Innovation and Wearable Computing

A Proposed Collaborative Policy Design Framework

The expanding market for wearable computing devices, driven by the confluence of information and communication technology and public acceptance of a design aesthetic, suggests nearly limitless potential for consumer uses. However, designers, technologists, and policymakers often operate independently, leading to products that are out of sync, lack interoperability, or are hindered by well-meaning (but obstructive) policy. Here, a collaborative policy design framework is proposed that will enhance developing wearable devices and guide interdisciplinary collaborators as they explore the various implications and effects of device design in social, technological, and regulatory contexts.

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The rapidly expanding market for wearable computing devices (wearables), driven by the confluence of information and communication technology, availability of wireless access, and public acceptance of wearable designs, suggests a wide range of consumer uses. As device adoption spreads, cultural and social factors can be both barriers and opportunities, with consequential public policy ramifications. But all too often designers, technologists, and policymakers operate independently, resulting in products that are out of sync, without interoperability, and hindered by well-meaning (but obstructive) policy.[1]

Too often devices are designed with technological functions in mind while disregarding the complex social, cultural, and policy contexts they operate within. Normative assumptions of technology use have changed over time, and we can rarely predict how society will respond to and be changed by new technologies. A key characteristic for design, however, is to anticipate new innovations and the resulting sociological impacts. Thus, here we examine the interplay of the design of technology — specifically, wearable computing devices, in terms of the social and cultural systems in which they're used, and potential policy and technological

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barriers and opportunities that impact the design and deployment of wearables. Based on insights generated from multistakeholder policy development research,[2] we identify key components of a collaborative policy design framework that could enhance the optimal adoption and diffusion of wearable computing devices.

Elements of Design: Infrequently Considered Policy Inputs

Design is the first step in the process of developing technologies that can affect the quality of our lives and society in a beneficial way. The design of wearables operates along a number of dimensions that are of specific importance to this domain. When considered at the beginning of the process, these parameters can inform or obviate the need for additional remediation later. These include physical parameters, context of use, privacy and security, conspicuousness, observers' experience, sensory requirements, and regulation, among others.

Physical Parameters

Francine Gemperle and colleagues lay out certain physical guidelines for designing technology for wearability.[3] These guidelines become even more important when viewed through the lens of policy. Designing for physical wearability with an eye toward accessibility should be a goal for any wearable device. This means that weight, heat, and body placement matter, especially when designing devices for people with disabilities, the aging, and other populations with functional limitations.[4]

Context of Use

Much of the cultural acceptance of a wearable device is related to its context of use. A device used by an authority figure, for instance, might seem more threatening or intrusive; conversely, a conspicuous technology that assists a person with a disability might be perceived as less intrusive by people around the wearer, who might accept reduced privacy from wearable sensors if they provide measurable wellness or lifestyle benefits. Thus one design objective might be to indicate via signaling the use being employed.

Privacy and Security Requirements

Somewhat related to the context of use are the concerns over the privacy and security of data; these are arguably the leading issues influencing current wearable technology policy and legislation. The use of the Google Glass devices in public places has resulted in many wearers being banned from locations such as movie theaters, restaurants, and even the Google shareholder meeting due to the presence of a point-of-view camera.[5] The expectations of privacy and security are highly influenced by the context of use.[6] For example, J. Alex Halderman and colleagues discuss how mobile picture taking can be viewed differently even in the same location: a recording in an office meeting could be considered a useful record or an invasion of privacy, depending on the context.[7] Similarly, users willingly accept a potential loss of privacy if the technology's utility is sufficiently compelling; however, this might be built on the incorrect assumption that wearable users are aware of the degree and amount of information they might be trading for convenience of use.

