THE USER EXPERIENCE OF THINGS

Why Ubiquitous Sensing and Software Require a New Approach to User Experience Design

A research report containing inputs from more than 23 ecosystem leaders

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Executive Summary

The disciplines of 'User Experience' (UX) and Human–Computer Interaction (HCI) were born decades ago, in a world of mainframes, industrial machinery, and large desktop computers. Yet our notion and understanding of ***what it means to interact with computers*** is transforming radically. Together with it, the need to re-think user experience design.

First, our interactions are shifting from laptop to mobile, and increasingly across other devices and connected form factors. As we add sensors and connectivity to our bodies, appliances, homes, cars, buildings, machines and just about everything else—a phenomenon often called the 'Internet of Things' (IoT)— interaction with the Internet grows evermore indistinguishable from interaction with our physical world. Second, software innovation is expanding rapidly as more robust processing power paves the way for significant advances in artificial intelligence, deep learning, natural language processing, computer vision, and beyond. These advancements offer altogether new modes interaction with devices like voice, gesture, and motion recognition, among others. Consumers' expectations are shifting too: always on, always accessible, and always easy. App culture, graphical user interfaces (GUIs), social media, ubiquitous Wi-fi are rapidly recalibrating consumers' demand for real-time and decreasing tolerance for clunky, high friction interfaces and brand experiences.

To meet these demands, businesses face ever-growing pressure to 'digitally transform'—even if they aren't entirely sure what that means. Architecting innovative and sustainable data-driven business models across an ecosystem of partners, while preserving customer and shareholder value, is no small feat, particularly for analog product companies accustomed to product-centric revenue models. Complexity mounts as more and more systems, services, and devices come online and the data they wield must be ***managed, analyzed, and secured***.

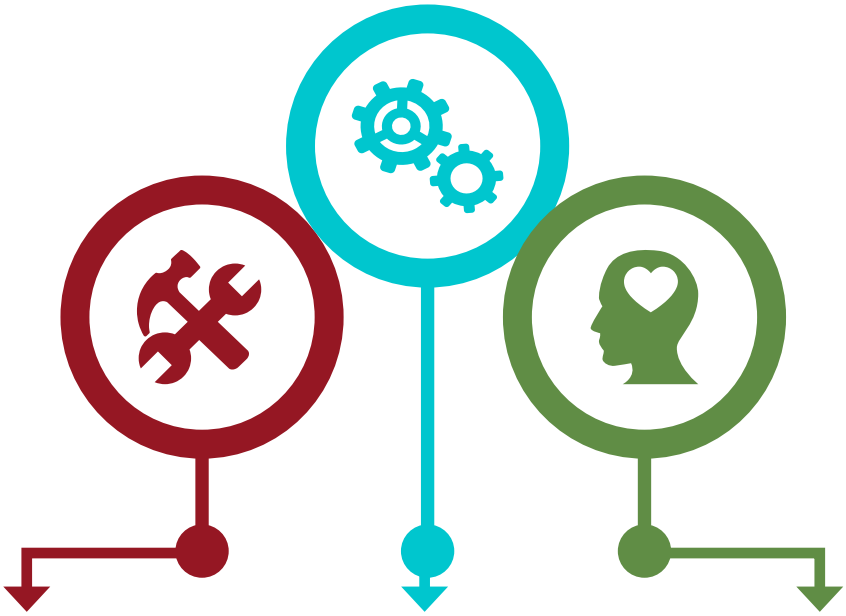
The result of colliding technological, social, and business forces is the imperative to re-think of the role and development of UX. To effectively design any connected product or experience is to design the coordination of a whole system—not just a product. In the digital era, savvy designers are developing products that ***enable*** other companies' products; interfaces that can be built upon; hubs of value in which other companies in the ecosystem increase their own products' value by integrating with yours.

While product leads typically spearhead these efforts, our research finds significant collaboration and alignment across other business functions and partners, never mind end users, is essential. This research provides product leaders, executives, and innovators guidance for re-thinking product programs, and includes new frameworks for user experience design and product development in a connected world.

CHAPTER 1

What is User Experience? (UX)

"User Experience" is the sum of our relationship with a product, company, service, or system. It encompasses the practical, technical, and emotional sum of this relationship.



PRACTICAL

How interaction occurs—which senses, gestures, and inputs we use to interact with our devices and surrounding environment

TECHNICAL

The technological componentry—materials, hardware, software, firmware, protocols, etc. that form and enable interaction

EMOTIONAL

How the interaction makes us feel, encompassing emotions, perceptions, physical and psychological responses, behaviors before, during, and after use

The fate of any interaction—product, service, brand, system, or otherwise— begins (and ends!) with user experience it creates (or destroys!).

Our physical world is becoming a landscape of recordable interactions; of innumerable instances of exchange between any two or more people, objects, events, locations, or companies. This 'Interaction Economy,' (an ecosystem of data-driven services, if you like) is powered by these exchanges, wherein data is the primary and constant currency of exchange, innovation, and value.

CHAPTER 2

Why is UX Different in the Internet of Things?

What the Internet of Things introduces -- or better said, ***unites*** -- is data, interactions, and the physical world. But coordinating these to deliver great UX is easier said than done. Connected devices and infrastructures introduce their own unique complexities that often create new friction to user experience. Using a connected thermostat, for instance, is only a better experience than a regular analogue thermostat if it's easier, more efficient, and offers something valuable the old version did not. The second it freezes, misfires, goes down, requires too many decisions or steps to use, or worse, threatens privacy, security, or trust, its value evaporates. Indeed, many manufacturers have struggled to bring connected products to market because of just how complicated development and management are, never mind the risks of botching customer relationships as a result.

First, connected products are not singular objects, but inherently require a system to function. They tend to exist within much larger networks of devices, many of which originate from different manufacturers. In consumer contexts, this might be a connected door lock interacting with other in-home products like lightbulbs, a security system, and smart thermostats. In industrial or municipal environments, this could include thousands of streetlamps which need to be integrated with parking meters, environmental sensors, traffic systems, and so on. Even at the most basic level, most IoT services include one more devices, a gateway device, an associated cloud service, and some range of applications running on other devices in order to function as intended. When each part of the system is working, the system is invisible, but even when one part falters, the laps can significantly impact UX. The design of these systems is now synonymous with the design of the connected product.

Second, connectivity and networking can be tricky; reliability isn't impossible, but it may be costly. Design configurations at the technical level can make or break integration requirements. Depending on the use case, different implementations require different types of networking (e.g. Wifi, Bluetooth, Cellular, Zigbee, Thread, LPWAN, LoRa, etc.) as well as different connectivity protocol (e.g. MQTT, HTTP, XMPP, CoAP, DDS, AMQP, etc.).[1]

FIGURE 1: POSTSCAPES ORGANIZES IOT-RELATED PROTOCOLS INTO 8 CATEGORIES ACROSS THE STACK

1. **Infrastructure** (ex: 6LowPAN, IPv4/IPv6, RPL)
2. **Identification** (ex: EPC, uCode, IPv6, URIs)
3. **Comms / Transport** (ex: Wifi, Bluetooth, LPWAN)
4. **Discovery** (ex: Physical Web, mDNS, DNS-SD)
5. **Data Protocols** (ex: MQTT, CoAP, AMQP, Websocket, Node)
6. **Device Management** (ex: TR-069, OMA-DM)
7. **Semantic** (ex: JSON-LD, Web Thing Model)
8. **Multi-layer Frameworks** (ex: Alljoyn, IoTivity, Weave, Homekit)

(SOURCE: POSTSCAPES.COM)

"Making connected products *just work* is hard," shares Renee Neimi, head of smart home business at Logitech. "Simplicity requires companies make super hard choices at every level—user, options, technology, function, workflow. What you choose to do is as important as what you don't do."

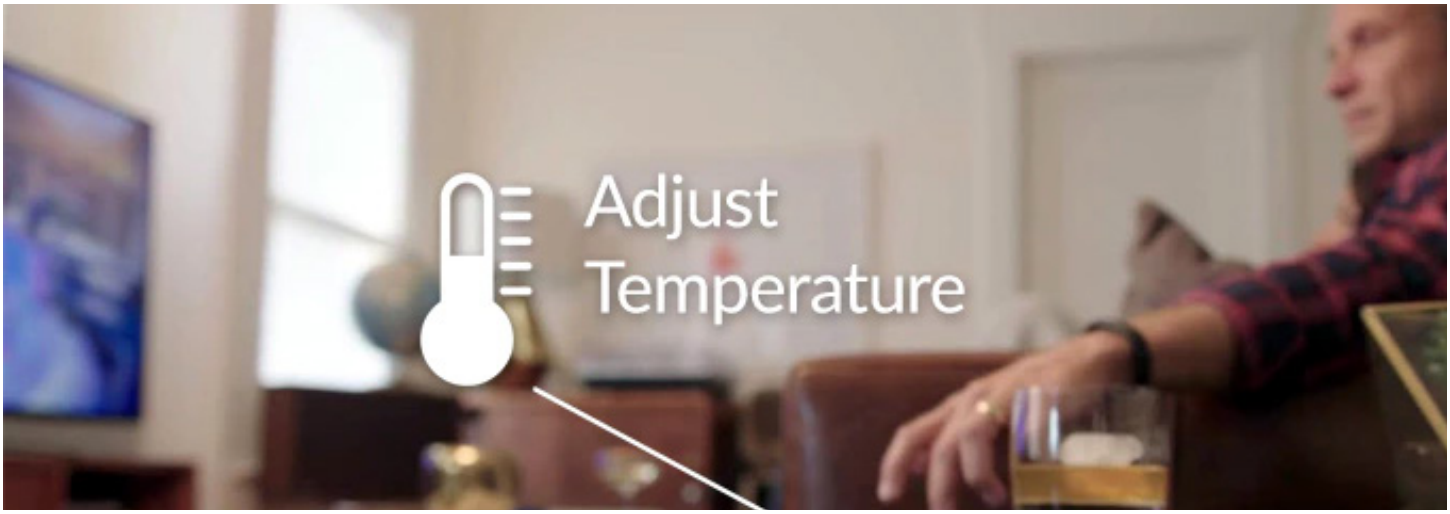
From a user experience perspective, what this alphabet soup spells is a dire need for interoperability between devices, an enormous challenge in the IoT space today. During the development of connected products, engineers are tasked with making numerous technical decisions that will underpin the device's ability to interact with other devices, networks, and systems, and so should be viewed as essential UX decisions.

Application programming interfaces (APIs), connectivity protocols, and even power/energy sources are examples of critical collaboration points for UX designers and engineers. APIs in particular allow for data from one device to be used in applications for other devices. Interoperability isn't just about data, it also carries design implications: if the design of the API doesn't align with other UX requirements, the utility of the product can be compromised or altogether too limited to justify adoption.

The imperative for interoperability nods towards another distinction when it comes to building for UX with IoT products. Developing user empathy is a matter of understanding current pain points. Yet, many connected product experiences lack real precedent, or what precedent exists does not include the characteristics made possible through sensors, actuators, screens, or integrations.

For instance, the Knocki is a small wireless device that converts ordinary surfaces like walls, tables, doors, etc. into control interfaces. Knocki-enabled surfaces allow users to trigger specific requests just by tapping or knocking simple patterns anywhere on the surface. Via mobile app, users can define what specific actions are triggered by specific tap patterns. Through integrations with a variety of connected devices and software services, users can program complex requests like knocking twice to automatically push snooze on the alarm and start the coffee maker, tap the coffee table to turn on the TV, or simpler ones like tapping a gesture to locate a lost smartphone.

FIGURE 2: KNOCKI: AN INTRIGUING PRODUCT WITHOUT CLEAR PRECEDENT



(SOURCE: KNOCKI)

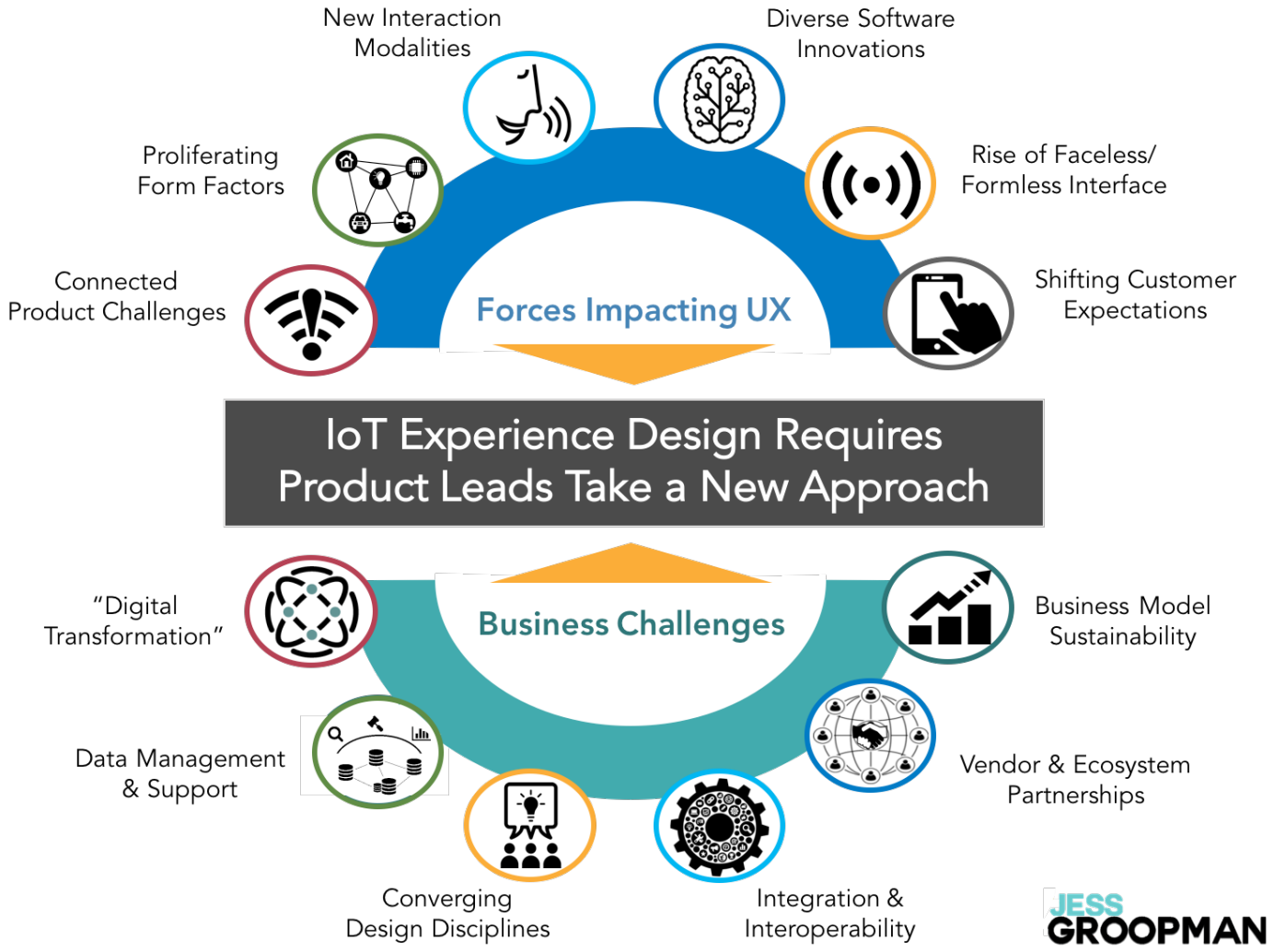
Third, our research finds that connected devices are rarely a 'set and forget' initiative. Manufacturers' work doesn't end at the point of sale, but instead connected products require ***ongoing*** support, security and performance monitoring, and new governance structures to uphold customer expectations and trust. Since experience is indeed ***the sum*** of practical, technical, ***and emotional*** interactions, the management and coordination across stakeholders is foundational to delivering effective UX in the IoT.

