:* Reduction in barriers to learning and engagement, greater independence in attending school.

Policy/Device Design Process Outputs:

Completing these preliminary stages of the framework should yield initial device prototypes that are:

- *design compliant*, (e.g. always on, inconspicuous, powerful system that is providing continuous real-time information to help cue the user based on contextual input from the environment via audio and video capture);
- *use compliant* (e.g. metrics for determining if student use of the RA, requirements for signaling when it is in use, device is easy to wear, in instances the system may only be able to access a limited subset of information, accommodations the school must provide such as the ability for the student to charge device during the school day);
- *policy compliant* within the constraints of regulatory considerations (e.g. data reporting, privacy, accessibility, device interference). This information is used to solicit feedback from stakeholders and feedback into policy and device design process for refinement.

3.2. Future Visions: The Constructed Identity merges the digital and physical

We already have a long history of identity construction predating computing technology. And in the last seventy years, with the adoption of the successor to the Internet, the IoT framework, it has become standard in the hybrid digital/physical realm. First, we saw users taking to virtual worlds, ranging from Multi-user Dungeons (MUDs) to 3D and enhanced 3D fantasy worlds such as “Second Life” and “World of Warcraft” to create alternate identities. The relatively primitive closed environments (i.e. your new identity did not extend beyond the proprietary system, but allowed for extreme flexibility in identity construction) evolved into augmented information overlays blending and at times, replacing the purely physical world. Now in the world of post-social media, the constructed environments are very open and public, but far more regulated in the ways one can manipulate identity (i.e constructed and presented persona). The consequence of ubiquitous computing and increasingly powerful wearable (and implantable) devices was that culture represented the consequences of the intertwining of the digital and physical, the real, the constructed and the augmented. A totally “unconstructed” individual identity is as unimaginable as clothes without zippers or housing without electricity.

The concept of privacy in our society has continued to change as technology reduces the cost and difficulty of knowing information about everyone, and conversely the complexity of concealing or maintain privacy becomes beyond the reach of most individuals. Rather than fighting a losing battle for privacy, most individuals opted to intentionally construct identity as a way of maintain control of how they were perceived most commonly, by using an identity construction device (ICD). Years ago adoption of social media resulted in people becoming more open about previously personal aspects of their lives. Thus the origin of the “persona as avatar”, as wearable technology provides increasingly more open and flexible power to construct identity. There is even the possibility, explored in science fiction, of completely altering one’s appearance and the physical world dramatically via augmented reality (Vinge, 2006).

One of the key aspects of the constructed identity is the tuning of identity presentation: by selectively foregrounding information about yourself in a particular setting, choosing when and how to reveal your augmentation status (via sensory and informational channels), and configuring the level of technological assistance/augmentation you are using based on need and preference. One configuration of the tech might be appropriate for a party setting, for instance, where the user chooses to put his technology overtly on display, as part of a fashion statement while another configuration is discreet and less intrusive during a family dinner. It was critical that wearable researchers from all domains acknowledge that the aesthetics of wearables was an important component of constructing identity. Anything we wear is the result of a conscious decision regarding the image we want to present to the world. Even choosing to wear very plain clothes or to always wear the same outfit is in itself a strong statement. Wearable research therefore had to study this interaction between the need for functionality mediated by personal preference, the surrounding environment and social expectations.

Speculative fiction also provided some concepts that drive this future vision of constructed identity and the social contract to acknowledge that image. Mieville's (2010) "The City & the city" explores a provocative vision of culture and presents a fantastical approach to the co-existence of societies, where two cities are physically overlaid in space, but the residents of one city have learned to "unsee" the existence of the other. Could we just decide as a society to not "see" parts of a person's identity that are currently "turned off" or hidden? What if in the future we have the ability to project a particular identity of our choosing to the world (not necessarily literally). Will a new social contract emerge where others will perceive you as the constructed version of yourself over the "real?"

The image in Fig. 4 is a tool that helps us develop use cases and personas as we explore the importance of Observer/Community experience in this future. This stylized image puts the viewer in the role of bystander in our wearable future world. Perusing the image reveals that it is not clear who is assisted/augmented and who is not and the line is blurred between who is easily perceived as "disabled" and who is not. For some people in the scene wearable technology is visible but the functionality/sensing capabilities of the technology are not. For others their technology is opaque/hidden or possibly not used; all that a bystander experiences is the person's abilities (whose source is unclear). The image also shows users with similar capabilities/needs who have chosen different assistive/augmentative technologies based on personal preference and who may also be "tuning in" differing level of technological transparency (or constructed identity) for themselves.