Conspicuousness

As technology becomes mobile and coupled with our physical bodies via wearables, an important design decision is how conspicuous should the technology be? How noticeable is the device to an observer? This aspect has both cultural/social as well as policy import. In the past, the wearable designer might have aimed to make the technology "disappear." For instance, with a device used in an assistive capacity, the approach might have been welcomed by the target user, as she might not wish to advertise her disability. However, as a matter of public purpose (for instance, for law enforcement) it might be desirable for such technologies to be identifiable so that those around a wearable user can be aware of what technologies are present and/or in-use. This would hold true for both legal (regulated) as well as illegal purposes.

Observers' Experience

The design of a new device tends to focus on the user's experience, but the manner in which people adjacent to the user experience and perceive the technology is another consideration.[8] Increased mobile phone use in public over the past decade is an example of technologies that disrupt the environment, or cause users to behave in unexpected ways, and consequently suggest the need for developing new

social norms, as well as additional public policy and legislation. Society changes in unpredictable ways in response to new technologies, and designers must attempt to consider how a wearable device will be experienced by everyone in the environment, or risk the technology's social or legal rejection.

Sensory Requirements

With previous technologies such as the television and personal computer, a designer could assume that the device during use was the user's primary focus. However, wearable devices are often used to *support* the user during a different primary task (for example, working out at the gym, giving a presentation, driving, crossing the street, and so on). Designers must consider the user's cognitive load, and how much of the user's sensory and cognitive bandwidth will be consumed by the interface (including occlusion of the visual field, use of auditory frequency spectrum, or physical space). It's critical to minimize the sensory demands of a wearable and/or understand the effects that use has on the wearers' capabilities, so that the device is designed for safe usage and policies are developed that protect users (and those around them) from harm. The regulation of text messaging while driving is a pertinent example here.

Assistive and Augmentative Technology Policy

Assistive technology is designed to assist the user in completing tasks, and as a design objective, augments a user's extant abilities, especially for people with disabilities. According to the US Americans with Disabilities Act (ADA; see www.ada.gov/pubs/adastatute08.htm), "a person with a disability is a person who has a physical or mental impairment that substantially limits one or more major life activities. This includes people who have a record of such an impairment, even if they do not currently have a disability." But when considered more broadly, assistive technology serves to bridge a gap between capacity and desire. All too often overlooked in the design process,[2] people with disabilities represent a sizable population in the US, and yet are among those for whom such devices would facilitate great social inclusion. For comparison, the World Health Organization (WHO) estimates that about 15 percent of the world's population, or around 1 billion people, live with disabilities, and as such they're considered to be the world's largest minority.[9]

Wearables — as devices that are always on and available — are a key tool for facilitating participation by people with disabilities, and those with varying degrees of ability. Widespread acceptance of mass-market mobile wireless communication technology has been a boon for the community, from not only a cost perspective, but also in terms of social acceptance of capacity-enhancing devices.[2] Hearing-impaired users who traditionally use a teletype (TTY) machine can now text each other using equipment designed for the general public. Video chat over mobile devices allows use of American Sign Language to communicate for the deaf and hard of hearing.

The next step in the evolution of wearables is developing increasingly sophisticated, ubiquitous, and inconspicuous devices. Thus an assistive device that's designed to enhance the abilities of abled-bodied people offers the opportunity to become further *augmented* via technology. It's these innovations that offer tremendous potential to transform our quality of life and our culture in positive and negative ways. As is frequently the case with innovations, they also pose a considerable challenge to designers and policymakers. What social conventions, procedures, public policy, and new legislation will be required in response to this augmentative technology?

