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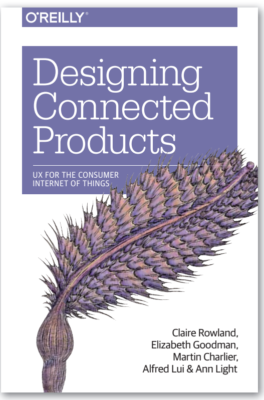

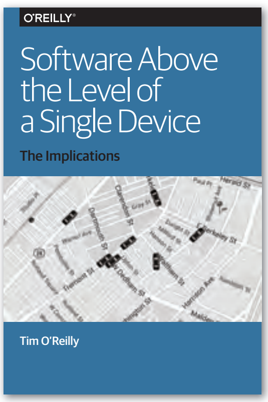

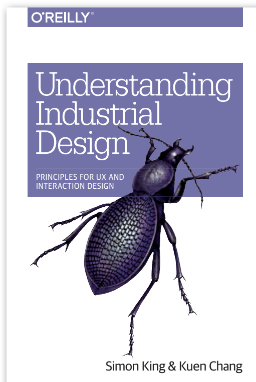

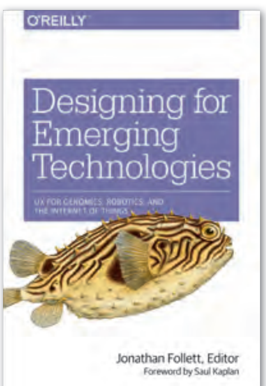

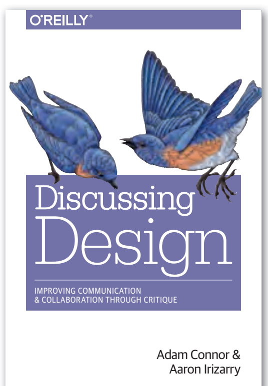

Designing for the Internet of Things
A Curated Collection of Chapters from the O'Reilly Design Library

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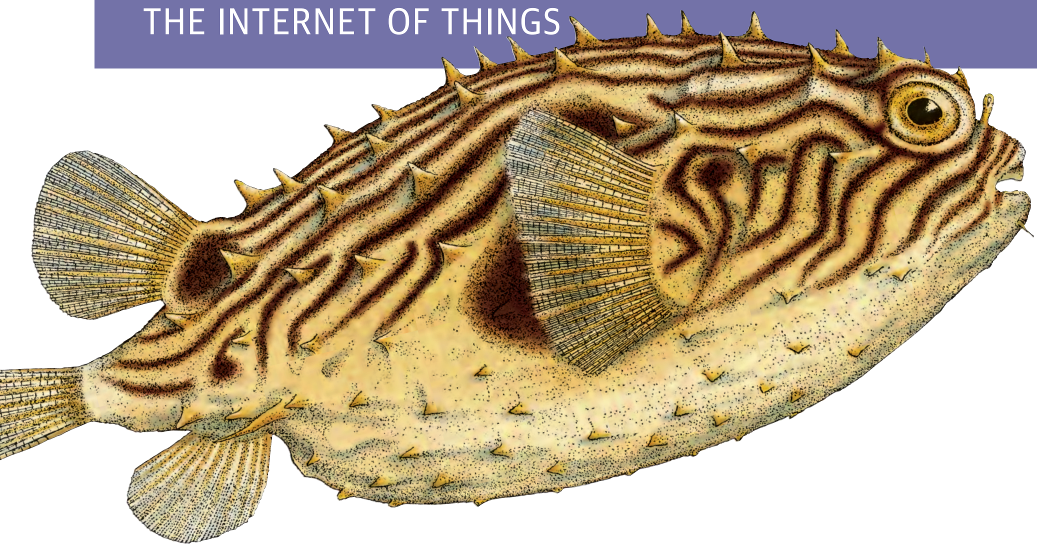

Jonathan Follett, Editor

Foreword by Saul Kaplan

Designing for Emerging Technologies

UX for Genomics, Robotics, and the Internet of Things

Edited by Jonathan Follett

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Learning and Thinking with Things

STEPHEN P. ANDERSON

Tangible Interfaces

The study of how humans learn is nothing new and not without many solid advances. And yet, in the rush to adopt personal computers, tablets, and similar devices, we've traded the benefits of hands-on learning and instruction for the scale, distribution, and easy data collection that's part and parcel to software programs. The computational benefits of computers have come at a price; we've had to learn how to interact with these machines in ways that would likely seem odd to our ancestors: mice, keyboards, awkward gestures, and many other devices and rituals that would be nothing if not foreign to our predecessors. But what does the future hold for learning and technology? Is there a way to reconcile the separation between all that is digital with the diverse range of interactions for which our bodies are capable? And how does the role of interaction designer change when we're working with smart, potentially shape-shifting, objects? If we look at trends in technology, especially related to tangible computing (where physical objects are interfaced with computers), they point to a sci-fi future in which interactions with digital information come out from behind glass to become things we can literally grasp.

One such sign of this future comes from Vitamins, a multidisciplinary design and invention studio based in London. As Figure 5-1 shows, it has developed a rather novel system for scheduling time by using... what else... Lego bricks!

Figure 5-1. Vitamins Lego calendar[1]

Vitamins describes their Lego calendar as the following:

> ...a wall-mounted time planner, made entirely of Lego blocks, but if you take a photo of it with a smartphone, all of the events and timings will be magically synchronized to an online digital calendar.

Although the actual implementation (converting a photo of colored bricks into Google calendar information) isn't in the same technical league as nanobots or mind-reading interfaces, this project is quite significant in that it hints at a future in which the distinctions between physical and digital are a relic of the past.

Imagine ordinary objects—even something as low-tech as Lego bricks—augmented with digital properties. These objects could identify themselves, trace their history, and react to different configurations. The possibilities are limitless. This is more than an "Internet of Things," passively collecting data; this is about physical objects catching up to digital capabilities. Or, this is about digital computing getting out from behind glass. However you look at this, it's taking all that's great about being able to pick up, grasp, squeeze, play with, spin,

1 *http://www.lego-calendar.com*

push, feel, and do who-knows-what-else to a thing, while simultaneously enjoying all that comes with complex computing and sensing capabilities.

Consider two of the studio's design principles (from the company's website) that guided this project:

- It had to be *tactile*: "We loved the idea of being able to hold a bit of time, and to see and feel the size of time"
- It had to work both *online and offline*: "We travel a lot, and we want to be able to see what's going on wherever we are."

According to Vitamins, this project "makes the most of the tangibility of physical objects, and the ubiquity of digital platforms, and it also puts a smile on our faces when we use it!"[2] Although this project and others I'll mention hint at the merging of the physical and the digital, it's important to look back and assess what has been good in the move from physical to digital modes of interaction—and perhaps what has been lost.

KANBAN WALLS, CHESS, AND OTHER TANGIBLE INTERACTIONS

Oddly enough, it is the software teams (the folks most immersed in the world of virtual representations) who tend to favor tangibility when it comes to things such as project planning; it's common for Agile or Scrum development teams to create *Kanban* walls, such as that shown in Figure 5-2. Imagine sticky notes arranged in columns, tracking the progress of features throughout the development cycle, from backlog through to release. Ask most teams and they will say there is something about the tangibility of these sticky notes that cannot be replicated by virtual representations.

There's something about moving and arranging this sticky little square, feeling the limitations of different size marker tips with respect to how much can be written, being able to huddle around a wall of these sticky notes as a team—there's something to the physical nature of working with sticky notes. But, is there any explanation as to "why" this tangible version might be advantageous, especially where understanding is a goal?

2 *http://www.special-projects-studio.com*

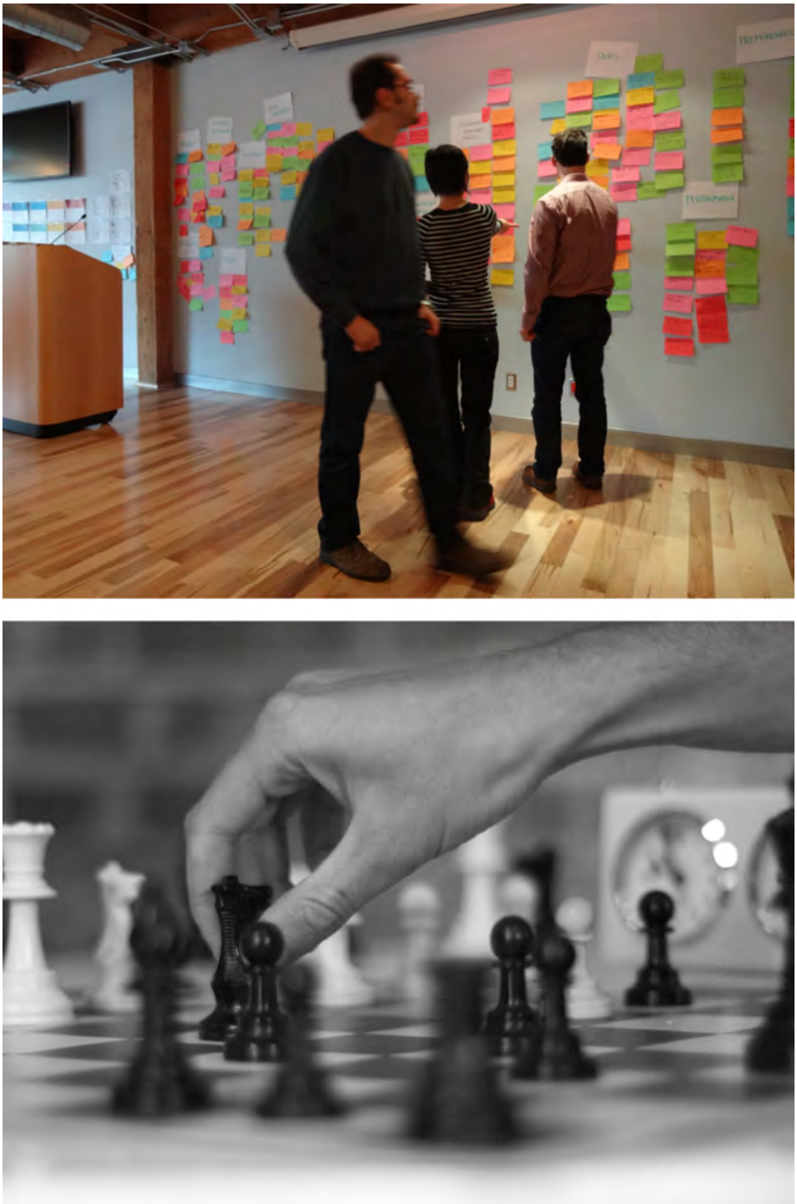

Figure 5-2. Kanban walls[3] and chess[4]

3 Photo by Jennifer Morrow (*https://www.flickr.com/photos/asadotzler/8447477253*) CC-BY-2.0 (*http://creativecommons.org/licenses/by/2.0*)

4 Photo by Dean Strelau (*https://www.flickr.com/photos/dstrelau/5859068224*) CC-BY-2.0 (*http://creativecommons.org/licenses/by/2.0*)

Before answering that question, first consider this question: where does thinking occur?

If your answer is along the lines of "in the brain," you're not alone. This view of a mind that controls the body has been the traditional view of cognition for the better part of human history. In this view, the brain is the thinking organ, and as such it takes input from external stimuli, processes those stimuli, and then directs the body as to how to respond.

Thinking; then doing.

But, a more recent and growing view of cognition rejects this notion of mind-body dualism. Rather than thinking and then doing, perhaps we think through doing.

Consider the game of chess. Have you ever lifted up a chess piece, hovered over several spots where you could move that piece, only to return that piece to the original space, still undecided on your move? What happened here? For all that movement, there was no pragmatic change to the game. If indeed we think and then do (as mind-body dualism argues), what was the effect of moving that chess piece, given that there was no change in the position? If there is no outward change in the environment, why do we instruct our bodies to do these things? The likely answer is that we were using our environment to extend our thinking skills. By hovering over different options, we are able to more clearly see possible outcomes. We are extending the thinking space to include the board in front of us.

Thinking through doing.

This is common in chess. It's also common in *Scrabble*, in which a player frequently rearranges tiles in order to see new possibilities.

Let's return to our Kanban example.

Even though many cognitive neuroscientists (as well as philosophers and linguists) would likely debate a precise explanation for the appeal of sticky notes as organizational tools, the general conversation would shift the focus away from the stickies themselves to the role of our bodies in this interaction, focusing on how organisms and the human mind organize themselves by interacting with their environment. This perspective, generally described as *embodied cognition*, postulates that thinking and doing are so closely linked as to not be serial processes. We don't think and then do; we think through doing.

But there's more to embodied cognition than simply extending our thinking space. When learning is embodied, it also engages more of our senses, creating stronger neural networks in the brain, likely to increase memory and recall.

Moreover, as we continue to learn about cognition ailments such as autism, ADHD, or sensory processing disorders, we learn about this mind-body connection. With autism for example, I've heard from parents who told me that learning with tangible objects has been shown to be much more effective for kids with certain types of autism.

Our brain is a perceptual organ that relies on the body for sensory input, be it tangible, auditory, visual, spatial, and so on. Nowhere is the value of working with physical objects more understood than in early childhood education, where it is common to use "manipulatives"—tangible learning objects—to aid in the transfer of new knowledge.

MANIPULATIVES IN EDUCATION

My mother loves to recall my first day at Merryhaven Montessori, the elementary school I attended through the sixth grade. I recall her asking, "What did you learn today?" I also remember noticing her curiosity at my response: "I didn't learn anything—we just played!"

Of course "playing" consisted of tracing sandpaper letters, cutting a cheese slice into equal parts, and (my favorite) counting beads; I could count with single beads, rods consisting of 10 beads, the flat squares of 100 beads (or 10 rods, I suppose), and the mammoth of them all: a giant cube of 1000 beads! (See Figure 5-3.) These "manipulatives" are core to the Montessori method of education, and all examples—dating back to the late 1800s—of learning through tangible interactions. Playing is learning, and these "technologies" (in the anthropological sense) make otherwise abstract concepts quite, concrete.

But why is this so?

Jean Piaget, the influential Swiss developmental psychologist, talks about stages of development, and how learning is—at the earliest ages—physical (sensorimotor). As babies, we grasp for things and make sense of the world through our developing senses. At this stage, we learn through physical interactions with our environment. This psychological theory, first proposed in the 1960s, is supported by recent advances in cognitive neuroscience and theories about the mind and body.

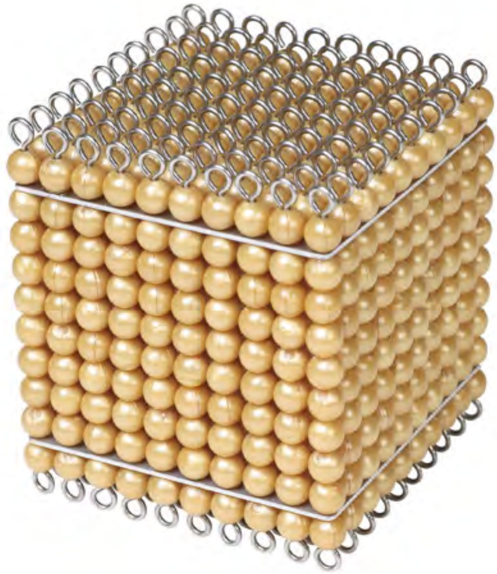

Figure 5-3. Montessori beads[5]

Essentially, we all start off understanding the world only through physical (embodied) interactions. As infants, even before we can see, we are grasping at things and seeking tactile comforts. We learn through our physical interactions with our environment.

Contrast this with the workbooks and photocopied assignments common in most public schools. These pages represent "what" students should be learning, but ignore the cognitive aspects of "how" we learn, namely through interactions. Much of learning is cause and effect. Think of the young child who learns not to touch a hot stove either through her own painful experience or that of a sibling. It is through interactions and experimentation (or observing others) that we begin to recognize patterns and build internal representations of otherwise abstract ideas.

Learning is recognizing or adding to our collection of patterns.

5 As featured on Montessori Outlet (*http://www.montessorioutlet.com*)

In this regard, computers can be wonderful tools for exploring possibilities. This is true of young children playing with math concepts, to geneticists looking for patterns in DNA strands. Interactive models and simulations are some of the most effective means of sensemaking. Video games also make for powerful learning tools because they create possibility spaces where players can explore potential outcomes. Stories such as *Ender's Game* (in which young children use virtual games to explore military tactics) are a poignant testimony to the natural risk-taking built into simulations. "What happens if I push this?" "Can we mix it with...?" "Let's change the perspective." Computers make it possible for us to explore possibilities much more quickly in a playful, risk-free manner. In this regard, physical models are crude and limiting. Software, by nature of being virtual, is limited only by what can be conveyed on a screen.

But, what of the mind-body connection? What about the means by which we explore patterns through a mouse or through our fingertips sliding across glass? Could this be improved? What about wood splinters and silky sheets and hot burners and stinky socks and the way some objects want to float in water—could we introduce sensations like these into our interactions? For all the brilliance of virtual screens, they lack the rich sensory associations inherent in the physical world.

VIRTUAL MANIPULATIVES

For me, it was a simple two-word phrase that brought these ideas into collision: "virtual manipulatives." During an interview with Bill Gates, Jessie Woolley-Wilson, CEO of DreamBox, shared a wonderful example of the adaptive learning built in to their educational software. Her company's online learning program will adapt which lesson is recommended next based not only the correctness of an answer, but by "capturing the strategies that students [use] to solve problems, not just that they get it right or wrong." Let's suppose we're both challenged to count out rods and beads totaling 37. As Wooley-Wilson describes it:

> You understand groupings and you recognize 10s, and you very quickly throw across three 10's, and a 5 and two 1's as one group. You don't ask for help, you don't hesitate, your mouse doesn't hesitate over it. You do it immediately, ready for the next. I, on the other hand, am not as confident, and maybe I don't understand grouping strategies. But I do

> know my 1's. So I move over 37 single beads. Now, you have 37 and I have 37, and maybe in a traditional learning environment we will both go to the next lesson. But should we?

By observing how a student arrives at an answer, by monitoring movements of the mouse and what students "drag" over, the system can determine if someone has truly mastered the skill(s) needed to move on. This is certainly an inspiring example of adaptive learning, and a step forward toward the holy grail of personalized learning. But, it was the two words that followed that I found jarring: she described this online learning program, using a representation of the familiar counting beads, as virtual manipulatives. Isn't the point of a manipulative that it is tangible? What is a virtual manipulative then, other than an oxymoron?

But this did spark an idea: what if we could take the tangible counting beads, the same kind kids have been playing with for decades, and endow them with the adaptive learning properties Woolley-Wilson describes? How much better might this be for facilitating understanding? And, with the increasing ubiquity of cheap technology (such as RFID tags and the like), is this concept really that far off? Imagine getting all the sensory (and cognitive) benefits of tangible objects, and all the intelligence that comes with "smart" objects.

EMBODIED LEARNING

You might wonder, "Why should we care about tangible computing?" Isn't interacting with our fingers or through devices such as a mouse or touchscreens sufficient? In a world constrained by costs and resources, isn't it preferable to ship interactive software (instead of interactive hardware), that can be easily replicated and doesn't take up physical space? If you look at how media has shifted from vinyl records to cassette tapes to compact discs and finally digital files, isn't this the direction in which everything is headed?

Where learning and understanding is required, I'd argue no. And, a definite no wherever young children are involved. Piaget established four stages of learning (sensorimotor, pre-operational, concrete operational, and formal operational), and argued that children "learn best from concrete [sensorimotor] activities." This work was preceded by American psychologist and philosopher John Dewey, who emphasized firsthand learning experiences. Other child psychologists such as Bruner or Dienne have built on these "constructivist" ideas, creating materials used to facilitate learning. In a review of studies on the use of manipulatives in the classroom, researchers Marilyn Suydam and Jon Higgins concluded that "studies at every grade level support the importance and use of manipulative materials." Taking things one step further, educator and artificial intelligence pioneer Seymour Papert introduced constructionism (not to be confused with constructivism), which holds that learning happens most effectively when people are also active in making tangible objects in the real world.

OK. But what of adults, who've had a chance to internalize most of these concepts? Using Piaget's own model, some might argue that the body is great for lower-level cognitive problems, but not for more abstract or complex topics. This topic is one of some debate, with conversations returning to "enactivism" and the role of our bodies in constructing knowledge. The central question is this: if learning is truly embodied, why or how would that change with age? Various studies continue to reveal this mind-body connection. For example, one study found that saying words such as "lick, pick, and kick" activates the corresponding brain regions associated with the mouth, hand, and foot, respectively. I'd add that these thinking tools extend our thinking, the same way objects such as pen and paper, books, or the handheld calculator (abacus or digital variety—you choose) have allowed us to do things we couldn't do before. Indeed, the more complex the topic, the more necessary it is to use our environment to externalize our thinking.

Moreover, there is indeed a strong and mysterious connection between the brain and the body. We tend to gesture when we're speaking, even if on a phone when no one else can see us. I personally have observed different thinking patterns when standing versus sitting. In computer and retail environments, people talk about "leaning in" versus "leaning back" activities. In high school, I remember being told to look up, if I was unsure of how to answer a question—apparently looking up had, in some study, been shown to aid in the recall of information! Athletes, dancers, actors—all these professions talk about the yet unexplained connections between mind and body.

As magical as the personal computer and touchscreen devices are, there is something lost when we limit interactions to pressing on glass or clicking a button. Our bodies are capable of so much more. We have the capacity to grasp things, sense pressure (tactile or volumetric), identify textures, move our bodies, orient ourselves in space, sense changes in temperature, smell, listen, affect our own brain waves, control our breathing—so many human capabilities not recognized by most digital devices. In this respect, the most popular ways in which we now interact with technology, namely through the tips of our fingers, will someday seem like crude, one-dimensional methods.

Fortunately, the technology to sense these kinds of physical interactions already exists or is being worked on in research labs.

(Near) Future Technology

Let's consider some of the ways that physical and digital technologies are becoming a reality, beginning with technologies and products that are already available to us:

- In 2012, we saw the release of the Leap Motion Controller, a highly sensitive gestural interface, followed closely by Mylo, an armband that accomplishes similar *Minority Report*–style interactions, but using changes in muscles rather than cameras.
- When it comes to touchscreens, Senseg uses electrostatic impulses to create the sensation of different textures. Tactus Technologies takes a different approach, and has "physical buttons that rise up from the touchscreen surface on demand."
- To demonstrate how sensors are weaving themselves into our daily lives, Lumo Back is a sensor band worn around the waist to help improve posture.
- We've got the Ambient umbrella, which alerts you if it will be needed, based on available weather data.
- A recent Kickstarter project aims to make DrumPants (the name says it all!) a reality.
- In the wearables space, we have technologies such as conductive inks, muscle wire, thermochromic pigments, electrotextiles, and light diffusing acrylic (see Figure 5-4). Artists are experimenting with these new technologies, creating things like a quilt that doubles as a heat-map visualization of the stock market (or whatever dynamic data you link to it).

Figure 5-4. A collage of near-future tech (from left to right, top to bottom): Ambient umbrella, DrumPants, the Leap Motion Controller, Lumo Back, Mylo armband, Senseg, and Tactus tablet

If we look a bit further out:

- Sites such as Sparkfun, Parallax, or Seeed offer hundreds of different kinds of sensors (RFID, magnetic, thermal, and so on) and associated hardware with which hobbyists and businesses can tinker. Crowdfunding sites such as Kickstarter have turned many of these hobbyist projects into commercial products.
- Smartphones have a dozen or more different sensors (GPS, accelerometer, and so on) built in to them, making them a lot more "aware" than most personal computers (and ready for the imaginative entrepreneur). And while most of us are focused on the apps we can build on top of these now-ubiquitous smartphone sensors, folks like Chris Harrison, a researcher at Disney Research Labs, have crafted a way to recognize the differences between various kinds of touch—fingertip, knuckle, nail, and pad—using acoustics and touch sensitivity; the *existing* sensors can be exploited to create new forms of interaction.
- Indeed, places such as Disney Research Labs in Pittsburgh or the MIT Media Lab are hotspots for these tangible computing projects. Imagine turning a plant into a touch surface, or a surface that can sense different grips. Look further out, and projects like ZeroN show an object floating in midair, seemingly defying gravity; when moved, information is recorded and you can play back these movements!
- How about a robotic glove covered with sensors and micro-ultrasound machines? Med Sensation is inventing just such a device that would allow the wearer to assess all kinds of vital information not detectable through normal human touch.

There is no shortage of exciting technologies primed to be the next big thing!

We live in a time full of opportunity for imaginative individuals. In our lifetime, we will witness the emergence of more and varied forms of human-computer interaction than ever before. And, if history is any indication (there's generally a 20-year incubation period from invention in a laboratory to commercial product), these changes will happen inside of the next few decades.

I can't help but wonder what happens when ordinary, physical objects, such as the sandpaper letters or counting beads of my youth, become endowed with digital properties? How far off is a future in which ordinary learning becomes endowed with digital capabilities?

THINKING WITH THINGS, TODAY!

Whereas much of this is conjecture, there are a handful of organizations exploring some basic ways to make learning both tangible and digital.

Sifteo Cubes

The most popular of these technologies is, of course, the Sifteo Cubes (see Figure 5-5). Announced at the February 2009 TED conference, these "toy tiles that talk to each other" have opened the doors to new kinds of play and interaction. Each cube, aside from having a touchscreen, has the added ability to interact with other cubes based on its proximity to a neighboring cube, cube configurations, rotation, and even orientation and gesture. In various games, players essentially reposition blocks to create mazes, roll a (virtual) ball into the next block, and do any number of other things accomplished by interacting with these blocks the way you would dominoes. They've been aptly described as "alphabet blocks with an app store." Commenting on what Sifteo Cubes represent, founder Dave Merrill has said "What you can expect to see going forward are physical games that really push in the direction of social play."