In this future, users produce and transmit a guide for others in the world around them, information on how they want to be approached and interacted with. Goffman would say that it is the presentation of ourselves that gives others cues as to how to interact with us (Goffman, 1959). He goes on to explain that most people take this inferential information as a fact of who one is and act accordingly. "The others find, then, that the individual has informed them as to what is and as to what they *ought* to see as the 'is'" (Goffman, 1959).

Moving from the physical to the digital, when we think about digital social systems some of them allow for this presentation of self. Wrapped up in this idea of digital self-presentation is the notion of privacy. Privacy in this context is not about security, but instead refers to the ability of the user to decide what to share and what not to share. A physical person can decide not to answer the door if they do not want to be bothered at home. Some platforms like Linkedin and Facebook allow for what Palen calls a *disclosure boundary* (Palen, & Dourish, 2003). Linkedin is an example of situating a website within a clear digital setting. Goffman would argue that part of presenting oneself is deciding the location of the presentation. Linkedin clearly sets this digital location as a work/office/business structure, and this in turn gives cues to all those involved how to engage in discourse with each other. Because of its digital setting Linkedin has built in social signals for how to deal with disclosure boundaries. In the physical world the local setting affects the presentation. Facebook is much more casual, and recently provided an example of what happens when a social system decides to change its disclosure boundaries (or starts to enforce them), in essence "putting windows in doors." Self identified and self-presented drag queens with profiles on Facebook were told by Facebook to use their legal names instead of their drag names. This caused quite an upset in the 'shared meaning' and context of the social identities they had previously portrayed on their Facebook profiles. In a drag persona individuals used a different affectation and vernacular in their written correspondences and posts, which would not be associated with their presentation of self out of drag. The reason why many of the individuals used Facebook in the first place was because of its ability to portray (or create) a representation of self through the digital, giving a context and point of view to public facing posts. Unlike other more anonymous postings, these personas were true working self-presentations.

And this will inevitably led to potential conflicts between the constructed identities and how others chose to view the construct, in accordance with personal or community standards (consider smoking and decency laws). Technology was developed, not only for creating, presenting, and conveying an identity, but conversely, to preserve bystanders' rights to not be exposed to something undesirable. However, when the majority of life experience is mediated by technology there is an effect on our society, a phenomena also previously explored in Rainbow's End (Vinge 2006). Various social norms and regulations had to change in response to the advent of this technology. One societal conflict is centered around whether a person with a disability, who wants to project a different non-disabled identity, has the right to keep others from negating that constructed identity that for themselves. Previously we had the ability to the ability to block an individual's phone calls and social media messages. But these wearable systems made it possible for one person to make another person invisible or disappear from her sight, literally. This concept was explored in a 2014 episode of BBC's "Black Mirror" ("White Christmas") where a criminal's presence in the world was reduced visually and auditorily (via augmented reality) so that they appear only as muffled hazy silhouettes to everyone around them, in essence "erased" from society via technology. Once this technology became a reality, issues of a person's' right to erase themselves or others from the world were hotly debated. As it has in the past in society, public sector signifiers often override all other rules except those that violate constitutional privileges, such as emergency alerts on social media and more generalized communication platforms, but there are many gray areas without a clear path forward. There are similarities between debates regarding digital presentation of self and those that existed in the past regarding physical presentations, such as France's ban on face covering clothing such as the burqa (Bittermann, McKenzie, & Shoichet, 2016) and the legal battles over the use of public restrooms by people who are transgendered (Berman, 2016).

3.2.1 Application of Policy/Device Design Framework

We long had the capabilities of constructing identity in the digital world, conveying these virtual identities to others who otherwise had no knowledge of our actual physical appearance. However, with the advent of advanced and ubiquitous augmented reality and wearable computing technology, users can literally appear however they want (i.e. apply a virtual "skin"), and have the capability to change their outward visual identity whenever they choose.

Develop Use Cases: Wearable and IoT technologies allow people in public settings to dynamically control their visual appearance and the informational persona associated with their physical body. For example, a woman with physical disabilities uses the identity construction device (ICD), in the work environment, to appear able bodied and male.

Baseline Assessment: Significant literature notes that discrimination occurs based not only on actual, but also on perceived characteristics. Real time construction of identity projection theoretically allows this to be offset. However, ICD usage has required that a wide range of social and cultural conventions be continuously renegotiated to address expectations and obligations.