Although they're typically referred to as "assistive" and thought of as ancillary, in reality, we already take for granted augmentative technologies commonplace in the lives of persons with disabilities. Hearing aids, crutches, and eyeglasses are all used by the non-disabled population, and they're allowed as an accommodation while working at a job or taking a test. These are generally corrective (or assistive), but slight tweaks to the technology can enhance the capabilities of wearable users beyond the average, or even outside the normal range of capacities. For instance, Thad Starner was allowed by his PhD committee at MIT to use his wearable computer (the focus of his thesis research) during his qualifying exam. The committee debated and 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 as well as his wearable computer. This

is an early example where society had to consider at what point does assistive technology becomes technological augmentation, and consequently cheating or unfair.[10]

Western culture generally accepts technology that assists a user in becoming "normal," but technologies (from pharmaceuticals to mobile devices) that allow someone to exceed their natural abilities can be disturbing, or even potentially illegal in some uses. A host of potential debates will arise as we approach a transhuman future: should an augmentative device be required to be conspicuous such that people will be aware you're using it? What are the ramifications of an employer deciding 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 the capabilities of those more gifted to level everyone's chances (described in Vonnegut's 1961 short story "Harrison Bergeron")? These scenarios might seem like science fiction, but they might not be that far away, and are well within the approach of designers thinking outside the box. This can serve as contextual input into the design of policy.

Policy and the Development of Wearables

A policy is a deliberate plan of action devised to guide decisions and achieve rational outcome(s). *Public* policy can be thought of as "a set of interrelated decisions taken by a political actor or group of actors concerning the selection of goals and the means of achieving them within a specified situation where those decisions should, in principle, be within the power of those actors to achieve."[11] Design is a more creatively driven process, drawing on abstract ideas and exploring them in novel ways. Policy in the traditional sense, "by contrast, is often seen to be more cautious, perhaps incremental, and more circumscribed by the risks of failure."[12] We believe that working together leads to achieving more effective outcomes.

Design operates by taking into account not only the device's use, but also its (mis)use as it interacts with sociocultural context. There are a variety of ways that a new technology can be controlled to avoid negative effects. These include designing for intended use, and the pressure of social conventions, as previously discussed.

Another way is to implement standards, legislation, and regulations. Historically, changes to devices were made after the fact, either to bring them into compliance with a changed regulatory environment, or to add needed functionality. Wearables, particularly those that communicate externally, are regulated under several different standards, depending on the use case under discussion.

In the US, data flow over radio waves is regulated by the Federal Communications Commission (FCC), which concerns itself not only with radio emissions of the device per se, but potential interference with other uses in the vicinity. Although this is a consideration that designers are relatively familiar with, they might be less familiar with other regulations, such as accessibility requirements under the ADA that covers, for example, Web accessibility as a special case of a public accommodation.

It's possible to imagine, and hence to anticipate, that wearable interfaces will be required to be accessible to people with disabilities. Murkier issues surround what could be said to fall between specifically mandated regulation and law created as a consequence of legal cases brought to remedy conditions. This could include perceived (or real) privacy violations, negligence in handling data flow between devices, and potential challenges to social conventions not currently regulated, as technology is typically ahead of application. Here, the value of the approach of instituting teams of designers, technologists, policy specialists, and end users becomes apparent in the adoption of proactive policy design and standards, as was demonstrated to be an effective approach in enhancing the accessibility of wireless devices.[2]

The Wireless Rehabilitation Engineering Research Center (Wireless RERC), funded by the National Institute for Disability Rehabilitation Research (NIDRR), employs components of this approach as part of the process used for developing regulatory filings on accessible wireless technologies for submission to the FCC. Using input from participating stakeholders from the disability community, wireless industry, and policymakers, the Wireless RERC developed a set of policy options and engagement approaches to increase accessibility of wireless devices for frequently overlooked populations. Efficacy of the process is evident in the repeated

citing of the Wireless RERC FCC rulemaking approach, including both the center's basic user research as well as its collaborative partnership with cell phone manufacturers, carriers, and stakeholder groups.[2,13]

In a way analogous to the manner in which designers work, policy can be developed (designed), but with words instead of physical components or attributes. The developers of wearables, by necessity, are concerned with the specifics of the technology and the ways in which wearable computing interacts with other components of the system. With the exception of regulatory requirements, policy considerations tend to be more focused on the impact of the object's functioning on common public resources (that is, the wireless spectrum) and its interactions within the broader social context in which these things occur. In this respect, we think about policy not so much as *regulating* what developers can and can't do, but more as *informing* the general overriding principles that influence the development, deployment, and use of a given technology. Regulations are only one of several instruments in the toolkit of policy design, along with standard setting, stakeholder input, and public-private partnerships, to name a few examples.