CHAPTER 3

Trends & Forces Impacting User Experience Design

Beyond the unique considerations for connected product design, a number of other forces are rapidly influencing the opportunities, challenges, and tools businesses must negotiate in their quests to digitally transform. Our research finds the following forces are accelerating businesses' imperative to re-consider experience design.

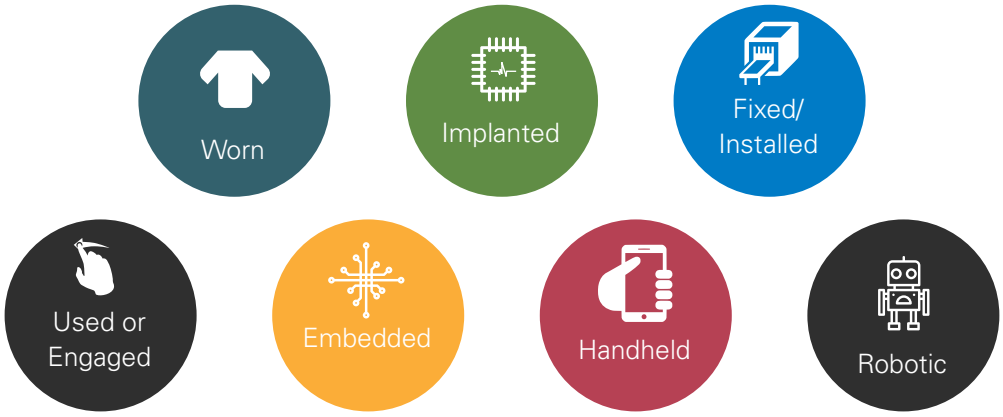
FIGURE 3: TRENDS & FORCES IMPACTING USER EXPERIENCE DESIGN



1. Connected Form Factors Are Proliferating

As costs to connect to the Internet decrease, the number of 'things' to which we're attaching sensors and connectivity protocol has skyrocketed. No longer are computers limited to desktops, laptops, tablets, or even smartphones, digital cameras, or kiosks. Connect[able] objects are as diverse as anything with a physical form. This represents a sea change for the manufacturing sector. In 2016, some 80% of product manufacturers — producing everything from wind turbines to toys—are already planning to or already underway with connecting their previously analogue products.[2]

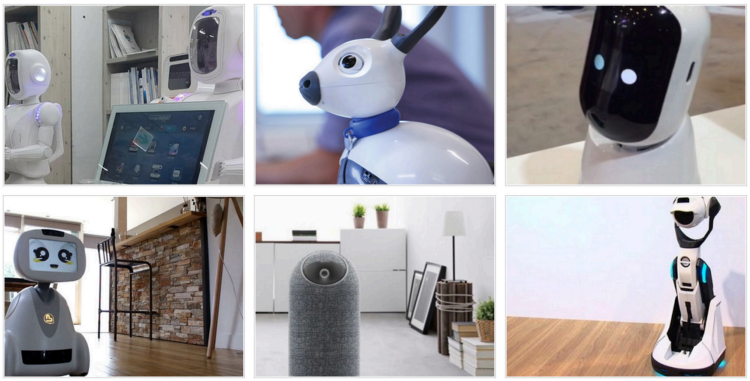
In the Internet of Things, devices are the 'things.' But the term device is expanding to now encompass just about sensor-enabled (connected) 'thing' that can be:



From entertainment systems to refrigerators to smart coffee makers to electronic toothbrushes to connected crockpots; all of these are now interfaces through which end users interact with the Internet. The umbrella category of wearables also includes the ever growing plethora of devices worn on the body or clothing, from connected shoes to fitness trackers to glasses and beyond. Although they typically have different use cases than wearables worn external of the body, 'implantables' are also a type of connected device. Sensor-clad patches, adherence, textiles, tattoos, or other embedded devices like cardiac pacemakers also fall into this category.

Fixed devices are those that are installed into an infrastructure or environment, such as a connected thermostat in the home, a beacon in a retail or municipal environment, or a monitor placed along the rows of a farm to measure the health of crops. From remote controls, TVs, and washing machines, to coffee-makers, vacuums, and slow-cookers, what used to simply be 'electronics' are all adding connectivity and mobile apps. Grills, stoves, toilets, golf clubs, forks, toothbrushes, pets, bikes, cars… you name it, someone is connecting it to the Internet. Consumer, commercial, and industrial robotics are growing in adoption world-over, supporting services like caretaking, customer service, and inventory operations… never mind challenging how we emotionally interact with machines.

FIGURE 4: ROBOTICS SUPPORT NUMEROUS CONSUMER, COMMERCIAL, AND INDUSTRIAL USE CASES



(SOURCE: SIMON MONTFORD)

Since a few early connected consumer products caught on in the early 2000's, the tech industry has been in a 'just because we can' craze to "make smart" even the most mundane objects. But just because we can doesn't always mean we should. When we render our bodies, homes, transport, marketplaces, institutions, or any other object or infrastructure 'connected,' our interactions with each transcend the time and space of the interaction. Data are stored and used to inform future interactions.

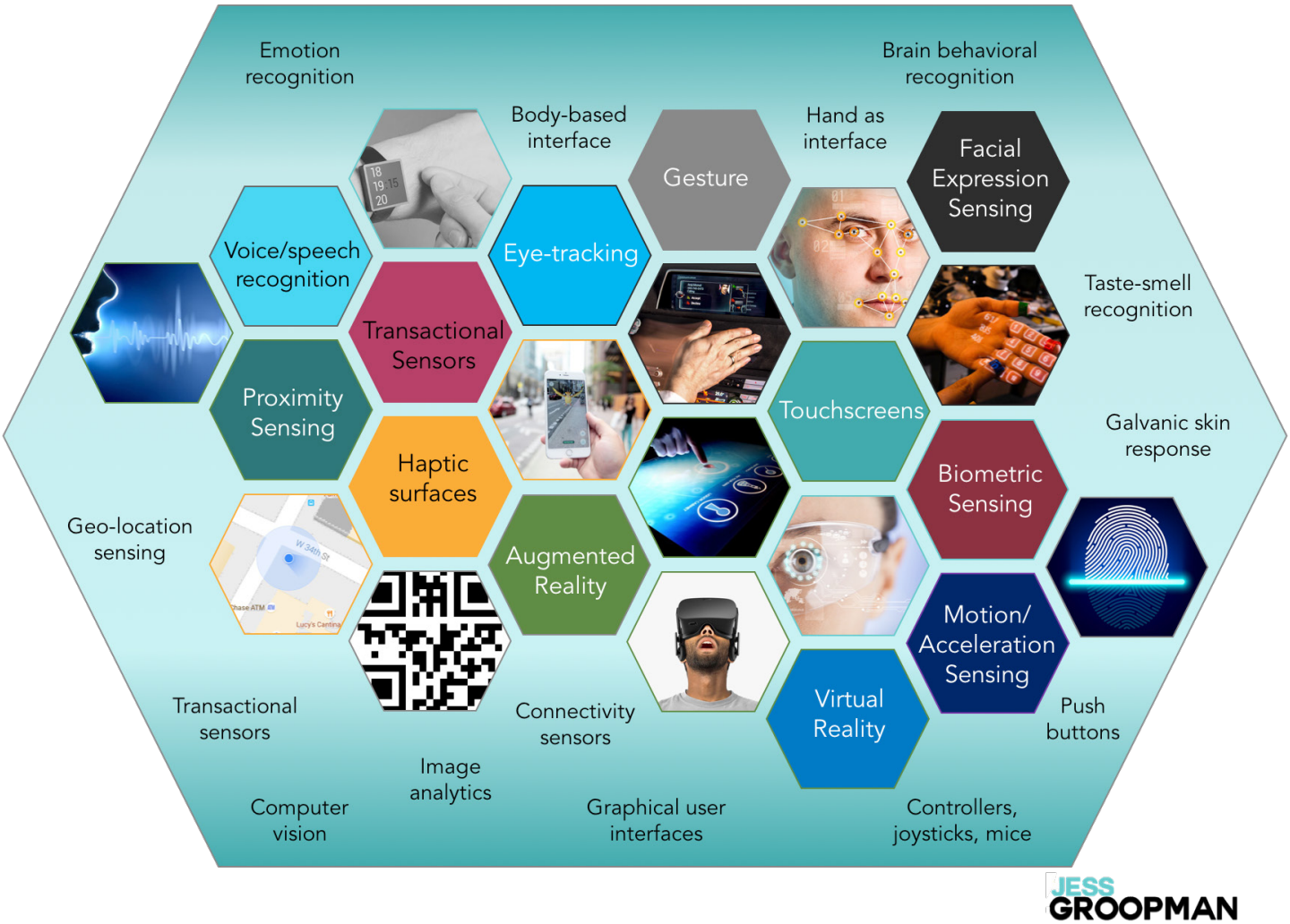
The proliferation of connected form factors is significant because for the first time in human history, interacting with the physical world constitutes a data-emitting event.

2. New Interaction Modalities Are Emerging

It's not just that new physical form factors are proliferating, it's also that the very modes through which we interact are diversifying. Typing, clicking, and scrolling are the universal standards for Internet interaction in the laptop world. Smartphones and tablets introduced more tactile input mechanisms like tap, touch, pinch, and pull. With improvements in natural language processing and machine learning, voice interaction has taken on new life with Amazon Echo, Google Now, Apple's Siri and Microsoft's Cortana. Each new mode of interaction introduces new complexities to the design process. Suddenly interface designers must account for intonation, pauses, accents, age, culture, speed, etc. Voice recognition is expected to reach more than 82% penetration in mobile devices by 2020, according to Tractica.[3]

Gesture is gaining traction as companies develop new technologies that detect 'common' movements to trigger interactions. Again, new design and development considerations crop up around posture, body language, culture, age, personality, and so on. Motion detection, geo-location sensing, biometric sensing, programmable push buttons, vibration detection, and a range of other modalities are all evolving the very method of human-machine interaction. What business designers must remember is that the modes in which we interact ***today*** do not constitute a complete list; consider the range of interaction modalities in development:

FIGURE 5: ADVANCING HARDWARE & SOFTWARE ENABLE EMERGING INTERACTION MODALITIES



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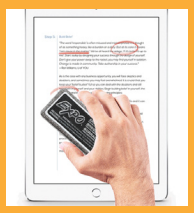
BMW INTRODUCES GESTURE CONTROL IN ITS 2016 7 SERIES

BMW's gesture control in the Series 7 includes features like turning up or down the volume by circling a finger clockwise or counter-clockwise; accepting a phone call by pointing toward the touch screen; rejecting a call by swiping hand to the right, and others.[4]

QEEXO EXPANDS VERSATILITY OF TOUCHSCREENS FOR COLLABORATION, GAMING, ETC.



Qeexo is a software, operable on any OS, that enhances touchscreens by empowering users to instantly summon virtual tools by posing their fingers, knuckles, nails, or hands in common gestures (e.g. drawing, screenshot, erasing, measuring, magnifying, applying pressure, etc.)

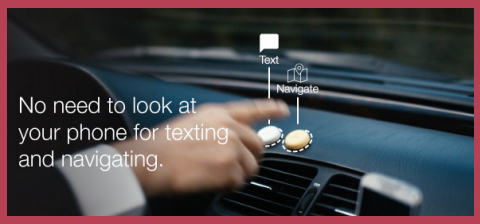
TACTERION'S SENSORSKINS MALLEABLE TO ANY SURFACE

Tacterion's "Sensorskins" are stretchable, sensitive cloth-like sensing technology that monitors pressure, grip, conduction, and input, rendering an interface out of any surface.

BIXI'S GESTURE-CONTROLLED DEVICE FOR HEADS-UP, HANDS-FREE ENVIRONMENTS

Bixi is a touch-free gesture-controlled device, attachable anywhere, that offers users customizable hands-free controls like adjusting infotainment while driving, lighting, audio, smart home devices, photography, and beyond.

FLIC BUTTONS ENABLE SMART FEATURES ANYWHERE



Flic is a wireless button, attachable anywhere, that users can program to trigger actions (e.g. smart-home, music, navigation, smartphone features) or order services (e.g. pizza, taxi, etc).

NEW TEMPO'S N-SHOW VIRTUAL MIRRORS DIGITIZE FITTING ROOM EXPERIENCE

New Tempo's N-Show powers 3-D virtual fitting rooms with gesture and motion recognition and machine learning so users can try on clothes, bags, and accessories, gesture their preferences, snap and share photos, and even transact mobile purchase… without physically having to touch or try anything.