Design Components:

- *Technological*: A major technological decision regarding ICD systems was (and is) related to how the information is presented to everyone around the user. One approach presents the augmentations to those wearing augmented reality glasses/contact lenses/cybernetic eyes. This approach gives those in the community the final control over what they experience. While other systems are based on projection units worn by the user, creating a virtual image that is seen without glasses. With this approach bystanders have no control over what they are presented. While both systems exist and seem to provide the same functionality, they have very different societal and policy implications since with one approach the control is in the hands of the public while in the other total control lies with the user/wearer.
- *Social*: From the beginning ICD usage has resulted in situations where the user chooses to project a view that is lewd (e.g. sexually explicit imagery), disruptive (e.g. 10m dragon blocking the view of others at a concert), or incendiary (e.g. an appearance that presents a mocking caricature of a public official) and public policy and regulation has had to change in response. Elements of the ICD user interface and presentation are designed to let bystanders know when the user is modifying their appearance? While it is very common for someone to have various personas, just as people have long had many usernames/accounts in online communities such as Reddit, it can be socially unacceptable in many public settings to purposefully hide the fact that different personas are actually linked to the same physical person. However, our society has also adapted to the concept that the same individual might have a drastically different appearance and persona depending on context. As it has become common for users to design different

"skins" for different contexts (e.g. the office environment versus the nightclub) and societal norms emerged regarding when and how you reveal your actual physical appearance to someone.

- *Legal*: There are legal concerns regarding the obfuscation of or co-opting of others' identities, particularly those uses of the ICD that mask physical attributes and can potentially lead to security risks. For example, you are not currently allowed to have your virtual "skin" active while going through customs or getting a driver's license, but there is ongoing debate regarding what is considered a person's "real" appearance for legal purposes. Many of our existing laws regarding attire and public decency were expanded to encompass the types of situations enabled by this technology.

Policy Components:
Drawing on the elements of the policy subsystem:

- *Opportunity*: Aside from a fashion or philosophical desire to construct an identity or appearance, valid in and of itself, intrinsic and expressed bias exists in many sectors of society based solely on appearance or perceived identity. ICD wearable technologies allow people more control over their identity and appearance and these options engender greater confidence in some by freeing them from their physical form and has helped ameliorate the effect of bias and prejudice in some situations.
- *Barrier Analysis*: Initially the ICD systems were very costly, and instead of empowering users, it served to further inequality and inequity in society by having these capabilities in the hands of the very few. This also caused some backlash against the technology from others in society, but over time, as with all technology, the costs reduced dramatically and ICD became ubiquitous.
- *Policy/regulatory*: Expectations of privacy, safety/security needed to be addressed, as very real dangers are possible with in-person interactions when the true characteristics of an individual are not apparent. Identity construction, as has long been the case in criminal activities, is still problematic. This area continues to require examination by legal scholars with respect to potentially balancing the rights of individuals accused of violating social conventions and law with the requirements of the public in maintaining order. Further there is still a set of unresolved ethical and legal questions regarding what are the rights of an individual who wishes to project an image consistent with their preferences (e.g. a virtual nude individual) with the beliefs of someone who would be offended by these presentations. Example regulatory response to the ICD includes law enforcement having the ability to turn off or "see through" the augmentations, additional laws about impersonating others, and a ban the use of virtual "skins" in certain public venues.
- *Stakeholder Objectives, Expectations, Concerns*: The stakeholders for the ICD are those concerned with issues of expectations of performance based on perceived appearance, the public sector/government, and individuals who vary from the norm, either because of characteristics or functional limitations.
- *Objectives:* Appearance consistent with the identity as desired by the individual, and in accordance with social and community conventions.

Policy/Device Design Process Outputs:

Applying these stages of the framework should inform development of an Identity Construction Device (ICD) prototype that is

- *design compliant*, (e.g. can be turned on or off as needed either manually, or automatically in compliance with user, or context - appropriate profiles), ubiquitous, powerful system that provides continuous real-time monitoring to help cue the user based on contextual input from the environment via audio and video capture); and which projects identity consistent with user desire, and which exhibits (displays) negotiated, contextually appropriate forms.
- *use compliant*, such as protocol negotiation with other users of wearable devices, as well as environmental signals (e.g., a virtual burqa might be prohibited in a high security setting, or a bikini in a church.) Here a very open sourced approach would be appropriate and one that is highly configurable as the sue compliance would be highly context and socially dependent. One approach might be develop identity “form books” with preconfigured (and modifiable) settings for common social convention in different venues.
- *policy compliant* within the constraints of regulatory considerations (e.g. data reporting, privacy, accessibility, device interference). All of this information is used to solicit feedback from stakeholders and feedback into design/policy process for refinement. Policy in this context would also relate to contextual considerations. For instance how might highly visual identities be translated into textual (or other common information signifiers) descriptions. Further what kind of meta-tagging systems might be necessary for security situations (for instance in public where CCTV might capture individual movements), or for use by AI (or simple computers) to ensure typical transactions.

