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Abstract:

The Internet of things (IoT) has unlimited potential to empower the lives of everyone. IoT devices increasingly appear in homes and power smart and connected communities. Related user experience design efforts must involve and consider people with disabilities, including the world's rapidly aging population of seniors. They must be able to use IoT device and app interfaces. While secure and private IoT device data collection and communication are important for everyone, related needs that are unique to people with disabilities must be addressed. Many current resources and developing efforts that can benefit UX designers to address these needs exist.

Keywords: Accessibility, Universal Design, User Experience, UX, Internet of Things, IoT, Smart Cities.

1 Introduction

The Internet of things (IoT) has unlimited potential to empower the lives of the world's citizens with disabilities, which includes the rapidly aging population of seniors. The IoT enables people with disabilities to live independently and ameliorate loneliness. To harness such potential, user experience (UX) design must include easy-to-use interfaces, privacy, security, and fairness for all. Without all four, the IoT will experience significant limitations in its growth.

UX designers must design IoT device and app interfaces so that all people can use them regardless of their situation, abilities, or context. An Industry Organization for Standards (2008) standard defines disability not as a personal trait but as a mismatch between people and their environment. This definition means paying attention to universal design can benefit everyone not only because all people acquire disabilities as they age but also because, by the ISO definition, all people experience disabilities in their daily lives. For example, in a noisy airport, people cannot hear important announcements but can see them instead via closed-captioned displays.

1.1. How the IoT Can Best Work for People with Disabilities and Everyone

The United States Centers for Disease Control (2018) estimates 25 percent of the U.S. population has a disability. The World Health Organization (2018) estimates 15 percent of the world's population (about one billion people) have disabilities. UX designers have an important role in making sure their organizations do not exclude these large populations as customers by ensuring they can use IoT device and app interfaces. Doing so reduces difficulty and encourages usage and retention by everyone.

1.1.1 Independent Living

Independent living is important for people with disabilities, which includes seniors. An independent life means they control the services they receive and who provides them and can work to afford them. Independent living is also important for society. High levels of care have high costs. The longer people with disabilities can live in their own homes and communities, the less they need to use expensive long-term services, such as assisted-living facilities. Medicaid, the largest health insurer in the United States, has estimated that long-term services and support comprised 20 percent of the US$553.8 billion total federal and state Medicaid spending (Medicaid, 2016). The IoT plays an important role in significantly mitigating these expenditures.

The IoT increasingly enables independent living. For example, IoT devices can detect motion, temperature, and air quality to help measure people's health. For the world's seniors and other people with disabilities, IoT devices can help monitor their health and activities of daily living. The data IoT devices collect can determine when people need medical help. In Japan, IoT devices are being used with its rapidly-aging population of seniors to control diabetes, such as with blood pressure monitors, pedometers, and body composition monitors (Forbes, 2018). IoT devices can detect falls and alert family members and caregivers. On a simple level, IoT sensors in apartment doors in assisted-living facilities can provide unobtrusive monitoring: if seniors do not open their doors by noon, staff can check on their wellbeing.

1.1.2 Loneliness

Independent living also ameliorates the loneliness people experience when they cannot live in their homes and communities or live in them in isolation. Isolation contributes significantly to poor health and a lack of happiness. Five years ago, in Japan, talking dolls started to become increasingly popular to help seniors ameliorate their loneliness and help with dementia while living in their own homes and communities (BBC, 2014). These dolls have the potential to be IoT devices that detect falls and monitor cognitive and physical health. Involving seniors in user experience design will help them embrace such technologies. For example, researchers in Australia supported seniors to lead the design of IoT devices by determining IoT interface qualities they would like and by experiencing IoT elements in familiar environments (Ambe et al., 2019).

Businesses and schools deploy robots, optimized for human interaction with conversation and touch screens, that welcome people, inform them, and help them navigate buildings (SoftBank Robotics, 2018). Robots also help children with autism learn to recognize and mimic facial expressions to interact with people and, thereby, mitigate social isolation (RoboKind, 2019). UX designers have the unique position to improve and develop interfaces and interactions of such devices and their apps.