Motion Math

Similar to Sifteo Cubes, in that interaction comes through motion, is the fractions game Motion Math (Figure 5-5). This simple app for the iPhone and Android uses the accelerometer to teach fractions. Rather than tapping the correct answer or hitting a submit button, as you would with other math software, players tilt their devices left or right to direct a bouncing ball to the spot correctly matching the identified fraction; you learn fractions using hand-eye coordination and your body (or at least your forearm). And, rather than an "incorrect" response, the feedback loop of a bouncing ball allows you to playfully guide your ball to the correct spot.

Figure 5-5. Edu tech (from top to bottom): GameDesk's Areo, the Motion Math app, and Sifteo Cubes

GameDesk

As exciting as Sifteo and Motion Math are, some of the best examples of whole body learning with technology would be the learning games developed by GameDesk. Take Aero, as an example. Codesigned with Bill Nye the Science Guy, Aero teachers sixth graders fundamental principles in physics and aerodynamics. How? According to GameDesk founder Lucient Vattel:

> In this game, you outstretch your arms and you become a bird. It's an accurate simulation of bird flight. And through that you get to understand the vectors: gravity, lift, drag, thrust. These concepts are not normally taught at the sixth grade level…

Vattel goes on to add that "a game can allow the concepts to be visualized, experienced…" And this is what is remarkable: that students are *experiencing* learning, with their entire body and having a blast while they're at it—who doesn't want to transform into a bird and fly, if only in a simulation?

GameDesk also works with other organizations that are exploring similar approaches to learning. One of those organizations is SMALLab Learning, which has a specific focus on creating embodied learning environments. SMALLab uses motion-capture technology to track students' movements and overlay this activity with graphs and equations that represent their motions in real time. In a lesson on centripetal force, students swing an object tethered to a rope while a digital projection on the ground explains the different forces at play. Students can "see" and experience scientific principles. "They feel it, they enact it," says David Birchfield, co-founder of SMALLab Learning.

The technology in these examples is quite simple—for Aero a Wiimote is hidden inside each of the wings—but the effect is dramatic. Various studies by SMALLab on the effectiveness of this kind of embodied learning show a sharp increase as evidenced by pre-, mid-, and posttest outcomes for two different control groups.

Timeless Design Principles?

Technology will change, which is why I've done little more here than catalog a handful of exciting advancements. What won't change, and is needed, are principles for designing things with which to think. For this, I take an ethnographer's definition of technology, focusing on the effect of these artifacts on a culture. Based on my work as an educator and designer, I propose the following principles for designing learning objects.

A good learning object:

Encourages playful interactions

Aside from being fun or enjoyable, playfulness suggests you can play with it, that there is some interactivity. Learning happens through safe, nondestructive interactions, in which experimentation is encouraged. Telling me isn't nearly as effective as letting me "figure it out on my own." Themes of play, discovery, experimentation, and the like are common to all of the learning examples shared here. Sifteo founder Dave Merrill comments that "Like many games, [Sifteo] exercises a part of your brain, but it engages a fun play experience first and foremost."

Supports self-directed learning (SDL)

When learners are allowed to own their learning—determining what to learn, and how to go about filling that gap in their knowledge—they become active participants in the construction of new knowledge. This approach to learning encourages curiosity, helps to develop independent, intrinsically motivated learners, and allows for more engaged learning experiences. Contrary to what is suggested, SDL can be highly social, but agency lies in hands of the learner.

Allows for self-correction

An incorrect choice, whether intended, unintended, or the result of playful interactions should be revealed quickly (in real time if possible) so that learners can observe cause-and-effect relationships. This kind of repeated readjusting creates a tight feedback loop, ultimately leading to pattern recognition.

Makes learning tangible

Nearly everything is experienced with and through our bodies. We learn through physical interactions with the world around us and via our various senses. Recognizing the physicality of learning, and that multimodal learning is certainly preferable, we should strive for manipulatives and environments that encourage embodied learning.

Offers intelligent recommendations

The unique value of digital objects is their ability to record data and respond based on that data. Accordingly, these "endowed objects" should be intelligent, offering instruction or direction based on passively collected data.

Each of these principles is meant to describe a desired quality that is known or believed to bring about noticeable learning gains, compared to other learning materials. So, how might we use these principles? Let's apply these to a few projects, old and new.

CYLINDER BLOCKS: GOOD LEARNING OBJECTS

In many ways, the manipulatives designed by Maria Montessori more than a century ago satisfy nearly all of these principles. Setting aside any kind of inherent intelligence, they are very capable objects.

Consider the cylinder blocks shown in Figure 5-6. You have several cylinders varying in height and/or diameter that fit perfectly into designated holes drilled into each block. One intent is to learn about volume and how the volume of a shallow disc can be the same as that of a narrow rod. Additionally, these cylinder block toys help develop a child's visual discrimination of size and indirectly prepare a child for writing through the handling of the cylinders by their knobs.

Figure 5-6. Montessori cylinder blocks[6]

How do these blocks hold up?

6 As featured on Montessori Outlet (*http://www.montessorioutlet.com*)

As with nearly all of Maria Montessori's manipulative materials, these objects are treated like toys, for children to get off the shelf and play with, satisfying our first principle, playful interactions. Because children are encouraged to discover these items for themselves, and pursue uninterrupted play (learning) time with the object, we can say it satisfies the second principle: self-directed learning. Attempting to place a cylinder into the wrong hole triggers the learning by either not fitting into the hole (too big), or standing too tall and not filling the space; students are able to quickly recognize this fact and move cylinders around until a fitting slot is found, allowing for self-correction, our third principle. As you play with wooden cylinders, using your hands, we can safely say this satisfies our fourth principle: tangibility. As far as intelligence, this is the only missing piece.

With this kind of orientation in mind, I'd like to share a personal project I'm working on (along with a friend much more versed in the technical aspects).

Case Study: An appcessory for early math concepts

When my kids were younger, I played a math game that never ceased to amuse them (or me, at least). The "game," if you can call it that, consisted of grabbing a handful of Teddy Grahams snack crackers (usually off of their plate) and counting them out, one by one. I'd then do simple grouping exercises, moving crackers between two piles or counting by placing them into pairs. The real fun kicked in when we'd play subtraction. "You have seven Teddy Grahams. If Daddy eats one Teddy Graham, how many do you have left?" I think I enjoyed this more than my kids did (to be fair, I'd also make a few additional Teddy Grahams appear out of nowhere, to teach addition). All in all, this was a great way to explore early math concepts such as counting, grouping, subtraction, and addition.

So, how does this game stack up on the design principles? The learning is playful (if not downright mischievous). And the Teddy Grahams are tangible. On these two attributes my game is successful. However, the game doesn't fare so well on the remaining principles: although my presence is not a bad thing, this doesn't encourage self-directed learning, and the correction comes entirely from me and is not discovered. As for the intelligence, it's dependent on my presence.

This left me wondering if this simple game, not all that effective without my presence, could be translated into the kinds of experiences I'm describing here? Could this be improved, to satisfy the identified five design principles?

Here's my concept: what if we combined my pre-math Teddy Graham game with an iPad? As depicted in Figure 5-7, what if we exchanged the crackers for a set of short cylinders (like knobs on a stereo), and what if we figured out how to get these knobs talking to the iPad. Could that work? Is that possible? Even though this could be accomplished with a set of Sifteo blocks, the costs would be prohibitive for such a singular focus, especially where you'd want up to 10 knobs. I'm treating these as single-purpose objects, with the brains offloaded to the device on which they sit (in this case the iPad). Hence, the "appcessory" label.

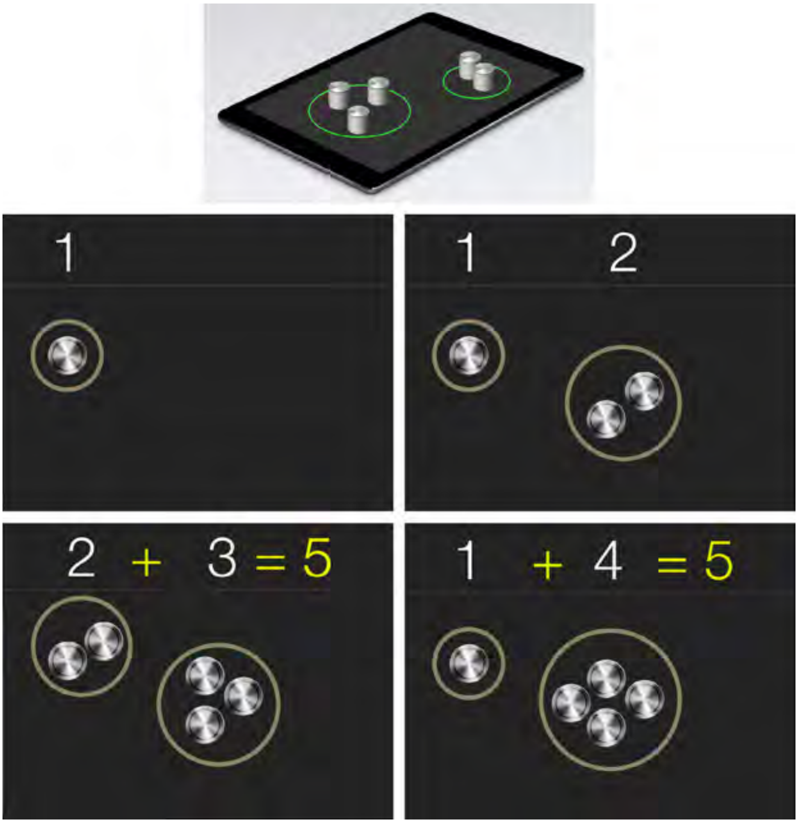

Figure 5-7. Appcessory concept and walkthrough

Here's a walkthrough of how the interactions might work:

- Placing one of these knobs onto the surface of the iPad would produce a glowing ring and the number 1.
- Adding a second knob in close proximity would make this ring larger, encircling both knobs (and changing the number to 2).
- Let's suppose you added a third knob farther away, which would create a new ring with the corresponding number 1.
- Now you have two rings, one totaling 2, the other totaling 1. If you slide the lone knob close to the first two, you'd end up now with one ring, totaling 3. In this manner, and as you start to add more knobs (the iPad supports up to 10, double that of other platforms), you start to learn about grouping.
- In this case, the learning is quite concrete, with the idea of numeric representations being the only abstract concept. You could then switch to an addition mode that would add up the total of however many groups of knobs are on the surface.

I could go on, but you get the idea. By simply placing and moving knobs on a surface the child begins to play with fundamental math concepts. As of this writing, we have proven out the functional technology, but have yet to test this with children. Although the app I'm describing could be built very quickly, my fundamental thesis is that by making these knobs something you can grasp, place, slide, move, remove, and so on, learning will be multimodal and superior to simply dragging flat circles behind glass.

How does this stack up on the five principles?

As with the earlier Teddy Grahams version, it is interactive and tangible. Moving this game to a tablet device allows for self-directed learning and feedback loops in the form of the rings and numerical values. As far as intelligence goes, there is no limit to the kinds of data one could program the iPad to monitor and act upon.

So where might this thinking lead, one day?

Farther Out, a Malleable Future

In the opening scenes of the Superman movie *Man of Steel*, one of the many pieces of Kryptonian technology we see are communication devices whose form and shape is constantly reshaping—a tangible, monochromatic hologram, if you will. Imagine thousands of tiny metal beads moving and reshaping as needed. Even though this makes for a nice bit of sci-fi eye candy, it's also technology that MIT's Tangible Media Group, led by Professor Hiroshi Ishii, is currently exploring. In their own words, this work "explores the 'Tangible Bits' vision to seamlessly couple the dual world of bits and atoms by giving physical form to digital information." They are creating objects (the "tangible bits") that can change shape!

Even though the team's vision of "radical atoms" is still in the realm of the hypothetical, the steps they are taking to get there are no less inspiring. Their latest example of tangible bits is a table that can render 3D content physically, so users can interact with digital information in a tangible way. In their video demonstration, a remote participant in a video conference moves his hands, and in doing so reshapes the surface of a table, rolling a ball around. The technology is at once both awe-inspiring and crude; the wooden pegs moving up and down to define form aren't that unlike the pin art toys we see marketed to children. Having said that, it's easy to imagine something like this improving in fidelity over time, in the same way that the early days of monochromatic 8-bit pixels gave way to retina displays and photorealistic images.

I mention this example because it's easy to diminish the value of tangible interactions when compared to mutability of pixels behind glass; a single device such as a smartphone or tablet can become so many things, if only at the cost of tangibility. Our current thinking says, "Why create more 'stuff' that only serves a single purpose?" And this makes sense. I recall the first app for musicians that I downloaded to my iPhone—a simple metronome. For a few dollars, I was able to download the virtual equivalent of an otherwise very expensive piece of hardware. It dawned on me: if indeed the internal electronics are comparable to those contained in the hardware, there will be a lot of companies threatened by this disruption. This ability to download for free an app that as an object would have cost much more (not to mention add clutter) is a great shift for society.

But...

What if physical objects could reshape themselves in the same way that pixels do? What if one device, or really a blob of beads, could reshape into a nearly infinitesimal number of things? What if the distinctions between bits and atoms become nearly indistinguishable? Can we have physical interactions that can also dynamically change form to be 1,000 different things? Or, at a minimum, can the interface do more than resemble buttons; perhaps it could shape itself into the buttons and switches of last century and then flatten out again into some new form. How does the role of interaction designer change when you're interface is a sculpted, changing thing? So long as we're looking out into possible futures, this kind of thinking isn't implausible, and should set some direction.

Nothing New Under the Sun

While much of this looks to a future in which physical and digital converge, there is one profession that has been exploring this intersection for some time now: museums.

Museums are amazing incubators for what's next in technology. These learning environments have to engage visitors through visuals, interactions, stories, and other means, which often leads to (at least in the modern museum) spaces that are both tangible and take advantage of digital interactions. The self-directed pace that visitors move through an exhibit pressures all museum designers to create experiences that are both informative and entertaining. And, many artists and technologist are eager to, within the stated goals of an exhibit, try new things.

Take for example the Te Papa Tongarewa museum, in Wellington, New Zealand. Because New Zealand is an island formed from the collision of two tectonic plates, you can expect volcanoes, earthquakes, and all things geothermal to get some attention. As visitors move about the space, they are invited to learn about various topics in some amazing and inventive ways. When it comes to discussions of mass and density, there are three bowling ball–sized rocks ready for you to lift; they are all the same in size, but the weight varies greatly. When learning about tectonic shifts, you turn a crank that then displaces two halves of a map (along with sound effects), effectively demonstrating what has happened to New Zealand over thousands of years, and what is likely to happen in the future. Visitors are encouraged to step into a house in which they can experience the simulation of an earthquake. The common denominator between these and dozens more examples is that through a combination of technology and tangible interactions, visitors are encouraged to interact with and construct their own knowledge.

Closing

Novelist William Gibson once commented that future predictions are often guilty of selectively amplifying the observed present. Steam power. Robots. Many of us are being handed a future preoccupied with touchscreens and projections. In "A Brief Rant on the Future of Interaction Design" designer and inventor Bret Victor offers a brilliant critique of this "future behind glass," and reminds us that there are many more forms of interaction of which we have yet to take advantage. As he says, "Why aim for anything less than a dynamic medium that we can see, feel, and manipulate?"

To limit our best imaginings of the future, and the future of learning, to touching a flat surface ignores 1) a body of research into tangible computing, 2) signs of things to come, and 3) centuries of accumulated knowledge about how we—as human creatures—learn best. Whether it's the formal learning of schools or the informal learning required of an information age, we need to actively think about how to best make sense of our world. And all that we know (and are learning) about our bodies and how we come to "know" as human beings cries out for more immersive, tangible forms of interaction. I look forward to a union of sorts, when bits versus atoms will cease to be a meaningful distinction. I look to a future when objects become endowed with digital properties, and digital objects get out from behind the screen. The future is in our grasp.

[13]

Architecture as Interface: Advocating a Hybrid Design Approach for Interconnected Environments

ERIN RAE HOFFER

The Blur of Interconnected Environments

We spend 90 percent of our lives indoors.[1] The built environment has a huge impact on human health, social interaction, and our potential for innovation. In return, human innovation pushes our buildings continually in new directions as occupants demand the highest levels of comfort and functionality.

Our demand for pervasive connectivity has led us to weave the Internet throughout our lives, to insist that all spaces link us together along with our handheld devices, that all environments be interconnected. Internet-enabled devices creep into the spaces we inhabit, and these devices report back on spatial conditions such as light, radiation, air quality and temperature, count the number of people stopping at retail displays minute by minute, detect intruders and security breaches, monitor locations and track characteristics of equipment and supply chain elements, enable us to open locked doors remotely using our mobile devices, and pass terabytes of data to backend systems that analyze, report, and modify the environments we occupy.

1 *http://www.arb.ca.gov/research/resnotes/notes/94-6.htm*

The space that surrounds us is transforming to a series of interconnected environments, forcing designers of space to rethink the role of architecture and the rules for its formulation. Similarly, designers of emerging technologies are rethinking the role of interfaces and the rules for their creation. During this period of experimentation and convergence, practical construction, and problem solving, architects must reinvent their roles and become hybrid designers, creating meaningful architecture with an awareness of the human implications of emerging technologies.

DESIGN TRADITIONS FROM ARCHITECTURE

Architects begin with a human need and develop solutions through inspiration and information—human, social, natural, economic and technological. The architect is charged to envision a new reality that addresses explicit and tacit needs, to create an expansive solution set that suits this vision. For millennia, architects have been given the task of imagining spaces to support people and human interaction, describing design intent, and producing concrete instructions for realizing designs as objects in the physical environment. Admittedly, many spaces are designed by builders or lay people, not by licensed architects. Whatever the professional and academic background of the creator, a building design stems from centuries of traditional practice and refined interaction models.

Upon encountering a device for the first time a user or occupant builds a conceptual model about it. The same approach plays out when humans encounter new environments. To design a space, an architect makes assumptions about the building's future occupants. As cognitive scientist and design critic, Donald A. Norman points out, "Good design is a communication between the designer and the user." This manifests through the appearance of the device (object or space) itself.[2] In terms of the built environment, Japanese philosopher Kojin Karatani observes that the dialogue between an architect and an occupant of a space occurs through a system of communication without commonly understood rules.[3]

2 Norman (2002)

3 Karatani and Speaks (1995)

Over time, architectural problems have become increasingly complex, driven by economics, technological innovation, and changing societal needs for buildings to support new functions and offer innovative features to improve efficiency and safety. Practitioners rely on a body of design theory that influences the products of architectural design, and highlights the duality of a profession whose aspirations are to create artifacts that serve practical needs at the same time that they encode meaning for individuals and communities.

The pervasion of Internet-enabled elements into the physical space of everyday life and work forces us to rethink both the requirements of our world and the way we design it. Today's consumers can connect a smartphone-enabled door to a system of security; comfort-focused devices that transmit video sense and adjust temperature and lighting. As interactive environments proliferate and these choices expand in the future, designers must expand theory to apply these new modes of interaction and meaning to our most pressing objectives.

ARCHITECTURAL DESIGN THEORY: MODELS OF INTERACTION AND MEANING

Architectural theory analyzes and describes architectural design in terms of appropriate elements, their relationships to cultural understanding, and the process of devising them. In this context, *theory* is an explanation that does not proscribe a specific end result. It is a structure of concepts, categories, and relationships intended to explain things or to advocate, not a defined roadmap or a step-by-step methodology.

No single comprehensive structure of ideas can be applied in the same rigorous way to resolve all design problems in architecture. It is unlikely that a formal set of rules lie behind all of the many complex decisions that produce an existing building. However, practitioners have long valued theory in making decisions on complex projects or to retrospectively clarify a body of work.

Architectural theory can be traced back to the first century BC. The Roman writer and architect Vitruvius[4] wrote a treatise that laid out the salient aspects of Roman architecture in a series of volumes. The *Ten Books of Vitruvius* illustrated the principles of design and construc-

4 Vitruvius (1999)

tion and emphasized the three "laws" placing architecture above mere building, namely that a work of architecture must possess the qualities of Firmness, Commodity, and Delight.[5] These three laws clarified that a work of good design must be physically and structurally sound, must support the functional and practical needs of its occupants, and must be aesthetically pleasing to the viewer.

By comparison, Hewlett-Packard User Experience Lead Jim Nieters's blog on Interaction Design lists the goals of an interaction model as being Discoverability, Learnability, Efficiency, Productivity, Responsiveness, and, not coincidentally, Delight.[6] Although these two thinkers lived in different times, these somewhat analogous sets of "laws" underscore the relevance of aligning UX design with the design of interaction and experience in physical space.

Since the time of Vitruvius, architectural theory has relied on classifications and definitions—grouping buildings into types, defining accepted applications of morphology, focusing on uses, appearances, and the appropriateness of combining elements from different periods, styles, or construction types. Theory has even suggested that the components of architecture exist as elements of a language that has a particular grammar, as elaborated in *A Pattern Language: Towns, Buildings, Construction* by Christopher Alexander et al. Alexander laid out the idea of pattern and usage as a way of building what he called "timeless." He states, "Towns and buildings will not be able to come alive, unless they are made by all the people in society, and unless these people share a common pattern language, within which to make these buildings, and unless this common pattern language is alive itself."[7]

Theorizing Digital Culture: New Models of Convergence

In more recent times, computers became prevalent in society and architects theorized about the impacts of digital culture. Observers of the design professions considered the implications of digital technology, both for the environments we would occupy alongside these new

5 As translated by Sir Henry Wotton in the 17th Century

6 Nieters, Jim, "Defining an Interaction Model: The Cornerstone of Application Design" blog post, *http://bit.ly/1nTB1h5*.

7 Alexander et al. (1977) and Alexander (1979)

devices, and for the process of design itself. Theorists in the 1960s and 1970s discussed cybernetics,[8] digital approaches to systems of work and habitation, and explored through programming Negroponte's concept of "the architecture machine,"[9] a theory about the ability of machines to learn about architecture as opposed to being programmed to complete architectural tasks.

More recent investigations of the merger of digital and architectural realms have been undertaken since the 1990s, with research considering the concept of adaptive feedback loops,[10] of environments such as Rodney Brooks' Intelligent Room Project,[11] or environments such as the Adaptive House.[12] These experiments explored the principles of combining digital with architectural environments and processes. Malcolm McCullough observed an impending future of opportunity when computing pervades architecture and activities are mediated in new ways. He commented that, "The rise of pervasive computing restores an emphasis on geometry.... In locally intensified islands of smarter space, interactivity becomes a richer experience."[13]

Theories and manifestos proliferated with a focus on the cultural and societal imperatives that should guide practitioners in navigating the choppy waters between meaningful and merely practical arrangements of space. As Michael Speaks described in his introduction to Kojin Karatani's *Architecture as Metaphor*, a tug of war ensues between two metaphors, "Architecture as Art" versus "Architecture as Construction."[14] If we are to believe Vitruvius, the aspiration of architecture has always gone beyond function and effectiveness to incorporate the difficult-to-define idea of "delight," a notion beyond aesthetics. In today's post-modern age, we expect a work of architecture to mean something to inhabitants and observers. Architecture has always con-

8 Frazer (1993)

9 Negroponte (1970)

10 Eastman, in Cross (1972)

11 R. A. Brooks. 1997. The Intelligent Room project. In Proceedings of the 2nd International Conference on Cognitive Technology (CT '97). IEEE Computer Society, Washington, DC, USA, 271-. *http://people.csail.mit.edu/brooks/papers/aizu.pdf*.

12 *http://bit.ly/1nTB2BH*

13 McCullough (2004)

14 Karatani and Speaks (1995)

veyed meaning, or "spoken to us" through form, since the time when illiterate occupants needed the cathedral to convey the meaning of religious texts. Alain de Botton stated that, "Belief in the significance of architecture is premised on the notion that we are, for better or worse, different people in different places—and on the conviction that it is architecture's task to render vivid to us who we might ideally be."[15]

ENTER INTERCONNECTED ENVIRONMENTS

Our intention as architects to design meaning into space broadens when we conceive of spaces as interconnected environments, linking devices to devices, and thereby connecting occupants with remote individuals, communities, and information sources. Although we have long incorporated the practical opportunities of automation—environmental control systems that manipulate building heat and cooling, raise and lower window shades, and control other architectural elements and systems with little or no human intervention—emerging technology can move us beyond digital integration with architecture as "practical construction" to digital integration with architecture as "art."

We are surrounded by smart homes, schools, workplaces, shopping malls, and even the city itself with its smart grid. These anticipatory models purport to make all decisions and do all the work for us. But, our models for digital interaction have evolved, and the conceptual models for user interaction now stretch to accommodate decentralized structures that include mobile "anywhere" access, feedback and input from "the crowd," increased transparency, simulation, and analysis. We are moving from anticipatory centralized models such as the Encyclopaedia Brittanica[16] to adaptive decentralized ones along the lines of Wikipedia.[17]

Christian Norberg-Schulz said that the job of the architect was to visualize the spirit of the place and to create meaningful places for people to inhabit.[18] Perhaps the modern person is less able to understand the meaning of architecture because our education and training no longer emphasizes this appreciation. Nevertheless, architects still

15 De Botton (2006)

16 *http://www.britannica.com/*

17 *http://www.wikipedia.org/*

18 Norberg-Schulz (1980)

aspire to produce buildings and spaces that go beyond function and effectiveness, which can become meaningful to people who occupy or encounter them. With the advent of digitally connected architecture, we have an opportunity to reinvent architecture as a source of meaning. Pervasive computing will provide feedback about perceptions and physical experiences as our bodies interact with our spaces. Documentation and analysis of feedback will increase our awareness of what it means to embody and occupy space. To move to this next stage, digital experience designers and architects must enlighten one another and collaborate to inspire hybrid models of design practice (Figure 13-1).