Emerging modes of technological interaction abound

Two hundred years ago it was absolutely unfathomable to think we would have drivable horseless carriages, carry powerful control and communications devices in our pockets, or have the ability to communicate in real time with others across the globe. It's important to point out that list of modalities in Figure 9 is not, and may never be, truly exhaustive as innovation is rampant in the UX, firmware, and software space.

Advancements in user interfaces have a way of replacing what is behind them entirely. The first databases replaced file cabinets; Desktop computers, and later mobile have (all but) replaced print media (newspapers, analog ads, catalogs, handwritten letters). Although the smartphone dominates our digital interaction mode today, many believe the tiny screens and keyboards, never mind socially awkward input methods leave something to be desired.

What each of these emerging modes of interaction are trying to do is scale the interface for the physical world. Since no one wants a single app or even screen for every device, object, or connected surface, engineers are working to develop 'common design languages' that are universal, or at least simple to learn yet flexible (never mind, interoperable) enough to command and control lots of devices. Google's Project Soli is working on gesture control as one such mode. Ivan Poupyrev, directing technical program lead at Google, is "basing this language on metaphors which are already established in the world. We're borrowing language from physical controls," such as rubbing index finger and thumb together to simulate turning up or down; tapping fingers to simulate a button; or sliding thumb along finger to simulate a slider. [5]

From augmented reality to 3-D printing to voice, gesture, motion, gaze-tracking, and far beyond, the interface for our interactions with the physical world may yet to exist, but will continue to evolve rapidly and in ways hitherto unforeseen.

FIGURE 6: GOOGLE'S PROJECT SOLI DEVELOPED SMARTWATCH RADAR TECHNOLOGY FOR GESTURE CONTROL

(SOURCE: GOOGLE'S ATAP RESEARCH LAB)

3. Back End Innovation is Transforming Front End Experience

Behind the proliferation of form factors and modes of interaction is a simultaneous explosion of programming intelligence encompassing all phases of data transmission, from data collection, processing, and storage, to analysis, attribution, assimilation and learning. Significant developments in artificial intelligence, taking place primarily on the software side, but increasingly at the firmware and device level as well, will enable new user experiences across all industries.

Whether we realize it or not, we are already accustomed to artificial intelligence powering product recommendations, media playlist suggestions, never mind sponsored content we consume on digital channels. What follows is a very brief overview of some of the most important software innovations impacting user experience today. These forms of application intelligence exist at varying levels of maturity today, the actual adoption for which is greater for some than others. What both product teams and strategists in all business functions must recognize is the technology toolkit and limitations of today are not necessarily reflective of tomorrow.

FIGURE 7: EMERGING SOFTWARE INTELLIGENCE IMPACTING USER EXPERIENCE

Machine Learning: A form of AI that allows machines to learn without being explicitly programmed, but rather focuses on the development of programs that teach themselves to grow and change in response to new data

Deep Learning: A form of machine learning that uses the model of human neural networks to handle big data set and make its predictions

Natural Language Processing: Enables computers to understand human language at it is spoken and written, including the ability to translate from one language to another, as well as produce its own speech and writing

Computer Vision: Attempts to identify images of objects that can be seen and/or patterns within data that cannot be seen by the human eye

Virtual Assistants: Automated software applications or platforms that assist end user through understanding natural language in written or spoken form, sometimes called chatbots or conversational interfaces

Bots: Software applications that run automated tasks (scripts) over the Internet. Typically, bots perform tasks that are both simple and structurally repetitive, at a much higher rate than would be possible for a human alone

Predictive APIs: APIs offered to enable 'off-the-shelf' predictive features; developers plug in data from existing apps

Blockchain: A distributed ledger for tracking and managing transactions, contracts, and records across parties with low or no trust

(DEFINITIONS COURTESY OF TRACTICA, WIKIPEDIA, AND PROGRAMMABLEWEB.COM)

The capabilities of emerging software innovations extend into hundreds of use cases, and nearly all impact user experience in some way. For example, robots and digital assistants use natural language processing and deep learning to more easily communicate with humans. A connected washing machine or HVAC system could leverage sensors, machine, and deep learning to better support predictive maintenance and algorithmically predict failure scenarios. Complex configurations of computer vision, deep learning, and machine learning are what enable the very performance of autonomous vehicles.

The future of UX will be more differentiated by back-end intelligence than tangible hardware or aesthetics.

As product (and service) organizations in every sector embrace connectivity to drive new avenues for value and differentiation, it's a significant mindshift to place so much importance and investment on the back-end of end products. Historically, it is the 'front-end,' the user-facing, the tangible form factor that drives innovation roadmaps: this season's new product line, the shiny new version of a widget, the waterproof edition, etc.

It's also essential to recognize the role software intelligence has in accelerating product development and innovations to user experience. Applying dynamic data and algorithms at both the product and cloud level make it possible for products to:

- Receive updates/ upgrades to functionality and features
- Repair security vulnerabilities through updates or patches
- Adapt and adjust product behavior
- Improve associated web-based and mobile UIs
- Act in concert with other products, applications, services, etc.

The faster companies can 'learn' from product data at scale, the faster they can apply learnings to better align with user objectives and eliminate friction. Such 'learning' takes on even greater implication when all products in a fleet benefit from the experiences of each individual product. In this context, software helps leverage and analyze data from individual products to more rapidly train and improve algorithms that inform the performance and intelligence of the entire group. Just as we have built channels on the web for collective intelligence (e.g. Quora, Reddit), the crowdsourcing of device perception and learning will also be enabled through software intelligence.

Recalibrating the function of product to emphasize and support service-driven business models over product-driven business models is central to competing in the connected world. This begins with embracing the importance of the formless, invisible aspect of user interaction.

4. The Rise of the Faceless & Formless Interface

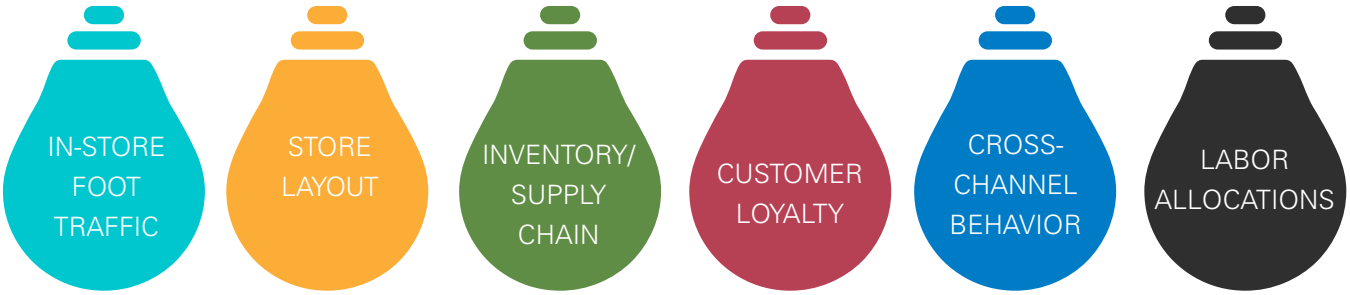
The convergence of all of the above forces—a proliferation of form factors, new modes of interaction, and processing intelligence—means that interface itself can all but disappear entirely. Consider that, in a connected world, user experience can be entirely free of form factor; sensors are embedded, and the transfer of signal for networking and/or data to the cloud or elsewhere are intangible and invisible.

But, as the saying goes, ***the best technology is invisible***, right? How will we interact with an invisible computer?

Embedded sensors, networked services, and artificial intelligence bring new meaning invisible technology: we can now have digital interfaces that are both faceless and formless. That is, objects or environments are able to collect, transmit, and make decisions around data without any visible, tangible, or ascertainable signal they are doing so. When a fitness tracker has no screen, we can't ***see or feel*** that it is tracking our steps, heart rate, location, etc. but we understand it is through its associated mobile app.

Gooee, a platform connecting lighting OEMs has outfitted a bulb with sensors, embedded processors, and Bluetooth connectivity to monitor temperature, humidity, ambient vs. color-tuning light, energy consumption, nearby motion, foot traffic, and LED performance. Shoppers' movements, whereabouts, lingering moments are all recorded and can be analyzed, integrated, and applied across multiple contexts:

(SOURCE: GOOEE.COM)

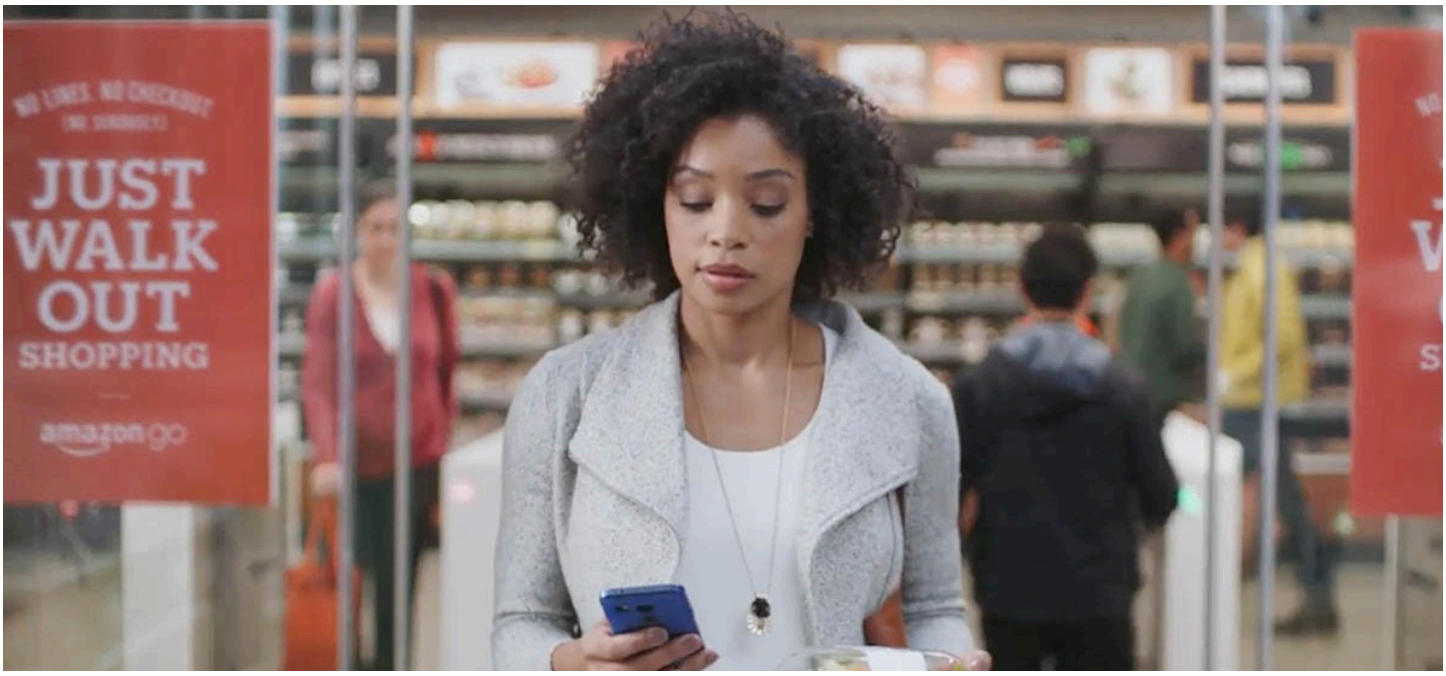


The invisible nature—their fixed installation; data emitted; application across use cases—simultaneously provides context and shapes experience, not just for shoppers, but manufacturer and enterprise adopters as well. Sensors in the bulbs also trigger preventative and predictive maintenance, energy management and conservation, security services, performance reporting, and interoperability with RFID, GPS, beacons, mobile, or other connected nodes. The environmental, workforce, and asset intelligence these lightbulbs enable translate to the bulb's service-driven business model, yet the product is almost entirely invisible.

Basic human actions like looking at or touching an object; speaking and listening; even feeling emotions (!) can now be recorded digitally, even without the express permission from the end user. Nonetheless, this is still user experience, because such data are incorporated directly into the experience itself. They may also be incorporated into ever-evolving user profiles and or data sets that define the "universe of knowledge" that drives machine learning or other forms of artificial intelligence. Even without artificial intelligence, such data will inform research and development and feature innovation.

Faceless and formless interfaces are a central driver in the evolution of user experience in the Internet of Things because they offer the [potential] *opportunity and risk* for 'seamlessness' hitherto impossible.

FIGURE 8: AMAZON GO'S 'JUST WALK OUT' TECHNOLOGY DESIGNED FOR INVISIBLE, CHECKOUT-FREE, TRANSACTIONS



(SOURCE: AMAZON)

As shoppers enter, they scan their smartphones in to register themselves (their Amazon account) for purchasing. By integrating an array of in-store sensing technology (shelf weights, for example) with sophisticated back-end analytics combining computer vision, machine learning, and deep learning, Amazon automatically tabulates all products selected and the transaction is complete when shoppers 'just walk out' from the store. From the standpoint of interacting with technology or tellers to check-out, the experience is all but invisible.

5. Shifting Customer Expectations

Technical innovations are far from the only forces driving the need to re-assess UX in the IoT. Social and consumer forces culminate to massive shifts in customer expectations. The digital revolution has turned the tables on companies. What was once a one-way broadcast model has transformed into a two-way communications model with the advent of social media and mobile. Today, consumers expect rapid responses when engaging with brands. When engaging via social media, for example, 67% of consumers expect a brand response within one day, with 42% expecting it within one hour.[6] This trend—and these expectations—are once again transforming radically. Not only are consumers online more, brands are inviting them more with opportunities to engage more frequently via more connected products, environments, apps, APIs, integrations, and services.

But expectations for brand availability and service are not the same as expectations for presence. Another force placing greater emphasis on design and user interface is consumers' technology fatigue. In the connected world, our attention is subject to constant requests, tiny pings, notifications, reminders, ads. Worldwide users are peering into smartphones, digital signs and scrolling billboards are flashing, all amidst a myriad of other screens, from in-store kiosks, to backseat taxi entertainment systems, and on and on. Even within devices, users suffer app fatigue. As brands vie for user attention, they must prioritize utility and 'pull,' not pushy advertising and superfluous brand messaging.