1.1.3   UX Accessibility

For the user experience of people with physical and/or cognitive disabilities, IoT device interfaces and apps should conform to universal design guidelines. The United States General Services Administration (2017) defines universal design as "The design and composition of an environment so that it can be *accessed, understood* and *used to the greatest extent possible by all* people regardless of their *age, size, ability* or *disability*" (emphasis in original). Universal design principles include flexibility, simplicity, and perceivability. They match well to accessibility principles, which serve as the foundation of the international Web content accessibility guidelines (WCAG) set by the Worldwide Web Consortium (2019a). These guidelines constitute laws in 40 countries (Worldwide Web Consortium, 2019b), which includes the United States (United States Access Board, 2018). UX designers following the WCAG not only reduce the risk their organizations will experience lawsuits (Feingold, 2019) and bad publicity but also make their IoT device interfaces and apps more usable by everyone.

One can inexpensively and easily implement conformance to universal design and accessibility guidelines if one builds it into IoT device and app interfaces from the start. Such conformance is expensive and difficult when trying to retrofit it in later design stages. The United States General Services Administration (2019) and the Worldwide Web Consortium (2019a) respectively have great resources for UX designers to learn about and implement universal design and accessibility guidelines.

1.1.4   UX Personalization and Performance

Personalization of IoT device and app interfaces enable a user experience customized in real time to meet their needs and expectations related to functionality and information. Interfaces absolutely require personalization. Companies and organizations that do not personalize will not achieve success in the marketplace. Thus, UX designers must develop IoT device and app interfaces that work for and engage everyone, which includes people with disabilities.
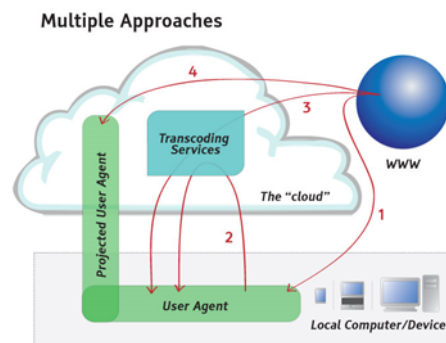

Figure 1. GPII-supported Models (Global Public Inclusive Infrastructure, 2011)

An international effort known as the Global Public Inclusive Infrastructure (see https://gpii.net) is developing cloud-based, auto-personalized IoT device interfaces and apps (user agents) based on user needs and preferences. IoT devices will recognize people, work with any assistive technology, and instantly conform their interfaces to people's preferences stored in the cloud. For personal computers, a GPII prototype known as Morphic enables users to save preference settings in a secure, private, cloud vault and have those settings instantly applied (Morphic, 2019).

Personalization includes performance. UX designers must design IoT device and app interfaces so they do not depend on real-time communication with cloud-based infrastructure. If interactivity starts slowly, assistive technologies people with disabilities use, such as screen readers, will not function immediately. Slow interface interactivity constitutes a user-experience problem for everyone.

Some standardized and emerging technologies can help. For example, an IoT protocol known as Message Queuing Telemetry Transport enables intermittent connections "because of its small size, low power usage, minimized data packets, and efficient distribution of information to one or many receivers" (MQTT, 2019). As another example, the Mozilla Developer Network (2019) has been experimenting with a network information application program interface (API) that "provides information about a system's connection in terms of general connection type (e.g., 'wifi', 'cellular', etc.). This can be used to select high definition content or low definition content based on the user's connection.".

1.1.5   UX Security and Privacy

For IoT devices, security and privacy includes direct access to the devices themselves, their interfaces, their apps, and their transfer of data via home networks and cloud-based infrastructure. An estimated 64 billion connected IoT devices will exist worldwide by 2025 (Techjury, 2019). Designers did not develop the vast majority with security and privacy in mind. They collect, analyze, and transmit unencrypted data—even about how our bodies work. In 2009, at the advent of the IoT, computer scientists found over a million insecure embedded IoT devices worldwide (Cui, Song, Prabhu, & Stolfo, 2009). Today, ten years after that warning, an insulin pump that Medtronic and the U.S. Food and Drug Administration developed without encrypted data transmission provides a good example. Researchers demonstrated an attacker could remotely withhold insulin or cause a lethal overdose (Newman, 2019). Thus, UX designers need to build secure IoT device and app interfaces.