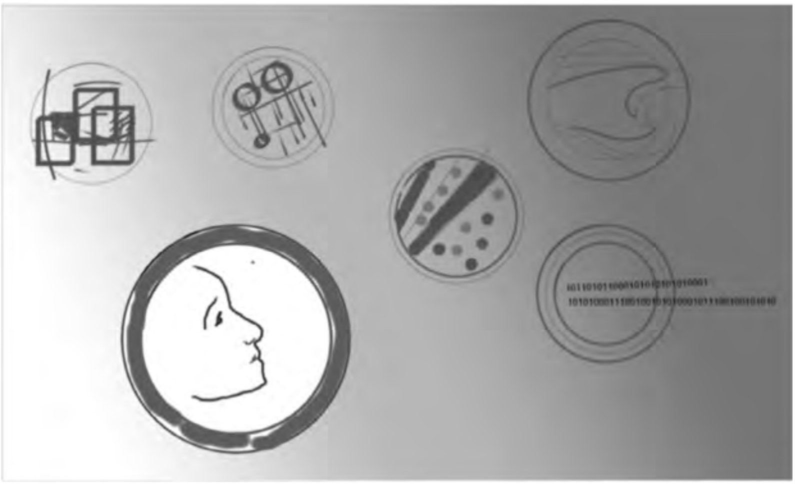

Figure 13-1. Hybrid design will emerge when the patterns of digital experience designers and architects converge (courtesy of the author)

Hybrid Design Practice

Traditionally, architects are trained to think about interaction in terms of form and physical occupation, activity, and movement bounded by space—walls, floors, and ceilings, illuminated by sun or artificial light, defined by materiality. There is no dominant theory that governs the work of all architects. Rather, practitioners follow a range of methods and apply design theories based on their academic training and compliance with firm methods in keeping with their own personal approaches. After spending time gathering information about the context and deepening their understanding of the problem, some architects aggregate programmatic elements into systems. Others might begin with a metaphor and work to fit client requirements into physical forms that represent their vision. Tomorrow's spaces will be formed from interconnected and intelligent components that are aware of the human presence, able to communicate, assess, and act. The role of the designer must evolve to incorporate both sets of skills—architect and interaction designer—so that we can create meaningful places that support systems of linked intelligent devices. This mix of methods and sensibilities can be termed *hybrid design practice*.

Hybrid design practice will augment metaphor or context awareness with maps of information and communication from digital sources and delivery systems. The work of hybrid design calls for new theories to help us create meaning from electronic communications and digital resources as well as physical ones. As McCullough observed, "The more that principles of locality, embodiment, and environmental perception underlie pervasive computing, the more it all seems like architecture."[19]

TRAPELO ROAD CASE STUDY

Figure 13-2 shows a rendering of Autodesk, Inc.'s Trapelo Road[20] office just outside Boston. This fit-out is an example of a project that aspires to integrate Internet monitoring and control systems in the architectural design of a commercial office interior. Sensors that collect data about comfort and energy utilization are linked to the building automation system, which taps into weather data from an external system. Data provided by the sensors helps facility managers realize energy efficiency improvements by refining the sequence of operation for building HVAC equipment while continuing to meet temperature requirements at business start time each day. Experimental projects applying sensor data at Trapelo illustrate how designers can become smarter about the way space and systems need to be laid out to enable sophisticated measurement and increased efficiency. Better data gained from interconnected devices embedded in architecture enables continuous diagnostics and automated commissioning so that anomalies in the system can be flagged more quickly and addressed sooner. The

19 McCullough (2004)

20 "Autodesk's East Coast Headquarters Draws Accolades for its Sustainable Design and Collaborative Building Process," EDC Magazine, August 2010, *http://bit.ly/1nTBik8*.

insight gained from sensors is now displayed to employees and visitors through a prominently placed plasma screen, potentially shifting occupant behavior as individuals “see” the impacts of their actions.

Figure 13-2. A Building Information Model of the Autodesk HQ provides a framework for information about usage and resources (courtesy of KlingStubbins)

Ultimately, this experiment suggests the way that the entire space could be reconfigured to put both information and means of control at the fingertips of all occupants at all times. But beyond the practicality of an application designed to drive energy efficiency, how will occupants of the space interpret the meaning inherent in the display—both in terms of the practicality of efficient use of energy and of the significance of the initiative in the context of the social community and issues of climate change?

HUMAN TO MACHINE, MACHINE TO MACHINE

The explosion of Internet and web creates new interaction models that lead to dynamic configurations of people, networks and machines. The hybrid design practice will accommodate these new interaction models. To our traditional human to human (H2H) and human to architecture (H2A) interactions, we’ve added human to machine (H2M) and machine to machine (M2M).

H2M interaction models connect humans to machines in "everywhere" mode—from any device, at any time and place. Manufacturers of building elements—garage doors,[21] ceiling fans,[22] appliances,[23] and many other automation systems—are smartphone-enabling spatial elements so that people can control devices and receive messages and images. Our machines are speaking to us. "The garage door was left open." "Your dog Ella's heart rate is elevated. She has found the stash of chocolate hidden inside the upstairs closet."

With M2M, a sensor or monitor device can capture an "event" (such as the state of temperature of light, or other environmental or asset conditions). The state can be transmitted over the Internet or a local network to a cloud-, desktop-, or server-based software application that analyzes, stores, or processes the information, or applies it to a downstream action. Apple Computer's iBeacons, based on Bluetooth Low Energy (BLE) technology, enable place-aware applications to light up when you enter a room (or at least when your smartphone does).[24] Beacons embedded in architecture can sense when you approach and reach out to you in location-specific ways.

EMERGING MODELS OF CONVERGENT DESIGN

Beyond machines, spaces themselves can speak to us. Alex Hawkinson of SmartThings[25] connected the architectural elements—floors, walls, ceilings, windows, and doors—of his home based on low-power sensor network standards such as Zigbee.[26] Wired editor Bill Wasik described this house as he predicted three phases of evolution on the path of ubiquitous and full integration of devices and digital intelligence into the physical world—proliferation (more devices, more sensors), interdependence (devices learn to rely on one another to take action), and integration (sets of devices organized into programmable systems).[27] Wasik's vision of the third stage of fully integrated devices suggests that hybrid design practitioners will be called upon to map space in terms of the

21 *http://www.liftmaster.com/lmcv2/pages/productfamily.aspx?famid=213*

22 *http://bit.ly/1nTBiAL*

23 *http://www.whirlpool.com/smart-appliances/*

24 *http://bit.ly/1nTBm3q*

25 *http://www.smartthings.com/*

26 *http://www.zigbee.org/Standards/Overview.aspx*

27 *http://www.wired.com/gadgetlab/2013/05/internet-of-things/*

system of data and decision flows as well as the flow of people and human activity, to work simultaneously as interaction designers as well as designers of physical space.

The age of space populated by integrated and interconnected devices will require an important skillset, which can be labeled *network understanding*. Albert-Lászlό Barabási of Northeastern University observed, "Today, we increasingly recognize that nothing happens in isolation. Most events and phenomena are connected, caused by, and interacting with a huge number of other pieces of a complex universal puzzle. We have come to see that we live in a small world, where everything is linked to everything else."[28] Barabási applies tools of network science to increase understanding of the way the information network of the Web is structured and how it develops. The complex linkages of the individual to a community, society, and a world are becoming manifest through architecture. Beyond providing opportunities for efficient communication and problem solving, this manifestation will change the nature of our relationship to architecture. Network understanding, or insight about the way elements exist in dynamic patterns of cause and effect, will be needed alongside traditional architectural skills. The hybrid design practice will incorporate network understanding alongside knowledge of technical requirements for particular spaces for human occupation.

Interconnectedness in the design process opens up opportunities to invite stakeholders or "the crowd" into decision making. Hybrid design practitioners will understand how to tap the wisdom of communities through a connected design process. Design influence by consensus is not new. It is often applied when projects require community support to thrive. Christopher Day, in his book *Consensus Design*,[29] discussed the benefits and pain of socially inclusive processes. A design professional gives up control over project decisions, faces the challenge of getting a group to align around the needs of a situation, and reaps the value of the contribution of many voices to strengthen a project. This practice requires leadership, social skills, and conviction in the outcome. Yet,

28 Barabasi (2003), *http://www.barabasilab.com/*

29 Day (2003)

how these skills will be translated into situations in which the crowd is geographically distributed and linked by the Internet remains to be seen.

Changing Definitions of Space

As interconnected environments become commonplace and our interfaces move from H2A to H2M to M2M and beyond to aggregations that link people and machines and architecture into emerging systems—H2M2M2A2H—we need to consider the meaning inherent in design decisions. Successful hybrid design demands insight about how people interact with space as much as knowledge about digital interfaces. The connectedness represented by these new models compels designers to understand the simultaneous effects of digital and spatial experience, to anticipate the effects of design on human, machine, and architectural contexts. And beyond successful problem solving to achieve functionality, the designer must consider what conceptual model of the future community is encoded in the solution.

Hybrid designers will embed architecture with programmable interconnected devices and apply knowledge, content, and interpretation that make interconnectedness meaningful in a social context as well as practical in a physical context. As increasingly sophisticated systems of information inherent in social networks are integrated into physical spaces, interconnected environments will do more than sense the need for change in environmental controls. Layers of information—virtual geometry and relevant data—will be interpreted and presented to us as we scan space with augmented reality devices. When we encounter architectural elements, we will have the opportunity to unpack history and connect to counterparts elsewhere in space or time. Upon arriving at my hotel room for the first time, I look out the window and have access to digital messages and artifacts left by decades of past occupants, pointing out noteworthy features of the city outside. The window can inform me of the best approaches to reducing the energy footprint during my stay by manipulating the window position, shading, or reflectivity. But the way this information is positioned relative to the room will make important statements about the relationship between these individuals and my occupation of this particular space at this specific time.

Space itself will become malleable, capable of reconfiguring to suit our profiles—presenting differences in lighting, materiality, even form as we move from place to place. The design of interaction between architecture and machine—A2M—incorporates the technology of smart buildings, structures whose systems are automated in order to improve their efficiency. In fact, the earliest building automation systems and "smart building" examples provide an important foundation for hybrid design. But emerging technologies—pervasive and mobile access, social community, and augmented reality, among others—will highlight new opportunities for innovation and development of A2M models.

Lorraine Daston noted the importance of objects in the environment and the deep connection of things to human communication. Daston states, "Imagine a world without things... without things, we would stop talking. We would become as mute as things are alleged to be. If things are "speechless," perhaps it is because they are drowned out by all the talk about them."[30] As we move toward a world filled with articulate things, a categorization of these new environmental elements positioned by their sphere of application will help us gauge the progress we've made, give us ideas for innovation, and start us on a path toward a hybrid design theory for interconnected environments.

A Framework for Interconnected Environments

To categorize the contribution of interconnected sensors and devices, observe that the modes of H2M interaction are already a primary differentiator for the applications that have emerged in the marketplace. A framework can help clarify opportunities that might exist at the intersection between modes of interaction—the different ways that humans engage with machine-enabled architecture—and spheres of inquiry—the different objectives that we have, or the purpose for engagement. By interrogating each cell of this framework, shown in Figure 13-3, a range of directions for hybrid design practice will emerge.

30 Daston (2004)

MODES OF INTERACTION

There are a number of modes of interaction, spanning information gathering, understanding, transmission, manipulation, and storage. Different interaction modes suggest the types of information to be stored, processed, and exchanged. Each mode addresses a specific question, and as a collection they offer the potential to build sequences of interactions, eventually linked to form increasingly sophisticated collections of tools, or systems.

1. Awareness: what can we measure, what can we learn?

   At a fundamental level, sensors track a condition in the environment. Sensors can report on the presence or movement of individuals or objects in a space. They can determine temperature, light levels, or detect moisture. Awareness of a condition is a fundamental step required for reporting and decision making.

2. Analysis: what useful knowledge can we glean from data?

   When an environmental condition is detected, the interconnected environment can make this information useful by using it in a predefined algorithm that layers data about the condition with a judgment about the implications of that condition. If the sensor reports light, the algorithm might compare the illuminated condition with data about current weather conditions, time, or solar positions. If it is nighttime, the office is closed, and the room is suddenly illuminated, this might mean that someone has entered a space unexpectedly. The Analysis interaction mode might include more sophisticated algorithms, for example to calculate the amount of energy used by the light, or heat that the light could predictably generate.

3. Communication: how should insight be reported?

   The judgment call stemming from the Analysis mode of interaction would activate the next mode in the sequence: Communication. If illumination is not anticipated, the next interaction is to send a message or flag an alert in a system that is monitoring the status of the environment. Messages would be directed to people or other machines. A system of integrated sensors, assessment, and communications could be designed to produce a complex set of effects based on situations and reactions.

4. Action: what action can a system initiate based on insight?

   In addition to Communication, a myriad of Actions could be integrated into a system of cause and effect. Such actions might impact the space in which a condition is being observed. For example, an unexpected light might be analyzed and found to produce excess heat in a space, which would call for draperies to be repositioned, or for a cooling system to be engaged.

5. Feedback: how can we assess the impact and learn from action?

   Ultimately, the detection, analysis, and action loop reaches a point where Feedback at a systemic scale becomes useful. After prolonged observation and analysis, assessment might determine a pattern of lights going on and off during certain periods. Appropriate judgments could be made and actions taken, based on this more holistic assessment. Ongoing assessment and prolonged interaction would improve decision making and suggest the most appropriate actions so that the space could reach an ideal environmental state.

6. Recollection: how can we retain knowledge for later access?

   As the system proceeds through cycles of interaction, there will be value in maintaining a record of observations and changes. Storing the details and organizing the data into patterns provides a resource that can be tapped to improve the intelligence and performance of the overall system as it evolves.

Spheres of Inquiry

Across all modes of interaction, three spheres of inquiry describe the different objectives that we have for understanding or transforming the world through physical or human systems. As developers and designers of tools, inspecting the opportunities through the lens of objectives helps to suggest the prominent marketplace for tools based on interconnected environments (see Figure 13-3).

1. Environmental: how can we optimize and minimize use of resources to produce ideal conditions by combining data gathered through monitoring with external data sources?

Interconnected applications naturally gravitate toward tracking and improving the environmental conditions they are ideally suited to monitor. Applications can alert individuals to dangerous conditions in a surrounding space, for example if toxins are building up in a confined room,[31] if noise levels have increased,[32] if a space is threatened by flooding when water is detected on the floor. Environmental alerts can range in scale from a single room, to a building, complex, or community scale. Environmental conditions for a specific building or campus can alert individuals or systems to take action to control energy usage, for example.

Interaction / Inquiry	Sensing/ Awareness	Insight/ Analysis	Communication/ Reporting	Action	Feedback	Memories/ Recollect
Environmental	Sense noise levels, spatial changes, temperature	Analyze environmental performance	Reports, dashboards of sustainable factors	Modify systems and spaces with mobile devices or interfaces	Provide feedback on performance impacts	Store environment patterns
Behavioral	Sense behaviors, movement	Analyze behaviors	Report on actions and impacts	Drive preferred behavior	Provide feedback on behavioral impacts	Stored space interaction patterns
Social	Sense social interactions	Analyze the impact of social interactions	Report on social network interactions and impacts	Drive preferred social interactions	Provide feedback on social interaction impacts	Store social interaction patterns

Figure 13-3. A framework for connected environments with examples of potential tools at the intersection of each interaction mode and sphere of inquiry

2. Behavioral: can we incent preferred behaviors? Can we monitor human interactions, and assess and modify conditions based on knowledge of preferences?

   Environments are capable of exerting pressure on individuals and shaping behavior. Data about behavior or environmental conditions force individuals to confront situations and these confrontations can drive change. The proliferation of interconnected devices to drive improved health behaviors (such as WiFi-connected

31 *https://www.alertme.com/*

32 *http://www.widetag.com/widenoise/*

pedometers and scales)[33] and other monitoring systems enable people to track themselves, fostering improvement in behavior from diet and nutrition health[34] to greener environmentally friendly living.[35]

3. Social: how can we produce network-based discussion and action through social connection? Can we modify settings to be conducive to human interaction?

   Architectural history teaches us that environments have tremendous power over the actions of communities and groups. They can be designed with the power to divide us, or to unite us. Interconnected environments will be capable of monitoring and impacting social patterns of interaction. Ranging from observation to assessment and action, the social sphere of application raises questions about how systems should be designed to provide the information and actions to the group and its constituents in a useful manner.

An Exercise in Hybrid Design Practice

Apply the Interconnected Environments Framework to design a space and an experience (see Table 13-1). You can use this sample narrative as a model:

> *Begin by considering an indoor place that has been meaningful for you. This might be a room from your childhood or a space you recently visited where a significant event occurred.*

1. Write a brief narrative describing how this meaning is connected to your relationships and to clusters of knowledge that you possess or seek to tap.
2. Launch your design process with key questions. How do the answers contribute to the engagement of the visitor with the meaning of the space—in the past, and in the future?

33 *http://www.fitbit.com/*

34 *http://quantifiedself.com/about/*

35 *http://www.makemesustainable.com/*

3. Design the space and outfit it with a series of Internet-enabled devices. Be specific about the devices; specify the data they gather. What does each device do to process, store, analyze, or transmit information?

4. Next, design an interaction for a visitor to this space that takes advantage of emerging technology to convey meaning and engage visitors through experience. Script or storyboard this interaction.

TABLE 13-1. Sample

	ENV	BEH	SOC
SENSING	What light, sound, smells, and temperature should the visitor experience? How can sensors augment what the visitor should be aware of while occupying the space?	Who is the visitor? What is the purpose of the visit?	What interactions should occur between multiple visitors arriving at the same time, or one after another?
ANALYSIS	What analysis should be done on the environment—changes in light, accumulation of heat?	What insights should the space produce about the visitor's behavior?	What actions of others outside the space should be considered? How should they be analyzed?
COMMUNICATION	How should spatial conditions be communicated and conveyed? How should the space be organized to present these reports?	How should behaviors be reported?	Which social interactions should be reported? How can they be useful to visitors to the space?

	ENV	BEH	SOC
ACTION	What actions should the space take when certain environmental conditions occur?	How can the space drive the visitor to take a specific action? Should it?	How will the visitor be connected to others? How will others shape the visitor's experience in the space?
FEEDBACK	What response should the space provide based on the visitor's physical movement, gestures, directional gaze, facial expressions, or vocalizations?	Can the space provide feedback on the effectiveness of the configuration to support desired outcomes?	Can feedback be collected on the impact of the space on driving desired social interactions?
RECOLLECT	Would it be useful to record the environmental changes in the space over time?	How can the space record, document, and recall the actions of visitors?	Should visitor responses be collected and presented over time?

Architecture as Interface

The process of spatial design evolves continually and emerging technology opens up new modes of inquiry in design on a regular basis. Today, rapid prototyping of physical components is possible with cost-effective 3D printing of a wide range of materials.[36] Some designers adopt a fabrication-based design process by aggregating manufactured or 3D printed components. Form-generating experimentation driven by algorithms[37] is as valid as by heuristics. The existing world can be captured, rendered digital, and used as a backdrop for design and experimentation in virtual environments.[38]

36 "California duo create 'world's first 3D printed architecture,'" dezeen Magazine, *http://bit.ly/1nTBYpN*.

37 *http://bit.ly/1nTBXly*

38 *http://autode.sk/1sSidAJ*

The adoption of a model-driven design process enables architects to consider issues of geometry and issues of information simultaneously through building information modeling (BIM).[39] With BIM, the designers employ digital elements conceived as architecture—with parametric geometry that parallels each spatial entity, attached to data that describes the entity in terms of costs, manufacture, and physical properties. A new breed of BIM tools will be needed so that designers can assess the impact of spatial and user interaction decisions across different modes of inquiry.

Augmented reality, which layers digital visualizations with real space, as shown in Figure 13-4, must next incorporate an information visualization aspect so that environments and interfaces can be experienced virtually before they are actually constructed and programmed.[40]

Figure 13-4. Layering of digital and information visualization (courtesy of the author)

39 Eastman, Charles and Sanguinetti, Paola "BIM Technologies That Inform Concept Design," AIA Conference 2009, *http://bit.ly/1nTC28Z*.

40 Sanchez (2013)

Perhaps it is time to revisit Alexander's notion of patterns in the environment and to develop a pattern language for the age of interconnected environments. In this new pattern language, each pattern would be a formal response to a design problem linking interactive systems with spatial environments. As a starting point, the framework suggests a range of patterns that can be developed to link modes of interaction with spheres of inquiry.

Consider the bevy of building types that we inhabit and reimagine them in new ways—whether homes, workplaces, or industrial, ceremonial, or social settings. A museum that responds to your background and interests by highlighting key exhibits modifies the text that accompanies the artifacts to suit your knowledge of history. An exhibit might connect you to others with similar responses or comments, spawning a network of virtual relationships. Consider a nightclub that reconfigures to accommodate an impromptu gathering and points you to a room filled with graduates of your college when the club's "operating system" assesses the profiles of all visitors and finds commonalities. As you enter, the walls of the room have already shifted to reflect your group's publically posted images of your time together, along with music of the time period. Surgical rooms maintain awareness of the presence and movement of particles linked to infectious diseases, which leads to movement of equipment and lighting and modification of airflow to protect the patient from harmful conditions and inform clinical professionals of medical history and environmental changes.

Conclusion

Tomorrow's spaces will be formed from interconnected and intelligent components that are aware of the human presence, and are able to communicate, assess, and act. The role of the hybrid designer must evolve to incorporate both sets of skills—architect and interaction designer—so that we can create meaningful places that support systems of interconnected intelligent devices.

The hybrid designer will not be responsible solely for "concretization" of the building as an object, as described by Christian Norberg-Schulz, but rather for orchestrating a new context—a dynamic system of elements that flex and adapt to support our needs for environmental, behavioral, and social settings. Its choreography will be influenced by an evolving set of actors. As Nishat Awan states, "The dynamic, and hence temporal, nature of space means that spatial production must be understood as part of an evolving sequence, with no fixed start or finish, and that multiple actors contribute at various stages."[41]

The hybrid designer will go beyond problem solving and practicality, to write the manifesto and express what it means to live in an interconnected society through architecture. To articulate how our buildings have become gateways to communities of connection and alternative experience. Or, to personify each building as a character in the story of a life, responding to you, shaping your environment to suit your needs, analyzing situations, providing feedback, and recalling past experience. In fact, by giving voice to architecture through interconnectedness, we may re-create a time when humans had a closer relationship to space and its meaning. If nothing else, at least we can become better listeners.

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[14]

Design for the Networked World: A Practice for the Twenty-First Century

MATT NISH-LAPIDUS

The Future of Design

Bruce Sterling wrote in *Shaping Things* (MIT Press) that the world is becoming increasingly connected, and the devices by which we are connecting are becoming smarter and more self-aware. When every object in our environment contains data collection, communication, and interactive technology, how do we as human beings learn how to navigate all of this new information? We need new tools as both designers, and humans, to work with all of this information and the new devices that create, consume, and store it.

Today, there's a good chance that your car can park itself. Your phone likely knows where you are. You can walk through the interiors of famous buildings on the Web. Everything around us is constantly collecting data, running algorithms, calculating outcomes, and accumulating more raw data than we can handle.

We all carry minicomputers in our pockets, often more than one; public and private infrastructure collects terabytes of data every minute; and personal analytics has become so commonplace that it's more conspicuous to not collect data about yourself than to record every waking moment. In many ways we've moved beyond Malcolm McCullough's ideas of ubiquitous computing put forth in *Digital Ground* (MIT Press) and into a world in which computing isn't only ubiquitous and invisible, but pervasive, constant, and deeply embedded in our everyday lives.

Augmented reality (AR) is here, already deeply engrained in our understanding of the world. The screen-based AR espoused by apps such as Layar is primitive compared to the augmentations that we all use on a daily basis. Google Maps, Twitter, Facebook, Nike FuelBand, and more are prime examples of how we are already augmenting our reality in fundamental ways that are less obvious and intrusive than digital overlays (which will see their day eventually, I'm sure). We have been augmenting our reality since the invention of clothing allowed us to live in harsher climates, and now we are augmenting it with networked technology giving us not just a sixth sense, but a seventh, eighth, and ninth, as well.

As augmentation and networks change our understanding of reality, we begin to understand old technology through our lens of new media. A chair is no longer solely a physical object that exists in our environment, it is now an interactive object by which specific behavior and person-to-person relationships can emerge from its use (Buchanan, 2011). A building is no longer only a collection of materials that defines a place, it is also understood through its interactions with people, the interactions it facilitates, and how it interacts or interferes with our networked augmentations. We are McLuhan-esque cyborgs, with media devices that extend our body and mind from the outside. Objects that exist as part of this network become more than their discrete pieces; we internalize their behavior and it changes the way we understand our world and ourselves.

We can see shifts in common language that allude to these changes. We talk about "downloading" knowledge from one person to another and "interfacing" with organizations. Words like "interface," "download," and "stream," once not commonly used outside of technological circles, are now part of our daily lexicon, used in reference to their technological meaning as well as applied to much older concepts in the physical world.