Moreover, consumers have diverse sentiments when it comes to how companies use, sell, and store their personal data. Distinct from data use in the 'laptop world,' research research shows that consumers are decidedly anxious about the user of their data when it is collected in physical environments; ***At least half of consumers*** surveyed express extreme discomfort with the use and sale of their data across all realms, from their bodies to public spaces, and everywhere in between.[7] In-home location tracking, personal identification, cross-channel integrations, and behavioral pattern recognition, and deep learning are core techniques companies use in connected products, yet they remain poorly understood by most consumers. Indeed, the implications of collecting so much personal data en masse remains poorly understood by most. What is clear is that crafting experiences that are both seamless and personalized, while maintaining privacy and data integrity is essential for long-term user trust.

CHAPTER 4

In the Internet of Things, UX Design is Strategy, Not a Tactic

Data-driven business models require that UX design be foundational to strategy development. Why?

First, design is no longer purely aesthetic, limited to single use cases, or contexts. From a product development standpoint, UX design and orchestration should be less about the product itself and far more about the ***objective*** it serves, and for whom. Considering the paramount role data and software play in UX development, connected products must align tightly with broader data strategies and business models.

Second, user experiences in the digital age must span multiple devices. Any customer (or employee) engagement strategy requires orchestration—through content and integrations— across all channels and touchpoints. Botched user experiences can thwart user loyalty, wallet-share, or worse, their trust. To remain competitive, businesses must (re)-envision the role of user interface as inextricably linked to any and all interactions a brand and user will ever have, not just 'right now' interactions.

Third, the Internet of Things requires companies shift mindsets and business models away from analog, product-centric business models to data-driven service-centric business models. From a product development standpoint, this means products should be designed less as static endpoints and more as hubs or platforms. Through software updates and integrations, connected products can appreciate over time, into new use cases, potential user segments, or business partnerships.

The common theme here is that both digital strategies and UX have a shared objective: to design an ecosystem of integrated context.

Some companies, such as LockState, a connected doorlock manufacturer and service provider, offer APIs for both front end and back end integration. With front end integration, partners like AirBnB and HomeAway build their own UI and pipe in data about locking systems.[8] With backend integration, LockState allows partners to add other connected devices into their platform. Providing modes of interoperability in multiple directions helps both partners and end users take fuller advantage of LockState's products than would be possible if data were only flowing one-way. Explains Nolan Mondrow, CEO of LockState, "we view hardware as means of introducing our customers to SaaS services we're developing. The "things" are just a springboard for deeper relationships with our customers and other providers in the market."

"Our charter is to the universal provider of smart lighting," shares Aaron Ganick, head of smart home from Lightify, part of Sylvania Osram. "We know in these early days of IoT, consumers aren't sure which platform to use so when we are designing our product and service, we want to be sure our product works with all systems out there. Lighting has to be easy and in the smart home, easy is a function of interoperability."

The very 'productization' phase of development, in which a concept becomes a commercial product, now requires a wide range of perspectives and talents (stakeholders); technical and business architecture considerations (systems and interoperability requirements); and as always a user-defined mandate for experience and value.

There are both business and technological enablers that shape what happens with UX—the way APIs are designed, for example dictate data flows, UX and functional capabilities, technical decision-making, and business/service model designs.

Below is a partial list of strategic questions [business and other] designers should ask:

- Who is and how well do we understand the audience(s) for this product?
- How will the experiences we create and the data-driven services we deliver as a result drive increasing value for both users and partners?
- Is it clear for users and our stakeholders why we are offering service and generating data in these environments in the first place?
- What data are we collecting ourselves, and why? What data are we aggregating from partners, and for what purpose?
- What are the core features and functionality required to deliver the product's promised value?
- How does/will the data we're collecting be used to support business decision-making?
- What are our metrics for successful strategy implementation? Are we collecting the right data points to support these metrics?
- How are we handling user data, opt-in, and data minimization to ensure security and trust?

Adheretech is a connected pill bottle whose design enables its business model: a multi-stakeholder platform for medication adherence optimization.[9] How does the design of the bottle and experience it creates drive the model?

For patients: The bottle itself is outfitted to provide patients (of any age, ailment, or tech savviness) audio or visual reminders to take their medications. Patients can select the media they prefer to receive alerts—SMS, mobile, landline, or directly on the bottle. For those interested, the company provides a secure feedback system so patients can share reasons for non-adherence, receive personalized interventions, even communicate with support networks. Patients pick up the pre-configured (no set-up required) connected bottle from the pharmacist when they collect their medication and drop it off when the prescription runs out for re-use or recycling. Both the product and experience are designed to minimize hassle, behavioral change, and most importantly, the need for training.

For healthcare providers: Pharmacists simply configure pill bottles with the same information they compile in traditional prescription preparations. When patients fail to take their medications, their care providers (be they doctors, nurses, caretakers, researchers, etc.) are alerted. Dashboards are tailored for unique user personas to facilitate simple interactions not unlike the current experience, while simultaneously providing a far richer exchange of data and insights about patient care, drug efficacy, toxicity, side effects, and treatment cycles.

From Adheretech's perspective, the strategic design of the system—partners, technology enablers, software, and hardware— enable a superior offering (growing broader and richer over time) compared to traditional competitors.

FIGURE 9: DESIGN AS STRATEGY: ADHERETECH'S CONNECTED PILL BOTTLE

(SOURCE: ADHERETECH)

CHAPTER 5

12 Best Practices for UX Design in the Internet of Things

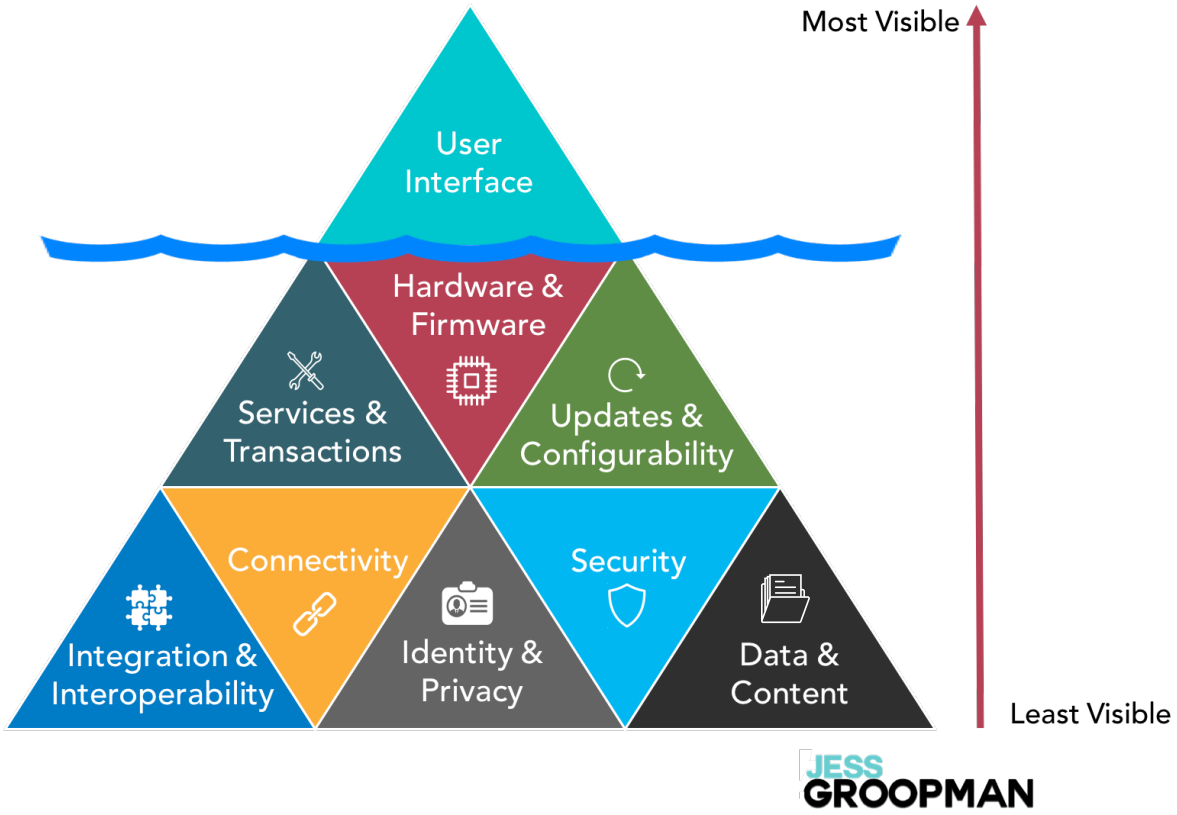
The simultaneous proliferation of form factors, interaction modalities, software and hardware intelligence—particularly when juxtaposed against consumers' increased expectations, apprehensions, and waning attention spans—means that businesses of every type must embrace UX as a fundamental strategic component across any digital initiative. Surfaced from our research of more than 20 ecosystem participants, what follows are an aggregation of best practices for user experience design suited for the digital age.

1. Re-define User Interface

The role of interface is no longer exclusive to the aesthetic, touch, or feel of a physical product. In a world in which data are generated by our interactions, interface becomes the interactive and tangible part of a far deeper and intangible whole. Interface becomes the means through which companies aggregate and deliver value. When poorly configured, it undermines the interaction, convenience, even trust users have in the brand delivering the experience.

As a result, businesses must begin by re-defining user interface in the context of their product or service. In our research of the space, we have found the old 'tip of the iceberg' a useful metaphor for conceptualizing the function and future of user interface. What is visible, tangible, perceivable—above the water if you like— is the user interface as we experience it through our five senses.

FIGURE 10: THE USER EXPERIENCE ICEBERG IN THE INTERNET OF THINGS



Yet what sits below the waterline—what we cannot see or touch— are a range of elements that develop and deliver the user experience of any connected object. These elements fall into the following eight categories:

Hardware & Firmware: The physical technology (hardware, firmware, sensors) embedded in the object that power its function

Services & Transactions: A company's ability to deliver service interactions and/or enact transactions by interacting with the device

Updates & Configurability: Software used to deliver new features to the device's experience, security, mobile app, or power consumption.

Connectivity: The protocol(s) and hardware (e.g. gateway, router, etc.) required for the device to connect to the Internet or other network(s)

Integration & Interoperability: How and to what extent data and functionality from the device are shared or accessed via other devices or 3rd parties, and vice versa (i.e. how 3rd party device data are used by the device)

Identity & Privacy: The object's ability to recognize individual user personas/avatars and associate interactions with their unique profiles, preferences, protections, and individual context

Security: What safeguards— hardware, firmware, software, code, or otherwise— comprise the security of the device itself

Data & Content: Data generated by interacting with the device and/or its associated mobile app; this also includes the resulting content that data trigger or generate

These eight core elements underlie user experiences and interactions any connected product. They define the parameters of any user experience development, whether a manufacturer designing a wearable, an automotive brand developing an in-car experience, or any 'thing' else. Furthermore, the sum of these tangible and intangible parts—hardware, software, firmware, code, integrations, services, and content— is dynamic, and dictates the evolution of the experience over time.

2. Design Systems & Solutions by Assembling Multi-Disciplinary Teams

Design is no longer a job left only to the creatives or engineers. Even traditional design disciplines are becoming hyper specialized thanks to technological diversity at every layer—architecture, hardware, web, app, etc. Furthermore, assuming that the role of design is solely to render existing products and services incrementally more attractive is no longer sufficient. Smart connected business opportunities cannot and will not come to fruition in silos or even single organizations. Our research finds that, although product design efforts are most commonly spearheaded by product leads, effective connected product and service design now requires deep collaboration across several disciplines. This involves coordination across design disciplines as well as functional disciplines.

FIGURE 11: UX DESIGN REQUIRES BROAD MULTI-DISCIPLINARY COORDINATION

The Internet of Things and data-driven services introduce new complexity to the design of connected products, services, and business relationships. The context, complexity, and depth of knowledge needed transcend any single individual or team. This applies to every level of design—from systems to services design, to product design, to graphics design and way beyond.[10]

UX expert, Claire Rowland echoes the need for collaboration at every phase of development. "It's really about knowing what questions to ask of each other, and when. When to talk to the hardware people, how to incorporate the app designers; Even when ostensibly, everyone is 'on board,' the challenge is knowing where and why to pull in those across other disciplines." This knowledge-sharing is essential to bridge different mental models and operating procedures, such as software engineers thinking ***iteratively*** about design, whereas hardware engineers think more ***absolutely***, given comparatively much longer development cycles.

"Designers are good at design. Business people are good at business," summarizes Ashley Etling, CCO of Red Clay Design, an online marketplace platform for connecting businesses with specific types of product designers. "What we realized early on was the need to think about, serve, and partner with ***the whole circle of product design*** in order to best serve our users. We have hundreds of designers on our platform, but also partner with Kickstarter, Indiegogo, MakersRow, and a network of manufacturers."