4.0 Conclusions and Call for Integrated Policy/Research Guidelines

All of the information generated by applying the policy framework to the exploration of future wearable scenarios can be used to elicit feedback from stakeholders and drive the process for refinement of a research program, which includes proactive engagement in the public policy process. Although these were both long-term, seemingly fantastical scenarios, we believe the issues of sophisticated human augmentation of abilities, and identity construction and presentation will be of increasing importance. Working through these imagined future examples highlight promising areas of research in many disciplines and helps us think up front about the drastic impact such innovations could have on our society, helping us to anticipate and work toward the “preferred” futures.

Overall, this approach to wearable research is part of our argument for a real-life versus lab based design process. Normally you design an object first (possibly with the participation of the user as in the project we discussed previously), but we argue that wearable system design must focus first on the use context. The tension here is between needs of the user versus the needs of others in the environment. The intimate integration of computational systems into our lives and physical world is intrinsic to wearable computing and brings a host of new design considerations that must be acknowledged early on in a research program. Wearable research systems as are they are designed now are often “stillborn”unless the team designs around environmental and societal contexts. What happens when the device is taken into various public settings? What if it interacting with the system makes the user appear look foolish (or dangerous)? What if the presence of the device or the augmentations it provides to the wearer makes those surrounding her feel paranoid or uncomfortable? In the natural world, offspring must fit into an ecosystem and community. If an organism is not adapted for the environment it will not survive. Similarly “in vitro” (“lab developed”) wearable systems whose “genetic” makeup was not evolved via inputs from the environment (either present or in an imagined future) will fail on deployment.

The policy/device design framework we have outlined is a work-in-progress previously “piloted” under the auspices of the Wireless RERC. In developing this framework, we examined critical components of a design thinking approach, not generally considered in a strict policy making process, and conversely, the ramifications of interjection of policy considerations into the design process. The framework brings into conversation the designer's focus on function, utility, and the social and cultural systems in which they are used, with the constraints generated by potential policy and technological barriers and opportunities that impact the design and deployment of wearable technologies. Finally, coupling the insights from a futures-based scenario building approach with the collaborative policy/device design framework helps generate new, innovative options which can enhance the effective development, adoption, and diffusion of wearable computing devices.

Acknowledgements
The authors would like to thank their Georgia Tech colleagues for feedback and support; specifically we appreciate the insightful input of the WCC Co-Director, Peter Presti.

This work was supported in part by the National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR) of the U.S. Department of Health and Human Services under grant number 90RE5007-01-00.

References

Assistive Technology Act of 1998 (United States). [https://section508.gov/assistive-technology-act-1998] Accessed 08.06.16.

Baker, P.M.A., Gandy, M., Zeagler, C. (2015). Innovation and Wearable Computing: A Proposed Collaborative Policy Design Framework. *IEEE Internet Computing* 19(5): 18-25.

Baker, P.M.A., & Moon, N.W. (2008). Wireless technologies and accessibility for people with disabilities: findings from a policy research instrument. *Journal of Assistive Technology*, 20(3).

Baker, P.M.A., & Moon, N.W. (2010). Policy development and access to wireless technologies for people with disabilities: results of policy Delphi research. *Universal Access in the Information Society (UAIS)*, 9(3), pp. 227-237.

Baker, P.M..A., & Bellordre, C. (2003). Factors influencing adoption of wireless technologies - key policy issues, barriers and opportunities for people with disabilities. *Information Technology and Disabilities,* Vol. IX(2).

Ballmer, S., *USA Today*, April 30, 2007.

Berg, J. W., Mehlman, M. J., Rubin, D. B., & Kodish, E. (2009). Making all the children above average: Ethical and regulatory concerns for pediatricians in pediatric enhancement research. *Clinical Pediatrics* 48(5):472-80.