A pertinent example of the complexity of policy and regulation in this domain is the case of hearing aids — an older type of wearable computing device. The Food and Drug Administration (FDA) regulates hearing aids, as medical devices, in the US. And, as a standalone device, this is fine. But in typical use, they interact with other technologies, such as cell phones. Cell phones are regulated by a totally different agency, the FCC. A problem arises if the regulatory standards governing these devices aren't developed in consultation, resulting in what could be called policy (in)operability. In this case, the devices were perfectly compliant with both regulatory agency standards, but due to lack of interagency (and interdomain) regulatory coordination, there were problems for the user. Ultimately it was resolved, but not without a lot of delay and expense for all concerned, as well as a potential deterrent to consumer adoption. It's also an example of the desirability to establish certain routine approaches to thinking through the problem in advance, including what kinds of characteristics wearables have and how they interact, not only with themselves but with the environment and social context surrounding them. Recognizing the problems of remedying this kind of device incompatibility was one of the impetuses to explore new policy design approaches.[2,14]

Policy Issues, Barriers, and Opportunities

It's useful to think of policy and design by looking at it from a designer's perspective. Many design parameters deal with contextual issues and associated barriers to deployment, as well as opportunities to facilitate device adoption. Issues include those of technology (for example, infrastructure hardware and software); usage (for instance, medical devices might require different oversight[14]); context (education, workplace, public, private, social, and online environment versus physical environment); jurisdiction or venue; and broad sociocultural considerations (including privacy, access, and security).

Device communication with the environment. Much of the concern expressed in public discourse is with devices sensing the environment and getting private information about the observed, or that a wearable might transmit personal information to an undesired location without the user having knowledge of the receiver, or the user being unaware that data are being shared at all.

Fidelity, information filtering, and selection. Another general assumption held by many users is that the information collected (that's sensed through the technology) is neutral — that is, that the technology objectively and accurately records "reality" (so far as it's objectively knowable). However, given the incredible degree of personalizability and malleability of digital data, this might not be the case. How can we assume fidelity of transmission, or trust, in the systems used?

Guidelines for displaying information. As wearables become not only common, but increasingly relied upon for everyday living, what are the legal ramifications of wearables' information display, which while accurate, might be misinterpreted by the individual? Or what if the device is incorrect? This ranges from the information's accuracy to its presentation and display, including the rate and nature of updating data in a dynamic mode. This is especially pertinent when wearables are used in an assistive manner (such as by people with disabilities). Thinking ahead,

considering the case of augmented reality, what kinds of accessibility will be necessary for the display (or conveyance of data)?

Regulating and trusting data. What policies and regulations or industry standards could be developed for the wearable systems so that all parties are protected? We see a number of potential parties of interest, including the user, device manufacturer, information source, regulators (either public, private, or a combination), and the user's caregivers. Developing these types of guiding policy instruments could occur in a variety of forms: public (at the state, federal, or international level — in the US, the FCC is an example, or the International Telecommunications Union is an international example); nongovernmental organizations (NGOs) or trade groups (Underwriter Labs or ICANN), and the industry/marketplace (such as the IEEE 802.11 wireless standard). Further requirements in the US include accessibility (such as ADA compliance), or potentially the FDA (if data bleed over into medical device use).