For companies leveraging internal resources, expanding the realm of product design talent is essential for UX. As one executive interviewed offered, "your development team should be including more liberal arts majors, not just engineers and computer scientists." Diverse backgrounds, in areas like cognitive psychology, physiology, art, anthropology, sociology, film, and others to help improve user experience design in key areas often overlooked in computer science. Some examples include:

- Copywriting
- Usability for non-tech-savvy
- Cultural resonance/offensiveness
- Privacy/sensitivity triggers
- Avatar relatability
- Persona development
- Ergonomy

This trend is echoed in the field of digital assistance and voice interaction, where more technology companies are hiring screenwriters to create scripts that 'sound more human-like' in order to drive better engagement with chatbots and voice assistants.[11]

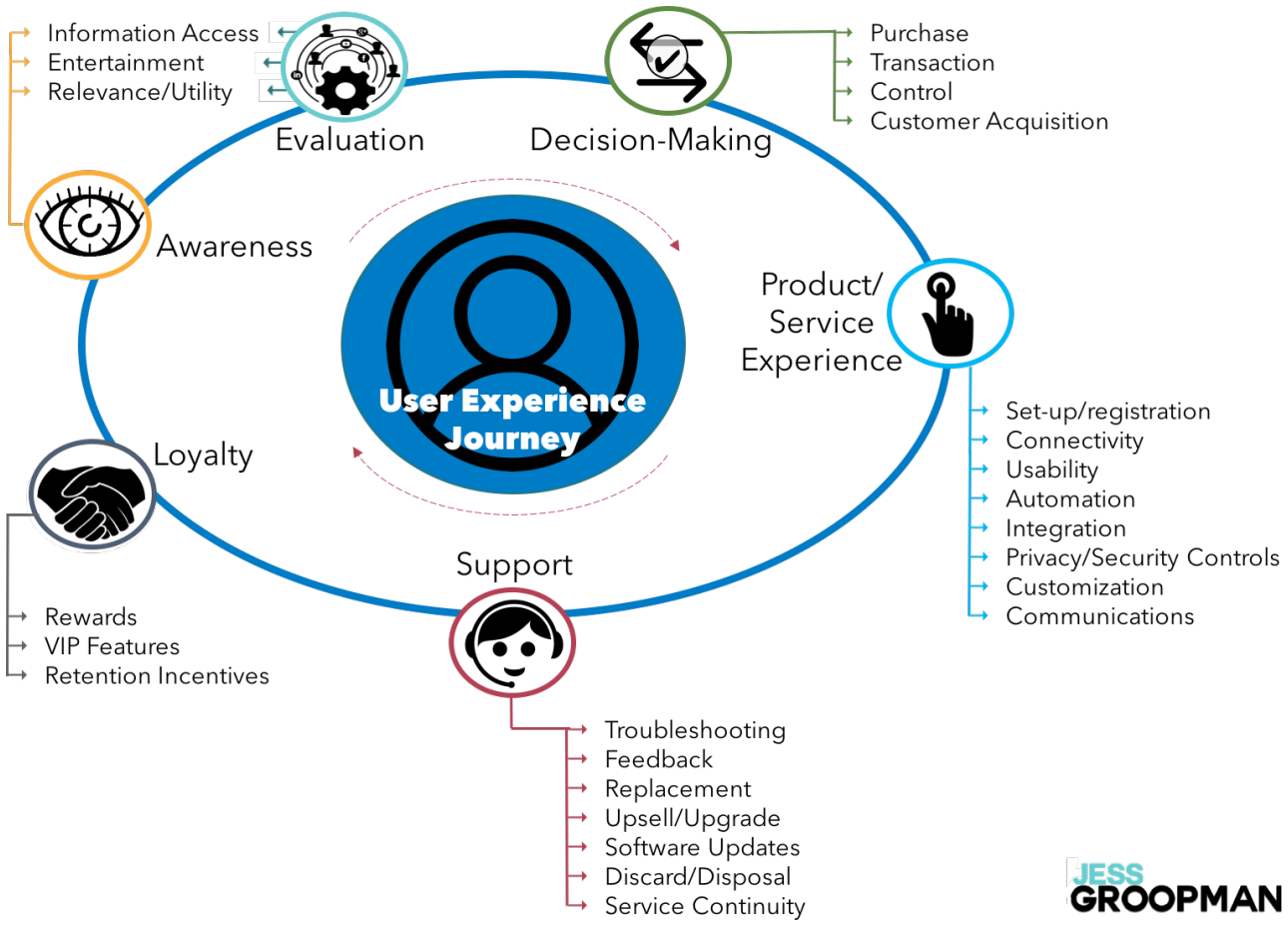
3. Design for User Centricity within Each Interaction

In design, everything starts and finishes with the user. As more devices, software applications, and data comprise a greater portion of the services to which consumers allocate their attention, ensuring true user-centric

experience ***at every touchpoint*** is essential. Companies that fail to meticulously design for users' ever-changing needs risk overwhelming or annoying customers, or altogether abandonment. In an age when customers expect personalized and (near) real time service, designers at every level simply must account for more contexts.

User experience may begin, include, or end with product, but it also includes all touchpoints connected and otherwise.

FIGURE 12: THE USER EXPERIENCE JOURNEY: A MAP OF OBJECTIVES



Context includes traditional 'customer journey' mapping characterizations, but also requires companies anticipate contexts from the user lens—that is, what users want and need to satisfy their context-specific objectives.

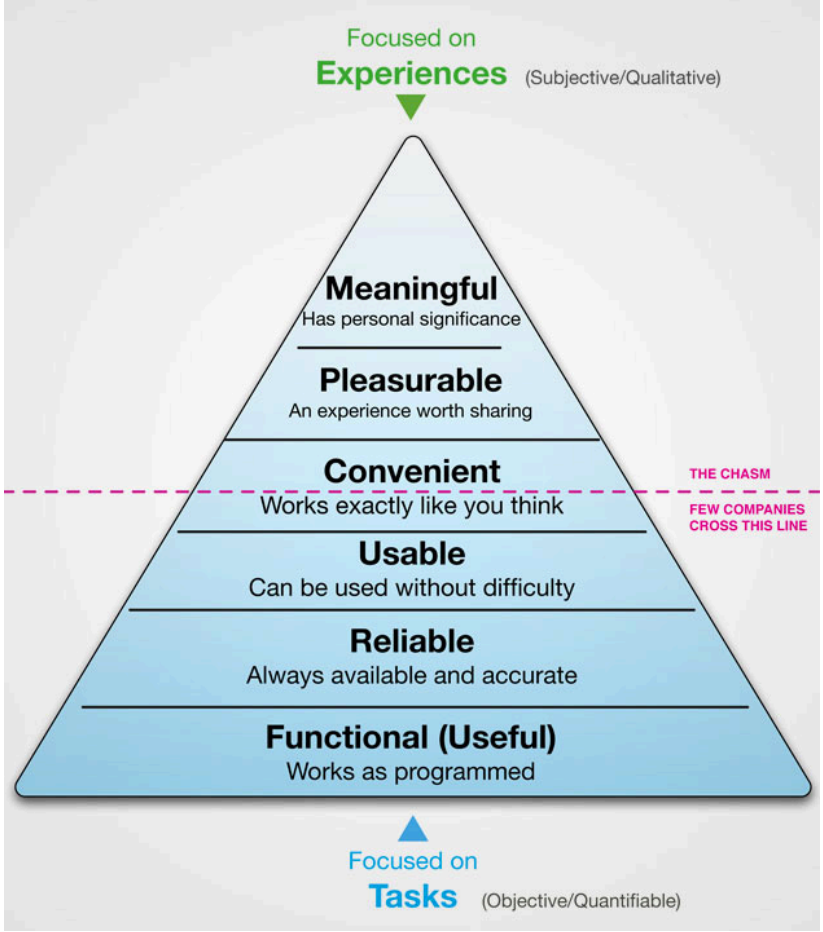
"Products no longer define UX, but are participants in the broader UX experience continuum," explains Niall Murphy, CEO of EVRYTHNG and IoT platform specializing in digital identity for products. "Products aren't always the point of departure for customer engagement. Customers might start elsewhere—social media, an offer, a game, or some other 'call-to-action'— at any given time, user interface isn't necessarily the product, but that engagement is just as important."

The good news is designing for environmental context helps inform optimal design decisions at all layers of the UX 'icebeg' (Reference Figure 12). Who and where a user is when interacting with a product or service offers useful cues for feature, form, and interaction development. For example, how time of day, season, holiday, news, social, health, safety, or other variable, sometimes sensitive dynamics impact the nature of the brand interaction.

If connected products, environments, and channels are designed as vehicles for interactions, content and integrations become the elements of dynamic service design. Designers must work with multiple teams (e.g. marketing, creative, sales) to ensure consistency in look, feel, terminology, and tone in messaging, as well as product aesthetics. For example, if a physical product has red and green buttons and a blue dial, the mobile app may mirror such features to foster familiarity and usability across channels. When considering UX across touchpoints, designers must also think about which touchpoints support which capabilities. Product designers will, for instance, prioritize certain features for a mobile app and instead of designing them into the connected product in order to keep hardware costs down. Orchestration of content, integrations, technology, and systems architecture requires product and service designers work together in lock-step to surface technological opportunities and constraints while preserving user-centricity.

Understanding and building for such an integrated context is no easy task, but designing connected products and environments to support 'right-time' service delivery is an essential to any UX strategy.

FIGURE 13: THE USER EXPERIENCE HIERARCHY OF NEEDS



(SOURCE: ABETTERUSEREXPERIENCE.COM)

A common tool used among UX designers is the 'User Hierarchy of Needs'—a sort of consumer-centric version of Maslov's famous Hierarchy of Needs. In the age of connected products and services, this continues to serve as a useful framework not only for designing a product, but for analyzing the design of a product or service within each phase of the user or customer journey. Questions to help bridge this gap include:

- Where, when, why, and how are users interacting with our products and services and how must that inform each need (i.e. functionality, reliability, usability, convenience, and so on)?
- How can we leverage user context and qualitative insights to create meaningful experiences even when serving functional use cases?
- What value are we providing (e.g. problem-solving, education, optimization, assurance, etc.) with each user interaction? How can we enhance this value over time?

When embracing user centricity, designers should also consider those who may not be current users. Design for inclusion. Just as the Internet brought access and potential opportunity to millions or billions of people, emerging modes of interaction help forge inroads with new segments of users. For UX designers, this is a great way to provide new value, both societal and business. Voice control, for instance, is transformative for the blind, almost blind, disabled, or elderly by allowing them to manage tasks that otherwise require human assistance.

4. Embrace Design & Technology to Minimize Steps between User & Objective

As connected form factors and interaction modalities grow more diverse, designers must constantly assess how they can ensure interaction is as simple as possible. Some environments are simply ill-suited for robust lists or feature sets. A smart watch is no place for extensive scrolling or search; driving in a car is no time for cumbersome selections or branded promotions; watching a movie is not the time for in-ear alerts. Many product companies make the grave mistake of over-complicating connected versions of their products. Too many buttons on a screen, too many levels to tap through to accomplish a task, too many features in an app, too much computation required, too many sensors (and not enough value) to justify a low battery life…

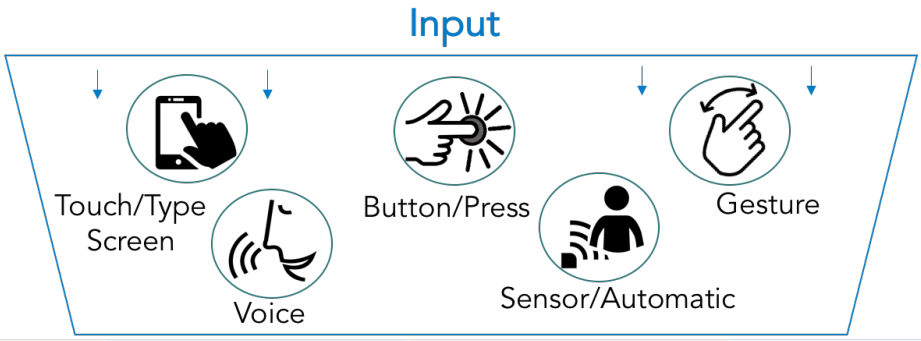
As technological capabilities increase, design becomes less about product and more about wielding both design and tech to minimize steps between users and their objectives.

While companies should be applauded for progressively embracing (not ignoring) emerging technologies, they should only incorporate them into product design to support greater simplicity and superior ease of use. Innovation for innovation's sake risks adding more friction to usability.

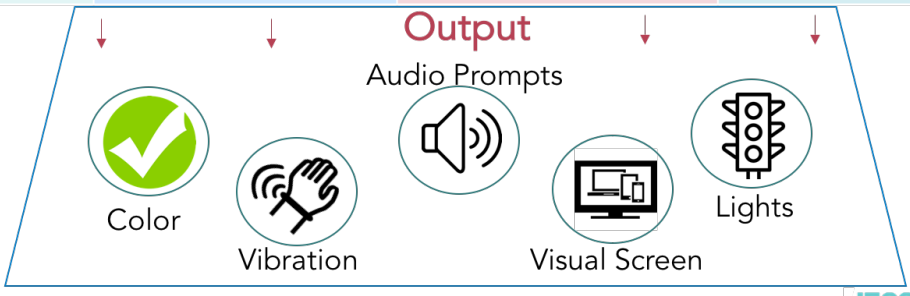
The best designs coordinate technologies to drive simplicity. The objective is to harness complexity to deliver ease, even intuition. Prioritize interoperability and, where appropriate, machine learning techniques to reduce the mental overhead of dealing with more technology. "Companies should avoid forcing users to become 'system administrators' of their homes or any other connected environments," explains Claire Rowland, UX expert. Thanks to advancements across numerous technologies and relatively lower barriers to entry, designers have more tools, libraries, and guidelines to build for users' unique contexts, broader and easier usability, greater energy efficiency, security, and convenience.