Berman, M., (2016) South Carolina Gov. Nikki Haley says her state doesn't need transgender bathroom law, *The Washington Post*, [https://www.washingtonpost.com/news/post-nation/wp/2016/04/07/south-carolinas-gov-nikki-haley-says-her-state-doesnt-need-transgender-bathroom-law/?utm_term=.fbc30db41fcb] Accessed 08.05.16.

Bernal, J.D., (1929, 1969), *The World, the Flesh & the Devil: An Enquiry into the Future of the Three Enemies of the Rational Soul*, Bloomington, Indiana University Press ix, 81 p. ISBN 0253194008.

Bijker, W. E. (1997). *Of Bicycles, Bakelites, and Bulbs: Toward a Theory of Sociotechnical Change*. Cambridge MA: MIT Press.

Bittermann, J., McKenzie, S., & Shoichet, C.E. (2016) French courst suspends burkini ban *CNN*, [http://www.cnn.com/2016/08/26/europe/france-burkini-ban-court-ruling/] , Accessed 08.01.16.

Bohn, J., Coroamă, V., Langheinrich, M., Mattern, F., & Rohs, M. (2004). Living in a world of smart everyday objects—social, economic, and ethical implications. *Human and Ecological Risk Assessment*, *10*(5), 763-785.

Boran, Marie (2011). Thad Starner: Wearable Computing for Smarter Living. *Technology Voice.* 03/16/2011 [http://technologyvoice.com/2011/03/16/thad-starner-wearable-computing-for-smarter-living Accessed 08.06.16].

Bostrom, N., & Sandberg, A. (2009). Cognitive enhancement: methods, ethics, regulatory challenges. *Science and engineering ethics*, *15*(3), 311-341.

Dator, J. A. (2002). *Advancing futures: Futures studies in higher education*. Westport, GT: Greenwood Publishing Group.

Dator, J., Sweeney, J. A., Yee, A., & Rosa, A. (2013). Communicating power: technological innovation and social change in the past, present, and futures. *Journal for Futures Studies*, *17*(4), 117-133.

Dator, J. A., Sweeney, J. A., & Yee, A. M. (2014). *Mutative media: communication technologies and power relations in the past, present, and futures*. Springer.

Davidson, T. (2013). Should Oscar Pistorius be Allowed to Compete at the Olympic Games? *Unpublished Thesis, Victoria University of Wellington, New Zealand*. [http://researcharchive.vuw.ac.nz/handle/10063/2715] Accessed 08.06.16

DiSalvo, C., Nourbakhsh, I., Holstius, D., Akin, A., & Louw, M. (2008). The Neighborhood Networks project: a case study of critical engagement and creative expression through participatory design. In *Proceedings of the Tenth Anniversary Conference on Participatory Design 2008* (pp. 41-50). Indiana University.

Drugge, M., Witt, H., Parnes, P., & Synnes, K. (2006). Using the" HotWire" to Study Interruptions in Wearable Computing Primary Tasks. In *2006 10th IEEE International Symposium on Wearable Computers* (pp. 37-44). IEEE.

Dunne, L. E., Profita, H., Zeagler, C., Clawson, J., Gilliland, S., Do, E. Y. L., & Budd, J. (2014). The social comfort of wearable technology and gestural interaction. In *2014 36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society* (pp. 4159-4162). IEEE.

Dunne, L. (2010). Beyond the second skin: an experimental approach to addressing garment style and fit variables in the design of sensing garments. *International Journal of Fashion Design, Technology and Education*, *3*(3), 109-117.

Feige, D., & Vonortas, N. S. (2016). Context appropriate technologies for development: Choosing for the future. *Technological Forecasting and Social Change.* [http://dx.doi.org/10.1016/j.techfore.2016.05.025]

Fortmann, J., Müller, H., Heuten, W., and Boll, S. (2014) How to present information on wrist-worn point-light displays. *In Proceedings of the 8th Nordic Conference on Human-Computer Interaction: Fun, Fast, Foundational (NordiCHI '14*). ACM, New York, NY, USA, 955-958.

Funk, J. L. (2015). Thinking about the future of technology: Rates of improvement and economic feasibility. *Futures*, *73*, 163-175.

Gilliland, S., Komor, N., Starner, T., & Zeagler, C. (2010). The Textile Interface Swatchbook: Creating graphical user interface-like widgets with conductive embroidery. In *International Symposium on Wearable Computers (ISWC*)(pp. 1-8). IEEE.

Goffman, E., (1959). *The presentation of self in everyday life.* Anchor.