A 2007 study on mobile phone usage conducted by Nokia concluded that the mobile phone is now one of the most essential items for daily use around the world, putting it in the same social category as wallets and keys.[1] They identified that it wasn't only the object itself that is important to people, it is the social identity it provides that people value. The phone is more than an object—it is a lifeline, a gateway through which people connect with their family, friends, livelihood, and community. This is even truer now with the prevalence of smartphones with always-on Internet access. The smartphone has become one of the current embodiments of the networked world; more than its function, more than its form, it is a social safety net that allows people to travel or live further away from their home and still feel connected.

The smartphone is still a tangible object, one that we can understand through our hands and eyes, and it has connections to the network that we can see and feel. A greater shift is occurring now through objects that connect in less visible ways—objects that act on our behalf, or against us, without our explicit knowledge. The ethical implications and choices made by algorithms that determine the flow of traffic, our food supply chain, market pricing, and how you measure your fitness are present in our lives but are largely below the surface. As connected systems spring up around the world, often bypassing the more outdated infrastructure we are dealing with here in North America, we need to begin considering the biases and implications of our choices when designing these systems, objects, and networks. For example, the current sensors used to trigger traffic lights often rely on induction pads embedded in the road. These sensors only detect cars and other large vehicles, and are unable to sense bicycles and pedestrians. There's an implicit decision made about the relative importance of different modes of transportation. A traffic system built on an inductive sensor network will always prioritize car and truck traffic over cyclists, for example, making the city a less hospitable place to ride a bike. This can in turn impact population density, pollution, congestion, parking, employment, injury rates, and more.

As we move even further into a networked world, we as designers of these new devices and services need to understand all aspects of our new environment. The complexity of design and architecture will only continue to grow and require a new definition of design foundations, practice, and theory.

1 Cui, Yanqing, Jan Chipchase, and Fumiko Ichikawa. 2007. "A Cross Culture Study on Phone Carrying and Physical Personalization." Nokia Research, *https://research.nokia.com/files/45590483.pdf*.

This might seem daunting, but no more so than the nature of mass manufacturing and new materials seemed to the early industrial designers and architects of the twentieth century. We must look to new media art practice, design history, and new research in order to apply our craft to our current context. Designers make things that reflect their environment, but also shape that same environment through the objects that they create, laying the foundation for the future.

We have strong foundations stretching back over a century of art, architecture, and industrial design. We don't need to begin again, but we do need to continue to evolve our practice to incorporate new techniques, tools, and capabilities that help us understand the potential of today's technology.

What are the aesthetics of feedback, immersion, and communication? How can we apply foundations of interaction, such as time and metaphor, to the exchange of data between machines that facilitates an athlete learning how to perform better? What is a beautiful network and how do we recognize and critique it? These are the questions we now face, ones that we will continue to explore through our work and try to answer with objects, systems, places, and conversations.

New Environment, New Materials

[W]e have witnessed a paradigm shift from cyberspace to pervasive computing. Instead of pulling us through the looking glass into some sterile, luminous world, digital technology now pours out beyond the screen, into our messy places, under our laws of physics; it is built into our rooms, embedded in our props and devices—everywhere.

—MALCOLM MCCOLLOUGH, *DIGITAL GROUND* (MIT PRESS), P 9

Over the past couple of decades, our environment has changed significantly.

Screens are everywhere all the time. This means that the complex interactions afforded by screens are even more important to understand and design properly.

Physical objects are now imbued with "smart" features using sensors, networks, and physical interactions that are often invisible, having no screen whatsoever. This makes physical object design more and more important for designing modern products, shifting focus back toward industrial design and architecture and away from the myopic attention to screens that interaction design has had recently.

Machine to machine communication is at the heart of many interactions and systems that we can't live without. This means that designers need to think about not just the human actors in a system, but also the objects, networks, and algorithms that run our environments.

This puts the modern designer in a bit of a sticky situation. As an example, a project on which we recently embarked at Normative includes a mobile app that communicates with a physical box of electronics affixed to the back of a ski that is laced with embedded sensors, as shown in Figure 14-1. That box also needs to be aesthetically pleasing and fit the skier's understanding of how a ski accessory should look and feel. The skier needs to enjoy working with the companion mobile app in a way that enhances the skiing experience. The box of electronics that reads the data from the sensors embedded in the ski needs to communicate that data to the mobile device, and has to communicate that it is doing something to the person on the skis through a simple display of LEDs and recessed buttons. All of this needs to happen in a way that makes sense to the skier, doesn't detract from skiing, and withstands the environment of the slopes.

Figure 14-1. An early ski prototype[2]

2 Copyright Normative, 2013

In this example there are many types of design at work—industrial design for the skis and the electronics box; graphic design for the labels, ski graphics, packaging, and mobile app interface; interaction design for the mobile app; system integration; and coordinated communication between the app and the box. This is in addition to all the engineering involved in the hardware and software to make this all work.

What we witness in projects such as this one is a shift in the way we're working from the industrial model of design → build → sell to a post-industrial model wherein all those things happen simultaneously in an integrated and iterative way within a small team. The initial prototype of the circuit was created by an interaction designer using an Arduino, and then an engineer and the designer worked together to refine the circuit through iteration. An integrated team of designers from different practices, creative technologists, engineers, and fabricators is required to design, build, and iterate on a system this complex.

At the heart of this team is a design practice that coordinates all the moving pieces, keeps the overall system in mind, and is the arbiter of the aesthetic and functional coherence of the final product. The lead designer needs to have a refined sense of aesthetics as it relates to the appearance of the physical product, the software, and the system that makes them work together. Figure 14-2 demonstrates this team effort at work as the prototype begins to transition toward a more polished product.

The overall aesthetics and quality of the interactive system, product, and associated software is the purview of this new breed of designer, including the impact and implications of the product. The modern designer needs to have a foundation in traditional design disciplines and interaction foundations, which acts as a framework for thinking about the form of objects and interfaces, as well as good understanding of systems theory, cybernetics (the study of feedback, relationships, and communication within a system), and culture, including a basic grasp of ethnography and anthropology in order to understand different contexts and cultures.

Figure 14-2. A higher fidelity prototype of the electronics and enclosure for the skis[3]

HAPPENINGS, CONVERSATIONS, AND EXPLORATION

In late 1968 Jack Burnham, a writer and art history professor, wrote the following in his paper *System Esthetics*:

> The specific function of modern didactic art has been to show that art does not reside in material entities, but in relations between people and between people and the components of their environments.

He was looking at the emergence of large-scale interactive artworks and art events in the 1960s. Artists began to see their work as more than the object itself; they began to think about how the object interacts with the audience and environment to create a conversation.

Artist David Rokeby explored the emotion and aesthetics of environmental feedback systems in his early works Reflexions, Body Language, and Very Nervous System in the 1980s. Rokeby created one of the earliest examples of gestural interface by building his own 8 x 8 pixel digital camera and programming his own software to read the video input and

3 Copyright Normative, 2013

create feedback in the form of sound and video.[4] To fully understand the aspects of movement and feedback systems he was interested in, he had to learn new technologies, create innovative solutions to unknown problems, and build his own sensors and output devices. If this sounds familiar, it's because these are exactly the same types of activities and problems facing designers and artists today. Figure 14-3 presents a series of images illustrating the results of people interacting with the system.

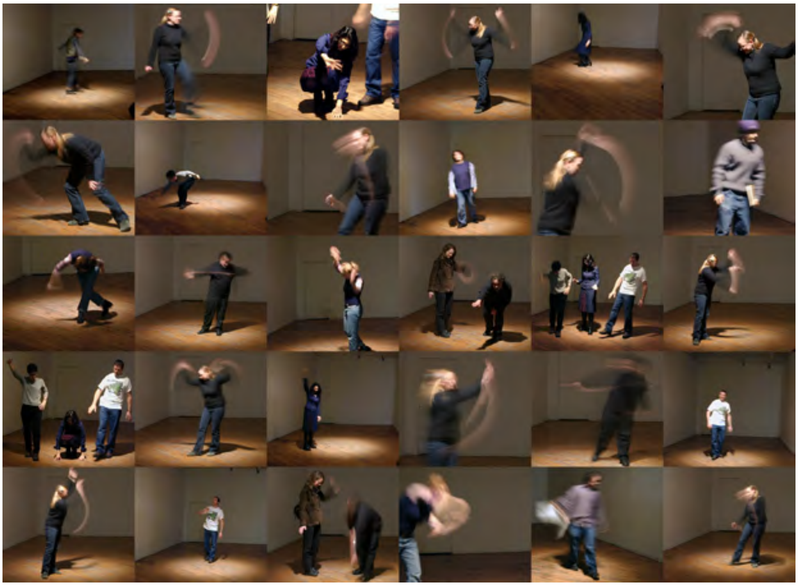


Figure 14-3. Various people interacting with David Rokeby's Very Nervous System (1986 – 2004) at aceartinc., Winnipeg, Canada[5]

To explore new concepts, behaviors, and environments, artists and designers need to develop a new set of tools and skills. Architects and interior designers use physical models, known as a maquette, to experiment with form, materials, lighting, orientation, and other properties of their designs. Similarly, designers working with emerging technologies need tools to experiment, mold, and model the elements of networked devices, software, and complex systems.

4 Rokeby, David. 1982–1984. "Reflexions," *http://www.davidrokeby.com/reflex.html*.

5 Photos by William Eakin, Liz Garlicki and Risa Horowitz. Image arrray design Mike Carroll. 2003.

The success of new design tools to help work with somewhat intangible materials has to be measured based on how well it helps the designer understand the parameters of her design, and make choices based on experiencing aspects of the design in context. These tools should allow for different levels of generative and synthetic activities, varying fidelity, working with high-level abstract notions all the way down to the small functional and aesthetic details of the final product.

The current generation of digital design tools (CAD, Adobe Creative Suite) created new ways of working on traditional types of outputs. They gave us the ability to create many more variations of layouts, the safety of undo and file versions, and access to previously impossible or difficult processes for creating effects and working with new source material. However, they did not fundamentally change the component pieces of the designer's process, toolbox, or output.

These tools are coming up short as designers are beginning to work with complex communications between people and machines, interactions and movement that happens over long periods of time and many individual devices, and large data sets that can't easily be visualized using manual methods.

To add to this complexity, the entire notion of finality has changed. Designers traditionally create outputs that remain static, or have a small set of variations, once produced. Modality in traditional products was more a result of context, use, customization, or modification. In new types of products there is no "final version," rather the product itself is a system, reacting to its environment and interactions, continually changing and evolving with use.

TWENTY-FIRST CENTURY FOUNDATION

Designers in the twentieth century needed to internalize and deeply comprehend things like 2D and 3D form, physical environments, and typography (to name a few areas of practice). The twenty-first century designer needs to build on these foundations with a number of new elements. The traditional elements of design were well established by Rowena Reed-Kostellow and her colleagues in the 1930s: line, plane, color, volume, value, and texture. She used these as the basis for her groundbreaking design foundations pedagogy at Carnegie Tech.[6] Dave Malouf presented an initial set of interaction design foundations in an article for Boxes and Arrows in 2007,[7] and then expanded upon it in a presentation at Interaction'09. He includes elements of time, abstraction, metaphor, negativity, and motion in his set of expanded foundations.

The things we design now are beyond screens and objects and we are challenged to think of the next set of foundations for designing these systems. We can begin to draw inspiration and knowledge from cybernetics, soft systems theory, and urbanism along with more commonly referenced practices such as architecture and anthropology.

When working with invisible technology and systems that cannot be observed easily, visualizations become even more important. Often, the only way that a system and all of its interactions and decisions can be understood is through illustrations and narratives that look at the impact as well as the cause of each part of the interaction.

As we examine these systems we should pay special attention to the qualities, aesthetics, of the elements of the system. A set of aesthetics qualities of a system includes new foundational elements that build upon traditional design foundations and Malouf's interaction foundations.

Texture

What is the connectivity of the system? How do the pieces interact with one another, both human and nonhuman? The texture of the network is what we think about when we look at how easy it is to interface with its different parts. If the connections are obvious and accessible, we might describe the interface as smooth; if the connection points are difficult or confusing, that could be described as rough.

The notion of texture can be applied to graphical interfaces, gestural or spatial interfaces, hardware controls, and APIs alike, among other things. How might one describe the qualities of their bank's system?

6 Hannah, Gail Greet. 2002. *Elements of Design: Rowena Reed Kostellow and The Structure of Visual Relationships*, Princeton Architectural Press.

7 Malouf, Dave. 2007. *Foundations of Interaction Design*. Boxes and Arrows, http://boxesandarrows.com/foundations-of-interaction-design/.

This could include their ATMs, customer service, transfer between institutions, and more. Often a designer (or critic) will only be concerned with a subset of a network system, but it's always good to pay attention to how that piece interacts with the whole and how the system responds to those inputs.

Agency

What is the component's capacity to act on the other parts of the network or the system as a whole? Can a person interfacing with the product influence the rules of the system? Or, are his potential actions constrained by other aspects of the system? How much freedom does each network component have within the system?

The agency of each actor within the system depends on its role. From a human perspective, agency can describe how much power a user can exert on other parts of the network, versus being limited to specific actions in specific contexts. Different actors will have different amounts of agency at different times.

Opacity

How clear is the network from the perspective of a participant or observer? Are the connections easily visible or are they hidden? The opacity of a network can influence how much agency each actor has and help to create the desired texture.

In our traffic-light example, we see a very opaque system, one where the means of interacting are often completely hidden. It would be easy to interact with the system and still not even know that it exists. In this example, the opacity has a direct impact on a person's agency, but if the system behaves properly, the texture might still be smooth. Roughness will become apparent if the system misbehaves and nobody can see what is happening.

Reflexivity

How do you know what is happening in the network? How does it inform the different actors, both human and nonhuman, what state it is in and if there are any problems? Feedback and communication is a vital piece of any system.

Reflexivity is the way in which the particular system provides feedback based on states, actions, and behaviors. This is an indication that the rules of the system are enforced. By providing feedback when a component attempts an action the system can let all of its parts know what is happening, if the action was completed, and what the new state looks like. The quality of this feedback is important to crafting the aesthetic of the system. Is it friendly? Verbose? Human readable? All of these things will change the overall feel of the products and services that are part of the network.

These are some possible aesthetic elements we can begin to use to discuss the qualities of a network system. None are inherently good or bad; they are the basis for a common language that lets us discuss the aspects of a network that affect its quality. An opaque network with little agency creates a certain type of interaction, one largely dictated by its owner. A low-opacity network with a lot of agency allows for more flexibility and potential wrangling by the person interfacing with the system.

The types of systems and products described by the above aesthetic language can be understood in two important ways (among others):

1. As a hard system: a system model that is concrete and constructed to achieve an objective. These types of systems are easy to analyze and model because they are generally made up of discrete pieces that each plays a set part, most often actual things that exist in the physical world.

2. As a soft system: a system model that is fuzzy and focuses on the understanding of the system from many perspectives. In this type of model each piece of the system is based on a subjective understanding of the whole, rather than specific objects that exist in the world.

For the type of design discussed in this chapter we are more concerned with soft systems, although both soft and hard must exist in order to fully understand and build a product or service in our networked world.

Soft systems methodology (SSM), a framework for thinking about epistemological systems, gives us tools to help understand an unstructured complex problem through modeling actions and subjective understanding of the situation. Unlike hard systems, soft systems models aren't about classification; instead the practice seeks to explain different relationships by describing them as they are seen, understood, and acted upon. A single set of objects and relationships could be described in many different ways, each one equally valid from a different perspective. Soft systems have always had a close tie to the way designers work. Peter Checkland, one of the SSM pioneers, said the following in his book *Systems Thinking, Systems Practice*:

> Its rationale lies in the fact that the complexity of human affairs is always a complexity of multiple interacting relationships; and pictures are a better medium than linear prose for expressing relationships. Pictures can be taken in as a whole and help to encourage holistic rather than reductionist thinking about a situation

Design's tradition of visualization and sketching fit very well with SSM's tendency toward visualization from the perspective of an actor within the system. In the networked world the designer's ability to understand, explore, and explain complex interactions between people and machines, and machines to machines, becomes even more important. SSM gives us a starting point to understand how to reframe complex situations through a process that begins by embedding oneself into the situation, expressing what you observe and understand that situation to be, and then creating diagrams that express that understanding. Once the system is visualized it can be compared to observed reality to understand which definition fits best in the given context and what actions one should take to affect the system, described in SSM as feasible and desirable changes. The use of visual tools helps the designers and stakeholders build the same mental model, rather than the ambiguity of individual conceptions.

Tools like this one become a primary piece of the twenty-first century designer's kit. Making sense of and expressing complex systems of relationships, communication, and feedback lay the foundation for good design decisions when dealing with complex networks, invisible interfaces, and nuanced interactions.

New Tools for a New Craft

Although much of the core design process is fundamentally the same as it was 30 years ago—beginning with exploratory methods including research and sketching, moving through models and prototypes of different fidelities toward a final product—the types of problems we're trying to solve and the tools we need to explore those solutions continue to change and evolve. New types of products require new types of models and prototypes. Animation, electronics, 3D printing, and interactive programming are all necessary parts of the designer's repertoire when working with emerging technologies and twenty-first century products.

Tools traditionally thought of as the domain of engineers, data scientists, and hackers are now entering the designer's toolbox. For example, a designer working with emerging technologies such as sensor networks, data collection, and microcontrollers benefits greatly by learning some basic electronics. Being able to put together a quick prototype by using a platform such as Arduino means that the designer can experiment with the possibilities available to him based on the types of sensors and data at his disposal. Even if the final product will use a different engineering solution, this basic toolset gives designers the capability to model the interactions, data, and physical aspects of a new product at a high level, and with practice, at a detailed level.

Working with large and complex data sets is becoming the norm for designers working on new products. This data can come from custom collectors, such as sensors embedded in products, or from the tangle of information available through web services. When working with large data sets, there is no substitute for working with the data itself. Tools such as Processing or JavaScript and the browser canvas object provide an easy way to start creating rich interactive visualizations from any data.

Rapid fabrication starts to shift industrial design away from being industrial and back to a more artisanal craft. Designers can now imagine a new physical form, model it with traditional tools such as clay, do a digital CAD drawing, and have it fabricated in plastic or metal within a few hours. This facilitates a kind of rapid iteration and prototyping for complex objects that would have been difficult 10 years ago. It also allows for small run production; whereas purely artisan craftspeople could produce only a few objects, and industrial production could only produce high volumes of objects, these new methods make it possible for designers to produce dozens of objects, each the same or slightly different.

These methods can be thought of as a similar process to industrial designers making clay or paper models, or architects using foam-core to make scale models of a new building. None of these things is analogous to the final form, but they are hands-on ways of exploring integral aspects of the design in a fast, cheap, and easy way. Including this in the design process helps illuminate new possibilities and filter out ideas that don't translate. These are ways of sketching with interactivity, responsiveness, and movement, iterating to a model of the product or pieces of the product.

Along with new tools come new collaborations. The *Maker* community and local hack-labs, both groups of people who deeply experiment with new technology for creative purposes, are now home to many technologists and designers working together to make interesting and future focused things. These collaborations result in products such as Berg's Little Printer, the plug-and-play robotics kit, Moti, and DIY home automation tools like Twine. Bio-hack labs are also beginning to pop up, pushing into biology and chemistry, and experimenting with bioengineering in an accessible way. One such group in Toronto, DIYBio Toronto, hosts regular workshops. Companies such as Synbiota, an open source repository for bio-hacking, are forming to support the community.

These are just the beginning, as startups and large companies move into this new space. One of the most successful examples on the market today is the Nest thermostat, which combines innovative physical controls with small screens, microprocessors, and software to add a level of smart automation to the home. A product that started out as a better thermostat is poised to be the hub of a much larger home control system.

How do we begin to work with these new technologies, networks, and systems? There are a few ways to dive in that will help to understand the potential, constraints, and complexities involved.

Experiment

Arduino and similar platforms are easy to find at local stores or online, and they are cheap. Pick one up, find a tutorial, and dive in. Have an idea for a project you'd like to try? Just try it, don't worry if it seems complicated. Start with the simplest piece. These systems give you all the pieces you need to build network-connected objects.

Learn new skills

If you've never programmed before, pick up a JavaScript, Processing, or Ruby tutorial. If you've never designed a physical object, get some modeling clay and sculpting tools and try to make some interesting shapes. If you've never designed software before, try to map out a flow or design an interface; start with pencil and paper.

Be critical

When you've made your first new thing, take some time to think about its qualities using some of the frameworks discussed earlier in this chapter. Use what you learn from this reflection in your next experiments.

Always think about how your new device, software, or system fits into the larger connected world. What possibilities does it create? What potential does it remove? What does it give to people, and what does it take away?

You won't be satisfied with your first attempt, but design is all about iteration. These types of new skills open many possibilities for your practice as a designer, allowing you to incorporate new technology, processes, and techniques into your work.

MAKING THE FUTURE IN WHICH WE WANT TO LIVE

The active ingredient of the work is its interface. The interface is unusual because it is invisible and very diffuse, occupying a large volume of space, whereas most interfaces are focussed [sic] and definite. Though diffuse, the interface is vital and strongly textured through time and space. The interface becomes a zone of experience, of multi-dimensional encounter. The language of encounter is initially unclear, but evolves as one explores and experiences.

—DAVID ROKEBY ON VERY NERVOUS SYSTEM[8]

David Rokeby used the preceding statement to describe the nature of his Very Nervous System interactive installation. These same words now describe our relationship to an ever-increasing amount of invisible architecture acting around us. The metaphorical handles and buttons that we design into these largely invisible systems will determine

8 Rokeby, David. 2010. "Very Nervous System," *http://www.davidrokeby.com/vns.html*.

people's ability to comprehend, manage, and benefit from the things we design. Returning to our traffic sensor example, when a hidden sensor at a busy traffic intersection is designed to trigger the lights based on certain physical aspects of a vehicle, the designer of that system needs to decide what types of vehicles are allowed to trigger the lights. Will it work for cars, bicycles, or humans? That choice is a decision that will impact the shape of the urban environment in a way that most people using the intersection will never fully see. How do you indicate the system's texture, agency, opacity, and reflexivity? Do you add symbols to the road to indicate the existence of a sensor and what will activate it? Do you opt for a different solution entirely because of the needs of the city? These are design problems at a systems scale and are becoming more and more common in the work we do every day. We need to make sure we are arming designers with the tools they need to make these types of decisions intentionally.

Design is a special craft, one that allows us to imagine the future as we would like to see it, and then make the things that will help get us there. Pre-industrial products were the output of a single craftsperson, and expressed their understanding and view of the world. Industrial products represented a move to mass production and consumption, where a designer could envision a product and millions of people could receive an identical object. This was the expression of the collective—the design of objects shaped our environment and culture on a large scale.

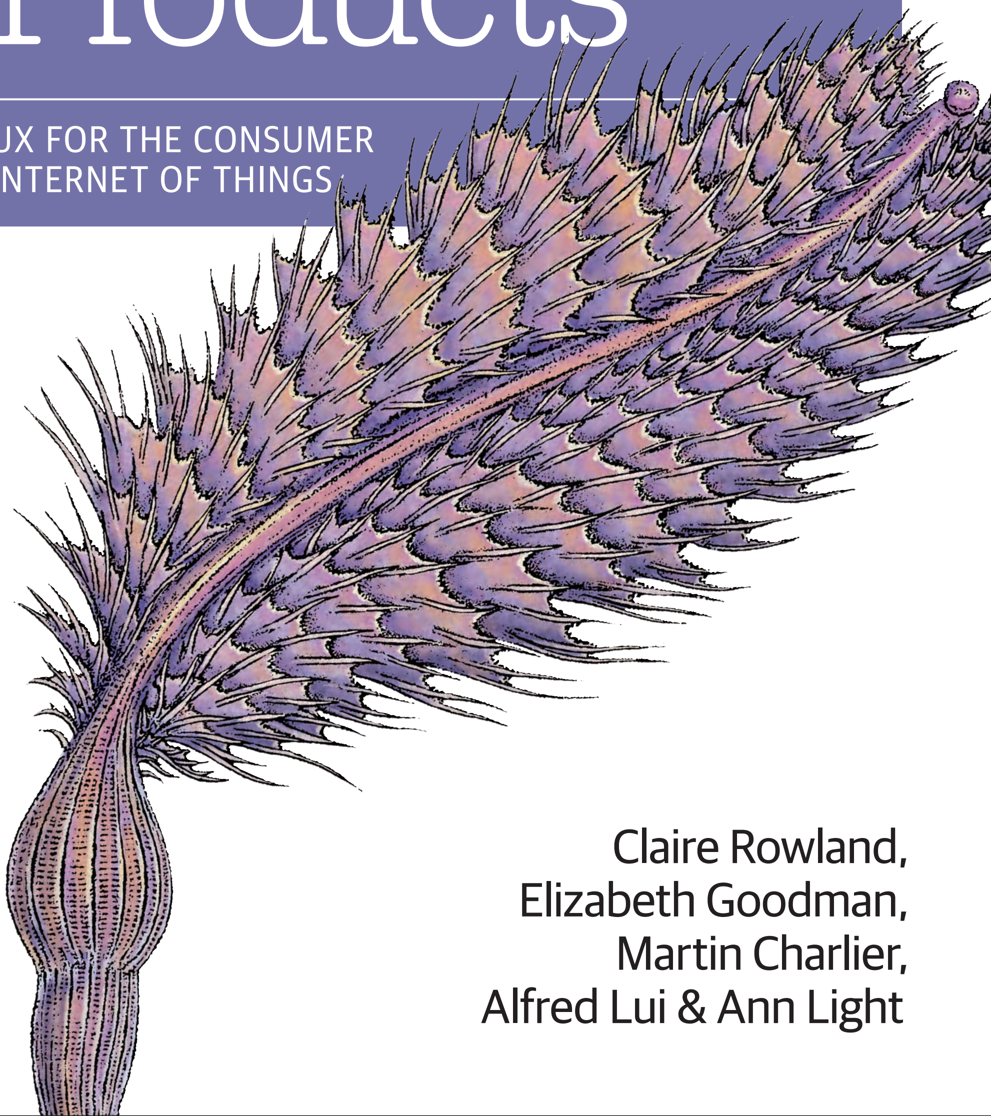
As we move deeper into a post-industrial era new products are the expression of the network. Small groups can now cocreate and produce objects at industrial scales, or can create complex objects at minute scales for their own needs. Where pre-industrial objects represented a one-to-one relationship between creator and consumer and industrial objects were one-to-many, post-industrial moves into a many-to-many world. Everybody is enabled to create and consume. With this comes a great freedom, but also a great dilemma. Do all these new objects help us create a better future? Do they represent the world we want to live in? Each new creation warrants a consideration of these questions as we continue to redefine our environment using new technology, and to see the world through our new, networked lens.