Our research surfaced the following considerations in user-centric connected product design:

FIGURE 14: USER EXPERIENCE ORIENTATIONS GUIDE DESIGN DECISIONS



UX Orientations	Description	Sample Scenario	UX Considerations
Objective	Task, improvement, cost, energy, or time-saving outcome motivating the user	Gesture or voice-based request for turning on lights superior to scrolling through mobile app; no confirmation needed	• Quick request • Quick feedback • Necessity of confirmation • Task/Info complexity
Personal Context	User's persona, age, health, culture, etc. must dictate design decisions	Wearable for seniors might be stylish and voice-activated to avoid concerns around disability, usability, or loss of control	• Task/Info sensitivity • Task/Info complexity • Form factor sensitivity
Universality	Ease of comprehension and usability to reduce or eliminate need for training	A check mark upon completion of a task is a universally recognized confirmation signal; be aware of cultural variations in gestures, colors, avatars, etc.	• Quick feedback • Status indications • User capacity
Energy/Power	Power requirements and implications inform optimal output	Connected door locks should never rely solely on Wi-fi incase connectivity is compromised. Consider the 'no-power' scenario.	• Low vs. high energy needs • Local vs. cloud • Minimum viable connectivity protocol • Battery vs. fixed
Fixed vs. Mobile Context	Spatial, location-based, temporal, or social considerations	Voice interaction is great for in-home, hands-free use cases such as cooking, but suboptimal while others are sleeping, or in public.	• Frequency of interaction • Conspicuousness • Environmental conditions • Hands-free/Heads-up • Noise allowance • Task/Info complexity • Single product vs. Multiples
Security	Safety and security improvements and/or risks introduced	Information delivery of sensitive alerts like health reports may not be best vocalized, but rather sent directly to password-protected mobile app.	• Hands-free • Heads-up • Task/Info complexity • Task/Info sensitivity
Consent	Level of personal/sensitive or private data required for transaction or interaction	While driving, if user requests a task that requires system to share data with 3rd party the user has not verified, alert user and/or solicit permission for transaction.	• Task/Info complexity • Task/Info sensitivity



JESS GROOPMAN

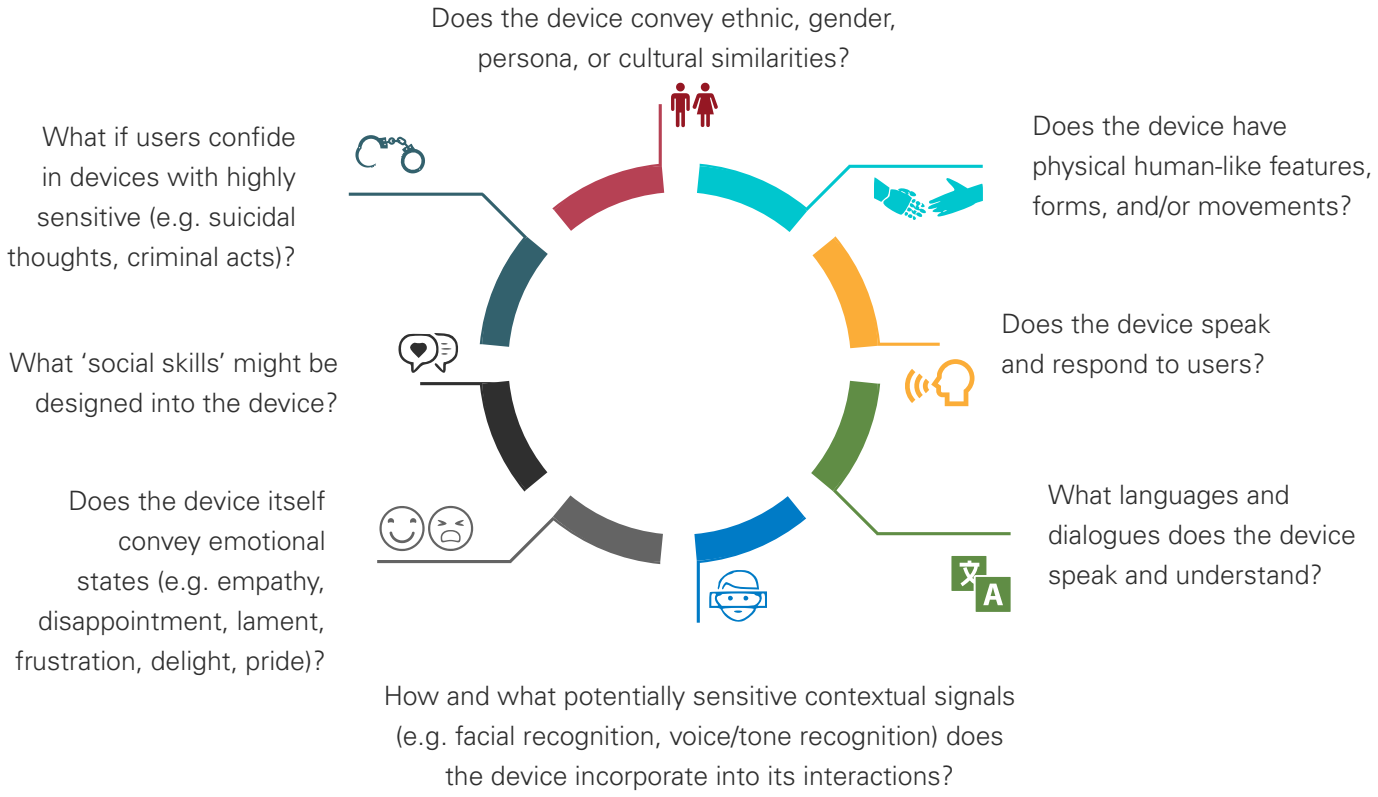
More options do not equal more intelligence. More bells and whistles do not always mean more value. Use these tools not for the sake of their luster or cool-factor, but to drive the simplest, most seamless user experiences possible. Incidentally, fewer steps (to move or tap through a workflow) typically drive greater conversion and success rates. Although simplicity seems obvious, it is often difficult to preserve when orchestrating software, mobile apps, integrations, and human-centric inputs.

For example, while driving, phones are a dangerous and terrible option for interaction. While the stakes for mobile phone use are lower at home, most people consider the home the environment for socializing with family, entertainment, preparing meals, recharging themselves— objectives for which phones are not ideal. Voice has, thus, emerged as an optimal interface in the home, where heads-up, hands-free, more social interaction is just easier. The same environmental cues can also inform software and graphical user interface decisions. Connected in-home products must, for example, prioritize data privacy controls, defaults, sharing, lighting, and child-safety given their inherent context. While in public, voice interaction is less ideal and in-ear or on-screen interaction may make more sense. Wearable alerts sent while users are not moving may serve different needs than those delivered while walking or running.

Keeping the user's context central to the design process forces companies to de-prioritize technology for technology's sake. Embrace emerging technologies to simplify user experience, not overcomplicate it!

5. Understand the Responsibility of Anthropomorphizing Products

Despite (or perhaps because of) decades of science fiction, the question of anthropomorphizing, or imposing human-like characteristics on the design of products remains an open one. This is a complex topic, which has cultural variance, technological and social implications beyond the scope of this report. Still, it is an important consideration that product designers must confront when plotting use cases and interaction scenarios during development.



According to Microsoft's research team for their Cortana voice assistant product, both men and women prefer a women's voice for their personal assistant.[12] **"Products aren't about rational design decisions. They are about psychology and how people feel." says Ryan Germick, who leads personality development for Google Assistant. "[Google Assistant] is a millennial librarian who understands cultural cues, and can wink at things."**

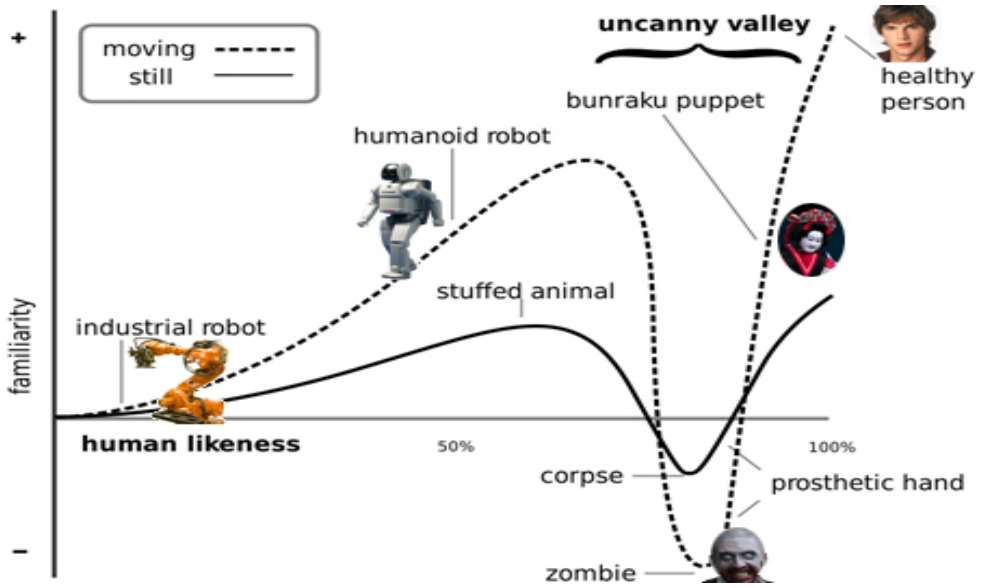
Mimicking affect or simulating human interaction is a very tricky needle for companies to thread. An efficient, yet playful, personally resonant or complimentary interaction can quickly add warmth to user experience. But crossing over into too personal, stalker-like, overly chatty, or annoyingly pre-configured and robotic turns creepy even faster. One company interviewed found that users didn't like when products responded too immediately to their requests, and that delaying their product's voice response by a fraction of a second made question-and-response interactions seem more natural and personalized. Designers in both voice and digital assistance also emphasize the importance of 'normal speak,' avoiding technical jargon, business terminology, awkward use of slang, or overly repetitive/chatty redundancies in responses.

"Companies can risk antagonizing users or simply creating extra noise or friction just to accomplish a very simple task like turning the lights on or off," explains Jerome Rota, chief design officer for Greenwave Technologies, and IoT platform specializing in smart home integration.

The Turing test is a test of a machine's ability to exhibit intelligent behavior equivalent to, or indistinguishable from that of a human.[13] Yet, as our expectations for technology increase rapidly, the bar is lifted. What is magical today becomes table stakes for tomorrow.

The ever important and inherent role of machine learning and artificial intelligence in these scenarios—whether a robot, wearable assistant, in-home speaker, web-based digital assistant, or otherwise— also means that all past interactions *accumulate and inform with the goal of automating* future interactions. These machine and deep learning models are indeed designed to make interactions more effective and targeted, "but such presumptuousness on the part of our devices can feel creepy and unsettling," Rota points out.

FIGURE 15: THE UNCANNY VALLEY OF HUMANOID FIGURES



(SOURCE: IEEE SPECTRUM)

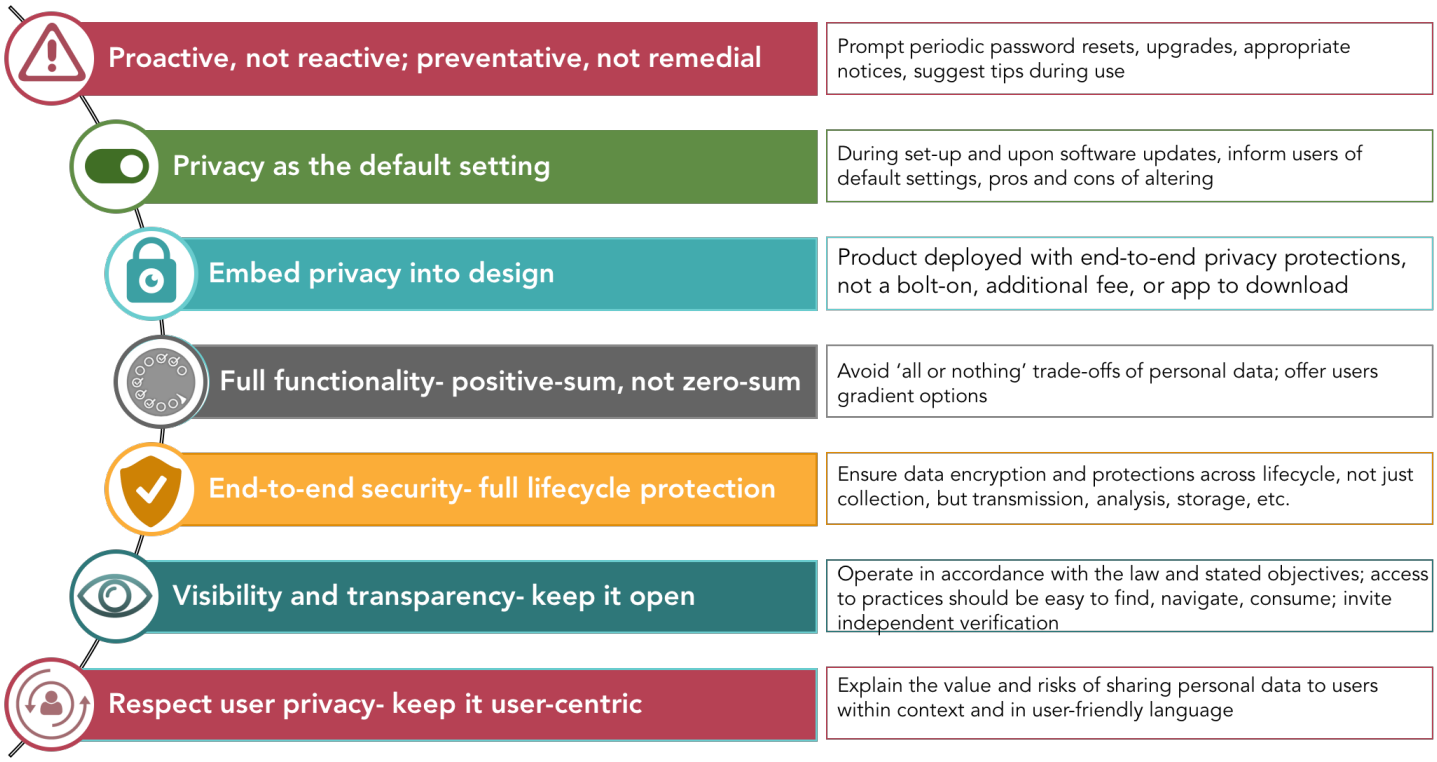
Masahiro Mori, a Japanese roboticist, first coined the term 'uncanny valley' in a 1970's research paper. The term is still often used in design principles today, characterized by the hypothesis that human-like objects that "appear almost, but not exactly, like real human being elicit feelings of eeriness and revulsion among some observers, and that the object's ability to move amplifies emotional responses."[14]

Mori's notion has been a source of great debate and continued research since its original publication. From hence as emerged numerous design principles relevant to IoT products, particularly as product manufacturers begin to weave artificial intelligence into physical form factors.[15] Most notably, perhaps, is the principle that design features should match in relativity to human likeness. If a device looks like a human, users expect it to be able to perform and interact like one; if it looks like it an appliance, users will not expect (even desire) human-like features. Put simply, the degree of human realism in behavior and interactions should correspond to the device's degree of human realism in appearance and movement.[16]