Harrison, C., Tan, D., & Morris, D. (2010). Skinput: appropriating the body as an input surface. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 453-462). *ACM.*

Jenkins, W., (1978). *Policy Analysis: A Political and Organizational Perspective.* New York: St. Martins Press, p. 15.

Harte, R.P., Glynn, L.G., Broderick, B.J., Rodriguez- Molinero, A., Baker, P.M.A., McGuiness, B., O'Sullivan, L., Diaz, M., Quinlan, L.R., & O'Laighin, G. (2014). Human centered design considerations for connected health devices for the older adult. *Journal of Personalized Medicine*. 4(2) 245-281.

Hayes, G.R. (2011). The relationship of action research to human-computer interaction. *ACM Transactions Computer Interaction*, 18(3) pp. 1–20.

Honan, M. (2013). I, Glasshole: My Year With Google Glass, *Wired*. 12.30.13. [http://www.wired.com/2013/12/glasshole/] Accessed 08.06.16

Kaplan, A., Skogstad, A. L., and Girshick, M. A. (1950). The Prediction of Social and Technological Events, *Public Opinion Quarterly* XIV, 93–110.

Kirkham, R. (2015). Can Disability Discrimination Law Expand the Availability of Wearable Computers? *Computer*, (6), 25-33.

Kim, S. Y., Lee, J. Y., Yeo, W. D., Park, Y. W., Song, I. S., & Hong, S. W. (2016). Development of post-evaluation model for future and emerging technology item reflecting environmental changes. *Futures* (*77*) 67-79.

Klann, M. (2007) Playing with fire: participatory design of wearable computing for fire fighters. *In CHI '07 Extended Abstracts on Human Factors in Computing Systems (CHI EA '07)*. ACM, New York, NY, USA, 1665-1668.

Komor, N., Gilliland, S., Clawson, J., Bhardwaj, M., Garg, M., Zeagler, C., & Starner, T. (2009). Is It Gropable?–Assessing the Impact of Mobility on Textile Interfaces, *International Symposium on Wearable Computers, ISWC'09* (pp. 71-74). *IEEE.*

Kram R., Grabowski, A.M., McGowan, C.P., Brown, M.B., Herr, H.M., (2010). Counterpoint: Artificial legs do not make artificially fast running speeds possible. *Journal of Applied Physiology*,108(4) 1012-1014.

Kreibich, R., Oertel, B., & Wolk, M. (2011). Futures Studies and Future-Oriented Technology Analysis Principles, Methodology and Research Questions. *HIIG Discussion Paper Series* No. 2012-05.

Kuber, R., Yu, W., & McAllister, G. (2007) Towards developing assistive haptic feedback for visually impaired internet users. *In Proc. SIGCHI*, ACM Press, 1525-1534.

Lindgren, M. & Bandhold, H. (2009). *Scenario Planning - Revised and Updated: The Link Between Future and Strategy*, Palgrave MacMillan.

Lyons, K., Skeels, C., Starner, T., Snoeck, C.M., Wong, B., and Ashbrook, D. (2004). Augmenting conversations using dual-purpose speech, *In Proceedings of the ACM symposium on User interface software and technology (UIST).*

Marconi, G., (1912) *Technical World Magazine*, October, page 145.

Miéville, C., (2010). *The City and the City*, Random House Reader's Circle, 352 pages, Del Rey; Reprint edition.

Miles, I. (2010). The development of technology foresight: A review. *Technological Forecasting and Social Change*, 77(9), 1448-1456.

National Council on Disability (NCD). (2011). *The Power of Digital Inclusion: Technology's Impact on Employment and Opportunities for People with Disabilities*. Washington D.C.: National Council on Disability (NCD).

Plato, Phaedrus, trans. by Alexander Nehamas and Paul Woodruff. From Plato: Complete Works, ed. by John M. Cooper. (1997). ISBN 0-87220-349-2, 228b.

Greig, P., Irvine, J., (2014). Privacy Implications of Wearable Health Devices. *In Proceedings of the 7th International Conference on Security of Information and Networks (SIN '14).* ACM, New York, NY, USA, Pages 117, 5 pages.

Palen, L., Dourish, P., (2003). Unpacking 'privacy' for a networked world, *Proc. Conference on Human Factors Computing. Systems. - CHI '03*, no. 5, p. 129.

Paris, D. G., & Miller, K. R. (2016). Wearables and People with Disabilities: Socio-Cultural and Vocational Implications. *Wearable Technology and Mobile Innovations for Next-Generation Education*, 167.