This era of post-industrial design brings with it new opportunities and more complex challenges, and we should dive in headfirst.

O'REILLY

Designing Connected Products

UX FOR THE CONSUMER INTERNET OF THINGS



Claire Rowland,
Elizabeth Goodman,
Martin Charlier,
Alfred Lui & Ann Light

Designing for Connected Products: UX for the Consumer Internet of Things

4

Product/service definition and strategy

Claire Rowland

Introduction

We all aspire to create the killer product or service that people want to buy and love using. The key to this is ensuring that the product solves an actual problem that people have, in a way that appeals to them. At a pinch, it might provide them with something new and wonderful that they never knew they needed. It sounds simple and obvious, but it can be remarkably difficult to get this right. Right now, the IoT market is skewed towards innovators and early adopters. There's huge potential to create great new products for consumers, but they may have to contend with new types of complexity.

This chapter introduces:

- Productization as part of IoT design *(see page 2)*.
- What makes a good product for different audiences *(see page 7)*.
- How products differ from tools *(see page 14)*.
- What makes a good product *(see page 19)*.
- Building service offerings around products *(see page 28)*.
- Business models in IoT *(see page 35)*.

This chapter addresses the following issues:

- Why a clear value proposition is a prerequisite to great UX design *(see page 4)*.
- Why products designed by and for innovators aren't necessarily right for general consumers *(see page 7)*.
- Why consumers want products, not tools *(see page 14)*.
- Why it's important to design the service offering around a product *(see page 33)*.
- How business models can shape UX *(see page 35)*.
- How digital business models may start to appear in real world products *(see page 37)*.

Making good products

What is productization?

Productization is the extent to which the supplier makes the user value of the product explicit and easy to understand. Compelling products don't just look good or otherwise fuel some underlying need for status (although those things are often important). They make it immediately apparent to their intended audience that they do a thing of real value for them: preferably something new than serves a previously unmet need.

Nest is probably the most famous IoT productization success story. Consumers were resigned to thermostats and smoke alarms being ugly, annoying boxes with usability flaws. It hadn't occurred to most people that they could be better. Nest products promise to do the job better than most of the competition, in the form of attractive and desirable hardware that users are happy to have on show at home *(see figure 4.1)*. Of course, they are premium products with a premium price tag. The point here is not that all products should be expensive, but that a good product should fulfill a clear need for the target audience, with a usable and appealing design. **This is the product's *value proposition*: the user's understanding of what the product does for them and why they might want it.**

Figure 4.1: Nest thermostat shown in home (image: Nest)

"Never underestimate the power of a simple explanation, or a product that looks nice. If people can understand it, they can want one for themselves. They're not scared of it. It stops being a weird thing that geeks do." Denise Wilton, designer (and former creative director of design agency BERG)[1]

Products can be services

When we talk about IoT, we tend to focus on the edge devices: the activity monitors, thermostats, connected pet feeders, and more. This is especially true when the devices themselves look novel (such as the Nabaztag rabbit shown in chapter 2) or striking (such as the Nest thermostat).

But while the devices are a key part of the UX, they are not the whole picture. They are all dependent on an internet service. This makes the user's relationship with the product much more dynamic. Instead of the traditional one-off purchase of a traditional physical product, the user interacts with the provider on an ongoing basis. The user's experience isn't just shaped by the device, it's shaped by the whole service. There might not even be a physical product at all: just as you can now pay for Dropbox storage or personal fitness

[1] From a talk at UX Brighton, November 2012

training, so you may pay for software or storage to help you make the most of connected devices, or personalized health or energy saving advice based around data gathered from your devices.

Author's note: In this book, we use the term 'product' loosely to refer to a packaged set of functionalities that solves a problem for people or fits neatly into their lives. That could be a physical device, a service, or frequently a combination of both.

Why is this in a UX book?

To some of you, this may seem outside the remit you normally associate with UX design. You may work in a company where productization is handled by product management, or perhaps marketing. In others, it might be considered strategic design. UX is not always involved in identifying the opportunity and framing the solution. But most UX designers would walk over hot coals to be involved from the start, especially if they have first hand knowledge of user needs from conducting research.

Whoever is responsible for it in your organization, it provides the strategic foundation for UX design. **It's not possible to design a great product or service experience if users don't want, or understand, the service in the first place.**

Value propositions help sell products. But they also drive UX. A clear proposition helps users decide whether to buy it in the first place, but also helps frame their mental model of the system and what it does *(see figure 4.2)*. When users are confident that they understand what the system does for them, they have a good basis for figuring out how it works (the conceptual model), and then how to use it (the interaction model). All the clever design in the world can't overcome a murky or unappealing value proposition.

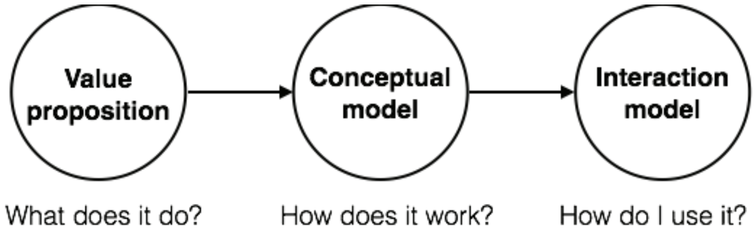


Figure 4.2: A good clear value proposition is fundamental to a great UX.

Why is this in an *IoT* book?

Productization is of course not a challenge that is unique to IoT. It is included in this book as it is a particular challenge for the consumer IoT field right now. Many products and services aren't yet offering good, practical solutions for proven consumer problems. Even where they are, the value isn't always apparent from the product itself or clearly stated in terms target users would understand.

This isn't a criticism of the many clever and talented people working in this field. Most of them are aware that consumer experience is a challenge.

It's a result of the novelty and inherent complexity of the products and services. We're still figuring out what we can do with the technology, and we're asking users to wrap their brains around some novel devices and capabilities.

It also reflects that new technology products and services are often conceived and developed by people with an engineering mindset who value highly configurable functionality. These initiatives can often seem complex and unclear in purpose to consumers because, in trying to do so much, they fail to communicate a clear value for using the service.

There is, of course, a market for products developed to meet the needs of highly technical users. There's also great value in products and services that help a wider range of people move beyond passive consumption of technology and learn how to construct their own solutions. For example, *If This Then That* offers an accessible way to coordinate different web services and even connected devices *(see figure 4.3)*. This is functionality that would previously only have been available to those with good programming skills.

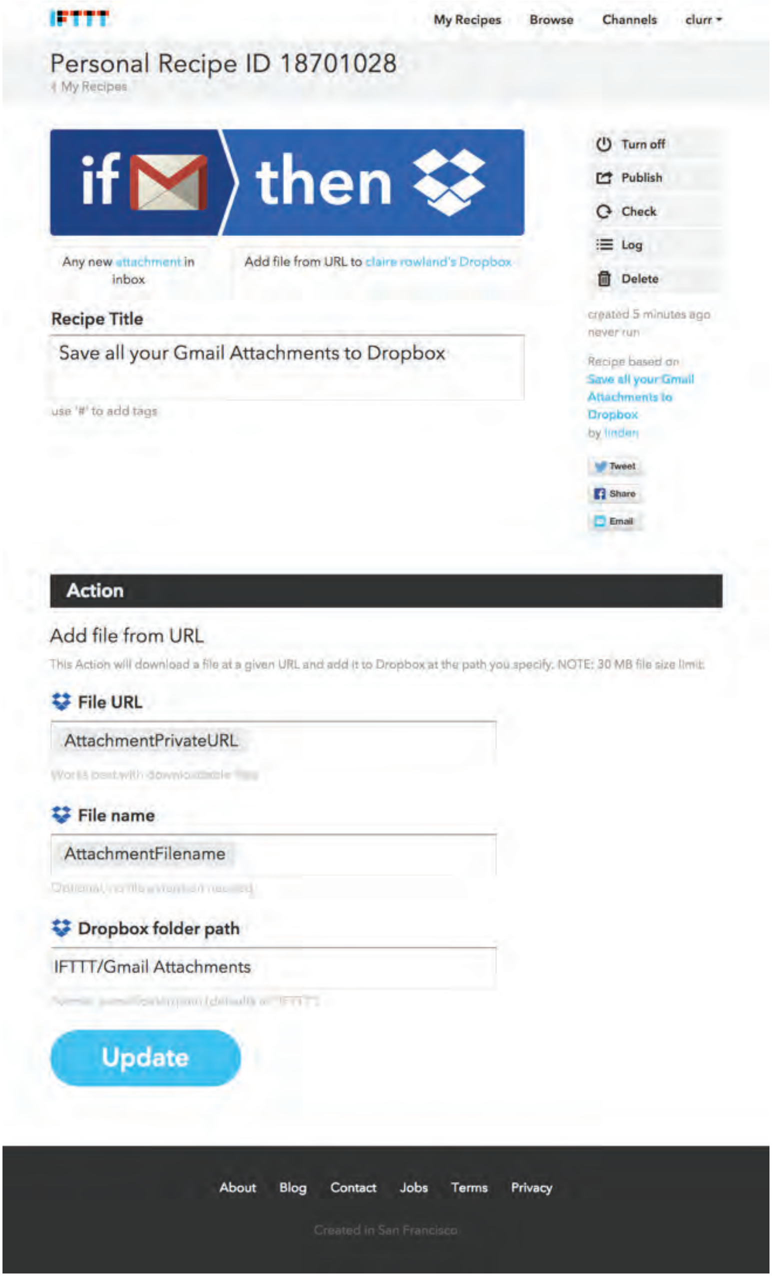


Figure 4.3: An If This Then That recipe for saving Gmail attachments to Dropbox

But the bigger challenge is in creating products and services that work for mass-market consumers. For this audience, the functionality – what the system does and how to use it - should be transparent. The underlying technology should be invisible. The user should be able to focus on getting the benefit from the product that they were promised, not on configuring it and maintaining it.

From innovation to mass market

The primary focus of this book is on creating consumer IoT products and services. In this section, we take a brief look at how technological innovations cross over into the mass market and consider what lessons there may be in here for IoT.

Innovators are not consumers

In 1962, the sociologist Everett Rogers introduced the idea of the technology lifecycle adoption curve, based on studies in agriculture[2]. Rogers proposed that technologies are adopted in successive phases by different audience groups, based on a bell curve (see figure 4.4). This theory has gained wide traction in the technology industry. Successive thinkers have built upon it, such as the organizational consultant Geoffrey Moore in his book 'Crossing the Chasm'[3].

In Rogers's model, the early market for a product is composed of innovators (or technology enthusiasts) and early adopters. These people are inherently interested in the technology and willing to invest a lot of effort in getting the product to work for them. Innovators, especially, may be willing to accept a product with flaws as long as it represents a significant or interesting new idea.

The next two groups - the early and late majority - represent the mainstream market. Early majority users may take a chance on a new product if they have seen it used successfully by others whom they know personally. Late majority users are skeptical and will adopt a product only after seeing that the majority

[2] Everett M Rogers, 2003, 'Diffusion of Innovations' (5th edition), Simon & Schuster.

[3] Geoffrey Moore, 1991, 'Crossing the Chasm', HarperBusiness.

of other people are already doing so. Both groups are primarily interested in what the product can do for them, unwilling to invest significant time or effort in getting it to work, and intolerant of flaws. Different individuals can be in different groups for different types of product. A consumer could be an early adopter of video game consoles, but a late majority customer for microwave ovens.

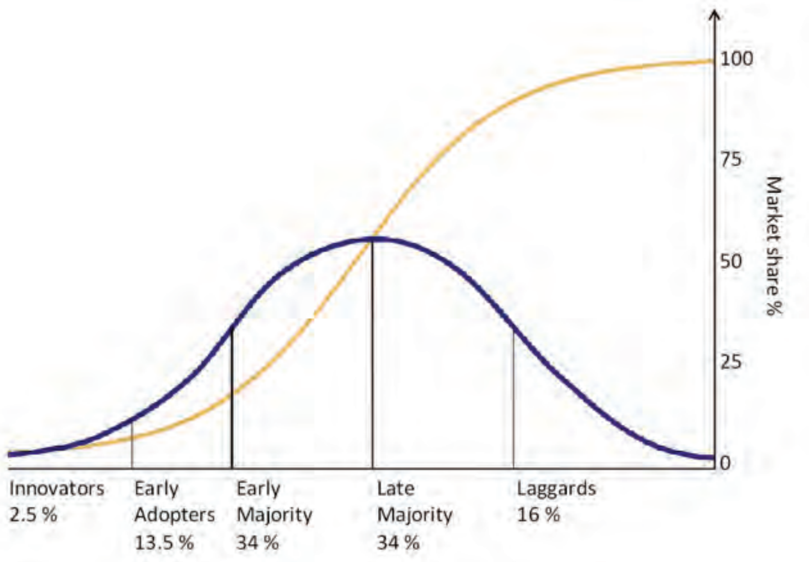


Figure 4.4: The diffusion of innovations according to Everett Rogers. The blue line represents the successive groups adopting the technology, the yellow line the market share (Image: Tungsten, via Wikicommons).

Geoffrey Moore identified a 'chasm' between the early adopter and early majority market (which he called visionaries and pragmatists). These groups have different needs and different buying habits. Mainstream customers don't buy products for the same reasons as early adopters. They don't perceive early adopters as having the same needs as themselves. Mainstream customers may be aware that early adopters are using the product. But this will not convince them to try it out themselves unless they see it as meeting their own, different, needs. So products can be successful with an early market, yet fail to find a mainstream audience.

An example of this in the IoT space is the home automation market. Systems such as those based on the power line protocol X10 have been around for close to 40 years. (Early examples ran over electrical power lines and analogue phone lines). The example in figure 4.5, from 1986, shows a system that allowed users to program and remotely control their heating, lighting and appliances over a (landline) phone. These are all applications that still seem novel and innovative to us; they would have excited the innovators of the 1980s even more.

Figure 4.5: Advertisement for X10 Powerhouse for the Commodore 64, from the January 1986 edition of Compute! Magazine (image via commodore.ca).

However, home automation remained a niche market. It was expensive. It required significant technical skill to set up and maintain. Even those mainstream consumers who had heard of home automation did not see much value in programming their heating, lighting and appliances. Had it been more affordable or easier to use, more people might have been willing to try it out. But only now are consumers starting to see the utility of connected home products. This is arguably driven by the rise of the smartphone, giving us a metaphor for the ‘remote control for your life’.

What’s different about consumers?

Mainstream consumers are now more aware of connected devices, but they need to be convinced that these products will actually do something valuable for them. A product that appeals to an audience that loves technology for its own sake cannot simply be made easier to use or better looking. To appeal to a mass-market audience, it may need to serve a different set of needs with a different value proposition. Chapter 5, Understanding Users, covers learning about user needs and some of the special considerations you might encounter when designing for IoT.

Mass-market product propositions have to spell out the value very clearly. Users will be subconsciously trying to estimate the benefit they’d get from your product as offset by the cost/effort involved in acquiring, setting up and using it, and you need to be realistic about the amount of effort they will be prepared to invest in your product. The further along the curve they are, the more users need products with a clear and specific value proposition, which require little effort to understand or use. And they have a very low tolerance for unreliability. Your product has made a promise to do something for them, and it must deliver on that promise.

This is not simply a question of lacking technical knowledge, and certainly not of users being dumb. That 10-step configuration process to set the heating schedule might seem trivial in the context of your single product. But it can feel overwhelmingly complex in the context of a busy life with many other more pressing concerns. For this reason, consumers tend to be most attracted by products that seem as if they will fit into their existing patterns of behavior and don’t require extra effort. For example, ATM cards and mobile phones were arguably successful because they reduced the need to plan ahead in daily activities (getting cash from the bank, or arranging to meet).

Value propositions for IoT

The guidelines above can of course be applied to any type of product or service. But connected products can be complex and often do novel things that are hard to communicate succinctly.

Core value propositions should be straightforward, e.g. a company offering smart meters may promise to "tell you where your energy spend is going", which is relatively simple. A good test of an IoT product proposition is that end users should not need to focus on its connectivity or onboard computing: it should just make sense.

But there may be complicating factors that users need to understand before buying. You may have to explain which other systems can interoperate with yours, or who owns the user's data and what they can do with it. (The technology and value of interoperability is discussed in further detail in chapter 10). You might have to guarantee how far into the future you will maintain the internet service (if your company is acquired, goes bust or discontinues the product).

The entrepreneur and academic Steve Blank describes 4 types of market in which a product can operate[4] (see figure 4-6). The type of market influences how you position the value of your product. Below, we look at what this might mean for IoT products:

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[4] Steve Blank, 2005: "The Four Steps to the Epiphany: Successful Strategies for Products that Win" (K&S Ranch Press)

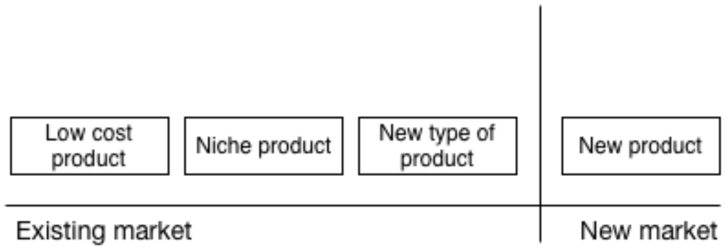

Figure 4-6: 4 types of market in which a product can operate

A new product in a new market

Embedded connectivity and intelligence will fuel the appearance of new classes of product and new markets. In consumer terms, the challenge is often to convince users of your vision. You have solved a problem they didn't realize they had, or had just accepted as 'the way things were'. The Glowcaps pill bottle top, mentioned in chapter 2, reminds users to take their medication and helps the patient's doctor track how frequently it is taken.

A new type of product in an existing market

Here, the challenge is to convince users that your product is the best solution to the problem. Perhaps it has better features or better performance. In IoT, these products may be familiar physical devices newly enhanced with sensing or connectivity (e.g. the Withings bathroom scales). Users need to understand the value that is added by the enhancements, such as easier weight tracking. They need to decide whether it's something they want, especially if it costs extra.

It might also be a technology that offers a step change in experience design. For example, airport terminals can be large and confusing. You would normally rely on signage to find your way around, but this isn't always clear, consistent or guaranteed to tell you what you need as and when you need it. You don't want to miss your flight, but nor do you want to end up sitting around at the gate for too long because you were cautious and got there too early. Apple's iBeacons technology (described in chapter 2) offers precise indoor location. Several airlines have been trialing the use of iBeacons to provide passengers with in-context information and directions (see figure 4.7).

Passengers can be directed to the correct gate more easily, based on their current location in the airport. If they are running late but are very close to the gate, knowing their location might help the crew decide to wait. And if their plane is delayed, the app could provide them with a voucher to a nearby restaurant or café.

Figure 4.7: Illustration of an airport iBeacon trial (Image: SITA).

A low cost entrant to an existing market

The falling cost of embedded computing enables cheaper alternatives to systems that used to be prohibitively expensive. For example, Lowes Iris (see figure 4.8) and Smart Things offer DIY home automation kits at a far lower cost than professionally installed systems. You may be aiming the system at people who could not previously afford this category of device, or trying to convince those who could that you're offering a worthwhile saving. Either way, it's important to convince users that the system performs the basic functionality just as well as more expensive options. Any compromise needs to be something that doesn't matter too much. You need to be clear upfront how you have achieved the cost saving: is the hardware cheaper? Does the system involve more work from the user (e.g. DIY setup)? Does it provide them with less personal (e.g. automated or lower bandwidth) customer service?

Figure 4.8: Lowes Iris Safe and Secure DIY home security kit (hub, motion sensor, two contact sensors, alarm keypad). (Image: Lowes).

A niche entrant to an existing market

Augmenting an existing product type with connectivity and potentially intelligence can create opportunities to address previously unmet user needs in an existing market. It may target a niche with specialist interests: for example, an energy monitoring system designed for those who generate their own electricity and may sell it back to the grid. Or it may introduce a premium product for those willing to pay more. The Nest thermostat offered the first intelligent heating solution with high-end hardware and polished UX design in a market previously dominated by ugly, unusable plastic boxes. This reshaped consumer expectations of what a heating controller could be, even in the part of the market that couldn't or didn't want to pay extra for a Nest.

Tools vs. products

For some specific connected devices, like a heating controller, there's a close mapping between function and value. It's easy for people to understand what it does. That's not enough to make it a *good* heating controller. But it's pretty clear what it does, and why you might want it. It will keep the house at a comfortable temperature and, perhaps, save money. Devices that are enhanced versions of pre-existing product types, like bathroom scales or baby monitors, have the advantage of being recognizable as things that meet a defined, familiar set of needs. You may have to convince customers as to why that product benefits from connectivity. And you may have to address concerns they have about adding connectivity or technical complexity to the product, such as security, privacy or usability. But at least the product is familiar.

Mass-market consumers, in areas in which they do not have deep technical or domain knowledge, generally expect a product to come designed and engineered to fulfill a specific need. The Nest Protect smoke detector and carbon monoxide alarm is a good example of a *product*[5]. The marketing website focuses on the ways in which it is a better safety alarm (see figure 4.9). Connectivity is only mentioned at the end, to say you'll be alerted on your phone if there's a problem when you're away from home.

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[5] Nest Protect has suffered from some interaction design problems. A Heads Up feature originally allowed users to disable false alarms (such as those caused by burnt toast) by waving at the alarm. But no-one had thought that, in the case of a genuine fire, users might also wave their arms (in panic). The alarm was therefore too easy to disable. Units were recalled and Heads Up was deactivated. But the Protect is still a good example of a clear product concept.

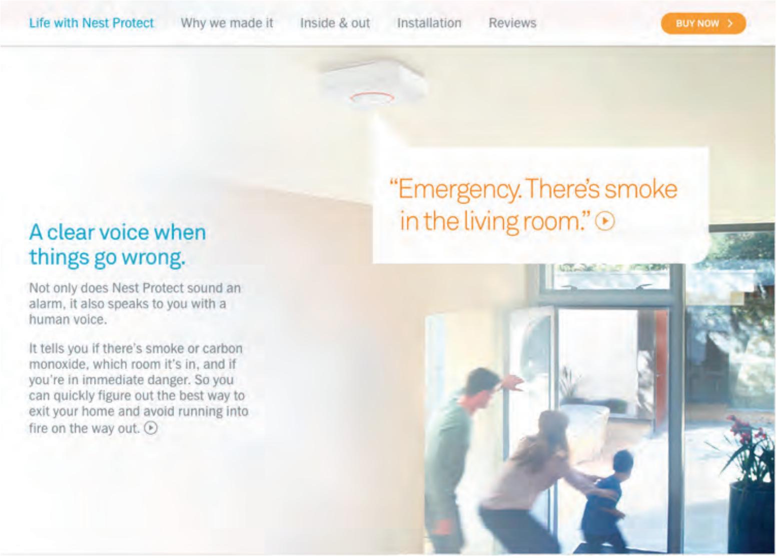


Figure 4.9: Excerpt from the Nest Protect marketing website. (Image: Nest)

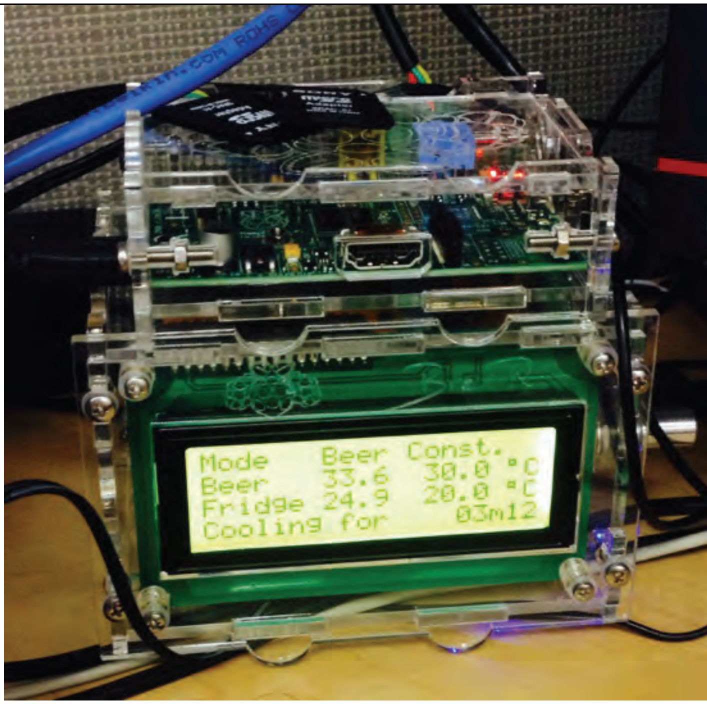
But many IoT services and devices can be configured to meet all kinds of needs. The onus is on the user to define their own needs and configure the device (or service) to achieve them. These are not products, but *tools*. Tools are often general-purpose devices, such as contact or motion sensors. The device has no inherent value to the user. The value comes when they are applied to solve a particular need, such as detecting intruders in the home, or warning you that you left a window open.