Proposed Framework for Wearable Policy Design

Our proposed wearables policy design framework (see Figure 1) is a process starting with the assumption that a design-thinking approach will yield more flexible policy outcomes. The process starts with an initial stage that considers typical design components, including appearance, behavioral considerations, technology, and sociocultural factors. This provides an "object" that designers can use to test against regulatory and legislative requirements. The second stage provides a comparable policy analytic approach: conducting a policy and contextual baseline assessment to determine what condition currently exists; a barrier and opportunity analysis, which building on the baseline assessment articulates potential barriers to wearable device development and distribution; and complementary opportunities that might be used to facilitate device development. Subsequently stakeholder input is solicited, and at this point the process merges with a design-thinking approach, considering users' needs.

A key component of policy design is articulating conditions, mechanisms, and outcomes to help the stakeholder identify or at least be aware of the potentials of devices and software. The expansion here is to consider that "users" in a policy context include policymakers and regulators, industry representatives, and standard-setting bodies. Efficacy of the approach will be evident in a reduced need for regulatory filings, and an expected increase in non-formal industry and multisector collaborative activities.

As a rule, the standard approach to development of policy can be organic — that is, as naturally emergent from the traditional policymaking process, or by design, by a range of stakeholders that can be public, private, or individual. In general, it's a distinct process not always involving those impacted, such as end users or developers, although US governmental agencies are increasingly making concerted efforts to open the regulatory process to be more inclusive. This is, however, still "after the fact."

Anticipating this, the third stage of the framework focuses on actual policy design and initially articulating objectives, outputs, and potential (anticipated) outcomes. Drawing on insights offered from the design input components to help craft policy scenarios, and coupled with the baseline policy assessment, collaborators explore team-based development possibilities using parallel processes focused on searching for new and creative possibilities, while policy specialists address regulatory and legislative constraints.

Overlaying unconstrained design scenarios with a map of constraints imposed by regulatory considerations lets the designer articulate alternatives that creatively address the potentials of new technologies while avoiding pitfalls that could derail progression if not recognized until later in the design process. Although this part of the framework is focused specifically on the wearable (policy) design process, an expansion of the model focuses outward at continued engagement with users, to help anticipate potential objectives. By employing design thinking to generate alternative scenarios, then the designer can anticipate and address the end users' potential objections, concerns, and even expectations. On the assumption that at least some of the concerns related to technology adoption are driven by ignorance or false perceptions, industry-sponsored outreach and awareness campaigns could be devised to help wearable users develop an understanding of the impacts of technology use, and ways of maintaining control of the technology. In this case, users can be seen as participants in the broader deployment process rather than simply being subject to technological change.