6. Design Safeguards Directly into Product (& Ecosystem)

It is essential for businesses to prioritize user privacy and product security when designing connected products, not just for UX, but for the safety and integrity of all parties and assets. It is incumbent on product manufacturers and designers not only to build for privacy in the product itself, but to take an active role in understanding how products contribute to personal data protection. The concept of 'privacy-by-design,' in which developers take privacy into account during each phase of the engineering process, is a foundational starting point for privacy protections and downstream UX. Consider the following principles of privacy by design,[17] as well as examples surfaced from our research of IoT UX design:

FIGURE 16: 7 PRINCIPLES OF PRIVACY BY DESIGN & EXAMPLES APPLICABLE TO IOT UX



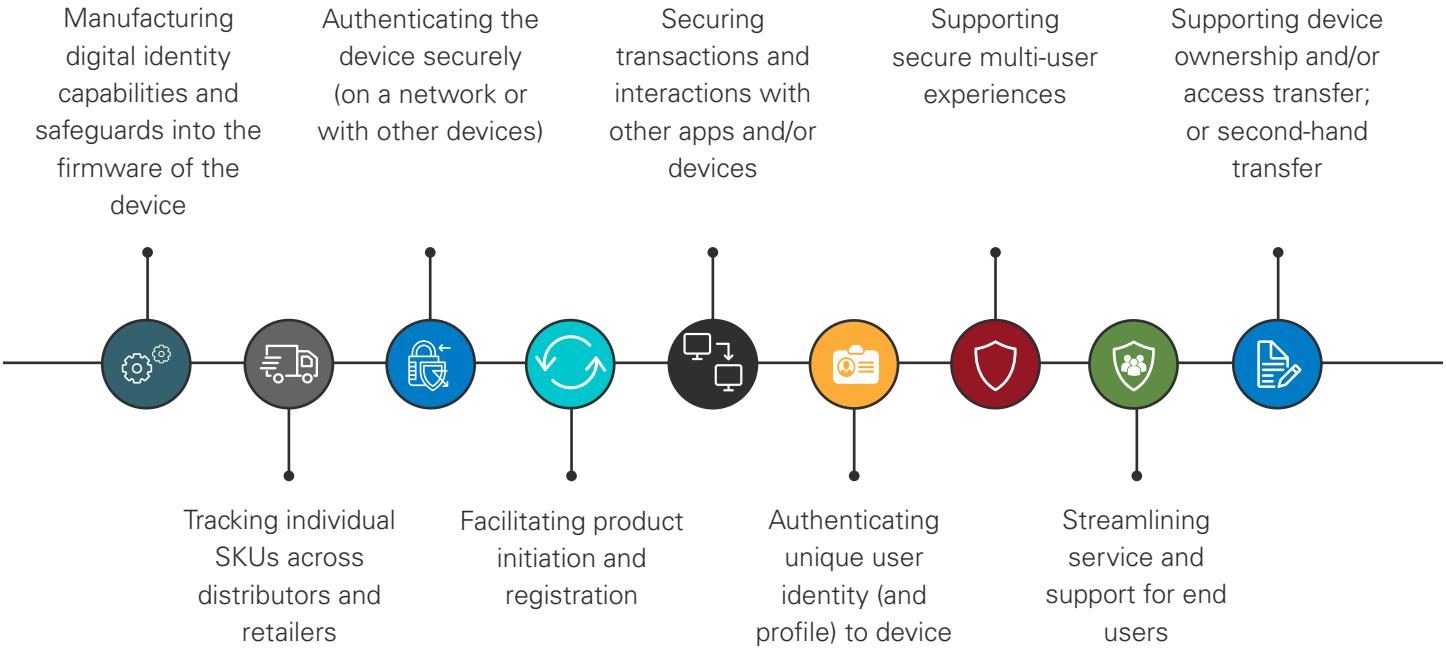
Privacy in the Internet of Things must also account for the immense (and growing) technological diversity, accountability of digital identity, the implications of devices and data in our most personal environments and interactions, as well as how each of these creates windows and incentives for hackability. Maybe the most critical point for the purposes of this research is for product designers and security developers to focus on, ***but also well beyond the product itself.*** Any connected application, whether a connected thermostat in your home or a fleet of sensor-clad wind turbines in the field, includes some configuration of devices, applications, networks, and of course, people. From a UX standpoint, consider how risks at the product and system level could:

- **Disappoint:** Through inconsistent experience or failed reliability or continuity
- **Intimidate:** Through over-notification, over-configuration, not warning users of data collection, hyper-personal prompts,
- **Frighten:** Through unexplained data collection, account compromise, difficult opt-in/opt-out, abrupt changes to workflows, data access, etc.

When taking inventory of threat surface (i.e., the landscape of potential vulnerability), organizations must assess risks across the entire stack and ecosystem.[18]

7. Prioritize Digital Identity Along the Supply Chain

Designers have a unique role and obligation to conceptualize, develop, and secure device identity over the course of product lifecycles. Since data and connectivity are inherent to IoT product service models, digital identity becomes the central mechanism for integrity of service, security, and experience throughout the supply chain.



The very value and risk of collecting so much data presents a sort of conundrum for businesses: To maximize sharability while also maximizing control and safety. Digital identity of devices is thus, a sort of portal to both maximize value and mitigate risk of connected products and their users, wherein authentication and access define governance.

EVRYTHNG, an IoT platform provider specializes in digital identity along the supply chain by providing a solution to manage billions of goods throughout their life cycle. In their #BornDigital program, they partner with silicon providers, manufacturers, and brands to support the data management for enterprise and consumer use cases like inventory tracking, product re-ordering, fraud/counterfeit prevention, loyalty points, personalized content, and more. From the point of original manufacturer, along each phase of the supply chain, and across each of these use cases, potential value begins with critical design decisions.

8. Design Customer (& Partner) Support Programs Alongside Products & Services

Although products and services are trending toward ever more autonomy, the reality is connected devices and services will require significant support from providers for the foreseeable future. Companies that have deployed connected products point to ongoing support and service as one of the top challenges they face.[19] It's not just that connected products are prone to various quirks, connectivity hiccups, or other bugs, it's that new features and data-driven use case evoke new questions. For many, interacting with a connected object introduces friction that is absent in 'the old way' of doing things, thereby undermining other shiny features in the process.

While design can help streamline usability, machines rarely work perfectly all of the time, and issues are sure to arise that require human intervention and training. Connected product initiatives can fall flat if proper support structures, including people, budget, training, and incentives, are not in place. A connected hot tub manufacturer, for instance, found that its product's ability to delight users sank when it forgot to train and equip field service teams with the appropriate protocols and communications when the product—whether tub or mobile app—failed.

Our research found this a common theme across product lines and industries, not only at the customer level, but across business partnerships as well.

We work with more than 30 brands over 300 product categories. When we take on another physical product into our ecosystem and application experience, they're involved. With us, partnerships include joint testing, joint development, design collaboration, and joint training for customer support," explains Matt McGovern, head of marketing and business development at Wink, an in-home IoT platform. Instead of re-directing customer issues to 1-800 numbers elsewhere, "When customers have an issue, that tight integration and curation of support needs is a differentiator. We will make it right."

While connected product support programs should obviously integrate with broader "omni-channel" customer support strategy and tactics, some additional steps companies can take include:

- Joint training across LOBs, especially Support, Sales, Marketing, Product, Commerce, R&D
- Joint development across partners
- Ongoing training for partners
- Collaboration and knowledge-sharing programs across support teams and communities
- Offer feedback opportunities for users via product or app
- Communicate resolutions to users, not just documentation

Finally, some organizations and IoT platform providers recommend developing 'relationship maps.' These are akin to technology stacks and may even include technical and systems architecture, but also map relationships to devices in integration, support, administrators, etc. During both development and ongoing management, these can be valuable tools for partners to understand who has access to what information, permissions, devices, applications, and who makes changes when it comes to the most critical phase of IoT product management: data management.

9. Design for Evolution, Not Revolution

Designers and innovators interviewed for this research stressed the importance of evolution, not revolution, when it comes to designing connected products. There are a number of reasons this is commonly seen as a best practice for IoT design.

First, most consumers are not early adopters of technology. Most of your potential customers just want ways to improve what they're already engrained in doing. Companies that set out to transform customer interaction, to reinvent how people get things done, and to make a bold statement in doing so will fail. When developing connected versions of existing products or sensor-enabled experiences, brands must think incrementally: start with subtle tweaks to how customers already interact. Simplicity, subtlety, instant gratification are more likely to drive adoption and utility than are significant deviations from current ways of doing things. Leverage existing templates for interaction to drive adoption and circumvent learning curves. Replace behaviors by tweaking one or two features or steps, and provide immediate accomplishment; minimize steps to achieve users' objectives.

Ask: would my grandmother understand how to do this?

Secondly, in some cases, there is no precedent for the connected version of an analog object and the experience it creates. This can be a significant challenge for designers, even when they understand the importance of inspiring evolution in (not replacing) user behaviors. One approach to this scenario is to (again) return to the user's context and identify obvious improvements ***within that context*** for which the product can intuitively support. For example, although the Amazon Echo appears to look like a music speaker, it is really unprecedented as a product category—its utility extends far beyond playing music. By assessing common user contexts for listening to a music speaker outloud—in the kitchen, living room, bathroom, bedroom— Amazon cleverly identified previously untapped opportunities for a speaker.

- Voice recognition and response for hands-free interaction
- Information integrations (e.g. Bing, Wikipedia) for easi(er) inquiry or in-home conversations
- Entertainment integrations (e.g. Amazon media, Spotify) for quick(er) custom media playback
- Utility integrations (e.g. smart home, e-commerce, Uber) for more quickly accomplishing tasks
- Minimal aesthetic interface (lighting cues only) to prioritize voice interaction

Instead of reinventing the speaker per say, Amazon merely leveraged user context, tweaked the mode of interaction (from buttons to voice), and intelligently and has subtly infuse services, sensors, and software into what would better be defined as an in-home assistant.

The third reason to design for evolution, not revolution, is more product than user experience-based. This is because the development of new physical products is very time consuming and expensive. On average, new

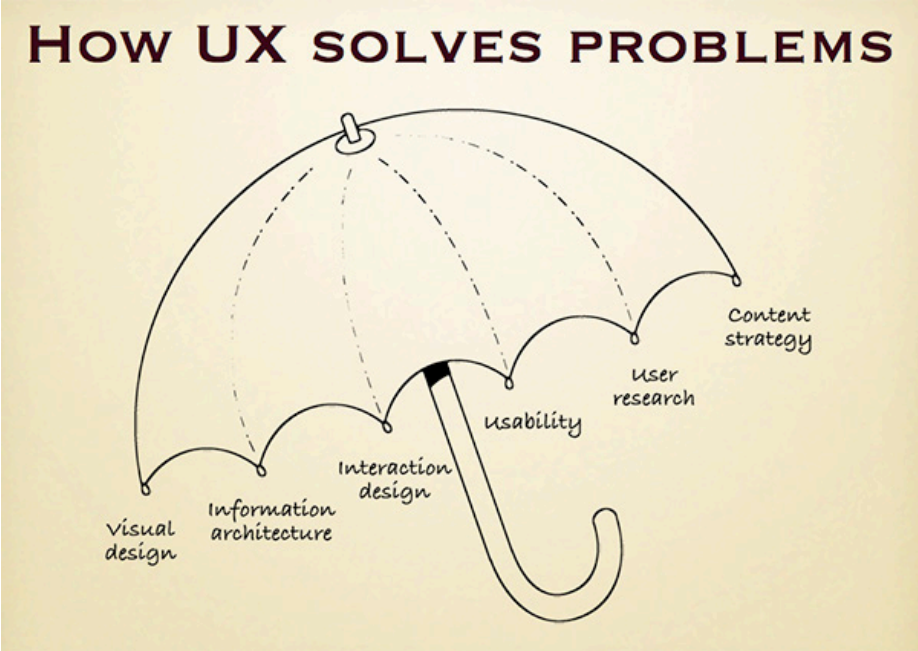
products take anywhere from 6 months to two years to develop fully, from a minimally viable product (MVP) to one ready for market. This 'hardware' development cycle is in stark contrast to the software development cycle: one of days or weeks, with constant tweaks and iterations defining the product rather than an endpoint destination. Connected products are the convergence of these two paradigms. IoT creates a way in which a product manufacturer can continuously improve an existing physical design without the significant R&D that entails developing an altogether new product. Here, building for evolution is again essential, not only so as not to waste resources unnecessarily, but to prioritize a physical design simple enough to support user-sensitive improvements in software and services. Across the board, those interviewed recommended deploying MVPs early on, with a clear understanding of what is minimum and what is viable, and letting users guide the development and direction of the product.

"In-market Voice of Customer is so much strong than pre-market," offers Melissa Hammerle, director of IoT Business at Fluke. "Once you have a product in-market, you have the opportunity to gather much richer feedback, not just through research efforts, but by creating the virtuous cycle between Product, Marketing, Sales, and Service. Each function sees a unique facet of the customer experience, and combining the cross-functional input enables more informed decisions on how to adjust each lever in order to best achieve business objectives and meet customer needs."

10. Design to Problem-Solve

In a world of 'smart' products and connected environments, businesses must view design as a useful vehicle for insights and problem solving. Alongside connected products, businesses must harness software intelligence and integrations to improve assets over time.

One way to think about this is to consider every data stream a voice. Through interactions, users are communicating their preferences, signaling intent, even expressing needs through action, inaction, or abandonment. Compared to traditional market research modalities like solicited focus groups or surveys, this real-time and 'in-the-wild' information is gold for companies committed to serving and anticipating their customers' needs.