The Belkin WeMo smart plug (see figure 4.10) is a tool. It can be used to turn power to any appliance on and off remotely from a smartphone, or using an automated schedule. But it's up to the user to define their own problem, realize that a smart plug could help, and configure it to solve the problem. An imaginative leap is required. In reality, many smart plugs end up being used on lamps. In our own research, users struggled to think of other uses for them (although ensuring hair straighteners/curling tongs were turned off was popular).

Figure 4.10: WeMo smart plug and app

Services can be tools as well. The aforementioned If This Then That (which can also be used to control WeMo smart plugs), aims to make it easier for non-technical users to link up and program devices and services.

Tools aren't bad. They can be very powerful for users with technical or domain knowledge. Users who have the time and motivation to configure a system to meet their own very specific needs and aren't daunted by the need to learn the system may really enjoy this process. This could be the home brewer who enjoys rigging his or her own fermentation chamber out of an old fridge (see figure 4.11). Or a horticulturalist might be motivated to learn about the technology to configure a remotely controlled plant monitoring, watering and feeding system. Tools give us the possibility to be creative and take control of our environment.



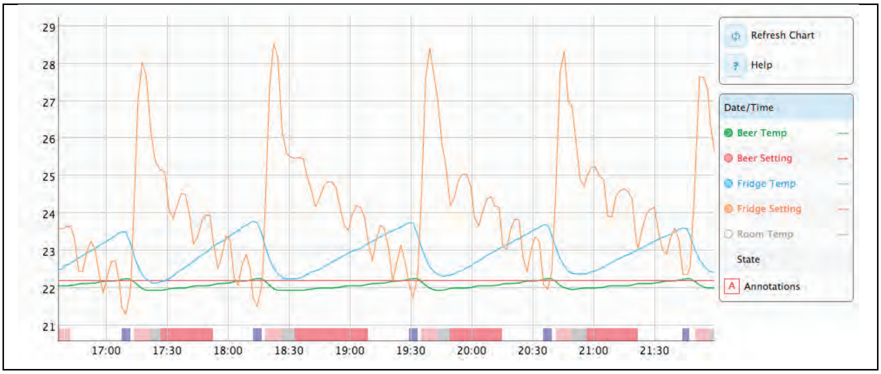


Figure 4.11: BrewPi is a fermentation temperature controller for brewing beer or wine. Running on a Raspberry Pi computer and Arduino[6], it comes with a kit to convert a standard home fridge or freezer into a fermentation chamber and is controllable via a web interface. (Images: Anthony Plunkett).

The IoT market, to date, has tended to create tools for innovators and early adopters. In an immature market that is exploring possibilities, that's fine. But it has tended to assume that the way to reach a mass audience is to make better-designed tools.

You can't turn a tool into a million-selling product just by making it usable. The WeMo plug comes with a well-designed smartphone app that walks users through the setup process fairly clearly and makes it easy to set up rules to control the plug. But the onus is still on the user to use the plug creatively. It's not actually the *plug* they want to control: it's the appliance. Controllable plugs are simply a first step in the journey towards controllable appliances.

In spring 2014, WeMo released a controllable appliance: the WeMo Crock Pot slow cooker (see figure 4.12). This allows the user to control the temperature and cooking time of a Crock Pot remotely from a smartphone app. Slow cookers might not be for everyone, but the context of use is a perfect fit for connectivity and remote control. Their value proposition is convenience: the meal that cooks itself while you're out all day. Remote control increases that convenience by allowing you to adjust the timing if you're home late. And

[6] At the time of writing the Arduino model is being phased out for a newer version based on the Spark Core development board.

being able to keep an eye on the device alleviates any anxiety about leaving a hot thing unattended in an empty house. It may be a niche appliance, but it's a well-formed product solution.

Figure 4.12: WeMo Crock Pot and smartphone app.

Mass-market consumers don't necessarily lack the knowledge, skill or imagination to solve their own problems. They may be perfectly capable of doing so but simply lack the time or have other priorities. At best they might only have time to solve a few of them.
There is a rich market for products that solve their problems for them!

What makes a good product?

Good products seem to appeal to common sense, and new good products are often greeted with the reaction 'well why didn't someone think of that before?'. But developing good products can be far harder than our 20/20 hindsight might lead us to think. This section looks at the general qualities of a good consumer product before considering what features come with IoT.

The product solves a real problem people have (and makes this clear)

Most products are acquired in order to solve a problem for the user. A good definition of the problem, and the audience, are essential to creating a clear value proposition. This is the definition of what your product does for people, and why they might want it.

A clearly communicated value proposition is fundamental to user experience. When people come across a product (or service), they try to form a quick judgment about its purpose, and whom it is for. If it's not immediately clear what the value proposition is, it may be dismissed: either because it is too hard to figure out, or because it does not appear to do anything of value for that person at that time. Worse, potential users may wrongly assume it is able to fulfill a purpose for which it is not really suited and waste time and/or money on a fruitless endeavor. (You may be happy to take their money in the short term, but over time too many unhappy customers will damage your reputation!).

It's all too easy to end up with a poor or unclear value proposition despite good intentions. This is often the result of failing to identify the right problem for the right audience. You might have added features to show off what the system can do, or because they are simple to build, dictated too much by the capabilities of the technology at the expense of the original purpose and user needs. Or maybe there are competing interests involved in feature scoping. It's common for systems to try to do lots of things. That may create a great tool for early adopters who like to tinker and customise, but it risks muddying the value proposition for a mass-market audience. Imagine you're making a wrist-top device for outdoor pursuits like hiking or climbing. The core features are an altimeter, barometer, compass, and perhaps GPS. It might be quite straightforward softwarewise to add on a calendar, to do list and, maybe, games. You can probably imagine a situation in which someone, somewhere, might use those features. But you'll be at risk of obscuring the key purpose of the device: helping users find their way and stay safe. Too much flippant functionality might even undermine the perception that the device offers good quality in its core functionality. And it will make it harder for users to access the key features they most want and need.

If your device can fulfill multiple purposes for the user, you'll have to invest extra effort in helping users understand its value. A home contact sensor is a generic piece of hardware with no inherent value to the user. The value is in the function it enables: used to detect when an intruder has forced a door open, or when a medicine cabinet has been opened. Early adopters may love the flexibility to use the sensor as a tool that can do all kinds of things. But you'll have to help mass market users understand what it could be for. For example, your app might offer specific window or cupboard alarm functionality to go with the device, even if these do much the same thing under the hood.

Connected products intended for the mass-market need to demonstrate a clear advantage over any predecessors. Connected things are not inherently better than non-connected things, just because they are connected. Despite being demo-ed at consumer electronics fairs year after year, the much-maligned internet fridge concept has so far felt like a solution in search of a problem. Research shows that people can imagine using intelligent fridges that provide information about their contents, nutrition and health, but this has not translated into demand.[7] Tasks such as managing shopping lists and looking up recipes simply don't feel as if they require a new, fridge-based screen. The idea of the fridge that automatically orders more shopping when goods run out is fraught with potential for irritating errors. If you have to make the fridge sync with your calendar or heating thermostat to see when you're on holiday in order to stop your regular milk order, maybe it's just simpler to buy your own milk after all.

Connected sensors enable many kinds of data in the world to be captured, quantified and made visible. Fitness tracking and energy monitoring (see e.g. figure 4.13) are obvious consumer examples of this. But beware you're not just counting things. Data should be used to provide genuine insights that users can act on.

[7] Matthias Rothensee, User acceptance of the intelligent fridge: empirical results from a simulation, IOT'08 Proceedings of the 1st international conference on The internet of things, 123-139

Fig. 4.13: The Efergy energy monitoring service helps users understand their electricity consumption. (Image: Efergy)

For more information on designing with data, see chapter 13.

Connectivity can enable remote control of devices. The core value of connected sockets and door locks is usually remote control (see figure 4.14).

Fig 4.14 The August door lock, app and hub (plugged into outlet).

Connected home systems that allow automated rules to be created are examples of products whose main value is in automation (see figure 4.16). Intelligent systems such as the Nest thermostat may promise to do the job (such as setting a heating schedule that best fits home occupancy) better than a human.

Fig. 4.15: An automated 'coming home' smart rule in the AT&T Digital Life tablet app

Tags or sensors embedded in objects allow them to be trackable and identifiable. The FedEx SenseAware service (figure 4.16) embeds a multi-sensor device inside sensitive shipments (such as medical supplies), allowing the sender to track the location of a parcel and the temperature, light levels, humidity and atmospheric pressure to which it has been exposed. If any of these fall outside a set range, a replacement parcel can be dispatched.

Fig 4.16: FedEx Senseaware sensor and web app

It goes almost without saying that your system needs to be reliable enough to fulfill its promise. Glitches and outages are inevitable in most systems and early adopters will forgive these more readily. But if there are contexts of use in which you cannot afford failure, the product must be 100% reliable. For example, emergency alarms for elderly or vulnerable people must always work. You'll need a backup power supply and connectivity (see figure 4.17), and regular checks to ensure these work.

Fig 4.17 The hub of the Scout security system has a backup battery and 3G cellular chip so it won't stop running during power and internet outages.

The product comes at a cost (financial, or effort exerted) which seems in proportion to the perceived value

A good product needs to balance the cost and effort required from the user against the value it delivers. If the value is very high, users may be prepared to pay more, or invest more time in configuration.

Determining a price point is a tricky matter in itself. You'll have to consider manufacturing costs, competition and market conditions, and what users are prepared to pay.

You'll also need to consider the cost to the user of switching from whatever they were using previously. Household technology, like heating and alarm systems, tends to last years and users won't want to replace working boilers, sensors or other kit at great expense without a significant benefit[8]. If you can support retrofit – new technology that can easily be integrated into old systems – without greatly increasing the cost of your product, you'll increase the potential market for the product.

In the context of UX, the perceived cognitive effort to use your product and the time it will take to get it set up and working affect who will buy it, and why. Be careful in your judgment here. In the thick of a project when you are excited about your idea, it's easy to overestimate how motivated users are to invest time in your product.

Smart homes are a typical example here. It's been possible to connect up lighting, heating, appliances and entertainment systems for around 40 years, as we saw earlier. But you needed to be an enthusiast to set it up and program it (or wealthy enough to pay someone else to do that). A niche of users has taken great pride in their automated homes, but others have found them fraught with support issues, technology failures, and a poor fit with the needs of other guests and residents. Mass-market users often view home automation with suspicion: home is a very personal context, and one in which we are often loath to introduce novel technologies that might break our established routines. Most of us don't want to have to do a load of programming just so we can turn lights on and off. We manage that well enough already and it's an effort to switch unless the benefits are really evident.

Adding extra cognitive effort to everyday tasks is a common risk. The UX strategist Scott Jenson proposes the idea of the 'surprise package': the mature consumer product that is 'enhanced' technologically, turning it back into an early adopter product. As Jenson puts it: "Companies take product concepts

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[8] C.F. the model of shearing layers, which describes buildings as a set of components that evolve and obsolesce over different timescales. 'Services', like HVAC and plumbing, are expected to last 7-15 years. This concept originates from architect Frank Duffy and was developed by Stewart Brand in his book 'How Buildings Learn: What Happens After They're Built'(1994, Viking Press).

that are now far into the laggard range of stability and established behavior, and they change the product significantly. … The new product is effectively repositioned 'back to the front' of the curve, creating a high-tech product that can only be used or appreciated by the forgiving and accomplished early-adopter group of consumers. This is where much of the consumer backlash appears, as safely mature and benign products such as TVs, radios, thermostats, home phones and even cars are turned back into early adopter products, and then sold to an unsuspecting laggard audience." [9]

TV is a great example. TV used to be an instant-on experience. We may have had less choice of channels and no on-demand services, but you could be watching *something* within a second or two of turning it on. It can now take minutes. You may be faced with software updates for your set-top box and/or connected TV (perhaps for apps you don't even want but can't delete), then minutes of navigating around a program guide or on-demand service using a cheap remote control poorly equipped for the job.

If your product is replacing an existing consumer product or way of getting something done, pay attention to what was good about the old way of doing things. Try to preserve that and enhance the experience, rather than adding new complexity.

The product is pleasing to use

The hard-headed cost/benefit analysis is important for any product, but the best products speak to us on an emotional level too. This is partly about aesthetics, but it's not just about bolting pretty design on top of functionality. We form an integrated impression of the functionality and design of the product, and how well that fulfills our practical and emotional needs and fits (and perhaps communicates) our sense of who we are[10]. Figuring out the right

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[9]Scott Jenson, 2002, 'The Simplicity Shift' (Cambridge University Press). Available from http://www.jensondesign.com/The-Simplicity-Shift.pdf

[10] Lionel Tiger's 'The Pursuit of Pleasure' is an interesting viewpoint on the anthropology of what makes products appeal. (Lionel Tiger, 1992, 'The Pursuit of Pleasure'. Boston: Little, Brown 1992).

experience is about design as well as product strategy, which is covered in more depth in chapter 5, ‘Translating Research into Product Definitions’.

Services in IoT

Devices and services

At the start of the chapter, we set out that an IoT ‘product’ is frequently a hybrid of physical device(s) and service provision. At the very least, the connections that keep the connected device connected are services and there may be others to consider in making a product good.

When people buy a product, they expect to have the right to use it for as long as they like. When the product is dependent on an internet service, there is a reasonable expectation that that service will continue to be available, for taking it away would render the product at worst useless and at best limited. After all, you would not expect your home heating or lighting to cease to function because the company that produced the original system had gone out of business, or no longer wished to support you. (There is an inherent tension here between the old world of physical products, and the new world of internet/web services. On the web, new services appear and old ones are ‘sunsetted’ on a regular basis. This is acclaimed as progress. A physical product is likely to come with expectations that it will last for at least a few years. If the service stops working, the lifespan of the device is shortened, creating landfill (and unhappy users). Service providers have a responsibility to ensure that they are able to maintain and improve their internet services, so that the product has a reasonable lifespan.)

The service forms part of that experience. The relationship between the device and service can vary. <-EXPLAIN MORE

Connected heating controllers and door locks are examples of systems where the *device* is likely to be the focus: we might call them *service-enabled devices*. Users view the device as the most salient part of the system. For example, Nest users are likely to say ‘I have a Nest’, referring to the thermostat to represent the entire system. (It's far less likely you'd hear someone saying 'I use Nest', 'I have Nest or 'I have a Nest system'.) Because the device is so central to the UX, users will have high expectations of its design and functionality. The service enables remote access and smarter functioning, but in the user's mind it is a way to control the device (Seefigure 4-18).

4-18 – example of produdct advert with device front and centre, e.g. Nest?

A security alarm is an example of a system where the *service* is the focus: we might call it a *device-enabled service*. The alarm service is what users care about. The sensors and other devices are generally low profile and most of the intelligence sits in the internet service or gateway software. You could add or swap out devices without affecting the core functions of the service.

Key factors that indicate that the service may be the focus of your user experience, not the device itself, may be that:

- Interactions are distributed across multiple devices, so no single device is the center of attention
- Most functionality lives in the cloud service or gateway software (perhaps because local devices don't have much computing power); and/or
- Devices can be added, removed or swapped without changing the core functioning of the system;

As the UX expert Mike Kuniavsky describes it, the device is an *avatar* for the service.[11]
The Oyster travel card (see figure 4.19 below) is a stored value contactless smart card used on London public transport. It can hold various types of tickets or a credit balance for travel on the underground, trains, buses, trams and boat services. ('Stored value' means that the credit is notionally held on the card itself, rather than in a separate account, as with a debit card.)

Passengers add tickets or money to the card itself via online purchase, ticket machines at stations or by setting up regular debits from their bank accounts.

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[11] Mike Kuniavsky, 'Smart Things: Ubiquitous Computing User Experience Design', Morgan Kaufmann 2010

They swipe the card on a reader at the start and end of journeys to validate their tickets or deduct credit. The Oyster saves time and money processing ticket office transactions and reduces the number of paper tickets. To encourage use, fares are substantially cheaper than paper tickets.

Figure 4.19: the London Oyster card

The Oyster card itself is not much of a smart object. It's just a piece of plastic containing an RFID chip and a small amount of memory. The RFID chip passes a unique ID to a reader when a passenger swipes in. The memory holds information about the tickets or money stored on it, so the reader does not need to contact the back office service in real time every time the user swipes the card. This speeds up the rate at which passengers can pass through ticket barriers, which is vital during rush hour. Readers transmit transactions to the back office in batches.

The Oyster card is an icon of London life, but it is really just an avatar for the service. Without the card readers or the ability to top it up it wouldn't be much use to you. The Oyster service involves smooth coordination between many different channels, such as the Transport for London website, the ticket machines, ticket offices and shops that sell top ups, the readers themselves, and the back office systems (see 'Service ecosystems', below).

Technically, the Oyster card itself is not even an essential part of the service: Oyster can also be used via NFC enabled phones and bankcards. In future, the dedicated Oyster card might even disappear, but the service will remain. But services are intangible, and avatars can provide a concrete, tangible focus that helps us understand the service.

Right now, IoT systems are still pretty novel and not well understood, at least by consumers. It's easy to look to individual devices as a handle to understand the system, whether or not this is accurate. (We've heard smart meter users refer to the in-home counter-top display as the 'smart meter', and the actual smart meter as the 'computer under the stairs': see figure 4.20). You might need to play up the role of the devices in communicating what your system does (*presenting it as a service-enabled device*), just to help consumers understand it.

Figure 4-20: In-home display

Over time, as we all become more accustomed to the products around us having intelligence and connectivity, our ability to understand connected products as *services* without depending on physical manifestations may become more sophisticated. The idea of a heating system without a visible controller, or a door lock without a visible lock may seem strange right now, but in time, as long as they work, we might be more open to such things.

It will probably always be appropriate for some systems to have highly visible devices, and for some to focus more on service design (see figure 4.21). The key is to pitch your UX to best suit your product, and the needs of your users.

If your service is the focus of the UX, you can still make beautiful devices but make sure the service design is at least as good. And if the device is the hero of your UX, make sure it's attractive, usable and does what it needs to do, elegantly.

4-21: Diagram or table: service enabled device vs device enabled service.

Service ecosystems

Services are delivered through the interactions of networks of people, organizations, infrastructure and physical components. The devices, and even the digital components, are only part of the experience. A part of the Oyster experience is the interactions you may have with station staff when buying a ticket or asking for help. In order to help you they will have been trained to provide good customer service, but they will also need access to good information about the transactions on your card and system information. Making this whole system work smoothly is a lot more complicated than just making cards, machines and a website: it requires someone to take a holistic view of how the service is experienced, and make sure all the components work reasonably smoothly together (see figure 4-22).

Figure 4.22: the London Oyster ecosystem

Complex IoT services, such as a connected home, require the co-ordination of multiple devices working together, perhaps even using a degree of intelligence to automate some functions without explicit user instructions (for example, turning off the electricity supply if a gas leak is detected). There may be multiple digital interfaces. There may even be co-ordination between multiple digital and physical services, for example, a heating system may use data from a 3rd party weather service, and the user might have the option of taking out a service and repair contract.

This is called an ecosystem.

If you're designing a service, you'll need to take a more complete view of all the parts of your service, and the relationships between them. For example, you may need to think about handling software and component upgrades across your devices. Ovens may require new controller boards, and washing machines may demand firmware upgrades (see figure 4.23). You'll need to design processes for handling these issues with consumers.

Figure 4.23: The Samsung WW9000 connected washing machine supports over the air firmware updates. (Image: Samsung).

There may well be customer support, marketing, sales, and perhaps professional installation and maintenance too.

*"You see companies that have poached Apple designers, and they come up with sexy interfaces or something interesting, but it doesn't necessarily move the needle for their business or their product. That's because all the designer did was work on an interface piece, but to have a really **well-designed product** in the way Steve would say, this 'holistic' thing, is everything. It's not just the interface piece. It's designing the right business model into it. Designing the right marketing and the copy, and the way to distribute it. All of*

those pieces are critical." Mark Kawano, founder of Storehouse and former Apple User Experience Evangelist[12]]

Building a service offering

Thinking at the service experience level encourages us to take a broader look at user needs, not just the interactions with the website, mobile app or embedded devices. Chapter 5 explores understanding user needs in more detail. In this chapter we'll consider how this might create new opportunities to look at the wider service package you may offer customers.

For example, take home security. We typically think of alarm systems as something that makes a loud noise and act as a visible deterrent on the home. A connected system can tell you when someone is breaking in, and perhaps film them. But if you're not able to get home, and no-one else can respond, you can't do anything about it. Connectivity has alerted you to the problem but also enabled you to feel powerless to act.

In this case, you might have the option of paying for a professional monitoring service. The security firm (with your permission) can view your cameras before sending someone out.

IoT services often provide opportunities to capture data, which can be used to improve the service offered, perhaps through better customer service or smarter support. For example, diagnostic data about the functioning of a boiler could be used to identify systems at risk of breakdown and schedule an engineer visit *before* they fail. You might even package the cost of the service contract with the monthly fee for maintaining the service. Users may be happier to pay for something like this than to cover the cost of maintaining your internet servers!

Professional installation or configuration may also be an opportunity for complex systems such as home automation technology. Time It Right[13],

[12] Mark Wilson, 4 Myths about Apple Design, From an Ex-Apple Designer, Fast Company July/August 2014 (http://www.fastcodesign.com/3030923/4-myths-about-apple-design-from-an-ex-apple-designer)

[13] http://autotimeonline.com/

designed for the needs of the Orthodox Jewish community, is a culturally specific example (see figure 4.24) There may in future even be a role for independent IoT ‘plumbers’ who specialize in helping consumers install, maintain and repair connected home systems: a kind of role the technology blogger Anil Dash refers to as ‘blue collar coders’[14].

Figure 4.24: Time It Right comes with a professional installation and configuration service (Image: Autotime).

Another service opportunity may involve helping users secure lower prices or better service from 3rd parties, or otherwise benefit from the data that comes from your system. In the sustainable housing development of Little Kelham in Sheffield, northern England residents have smart meters to track energy use and band together to bulk buy electricity (see the connected home case study between chapters 4 and 5).

Personal services, such as installation or intensive customer support, are not necessary for all services and may not be practical within your business model. But it’s worth considering the bigger context of user’s expectations around the service you’re offering, and how their needs will change over time, to make

[14] http://dashes.com/anil/2012/10/the-blue-collar-coder.html

sure your service isn't missing something they think they need, or to spot opportunities to improve the overall experience.

Business models

Establishing the relationship between your system and the surrounding service is, in part, deciding on your business model. Put crudely, this can be summarized in two questions: what will people pay for? And what do you need for production to be sustainable?

What is a business model?

A business model is the blueprint for how a business creates value for customers, and makes money. For example, a classic business model is the 'bait and hook' one used by printer manufacturers. They charge a relatively low price for the initial hardware but make money on toner cartridges.

The model maps out how the business will make money, either from increasing revenue (selling more) or decreasing costs. Increasing revenue can be approached by:

- Generating new business from new customers
- Generating *more* business from existing customers

And even a not-for-profit organization needs a sustainable business model in order to survive.

How do business models affect UX?

Business models shape the way users perceive the value of the service and the fairness of pricing. This can make the product proposition more or less appealing. Users will approach the product or service with a positive, trusting mindset, or a more skeptical or even negative one. This sets the tone for the rest of their interaction.

For example, the major energy companies in the UK have recently come under pressure for perceived unfair pricing practices. All are rolling out smart energy meters, which generate data that can be used to offer customers tips on saving energy and therefore money. But customers who feel that prices have not been set fairly treat this money saving advice with skepticism. This has a knock-on effect on the perceived UX of the energy saving service. Issues of trust need to be tackled upfront in the design, perhaps through presenting pricing in more transparent ways.

Device and service models

In the traditional product business model, the provider charges once, upfront, for hardware. This is how we are used to buying, for example, cars, or household appliances. For a long time, this was also how we bought software.

In service models (of which many digital models are examples), the provider charges for ongoing service provision. Music subscription services such as Spotify or storage like Dropbox are examples of service business models. A non-connected product can be supplied as a service; for example, renting a car through a traditional rental company is a service. The customer pays for use of a car, not for ownership of a particular car. Adding connectivity to objects increases the potential for service models.

The choice of business model is a balancing act between where the customer perceives the value to be and what they expect to pay for, and what it costs you to provide. IoT is new, which means that what the customer expects to pay for is not always a reflection of the costs you may incur!

For example, your connected heating controller requires an internet service to provide you with remote control via your smartphone app. That costs money to maintain, especially when you consider that the lifespan of a heating controller might be 10 years or more. The provider might factor that cost into the price they charge you for the product upfront, but that might make it more expensive compared to competitor products. Or they might choose to charge you a regular fee for ongoing service provision. But they might find that customers aren't used to paying an ongoing fee to keep their heating working! In that case, the company might try to add value to this service, by turning it into a platform that also supports other devices (like connected lighting or energy monitoring), or adding extra service components, like a maintenance contract.

As discussed above, the perceived value may rest in different places for different types of connected device/IoT system. Is it the overall service users think is most valuable, or one or more of the devices that deliver it?