Profita, H. P., Clawson, J., Gilliland, S., Zeagler, C., Starner, T., Budd, J., & Do, E. Y. L. (2013). Don't mind me touching my wrist: a case study of interacting with on-body technology in public. In *Proceedings of the 17th annual international symposium on International symposium on wearable computers* (pp. 89-96). *ACM*.

Raymond, M. (2010) *The Trend Forecaster's Handbook,* Laurence King Publishing Ltd.

Rhodes, B.J., Starner, T., (1996). Remembrance Agent: A continuously running automated information retrieval system, *The Proceedings of The First International Conference on The Practical Application Of Intelligent Agents and Multi Agent Technology (PAAM '96*), pp. 487-495.

Roth, S., & Kaivo-oja, J. (2015). Is the future a political economy? Functional analysis of three leading foresight and futures studies journals. *Futures*.

Shinohara, K. and Wobbrock, J.O. (2011). In the Shadow of Misperception: Assistive Technology Use and Social Interactions. *Proceedings of CHI*, ACM Press. 705–714.

Starner, T., (1996). Human Powered Wearable Computing, *IBM Systems Journal*, Volume 35 (3), pp. 618-629.

Thorpe, E.O. (1998). The invention of the first wearable computer, *The Second International Symposium on Wearable Computers: Digest of Papers*, IEEE *Computer Society*, pp. 4–8.

Toney, A., Mulley, B., Bruce H. Thomas, Piekarski, W. (2003). Social weight: designing to minimize the social consequences arising from technology use by the mobile professional. *Personal Ubiquitous Computing* 7: 309–320.

Torfing, J., Ansell, C. (2016). Strengthening political leadership and policy innovation through the expansion of collaborative forms of governance. *Public Management Review*, 1-18.

Van der Steen, M. A., & van Twist, M. J. W. (2013). Foresight and long-term policy-making: An analysis of anticipatory boundary work in policy organizations in The Netherlands. *Futures*, *54*, 33-42.

Vinge, V. (2006). *Rainbow's End: A novel with one foot in the future*, Tor Books; 1st edition.

Vonnegut, K., (1961). Harrison Bergeron, *The Magazine of Fantasy and Science Fiction*, October 1961, ed. Robert P. Mills, Mercury Press, Inc.

Warnke, P., Schirrmeister, E. (2016). Small seeds for grand challenges—Exploring disregarded seeds of change in a foresight process for RTI policy, *Futures*, Volume 77, March 2016, Pages 1–10.

Watson, R. (2010). *Future Files: A Brief History of the Next 50 Years*, Nicholas Brealey Publishing, London.

William, D., Wright, M. (2016). Hunting humans: A future for tourism in 2200 *Futures*, Volumes 78–79, April–May 2016, Pages 34–46

Williams M.A., Buehler, E., Hurst, A., and Kane S.K. (2015). What not to wearable: using participatory workshops to explore wearable device form factors for blind users. *In Proceedings of the 12th Web for All Conference (W4A '15)*. ACM, New York, NY, USA, Article 31 , 4 pages.

Wilson J., Walker B.N., Lindsay, J., Cambias, C., and Dellaert, F. (2007). SWAN: System for Wearable Audio Navigation *11th IEEE International Symposium on Wearable Computers*, Boston, MA, pp. 91-98.

Wolf, F. and Kuber, R. (2014). Developing tactile feedback for wearable presentation: observations from using a participatory approach. *In Proceedings of the 16th international conference on Human-computer interaction with mobile devices & services (MobileHCI '14).* ACM, New York, NY, USA, 543-548.

World Health Organization (2014). Disability and Health Fact sheet N°352, World Health Organization, December 2014. http://www.who.int/mediacentre/factsheets/fs352/en/ Accessed 08.06.16.

Wu, M., Baecker, B., and Richards, B. (2005). Participatory design of an orientation aid for amnesics. *In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '05*). ACM, New York, NY, USA, 511-520.

Zeagler, C., Gilliland, S., Profita, H., & Starner, T. (2012). Textile Interfaces: Embroidered Jog-Wheel, Beaded Tilt Sensor, Twisted Pair Ribbon, and Sound Sequins. *16th International Symposium on Wearable Computers (ISWC),* 60-63 IEEE.

Figure 1 above presents a vision of a" familiar future" where wearable technologies are ubiquitous but their individual applications are heterogeneous. Based on needs, context, and personal choice people display (or conceal) their use of technology in different ways. People may also adjust the visibility of their disabilities and their level of technological augmentation depending on environment.