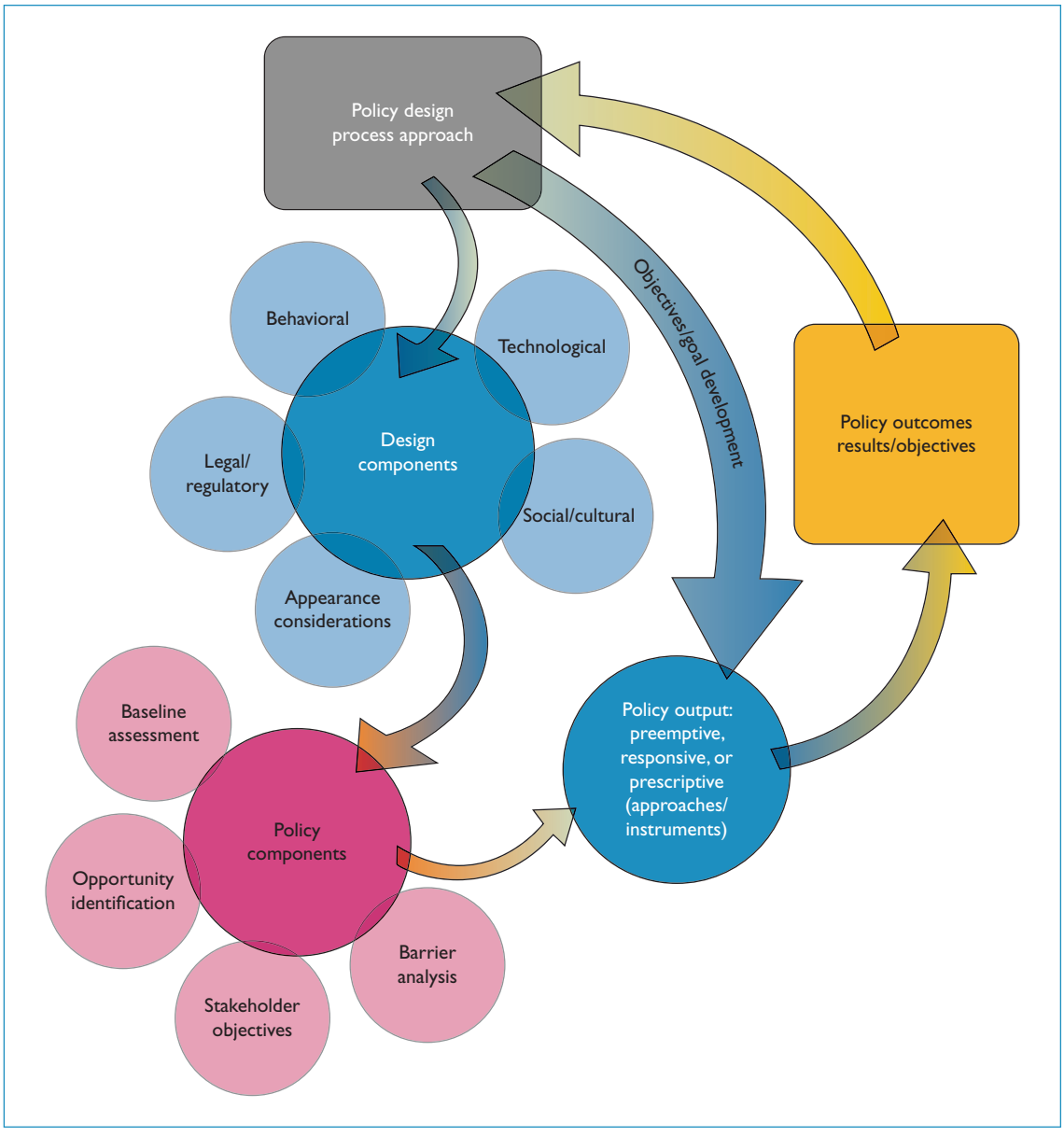

Figure 1. The wearables policy design framework starts with an initial stage that considers typical design components, including appearance, behavioral considerations, technology, and sociocultural factors. In addition, policy considerations are factored in as part of the initial design conception rather than after the prototypes have been built.

The final stage of the proposed model is evaluation and feedback. As feedback comes from users and other stakeholders in the policy 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 or employs other policy-driven engagement and outreach approaches to address users' concerns or respond to regulatory bodies. Evaluation components would include usability testing and stakeholder focus groups, which developers could use for input into regulatory filings.

The policy design process we outlined is as yet untested as proposed, although most components have been employed in discrete, domain-focused manners,[2,13] and we're testing the idea by applying the model to the development of a proposed large engineering research center focused on wearable technology. We've examined critical components of a design-thinking approach,

which isn't generally considered in a traditional policymaking process. The framework brings into conversation the designer's focus on function, utility, and the social and cultural systems in which they're used, with the constraints generated by potential policy and technological barriers and opportunities that impact the design and deployment of wearable technologies. Developing a large, multidisciplinary center focused on wearable technology represents an ideal test bed for the collaborative policy model we propose. The development itself employs tools of the proposed framework in that it engages policymakers, engineers, and social scientists in the organizational design process. Changes in the objectives, processes, and focus of the proposed center that occurred as a result of the collaborative process reinforce our proposed collaborative policy design framework as an effective approach to generate new options to enhance the effective development, adoption, and diffusion of wearable computing devices.

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