IoT is immature and there's perhaps a tendency for users to focus more on devices, as these are novel (as we suggested earlier). Service providers may focus on more on services, as that's where the potential for long-term customer engagement sits. You may think that you are offering a health management service, but if your users see beautiful bathroom scales then persuading them to pay for an ongoing service may be tough. The key for a business model is that customers feel they are paying a fair price (whether in terms of money or sharing their data) for the value they receive, and you are making the money you need.

Bringing digital business models to physical products

Building digital services around physical products enables suppliers to apply novel business models, more commonly found in the digital realm, to physical products.

Combining physical devices and services is likely to lead to some interesting, novel and disruptive business models that challenge our preconceived ideas of what it is to own and use a product.

Business models we are accustomed to in the digital realm might make their way into the physical world. For example, we are accustomed to using websites that are free at point of use but make money from selling eyeballs to advertisers. It's not a huge stretch to imagine that physical devices might be given away in exchange for advertising or user data. The ubiquitous computing researcher Pertti Huuskonen jokes about the freemium fridge. Your supermarket gives you a free fridge with a screen that forces you to watch an advert every time you open it. Or the fridge might track the products you put in it and eat, and where you bought them, and share that data with the supermarket, and other advertisers. Users could buy their own fridges, essentially paying for ad free experiences or privacy, or get free or cheaper appliances in exchange for their eyeballs and data. In future, privacy may be a rich person's luxury[15].

More positively, there are benefits to digital service business models. There are opportunities to develop ongoing relationships with customers, understand more about the people who buy your products and what they do with them, and tailor services better to their needs. Users are accustomed to (and mostly comfortable with) web-based services that capture and store information about them to provide a better service. The sensing and processing capabilities of IoT devices open up potential to extend these personalized services to the physical world.

You may be able to capture user behavior that wasn't previously visible, perhaps in real time: e.g. how people are using energy via smart metering, identifying and tracking people in a physical space, or monitoring traffic levels via aggregated data about the density and speed of movement of drivers' smartphones. Knowing how often or intensively a product is used, and what for, enables you to tailor the service, sell supplies, improve the next version, or offer additional services. For example, some Nespresso coffee machines now come with a SIM card, allowing Nespresso automatically to send more capsules when the customer is running low (see figure 4.25 below).

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[15] Pertti Huuskonen, personal communication and 2007, 'Run to the Hills! Ubiquitous Computing Meltdown", Proceedings of the 2007 conference on Advances in Ambient Intelligence, Pages 157-172 (available at http://www.cs.swan.ac.uk/~csmax/csrsRG.pdf)

Figure 4.25: The Nespresso Zenius coffee machine comes with a SIM card. (Image: Nestle Nespresso)

You could charge users based on their behavior. For example, car insurance policies such as Insure the Box in the UK, base pricing on actual driver behavior rather than demographics. This may benefit responsible drivers who are in a demographic category considered to be at high risk of accidents, such as under 25s.

Products can proactively maintain themselves or provide data to enable smarter support: as discussed earlier, boilers could identify when they are developing a fault and be serviced before they break down; appliances could share fault data with the manufacturer so customer support can help users diagnose and fix more of their own problems. It is possible to vary pricing based on time of use, for example charging more for electricity at certain times of day to manage demand.

A good UX design needs to balance the needs of the business with the needs of the user. Even if you are not shaping the business model of the product you are working on, you at least need to understand it. The best business models serve the interests of customers as well as the business. The car insurance example above provides cheaper insurance to drivers who would otherwise be penalized on grounds of age, but also allows the company to reduce costs and uncertainty through more accurate risk profiling. User and business needs can be in tension: for example, a connected home service might rely on heavy upselling of new products. Here, design can make the difference between the upsell advertising being either useful or at least minimally intrusive, or downright irritating or something that causes users to stop using the system altogether.

Summary

A clear *value proposition* ensures users understand what your product does, and whether they want it. This is essential in order for them to understand how it works, and how to use it.

Innovators and early adopters are inherently interested in technology and forgiving of imperfections. Mass-market consumers often have different needs.

Many IoT systems are *tools*: they require the user to frame their own problem and configure the system to solve it. Consumers tend to look for *products* that promise to solve a particular problem for user and come already configured to do that. They expect the cost and effort of using the product to be in proportion to the value it brings them.

IoT creates new opportunities for information gathering, sharing, remote control and automation. But there are common pitfalls that can limit a product to early adopter markets. In particular, be careful of introducing *new* complexity to mature consumer products.

The UX of an IoT product might be focused around the device or the service. All IoT systems depend on some kind of digital service, and perhaps offline service components too, like professional installation, maintenance or customer support helplines. Ensuring these work well together is an important part of the overall UX.

Business models shape the way users perceive the value of the service and thus the UX. Bringing connectivity and intelligence into devices may lead to digital business models appearing in the physical world.

9

Cross-device interactions and interusability

Claire Rowland

Introduction

In systems where functionality and interactions are distributed across more than one device, it's not enough to design individual UIs in isolation. Designers need to create a coherent UX across *all* the devices with which the user interacts. That means thinking about how UIs work together to create a coherent understanding of the overall system, and how the user may move between using different devices.

This chapter explores *interusability* - the user experience of interconnected devices and cross-platform interactions – and how to make a bunch of diverse devices feel like they are working in concert.

This chapter introduces:

- Sentence about cross-platform UX and usability *(see page 2)*
- What is interusability? *(see page 4)*
- The role of conceptual models in understanding what a system does, and why these are especially complex in IoT *(see page 5)*
- Composition: distributing functionality between devices *(see page 14)*
- Consistency across multiple UIs *(see page 24)*
- Continuity of data and interactions across devices *(see page 30)*
- Applying interusability thinking to broader contexts *(see page 42)*

This chapter addresses the following issues:

- What makes a cross-device system feel coherent *(see page 4)*
- Why it's complicated to understand how an IoT system works, and how we might help users with this *(see page 7)*
- Deciding on the best way to distribute functionality between different devices in the system *(see page 14)*.
- Determining which UI elements and interactions need to be consistent across devices, and which don't *(see page 25)*.
- Dealing with data and content synchronization issues in the UI *(see page 31)*.
- Designing interactions that require switching between devices *(see page 39)*.

Cross-platform UX and usability

Many of the tools of UX design and HCI originate from a time when an interaction was usually a single user using a single device. This was almost always a desktop computer, which they'd be using to complete a work-like task, giving it more or less their full attention.

The reality of our digital lives moved on from this long ago. Many of us own multiple internet-capable devices such as smartphones, tablets and connected TVs, used for leisure as well as work. They have different form factors, may be used in different contexts and some of them come with specific sensing capabilities, such as mobile location.

Cross-platform UX is an area of huge interest to the practitioner community. But academic researchers have given little attention to defining the properties of good cross-platform UX. This has left a gap between practice and theory that needs addressing.

In industry practice cross-platform UX has often proceeded device by device. Designers begin with a key reference device and subsequent interfaces are treated as adaptations. In the early days of smartphones this reference device was often the desktop. In recent years the 'mobile first' approach has encouraged us to start with mobile web or apps as a way to focus on optimizing key functionality and minimize ‘featuritis’. Such services usually have overarching design guidelines spanning all platforms to ensure a degree of consistency. The aim is usually on making the different interfaces feel like a family, rather than on how devices work together as a system.

This works when each device is delivering broadly the same functionality. Evernote, eBay and Dropbox (see figure 9.1) are typical examples: each offers more or less the same features via a responsive website and smartphone apps. The design is optimized for each device, but provides the same basic service functionality (bar a few admin functions that may only be available on the desktop).

Figure 9.1: Evernote offers broadly the same service functionality across different device types

But this approach breaks down when the system involves very diverse devices with different capabilities working in concert. In IoT, many devices do not even have screens, or an on-device user interface. Multiple devices may have UIs with very different forms or specialized functionality (see figure 9.2). Even if the UI is only on one device, the service still depends on all the devices working together in concert.

Figure 9.2: The Smart Things ecosystem contains a range of specialized devices that complement each other.

It’s not possible to design a system like this by thinking about one device at a time: this is likely to create a disjointed experience.

In order to use it effectively, the user has to form a coherent mental image of the overall system. This includes its various parts, what each does and how different objectives can be achieved using the system as a whole. Traditional single-device usability doesn’t tell us very much about how to do this.

What is interusability?

Charles Denis and Laurent Karsenty first coined the term ‘inter-usability’ in 2004 to describe UX across multiple devices[1]. Conventional usability theory is under-equipped to cope with cross-platform design. However, one 2010 paper by Minna Wäljas, Katarina Segerståhl, Kaisa Väänänen-Vainio-Mattila and Harri Oinas-Kukkonen proposes a practical model of interusability[2].

Wäljas et al propose that the ultimate goal of cross-platform design is that the experience should feel *coherent*. Does the service feel like the devices are working in concert, or does the UX feel fragmented?

They define three key concepts for cross-platform service UX, which together ensure a coherent experience:

- **Composition**: how devices and functionality are organized
- Appropriate **consistency** of interfaces across different devices
- **Continuity** of content and data to ensure smooth transitions between platforms

The paper was published in 2010 and the services evaluated (including Nike+ and Nokia Sportstracker) now inevitably feel a little dated. But we have found the model still holds up well in our own work designing IoT services, and it’s a key reference for the rest of this chapter.

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[1] Denis, C. and Karsenty, L. (2005) Inter-Usability of Multi-Device Systems – A Conceptual Framework, in Multiple User Interfaces: Cross-Platform Applications and Context-Aware Interfaces (eds A. Seffah and H. Javahery), John Wiley & Sons, Ltd, Chichester, UK

[2] Wäljas, M., Segerståhl, K., Väänänen-Vainio-Mattila, K., Oinas-Kukkonen, H.: Cross-platform service user experience: a field study and an initial framework. In: Proceedings of the 12th International Conference on Human Computer Interaction with Mobile Devices and Services, MobileHCI 2010, p. 219. ACM, New York (2010). I’ll refer to this paper several times in the rest of this chapter as Wäljas et al, although I understand that Katarina Segerståhl was the primary researcher. Her PhD, available at http://herkules.oulu.fi/isbn9789514297274/isbn9789514297274.pdf, builds on the same concepts.

Conceptual models and composition

In this section, we'll look at two related concepts that help us design systems spanning multiple devices.

Conceptual models refer to the way humans understand the overall system (and its interfaces) to work. Users need some understanding of how the system works in order to figure out how to interact with it. As we saw above, *composition* is a dimension of interusability. It refers to the way user-facing functionality is distributed between different devices: which device does what. The two concepts are related in cross-platform design: understanding which device does what is part of forming an effective conceptual model.

Conceptual models

The user model and the design model

The conceptual model may refer to the way the user understands the system, or the way the designers (or engineers) think about the system. Users develop a mental model of the system (a *user model)* that enables them to understand what it does, how to interact with it, and how it will behave. At first, this will be based on prior experience of other systems or similar activities. Over time they will develop the model through their experiences with the system itself. The way the designers or engineers think about the system will be reflected in the *design model* (this distinction was defined in Don Norman, 1988)[3].

As Norman puts it: 'The problem is to design the system so that, first, it follows a consistent, coherent conceptualization - a design model – and second, so that the user can develop a mental model of the system – a user model – consistent with the design model.'

The similarity between the design model and the user's mental model is a core determinant of usability in any system, not just IoT. How easy is it for the user to figure out how to achieve a particular goal using the system (which Norman

[3] Norman, Donald (1988). *The Design of Everyday Things*. New York: Basic Books.

refers to as bridging 'the gulf of execution'[4])? How easy is it for the user to understand what the system does in response ('the gulf of evaluation')? (See figure 9.3).

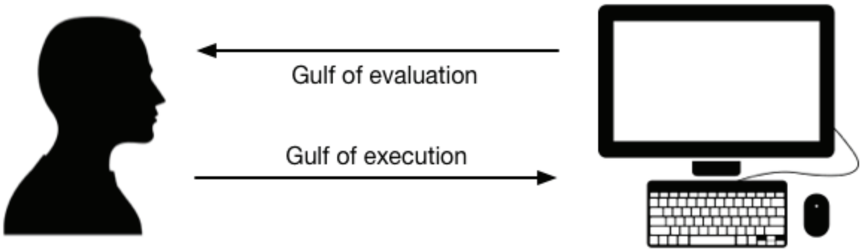

Figure 9.3: The gulfs of evaluation and execution. (User icon by Simon Child, computer icon by Alyssa Mahlberg, both from the Noun Project)

Ideally, the user model maps closely onto the design model. But frequently, the design model may not be a good fit for what the user wants to do, or users may only partially understand it. If the system doesn't conform to any prior expectations, users must develop a new mental model, based on trying to infer the design model. Users learn about the design model through the interface, behaviors of the system and documentation – which Norman refers to as the *system image* (see figure 9.4).

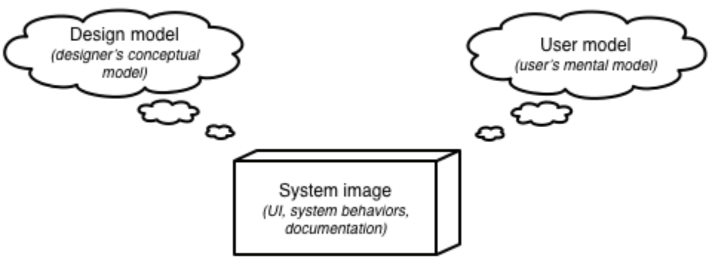

Figure 9.4: Diagram: the user, system and design model (redrawn from http://www.jnd.org/dn.mss/design_as_communication.html)

[4] Chapter 3 'Cognitive Engineering' in 'User Centered System Design: New Perspectives on Human-Computer Interaction', ed. Norman and Draper, Lawrence Erlbaum Associates, 1986

You can't design the user's mental model directly. But you can design the system image to convey the design model clearly (see figure 9.5). You should also define your design model explicitly; to make sure it's clear, consistent and not overly technical or complex for your audience.

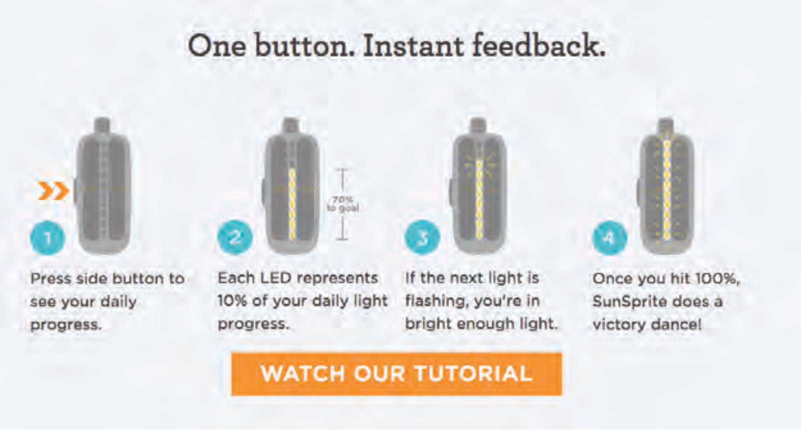

Figure 9.5: A system image: The Sunsprite Tracklight helps users monitor their daylight exposure. The instructions explain what it does, how to interact and data is displayed using the LEDs[5]. (Image from [1] https://www.sunsprite.com/tracklight/).

Multi-device services are conceptually more complex

Back when Norman first wrote about conceptual models, a system was generally a software application running on a standalone computer. Multi-device services make conceptual models more complicated. There are not just more interfaces, but more places where processing and functionality can live and where data can be stored. Because there are more nodes and connections, there are more points of failure and ways to fail. This is often where complexity is exposed: when the system is working well, it may not matter where your data or preferences are stored. But when parts or connections fail, the user has to understand something about how the system works in order to understand what is happening and why.

Take the example of a lighting system. The mental model of a lamp is simple: it has power, a switch, a fitting and a bulb (see figure 9.6). If the lamp doesn't work it's probably because the power has failed or the bulb has blown.

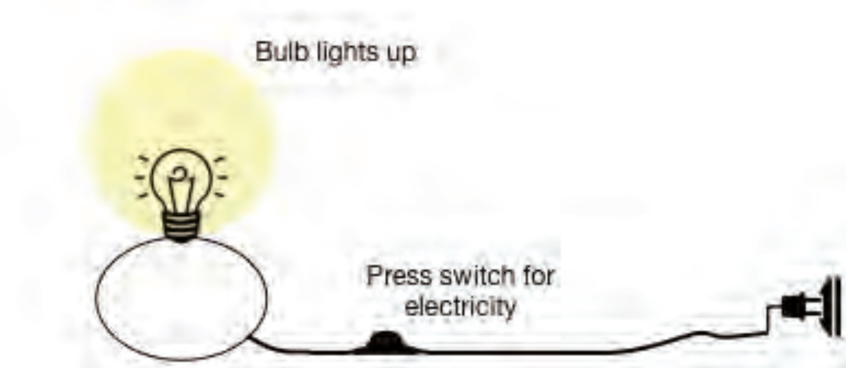

Figure 9.6: A conventional lamp has a simple conceptual model

A connected lighting system has bulbs, switches, fittings and power too (typically either the bulbs or switches will be connected). It also has an internet service, probably hosted remotely. It has a smartphone app and perhaps a web app too. It probably also has a gateway device. It has more parts (see figure 9.7) and more different kinds of part. It can also do more. It may run automated rules to turn lights on and off at certain times, or when certain trigger events happen (such as the security alarm being activated). The intelligence that controls the system may live in several places: in the bulb or switch itself, in the gateway, in the internet service, or even in the smartphone app.

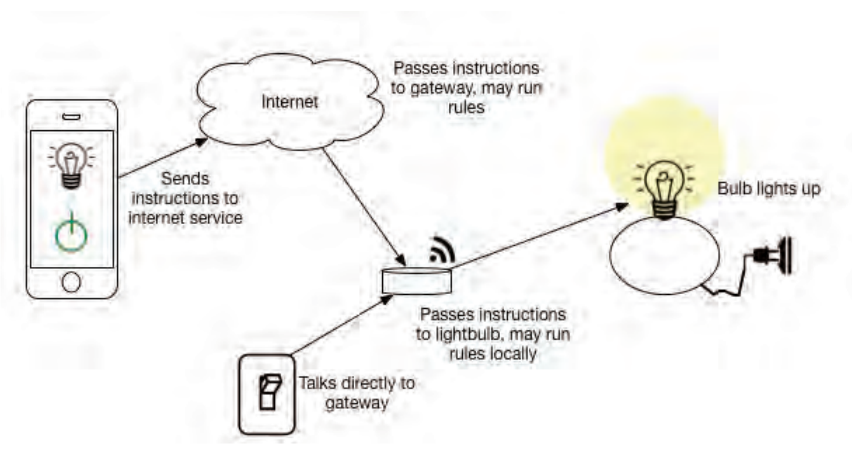

Figure 9.7: connected lighting can do more than conventional lighting, but the conceptual model is more complex. (Lightbulb by Marek Polakovic, wireless icon by Spencer Harrison. plug by Vithin Viswanathan, light switch by Sarah Hutchinson, all from the Noun Project.) MAY NEED WIFI GATEWAY ADDING

When everything is working well and connected, users don't need to concern themselves with which code is running where. But if a part of the system develops a fault or loses connectivity or the network is slow, the impact will depend on what that device is doing. Will the lights (or intruder alarm, or heating) stop working if the user's phone battery runs out or they have no signal? Or will they keep running even if the user cannot remotely access the home at that point? What if the home internet connection goes down? Will lighting rules continue to work locally? If they are stored in the gateway or edge device, they will. If they are stored in the internet service or smartphone, they will not (see figure 9.8).

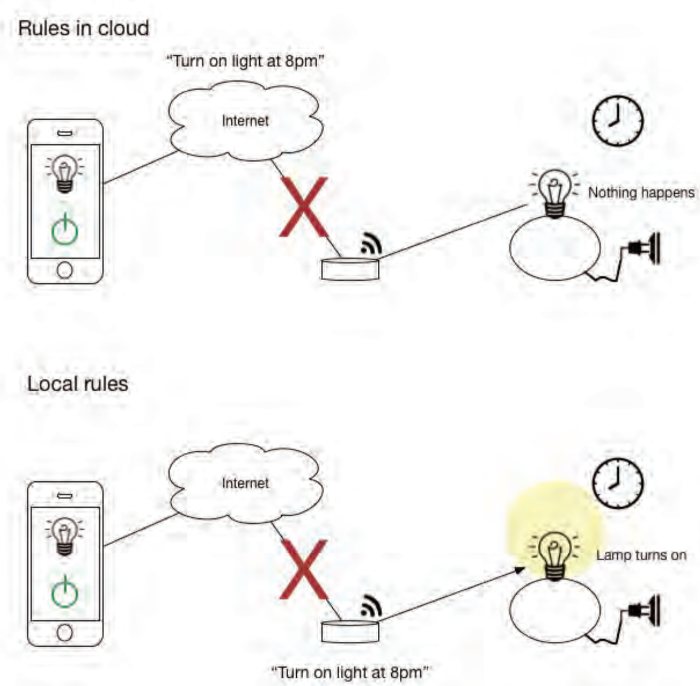

Figure 9.8: Home automation routines stored in the cloud will not run if the internet connection goes down. If they are stored locally, they will continue to run (although the user won't be able to see this or control devices remotely). (Clock icon by Christoph Robausch from the Noun Project) BOTH NEED WIFI GATEWAY ADDING

How you choose to distribute system intelligence is a system architecture issue, as discussed in chapter 3. What's most appropriate for your system will depend on what it does and your users' expectations. An intruder alarm should not fail completely because the internet went down. But it's not a disaster if your energy monitoring system is occasionally unavailable for short periods of time, as long as data is not lost.

The new challenge for UX is that this is a lot of complexity that users didn't previously have to worry about (see the discussion of the 'surprise package' in chapter 4). There are two ways to deal with this complexity: you can explain it, or try to hide it.

Although BERG are now defunct, the BERG Cloud bridge, the gateway for Little Printer, was a simple example of a device that explained how the system was working.. It had LEDs to show whether the device had power and an Ethernet connection, and upstream and downstream connectivity (see figure 9.9). It was labeled to explain that upstream meant that the bridge could see the BERG cloud internet service, and downstream meant that the ZigBee network used to connect to local devices was running. The gateway was communicating the system image.

Figure 9.9: the BERG Cloud Bridge.(Image: BERG).

The more complex the system, the more overwhelming it may be to explain in detail. In that case, it would be better to allow the user to work from a simplified mental model. Automatic gearboxes are complex mechanical systems that require only a simplified mental model in order to use (see figure 9.10). But this is a hard trick to pull off. The gearbox is mature technology and only performs one basic function. Also, consumers have lots of prior experience of driving cars on which to draw. IoT technology is newer, and often does things that are less familiar to users. Many IoT systems also have multiple functions, so it can be harder to reduce them to a simplified conceptual model.

Figure 9.10: automatic gearbox controls hide the complexity of the system behind a simplified conceptual model

One example of a product with a simplified conceptual model is Apple iBeacons (introduced in chapters 2 and 4). Imagine a user walks into a store for which they have a an app installed, their location is detected using iBeacons, and they are sent a push notification about a special offer. It’s good enough for that user to understand that the store knows they are there, thanks to the beacons, and the store has sent them a message.

Apple's own description of iBeacons is "a new class of low-powered, low-cost transmitters that can notify nearby iOS devices of their presence[6]". This can be read as implying that the beacons notify the iOS device of its location. This is a good enough model but it skims over some complexity.

What actually happens is: the beacon broadcasts a unique ID. The iOS device detects the ID, and looks up its location in an online database. It notes its own position by its proximity to the beacon. In looking up the beacon, it informs Apple of its location, and *Apple* then send the push notification.

9-11: iBeacons diagram: what the user needs to know, and what's actually happening

UX researchers at Ericsson have suggested that it is particularly difficult for users to understand *networks* of devices. Their informal research indicated that users currently think of connections between devices as being 'invisible wires'. As Ann Light, co-author of chapter 15, puts it: "Most people are disposed to think of things, not links; of nodes rather than relations"[7]. But this way of understanding is not helpful in making sense of complex networks with many interconnections and interdependencies[8]. **To understand a system, users must understand the links as well as the nodes.**

In 1983, the HCI specialist Larry Tesler (then at Apple) proposed the Law of Conservation of Complexity. Interviewed in Dan Saffer's book 'Designing Interactions', Tesler says: "I postulated that every application must have an inherent amount of irreducible complexity. The only question is who will have to deal with it[9]." His point was that shielding users from complexity would involve extra work from designers and developers.

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[6] https://developer.apple.com/ios7/, which now redirects to iOS8, original text retrieved via http://en.wikipedia.org/wiki/IBeacon#cite_note-5

[7] In conversation.

[8] Joakim Formo, The Internet of Things for Mere Mortals, http://www.ericsson.com/uxblog/2012/04/the-internet-of-things-for-mere-mortals/

[9] Dan Saffer, Designing for interaction, 2006, New Riders. Larry Tesler interview available at http://www.designingforinteraction.com/tesler.html

User understanding will improve over time with familiarity, but only if we, as designers, help them with clear system images. We need to figure out what complexity users will need to deal with, and where products and tools can be simplified. As a general rule, if the task or activity the user wants to perform is complex or requires a high level of skill, it's appropriate for the user to engage with that complexity. Or perhaps it's a job for a professional. If the task or activity can be expressed simply but the technology is complicated, there's a good case for designing around a simplified mental model.