Figure 2. Unlocked Lock For Open Data (McMurry, 2019)

In studying 81 IoT devices, including ones from Amazon and Google, Ren et al. (2019) found that most "lack[ed] any interfaces that indicate information exposure". UX designers could address this deficit via visual affordances, such as with the symbol of an unlocked lock, to indicate exposed information. Such transparency for users engenders trust and reduces confusion.

UX designers who design IoT device and app interfaces for an international audience must recognize security and privacy laws. In effect since 2016, the European Union's General Data Protection Regulation levies heavy fines against non-compliant organizations. UX designers can avoid such fines with the help of "Privacy and Data Protection by Design" (European Union Agency for Cybersecurity, 2015), a report touted "as a first step towards a design process for privacy-friendly systems and services".

UX designers must build with security in mind because to not do so means users may not have faith in IoT devices and may even fear them. An international survey to determine what matters most when people purchase IoT devices included the following found that (Internet Society, 2019):

- 75 percent of people distrust the way organizations share data

- 63 percent of people find connected devices "creepy"

- 50 percent of people know how to disable data collection, and

- 28 percent of people who do not own a smart device will not buy one due to security concerns.

As a legally blind person, I rely heavily on technology to help lead an independent life. I have 14 Alexa devices in my home. With these devices, I can use my voice to control the dozens of other IoT devices that I possess and cannot otherwise use because their designers did not develop them to be accessible to people with disabilities. However, these devices come with a significant downside. I have traded privacy for convenience. The Alexa devices upload my commands and conversations to Amazon's cloud infrastructure to analyze and, thus, improve my interactions with the Alexa devices.

New efforts to ameliorate this privacy issue include Solid, which Sir Tim Berners Lee, the inventor of the Internet, leads. With Solid, users can give their IoT apps permissions to read or write pieces of their data, decide where to keep their data, and decide who and what can use their data (Solid, 2018a). Using this technology also benefits UX designers because they create apps without first harvesting massive amounts of data, and their apps can leverage Solid data that already exist (Solid, 2018b).

1.2   Smart Cities and Connected Communities

The United States National Science Foundation (2017) defines (and funds efforts for) smart and connected communities as communities "that synergistically integrates intelligent technologies with the natural and built environments, including infrastructure, to improve the social, economic, and environmental well-being of those who live, work, or travel within it". Smart cities are urban areas that use IoT devices to collect and

analyze data to manage resources and enhance the quality of life for all people. Connected communities enable people to live happy, healthy lives, ameliorate loneliness, help each other in times of great need, and collaborate about issues that matter to the whole community.

Smart Cities for All helps cities discover and develop information and communications technology (ICT) for people with disabilities including seniors by being inclusive and accessible by design. This effort includes a free toolkit, in multiple languages, to help urban planners (and UX designers) determine the benefits of accessible ICT (Smart Cities for All, 2017).
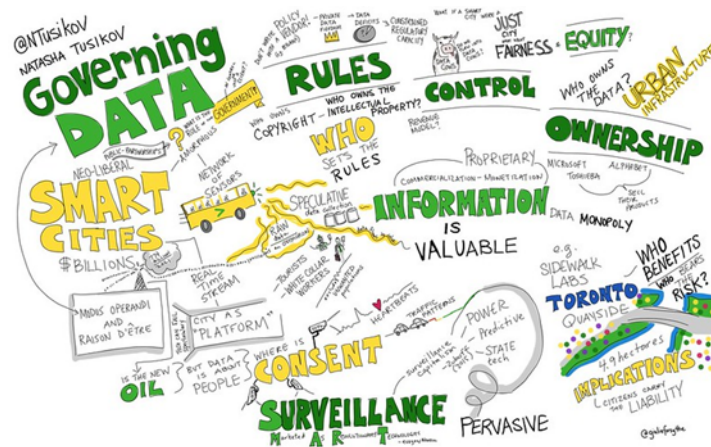
Figure 3. Smart Cities Data Governance (Forsythe, 2018)

1.2.1   Examples of Smart Cities

Many international smart-city efforts exist. The Government of India (2015) launched a large one called the "100 Smart Cities Mission" in 2015. It is one of the few such efforts that emphasize that smart cities "always put people first".