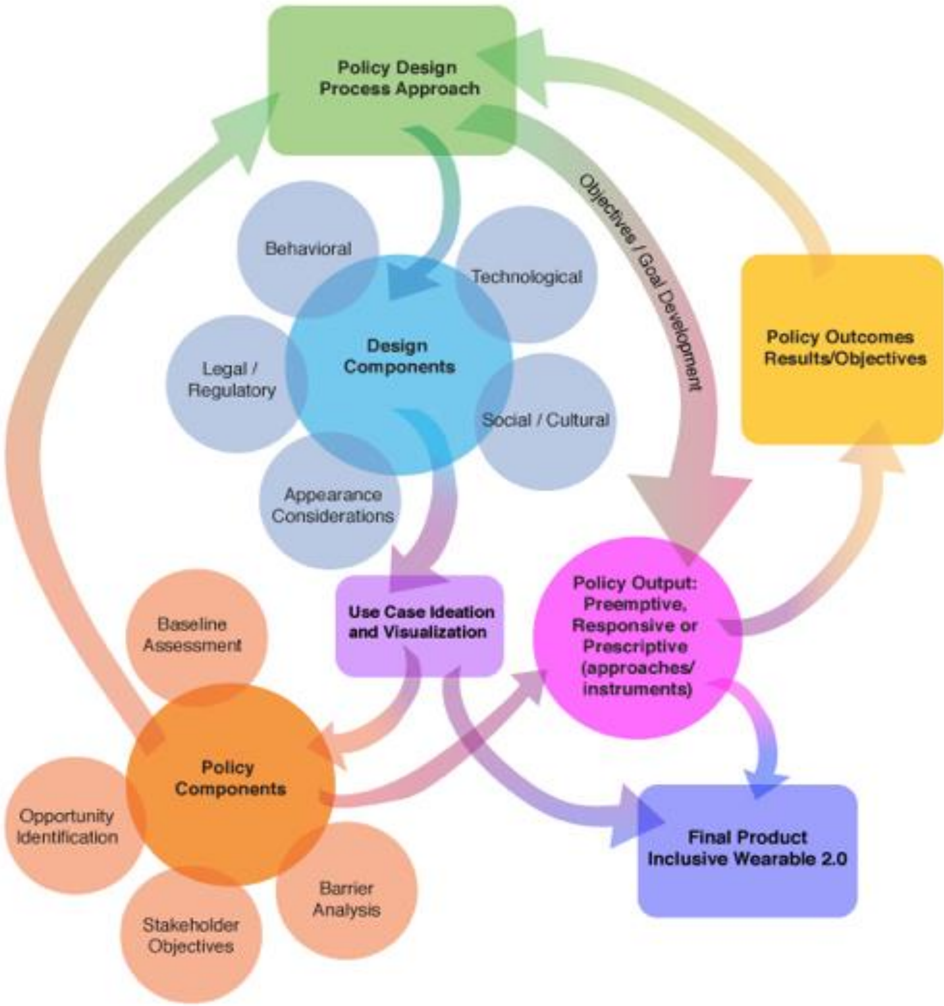

Figure 2. Wearables Policy/Device Design Framework

Figure 3. A stylized representation of a WT in use in the classroom capturing different stakeholders’ perspectives

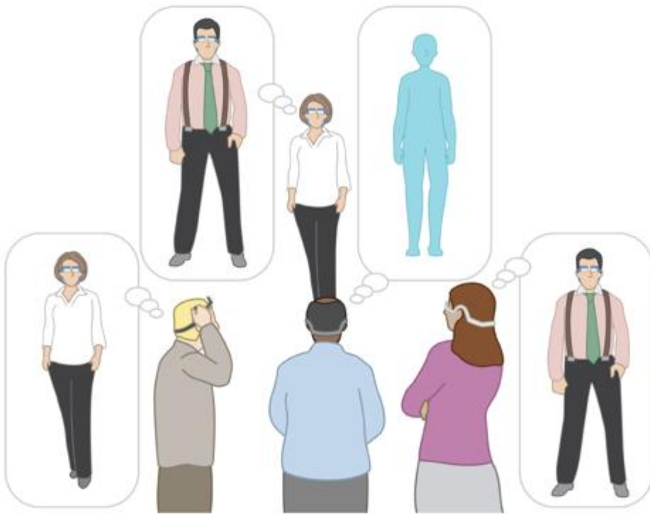

Figure 4. A representation of different stakeholders' experiences with an ICD system, including the wearer and bystanders in the same space