(SOURCE: DAN WILLIS, FORMER DIRECTOR OF MOBILE EXPERIENCE AT MARRIOT)

The key is connecting how data transmitted through interactions offer solutions for core product, service, and business challenges. By monitoring sensors attached to products, environments, or customers, and analyzing interdependencies across data sets, companies can ascertain ideas for improvement. One place to start is to look for current 'blind spots' when it comes to users, such as their great pain points during product set-up, where troubleshooting fails, or how users dispose of their products. Products and services should be designed to offer continuous streams of data that will help inform improvement to both operational (internal) and user-facing (external) use cases:

FIGURE 17: EFFECTIVE IOT DESIGN SHOULD INFORM ONGOING OPERATIONAL AND UX IMPROVEMENT

Operational	User-Facing
• Supply chain inefficiencies	• Effectiveness of hardware/physical design
• Training of sales and support agents	• Effectiveness of software design and intelligence (e.g. machine learning)
• Partnership value (e.g. channel, integration)	• Monitor usage patterns across user, device, and environment types
• Effectiveness of marketing collateral	• Solicit direct feedback from users in real-time
• Data utility and integrity	• Offer iterative software updates to services and applications

Gone are the days where a company loses sight of its customer and product the day it is sold. Hardware, software, and connectivity provide new means for companies to not only have visibility and dialog with customers, but to constantly learn from and better serve them.

"For connected products, key performance indicators (KPIs) are often around the number of connections and number of times customers access the app and why," says Kevin Meagher, SVP at ROC Connect and former head of smart home for Lowes. "If services are truly useful, customers will engage with the product or app frequently. That's when you can start to use the data to inform product development and enhancement."

Of course it's not just collecting data that separates effective IoT experiences. Constant assessment of data collection, curation, means of analysis, decision-making, as well as ethical and practical use of data is what separates short-term data-driven tactics from long-term data-driven strategy.

Are the data we're collecting appropriate? Are there areas where we are prioritizing convenience over integrity?

Does the data we're collecting and using answer our questions and actually improve user experience? Would different data be more appropriate?

What tools and biases are we using in our analysis of data? How can we ensure ongoing assessment of approach this question and take action to improve?

Are the data reliable? What are we missing or overlooking in curating data? Are we maintaining data integrity?

While some of these questions are more quantifiable than others, developing clear success metrics helps product teams and designers at all functions (see Figure 11) understand what data are most important and align around common goals.

11. Test, Test, Test. Test Again. And Keep Testing

Across the board, the companies we interviewed emphasized the critical importance of testing products 'in the wild.' Critical nuances in UX only surface when designers take the time to consider them. It is in both user and businesses' best interests for product designers to "immerse themselves deeply in the end-user experience to see, think, feel, and discover the way their users do," offers Jaime Raijman, Chief Design Officer for Knocki, a start-up focused on a gesture-controlled home automation device. For devices without a screen, this is even more important to avoid abandonment.

Test workflows as much as possible, assess the obvious, challenge assumptions, and constantly address bugs and issues. Usability testing and meticulous analysis of every aspect of user interaction from the perspective of the end-user is the only way to evaluate the designer's own assumptions and adapt the solution.

What manufactures and product designers must continuously remember is that they think differently than their users, indeed users themselves think differently than other users. Personas, or user archetypes remain an essential framework used to inform product, service, and content designs. Many of those interviewed assert the importance of segmenting and testing each persona's interaction with products and using insights to inform persona-specific R&D. Whether tech-savvy Kickstarter backers, single parents looking for time efficiencies, or elderly persons living at home; each will perceive ease or pains along product workflows in different ways and for different reasons.

"Testing is something you have to be passionate about. You have to drive simplicity at every moment, from packaging, to set up, to use. Ironically, in order to achieve simplicity requires complex testing to surface user habits, biases, behaviors, and pain points. Every time you test a workflow, you gain new insights into where the friction emerges, for whom, and aggregate these tiny iterations across the rest of the product."

Users think differently at different phases of the product's lifecycle. For example, the moment of ripping into the packaging to set up a product for the first time has an entirely distinct emotional backdrop and tolerance level than does the moment when the product fails.

Our research surfaced the following tips for testing connected product UX:

- Test hypotheses
- Test different aesthetics and surfaces
- Test different patterns in workflows
- Test product use with and without mobile app
- Provide prompts to some user groups and no prompts to others; compare findings
- Ask users their assumptions after product testing
- Observe user tendencies for problem-solving

- Test different testing methods
- Use both online and offline channels for testing
- Solicit feedback from users as much as possible

12. Design for Integrated Context & Interoperability

Our lives span multiple contexts; multiple domains, locations, devices, people, and needs. What designers must understand is that interaction with connected products and infrastructure will inevitably be a fraction of contextual signals across a far deeper ecosystem of events and interactions. Imagine a world of no technological, no brand, and no interoperability barriers. Removing the barriers of interoperability multiplies the value any one device (or brand) can achieve, but it's not easy. Designers will have less control over the broader experiences they enable as interfaces will manifest over an increasingly vast ecosystem of touchpoints and channels.

> *Can I request an Uber ride from Alexa, receive the ETA on my Apple Watch, split the fare with a friend on Messenger and rate the ride on my phone App?*

(SOURCE: UXDESIGN.CC)

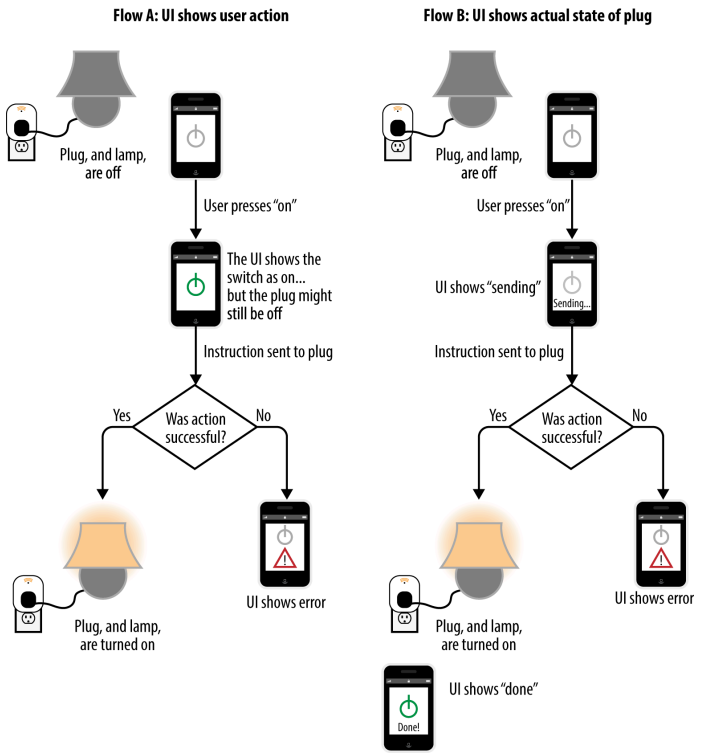
What businesses must overcome is the temptation to design connected products as a product, and instead re-imagine and re-calibrate what value they offer within a broader system. When designing for systems, the goal is coherence across all touchpoints. Think of coherence as an umbrella, under which consistency, composition, and continuity fall.

At the most basic aesthetic level, UIs across all devices, platforms, and content should feel ***consistent,*** 'like a family;' not identical per say, yet intuitively familiar and resembling of fellow touchpoints. ***Composition*** accounts for which devices or UI are best suited for which functionality. For instance, a wearable may be packed with sensors, but minimal in form factor and altogether screenless. More complex interactions or customizations might be handled on the device's associated mobile app. ***Continuity*** is the flow of interactions and data in a coherent sequence across devices.[20] This is essential for UX design in IoT because connected products will rarely be the singular endpoint for interaction. This, according to UX expert Claire Rowland, is about handling interstitial states gracefully; designing for the spaces between devices.

For example, if a user requests a transaction or change of state via one device, designers must consider how to convey the verification of the command versus the execution of the task on another device while accounting for variables like

- Network connectivity
- Latency
- Gateways and routers
- Multiple devices working together to complete the request
- Classic usability (e.g. reflecting/responding to request)
- Critical vs. trivial nature of use case
- Data ownerships and proprietary limitations

FIGURE 18: ROWLAND'S DEPICTION OF TWO UX OPTIONS FOR HANDLING DELAYS AND POTENTIAL FAILURES



(SOURCE: DESIGNING CONNECTED PRODUCTS, O'REILLY 2015)

In the "optimistic" example on the left, the UI confirms the user's action and backpedals if there is a problem. In the "pessimistic" example on the right, the UI confirms that the command is being sent to the plug but does not confirm that the plug has been turned on until it receives confirmation.[21]

What is essential is acknowledging the user request in a way that, first and foremost, is commensurate with reliability and 'mission criticality,' and second, does not undermine the value of the product. To illustrate the nuance, consider the difference between UX workflow in the following scenarios:

A user wishes to turn on a connected lightbulb in her kitchen using her mobile app. Impacts of latency are low, even if the app reflects the request has been made, technical hindrances carry relatively low risk. And the user could always ***just flick the lightswitch...***

A connected doorbell that takes more than 10 seconds to connect to the network, nevermind notify its user to signal instruction, runs the risk of taking so long the courier departs. Overall UX is hardly an improvement to the status quo in this scenario, although risks and pain points are still relatively minimal.

An elderly person's wearable device monitors location or biometric data and could be designed to send alerts to doctors or remote caretakers. If device states don't align, latency, data security, reliability, potentially even the user's safety carry much higher stakes.

The longer-term goal for UX design is less about each connected objects, device, home, car, or otherwise, rather it is about coordinating intelligent assistants and integrated contexts. Interactivity delivered so seamlessly and intuitively, it is all but invisible. At the time of this report's publication, there is still a dire need for adequate standards, connectivity speed, and device reliability to truly deliver this level of experience, although a variety of companies are advancing rapidly towards this objective.

To illustrate what this does not look like, consider the current state of the so-called 'Smart' Home. Wi-fi or Bluetooth enabled doorlocks, coffee-makers, lightbulbs, and hundreds of other appliances barely provide more value than their analogue counterparts. What 'wow' factors do exist are all too often undermined by the lack of interoperability between all these smart appliances. Each of these 'parts' hardly constitutes a better UX whole.

Instead, consider how all businesses in this scenario must re-imagine their value in a systems context to deliver a superior user experience, to achieve a whole, ***coherent*** experience that is greater than the sum of the parts. Integrations between all in-home devices, systems, mobile, and environmental data help the home itself anticipate user needs. Using voice, motion detection, and gestures, the user enjoys, confirms, or corrects prompts the home offers (e.g. lighting, airflow, and temperature based on weather, season, time of day; music, audio, news based on preferences; greater security; services only as desired. Through voice or a tap or two on a smartwatch, a user could control locks, security system, and communications with family. Such orchestration of contextually integrated, sensitive, and personalized experience delivery is only possible through interoperability, scenario design and recognition, and ecosystem integration.

Conclusion

Ubiquitous sensing and software are transformational to the design of connected products. The inherently distributed nature of infusing software and sensing into the messy and chaotic physical world creates new and distinct challenges for companies vying to design meaningful connected product experiences. Now more than ever, businesses must architect UX across entire systems— interoperable with other products and services; across teams; across customer journeys; across the supply chain, and so on. UX design is thus, no longer a tactic or aesthetic detail, but core to any customer and product strategy in the digital age.

RESEARCH METHODOLOGY

This research was developed through extensive primary and secondary qualitative research methods. We interviewed 23 market influencers, vendors, and adopters between July, 2016 – January, 2017. We also conducted countless briefings and discussions with industry innovators in the connected device and related software markets. Input into this document does not represent a complete endorsement of the report by the individuals or the companies listed herein.

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- Arrayent, Bob Dahlberg, VP Business Development
- Autodesk, Bryan Kester, Head of IoT, formally CEO of SeeControl
- Birmingham University, Charles Ikem, Research Specialist, Customer Experience
- Claire Rowland, Independent IoT UX Expert
- Dell, Niel Hand, VP Product Strategy & Innovation
- EVRYTHNG, Niall Murphy, Founder & CEO
- Fluke, now part of Fortive Corporation, Melissa Hammerle, Director of IoT Business
- Greenwave Technologies, Jerome Rota, Chief Scientist, Usability
- Intel, George Moakley, IoT Solutions Architect
- InTouch Solutions, Neal Welbourne, Director of Analytics Strategy
- Knocki, Jaime Raijman, Chief Design Officer
- Lightify, by LEDvance, Aaron Ganick, Head of Smart Home
- Lockstate, Nolan Mondrow, CEO
- Logitech, Renee Neimi, Head of Smart Home Business
- Mnubo, Aditya Pendyala, Co-Founder & Head of Growth
- RedClay, Ashley Etling, Chief Creative Officer
- ROC Connect, Kevin Meagher, SVP Business Development
- Silicon Labs, Dierdre Walsh, Director of Corporate Marketing
- SOMO Imagineers, Sergio Ortiz, VP Strategy & Experience Design
- Sony, Dimitris Kourepis, SVP Global Digital Marketing & UX
- UnaliWear, Jean Anne Booth, CEO
- Wink, Matt McGovern, Head of Marketing & Business Development
- Xively, Ryan Lester, Director of IoT Strategy

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Jessica Groopman is an independent industry analyst and IoT advisor specializing in consumer-side Internet of Things, blockchain, and AI. Her research and analyst practice concentrates on the application of sensors, machine learning, automation, and consumer protections in B2C and B2B2C businesses. Groopman is a regular speaker, moderator, and panelist at IoT industry events. She is also a frequent contributor to numerous 3rd party blogs and news/media outlets. Jessica is also contributing principal analyst with Tractica Research, contributing member of the International IoT Council, the IEEE's Internet of Things Group, IoT Gurus, and FC Business Intelligence's IoT Nexus Advisory Board. Jessica was also included in Onalytica's list of the 100 Most Influential Thought Leaders in IoT. Based in the San Francisco Bay Area, she works with both research firms as a contract analyst and supports clients across Retail, Smart Home, Wearable, and Tech verticals.

Jessica has served as research director and principal analyst with Harbor Research where she headed research and content strategy and helped lead Harbor's Smart Systems Lab program. Prior to Harbor Research, Jessica was an industry analyst with Altimeter Group where she covered Internet of Things and contributed to research around other disruptive technological trends such as real-time marketing, social media, and mobile commerce. Prior to that, Jessica lead research at Focus Research and was a research analyst at Tippit Research. Before she worked in business and technology research, Jessica's research experience was based mostly in academic anthropological fieldwork, specifically in ethnographic, linguistic, and archaeological research both in the United States and abroad.

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