Sidewalk Toronto—a partnership between Alphabet, Google's parent company, the tri-government agency Waterfront Toronto, and the local community—represents perhaps the first attempt in North America to develop a smart city. It seeks to create a "global model for combining cutting-edge technology and great urban design to dramatically improve quality of life" (Sidewalk Toronto, 2017). To accomplish that goal, the Sidewalk Toronto partnership has begun developing a construction process to foster faster and predictable projects and expansions to affordable-housing development and public transportation (Sidewalk Toronto, 2017).

All smart cities require embedded IoT devices, such as sensors, and apps for their governments, businesses, and the people who live in or visit smart cities to use. All IoT devices, their interfaces, their apps, and their data connect with cloud-based infrastructure, which presents an enormous opportunity for UX designers. Designers who embrace the diverse needs of all people, and include them in the development process, will be in a strong position to contribute.

1.2.2   Smart Cities Conundrum

Society benefits the most when data sets that IoT devices use represent outliers, such as people with disabilities. Yet, people with disabilities have strong incentives not to identify themselves. Of course, people with disabilities often become outliers in data sets commonly by their own choice. They do not identify themselves as people with disabilities due to discrimination they experience. Examples include denied employment, higher insurance costs, and housing discrimination. Many organizations use IoT devices data to serve the average person, yet the average person does not exist. Average represents only a mathematical construct. Thus, we are all outliers, which should serve as a strong incentive for UX designers to include people who have difficulty with their IoT device and app interfaces in the development process.

Treviranus (2018) provides a great example for why UX designers must include outliers, such as people with disabilities, in the development process. She has voiced concern about Sidewalk Toronto and, in

particular, "about what smart systems do with people that deviate from the norm or average" (Treviranus, 2018). The Canadian Ministry of Transportation gave her access to machine-learning models of autonomous cars (i.e., large IoT devices). Subsequently, she introduced to their training data the minimal-data use case of one person crossing an intersection by propelling a wheelchair backward (common for people with, for example, cerebral palsy). All the models killed (virtually ran over) the wheelchair user. When she then exponentially represented that use case in the training data, all the machine-learning models killed the wheelchair users with greater confidence. She speculated the machine-learning models "decided, based on the average behavior of wheelchairs, that wheelchairs go in the opposite direction".

1.3 Conclusion

UX designers have a lot to consider when developing IoT device and app interfaces. To help ensure the IoT work for all users and that users trust it, UX designers must build IoT device and app interfaces with accessibility, universal design, security, privacy, and fairness in mind. However, UX designers cannot do so on their own because they cannot count on their own experiences and knowledge to represent all people. Thus, development must involve outliers, such as people with disabilities. That and taking advantage of the described current and developing efforts will mean the IoT will work for everyone, including people with disabilities. The worldwide community of people with disabilities has a saying: "nothing about us without us".

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John Rochford has spent his entire career serving people with disabilities, especially those with intellectual disabilities and/or autism. He is a Program Director and a Faculty Member at the Eunice Kennedy Shriver Center, University of Massachusetts Medical School. He is an Invited Expert of the World Wide Web Consortium's Web Content Accessibility Guidelines Working Group; Cognitive and Learning Disabilities Accessibility Task Force, Low Vision Task Force, and two community groups. He has led teams of information-technology professionals to build accessible websites and online courses since the mid-1990s for state and nonprofit agencies serving people with disabilities throughout the United States. With partners including Worcester Polytechnic Institute and IBM Age and Ability Research, he conducts research and development of artificial intelligence (AI) driven web text simplification on a mass scale. He is a member of the U.S. State Department's American Expert Speaker Program, focusing on AI and disability empowerment and fairness.

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