We don't yet know what that looks like for IoT. For starters, if you need to explain to the user that part of the system is not working, it's important to explain why and what this means. For example, if you are alerting them that the security alarm has lost internet connectivity, you might choose to tell them that the cameras and alarm sounder are still active but that they will not receive alerts. Or if the user is travelling in a different timezone, you might want to show the current time at home on the heating control app, to indicate that schedule changes are based on the local timezone of the controller, not where they are now.

Composition

Patterns of composition

Composition refers to the way the functionality of a service – especially the user-facing functionality - is distributed across devices.

Good composition distributes functionality between devices to make the most of the capabilities of each device. Designers should take into account the context in which each device will be used, and what users expect each to do.

There are some common patterns to composition. Web services delivered across smartphones, desktops, tablets and connected TVs are often *multi-channel*. Each device provides the same, or very similar, functionality (in other words, there is a high level of *redundancy* between devices. Kindle, Netflix (see figure 9.12), BBC iPlayer, Facebook and eBay are all examples. Devices with small screens or limited input capabilities may only provide a subset of key functionality. But each device offers a similar basic experience of the service. Many users won't own or use all the possible devices on which the service could be used and this doesn't matter. It's perfectly possible to use the service via a single device and still have a good experience.

Figure 9.12: Netflix is a multi-channel service

However, many IoT services run on a mix of devices with different capabilities. Service functionality and user interactions will be distributed across different devices. Some functionality may be exclusive to a specific device. For example, in the Withings ecosystem, only the scale can measure body mass and only the blood pressure monitor can measure blood pressure. Some devices may be custom designed for the service. We've seen many examples of these already throughout the book, from connected door locks to smart watches and thermostats.

For reasons of cost, or practicality, these may have limited inputs and outputs that are quite different from a conventional 'computer' UI. A door lock may have a keypad and handle and perhaps an LED to show whether it is connected or not. It probably doesn't have a screen. In these systems, we have to figure out which device handles which functionality. Each device (and the internet service itself) may have a different role in terms of providing user interactions, connectivity, information gathering, processing or display. In the terminology of Wäljas et al. this is a *cross-media* system (figure 9.13 is an example).

Figure 9.13: Withings is a cross-media ecosystem

For example, a heating service as shown in figure 9.14 below may comprise:

- A boiler that heats the water
- An in-home controller/thermostat that tells the boiler when to switch on or off (this may be a separate thermostat and programmer, or just one device).
- A gateway that provides a low power connection to the controller and bridge out to the internet
- A cloud service that stores user account information and remote access to the system
- Smartphone and web apps that connect to the cloud service.

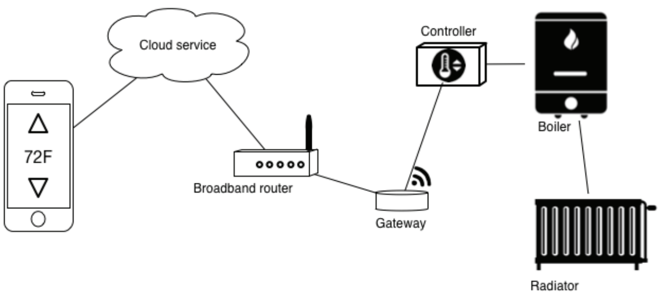

Figure 9.14: system diagram of a heating system (Thermostat by Iconathon, boiler by Axeny Virtinsky, radiator by Jose Hernandez from the Noun Project)

Both the Tado and British Gas Hive systems work in this way, but user-facing functionality is distributed differently. The Tado thermostat/heating controller has almost no UI (see figure 9.15). User can view the current temperature and set or alter the setpoint, but most interactions are handled on the smartphone[10]. This may keep manufacturing costs down. Smartphone interfaces are much cheaper to develop than physical interfaces, as components like screens and buttons are relatively expensive. It's an elegant choice for a small household occupied mainly by smartphone owners but there are trade-offs. If you don't have your phone to hand, or the battery is dead, or you're a guest in the house without access to the phone UI, you have limited control.

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[10] The first generation Tado controller had no onboard controls at all: all interactions were via the smartphone.

Figure 9.15: The Tado heating controller and smartphone app

The Hive Active Thermostat heating controller is a standard thermostat with on-device controls (see figure 9.16). The device is designed to be competitive on cost with non-connected heating controllers. So interaction design has to work within the constraints of an LCD screen and limited number of buttons. However heating can also be controlled by phone and web apps, which are probably easier for most people to use than the hardware. This means that heating controls are available to anyone in the house, whether they have access to the smartphone app or not.

Figure 9.16: The Hive Active Thermostat heating controller and smartphone app (Images: British Gas).

Some devices may not support any user interactions at all (see figure 9.17). Some devices may be simple sensors which simply provide data to the service, as in an air quality monitoring system. In this case, you may simply hand off all functionality onto a single mobile or web app. Although the overall service may be complex, the web or smartphone UI in this case is in some ways simpler to design as there is only one interface to consider. (Chapter 8, Interface and interaction design, considers the pros and cons of handling functionality via a mobile device versus a specialized embedded device).

Figure 9.17: The Greenbox garden irrigation controller is entirely controlled by a smartphone app (need alternative – 403 on greenboxhq.com).

When key tasks are available across multiple devices, users may still be able to use the service even when some devices are unavailable. For example, the Withings smartphone app can use the onboard accelerometer to measure activity, so even if the user has forgotten their dedicated activity monitor, they need not lose data (see figure 9.16).

Figure 9.18: The Withings mobile app can use accelerometer data to measure activity.

Even where different devices support the same tasks, they may be used in different situations. For example, the key advantage of connected heating systems is that the smartphone app enables control from anywhere, whether that's the other side of the world or the user's bed.

However, this isn't a recommendation to duplicate every piece of functionality across every device – redundancy isn't necessarily a good thing. Too many functions on a single device can make the UI harder to use, especially if the device has limited input/output capabilities. And user interaction components, such as screens and buttons, add significantly to manufacturing costs of embedded devices. The right decision will balance the usefulness, cost, and usability of putting various features on different devices.

For many systems, it makes sense to use a network of devices that are specialized for particular functions. For example, the Lively elderly care service uses specialized sensors to monitor the pillbox, fridge and the kitchen (see figure 9.19). This is referred to as *synergistic specificity*[11]: specialized components working together to deliver a service that is more than the sum of those components.

Figure 9.19: Lively elderly care system: safety watch for summoning help, with pedometer and medication reminders, hub, sensors for fridge and pillboxes and a custom sensor containing an accelerometer to detect movement. (Image: Lively)

Users may also want to add (or remove) devices to suit their individual needs, or combine them in different ways to fulfill different purposes – this is a *modular* system. In some cases, different devices can be used to perform different functions as part of different services. For example, a home monitoring system may offer contact, temperature, moisture, smoke and motion sensors. These could be used to detect occupancy for heating, lighting, and potential safety problems or intruders. A highly modular system can be very powerful, but may be more complex for users to understand, configure and use. To use the distinction from chapter 4, it's likely to be more of a tool

[11] Schilling, M. A. 2000. Toward a General Modular Systems Theory and Its Application

to Interfirm Product Modularity. Academy of Management Review, 25 for early adopters than a product that majority consumers will configure themselves. It's also more complex for designers to communicate which devices are doing what at each point.

Determining the right composition

For any service, there is often more than one possible suite of devices that could be used to deliver the service. The decision as to which is most practical will be influenced by the following factors. You may wish to prioritize, per task, which devices are optimal for each task, acceptable for the task, or not possible for this task.

What best fits the situation and context?

The most important consideration is what best fits the activity, situation and user needs. Certain devices need to live in one place where only one function is required, e.g. blind/window shade controllers or light switches. Others are used in a context that places constraints on form factors and interaction modalities. For example, climbers need their hands free, so delivering altitude, weather and location information to a wrist top makes sense. Using a mobile phone's music controls while driving would be dangerous. Key functionality should be mirrored on the car dashboard in a way that minimizes demands on attention. Features that are essential to one device may be inessential or even inappropriate for others.

The availability and reliability of the network connection is also key. If you have a good reliable connection you can afford to centralize more functionality, e.g. putting your irrigation system controls on a smartphone. If not, and you can't afford to lose access to functionality, you may need user controls (and perhaps more onboard intelligence) in the edge devices.

Can you work with pre-existing devices?

What hardware can you assume your user base already has and is familiar with using? For example, if users all have smartphones you can use these to handle complex interactions, determine location and identity, and in some cases handle local and internet connectivity.

Smartphones come with onboard sensors (such as accelerometers), which can be used for tasks such as activity tracking without additional hardware. However, custom form factors (such as wristbands) may provide a better experience in some contexts of use, such as the forthcoming clip-on fall sensor for the Lively safety watch for older adults. Specialist equipment may also tend to offer better performance through better quality parts, such as more powerful GPS chips or better battery life.

What interaction capabilities do the various devices have (or could you cost-effectively include on a custom device?)

You may be able to consider adding or removing interaction capabilities (like screens, buttons, audio beeps or LEDs) to embedded devices. However, these typically add to production costs, so you will probably need to keep these to a minimum and offload more complex functionality onto a mobile or web UI. If you're not able to influence the design of the embedded devices, you'll have to work with the interaction capabilities you have.

You may also decide that just because a device *could* support a particular function, it does not have to. Keeping things simple may make the device interface easier to understand. For example, a heating controller with a low-resolution screen and limited buttons might be best used for status information and in-the-moment controls (turn the heating up now!). You could offload more complex tasks such as schedule setting onto a web or mobile interface. The bigger screen size and richer interaction capabilities will enable a better design. You can also provide a 'good' way to do the task on a fuller featured device and a limited or compromised version on a less capable device which must occasionally work alone. For example, an intruder alarm system may provide an easy way to view which sensors triggered the alarm on a mobile interface. The task may also need to be possible on the alarm panel via a basic LCD screen, even though this is likely to involve many more button presses, perhaps navigating menus and modal states.

Does the system need to work if some devices are unavailable?

What happens if a device is unavailable, e.g. a smartphone is lost or the battery is dead? Does it need to be used by 3rd parties who may not have access to a web or mobile app, such as visitors to the home? Can the device work offline?

How accurate does sensing need to be?

If a service needs to know the rough location of its user, a smartphone can estimate this from for GPS/celltower signals. If it needs to know which room the user is in at home e.g. to turn the lights on and off, a smartphone could be used via Bluetooth LE connections, but will only be accurate if the user carries it with them at all times.

Do users have set expectations of devices?

Users may expect certain devices to conform to familiar form factors, or provide familiar functionality. For example, they are likely to expect a heating controller to have some way of turning the heating on, or up.

How do you balance cost, upgradeability and flexibility?

User interface components, such as screens and buttons, are expensive to add to embedded devices. You may therefore decide to limit interactions on the embedded devices themselves and do most of the interaction "heavy lifting" via mobile apps or web interfaces.

It can be difficult to add new features to devices that are already out in the field, especially if this requires modifications to the interface. Again, offloading interactions to smartphone and web apps, which can be modified relatively cheaply and quickly, may make sense.

What connectivity and power issues do you need to consider?

It may also be simpler to handle information processing in the cloud, as with the Withings scales and fitness trackers, which simply take readings, display them in real-time, but handle all other functionality in the online service. A weight and fitness service can handle temporary losses of connectivity gracefully, by storing data locally and syncing when the connection is available again. However, for other types of service this will not be acceptable, e.g. where safety or security is at stake. If a monitoring system for an elderly person loses connectivity, it might be acceptable for motion sensor data to be temporarily unavailable to the carer, as long as it is clear that connectivity has been lost and live data is not available. However, it would be completely unacceptable for the elderly person to be unable to use their emergency alarm during this time: the alarm should be able to fall back to using another form of connectivity.

In other words, the designer has to make an informed call on which tasks need to be available in different conditions: offline? With no power? Does the system make no sense if connectivity is lost? Is a suitable fallback available? I should not have to worry about being unable to enter and leave my own house because the front door lock has lost connectivity or has no power – and many other household functions must also be taken for granted to be effective.

What is the physical context of use?

Do any parts of the system need to have particular form factors/be used in certain contexts: e.g. worn on wrist, weatherproofed, used one handed?

How central to the service are the devices?

Are devices central to the conceptual model, or not? This may not affect the distribution of functionality, but it will affect the way in which you communicate the composition of the system.

9-20: (Summary table of composition patterns?)

Consistency

"Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions." Jakob Nielsen, 1994[12]

Consistency is well known as a general UI design heuristic. It's a simple concept to grasp. But knowing what needs to be consistent, and what does not, can be tricky. You may have to trade off one type of consistency for another. Do you make all the buttons look the same so they are easy to identify as buttons? Or does that cause confusion by implying that certain functions are similar, when in fact they are not? Too much consistency, or consistency between the wrong things, can be as damaging as too little.

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[12] Nielsen, J. (1994b). Heuristic evaluation. In Nielsen, J., and Mack, R.L. (Eds.), *Usability Inspection Methods*, John Wiley & Sons, New York, NY.

Consistency across multiple devices

In the case of cross-platform systems, designers also need to consider consistency across different devices. Consistency works to create a sense of coherence of the overall system.

Words, data and actions that are the same across devices should be understood to be the same. Words, data and actions that are different should be understood to be different. This helps users form a clear mental model of the system and its capabilities. Knowledge that users have gained about the system from one device can be transferred to help them learn how to use other devices.

Other elements that may need to be consistent to some degree across devices include

- Aesthetic/visual design (to make the devices look, feel and sound like a family)
- Interaction architecture (how functionality is organized) and
- Interaction logic (how tasks are structured or the types of control used).

Guidelines for consistency

Use consistent terminology

As a rule of thumb, the highest priority is to use consistent wording across devices. This ensures that data and actions across different platforms are understood to be the same thing. Whatever the display capabilities of each device, you can always give functions or data the same label even if you can't make them look the same.

For example, imagine you are working on a connected heating controller that offers 3 mode options: ON (heating is on continuously), AUTO (heating is running to a pre-programmed schedule), and OFF (see e.g. figure 9.21). These are already set in the fixed segment LCD display and cannot be changed. You might think that ON and AUTO are not the clearest terms. You'd prefer to change them to CONTINUOUS and TIMER or SCHEDULE in the smartphone app interface. However, this would create a disconnect: users then have to understand that ON and CONTINUOUS are the same thing.

Users are often intimidated by heating controllers and expect them to be confusing. And they might not have a strong enough mental model of the system to infer that CONTINUOUS and ON are the same thing. Having tested systems with similar issues, we found it was more important that these options were consistently named across devices. The value of better terminology in the mobile app is undermined if users don't understand that the functions are the same.

Figure 9.21: The Hive Active Heating controller is an example of a device with fixed segment LCD labels mapped to physical buttons.

Follow platform conventions

The second priority is for each UI to be consistent to the platform conventions of the device.

Mobile OS UI conventions are well documented in styleguides, e.g. the iOS Human Interface Guidelines[13] and Android Design[14]. There are some key

13

https://developer.apple.com/library/ios/documentation/UserExperience/Conceptual/MobileHIG/

differences, for example Android users may expect contextual menus on long press, a convention which does not exist on iOS, where the same menu would be displayed on another screen (see figure 9.22).

Figure 9.22: Android and iOS screens from the same mobile app showing different platform conventions

In general, for mobile devices and others that have established platform conventions, following these conventions will make it much easier for users to use your app even if it means some things are done in a different way than they are on any specialized connected devices. A heating control app for iOS must be a good iOS app as well as recognizably part of the heating service. It does not have to be a skeuomorphic representation of a heating controller. But this works both ways: a heating controller does not have to pretend to be an iPhone just because it has an iPhone app. The goal is to ensure that interfaces are appropriate to each device, yet also feel like parts of a coherent service.

Interaction elements such as buttons, menus and switches should be recognizable according to the platform conventions of the device. An iOS button should generally follow conventions for button styles on iOS rather than trying to look like the physical button on an embedded device.

Most importantly, specific interaction controls should be optimized to the platform. If a physical control uses a wheel, slider or handle, there is no need to replicate this on a small touchscreen device where it could be harder and more imprecise to use.

For example, the Nest thermostat incorporates a rotating bezel, which is used (amongst other things) to increase and decrease the temperature. The bezel makes a clicking noise as it is rotated. But the iOS app up/down controls are arrows. The designers could have shown a representation of a bezel onscreen for the user to tap and drag around. But the arrows are a much more efficient and precise control on a touchscreen (see figure 9.23). Adjustments to domestic temperature are typically within a degree or two, so precision is important to avoid overshooting.

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[14] https://developer.android.com/design/index.htmlio

Figure 9.23: The Nest thermostat and iOS app (showing Celsius temperatures).

Aesthetic styling

A consistent visual and aesthetic style across all platforms reinforces the perception of a coherent service. Consistent fonts and colors across devices are nice but may not always be practical. For example, the Nest thermostat uses the same font and colors to indicate temperature on the wall thermostat as the iOS app. But this isn't always going to be possible: a cheap monochrome LCD screen won't support a choice of fonts anyway. Replicating the LCD font on a web or smartphone app may impact readability. It's also a definite retro statement that may not be the look you're after. It's nearly always aesthetically clunky to make a screen design resemble a physical device.

Audio is another way to use aesthetic design to create a sense of coherence. Tapping the down/up arrows on the Nest smartphone app produces the same clicking noise per increment as the bezel on the wall thermostat. This is an elegant touch that adds a common aesthetic to each interaction without intruding on usage. It adds to the sense that the devices are a family and helps users form a conceptual model of how the system works.

Where visual elements also convey meaning it is vital that they are used in the same way. This is called *semantic consistency*. To continue with the heating example, you may use red/orange/blue colors to indicate temperature. Or a particular icon might indicate that the water tank is heating up. The icon may be higher resolution on devices with better screens, but it must be recognizably the same thing (see figure 9.24).

Figure 9.24: An icon (tbc) shown on a smartphone screen and Pebble watch

Interaction architecture and functionality

Interaction architecture is the logical hierarchy (or other structure) of the UI as mapped to the controls. This is likely to be less consistent across devices and more platform-dependent. Devices may have different functions in the service. Even where there is an overlap between functions, they may be optimized for different purposes. A wall thermostat might be optimized for small adjustments and switching mode (e.g. turning on the hot water). It might need to support changing the heating schedule, but that's always going to be a better experience on the mobile or web app. In optimizing the thermostat for quick adjustments, the designers might knowingly create a less-good UX for schedule changes. But they might view this as acceptable if users are likely to change schedules on a smartphone or website anyway.

As devices are used for different things, it's not necessarily desirable to group functions in exactly the same way. For example, a mobile or tablet screen can provide one touch access to many functions, facilitating a broad, shallow functional hierarchy. Fitting the same functions into a heating controller with an LCD screen plus 3 buttons may require a narrower, deeper hierarchy.

You may also need to use modes, in which the same buttons perform different actions in different states. Modes are typically more difficult to use, but they may be an essential compromise if you're stuck with the hardware (see e.g. figure 9.25). Structure your mobile or tablet app to be a great solution for that device, and don't let it be constrained by the limitations of the embedded device.

Figure 9.25: heating controller with modal functions

UIs on different devices don't all have to have the same features, but where they do, the functionality should be consistent. For example, if a heating controller supports a 6 phase schedule (6 phases throughout the day) but the companion phone app only supports 4, users will wonder what happened to the other two (see figure 9.26).

9.26 – Diagram: 6 versus 4 phase operation…

Consider the most likely combinations of devices

As a designer, you may have to think about design across a large ecosystem of devices. Users may not have all of these. Focus your effort to achieve consistency on the combinations of devices users are most likely to have. To stick with the example of a heating system, all your users might have a controller and smartphone app, but few will regularly use both iOS and Android apps. So it's important that the smartphone apps are both appropriately consistent with the controller. It's less important that knowledge users acquire from using one smartphone app is transferable to the other. For example, the location of the menu button, or the way that system settings are grouped and accessed, need not be the same across mobile platforms but should conform to the platform conventions (as discussed above under 'Follow platform conventions'). Few users will use both and those who do are likely to be familiar with both conventions.

Continuity

What is continuity?

In the film industry, continuity editing ensures that different shots flow in a coherent sequence, even if they were filmed in a different order. It would be disrupting to the narrative if a character's hairstyle changed within a scene, furniture moved around, or a broken window was suddenly intact again[15].

In cross-platform interaction design, continuity refers to the flow of data and interactions in a coherent sequence across devices. The user should feel as if

[15]Spotting continuity errors in movies is a sport. Sharp-eyed viewers share the errors they have spotted on websites such as http://www.moviemistakes.com,.

they are interacting with the *service* through the devices, not with a bunch of separate devices. There are two key components here. Data and content must be synchronized, and cross-device interactions must be clearly signposted. In my experience, some of the biggest usability challenges in IoT are continuity issues.

Data and content synchronization

It sounds obvious that different device UIs should each give the same information on system state.

Kindle Whispersync is a great example of synchronization. You can switch between reading on different devices - even swapping between the book and the audiobook - and your place in the book is always up to date (see figure 9.27).

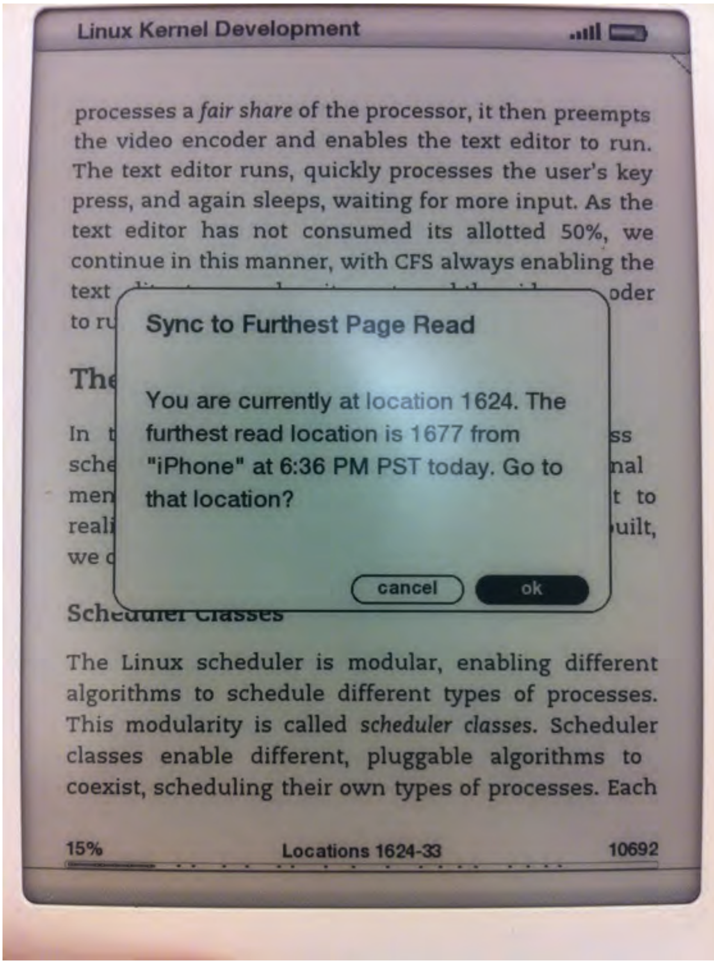

Figure 9.27: Kindle Whispersync UI dialog (Image by Kei Noguchi).

You'd expect this from any other connected device too. For example, your wall thermostat says it's 21C and the heating is on. You'd therefore expect your smartphone heating app to say the same thing, and not to tell you that it's actually 22C and the heating is off.

If you turn the heating off from the wall, then you'd expect the smartphone app to reflect that change in state right away. Right?

Unfortunately in IoT, as discussed in chapters 2 and 3, this isn't always possible. Devices that need to conserve power, such as those that run on batteries, often cannot maintain constant connections to the network as this uses a lot of power. Instead, they will connect intermittently, checking in for new data. This can cause delays and result in situations where some interfaces do not reflect the 'correct' state of the system. Network latency is also an issue: it's possible for the user to know that something has worked before the UI does. For example, they may be physically sitting near a light that they have just turned on and have to wait for a smartphone app UI to tell them what they already know.

To return to the heating example: in the UK, it's common for heating controllers to run off a battery[16]. So a heating controller may need to connect via a low powered network like ZigBee to a gateway, and only connect intermittently to check in for new instructions. There might be a delay of perhaps two minutes between a setting being changed on the smartphone app and the heating controller receiving that instruction.

This causes discontinuities in the UX. If a user changes the settings on the smartphone app (say, turning the temperature up from 19C to 21C), there may be a period of up to two minutes before the heating controller checks in to the service and receives the updated instruction. During this period, the phone UI could show that the system is set to 21C, and the controller UI will show that it is set to 19C. If the user is standing in front of the controller with the smartphone app, they will see two conflicting pieces of information about the current status of the system (see figure 9.28). This violates one of the most fundamental of Nielsen's usability heuristics, visibility of system status: "The system should always keep users informed about what is going on, through appropriate feedback within reasonable time."[17]

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[16] UK heating engineers prefer battery powered wireless controllers as they can be installed easily and sited anywhere without risk that rewiring will be needed. In the UK, mains power is 240V AC and any mains electrical work must be done by a qualified electrician. Even replacing an existing mains controller in the same location requires an electrician. This isn't an issue in the US, where HVAC controllers typically run on a special low voltage circuit, making them safe for homeowners to install themselves. This means that in the US, it's feasible to offer a controller that maintains a constant connection to a WiFi network, and the system can always be in sync.

[17] Nielsen, J. (1994b). Heuristic evaluation. In Nielsen, J., and Mack, R.L. (Eds.), *Usability Inspection Methods*, John Wiley & Sons, New York, NY.

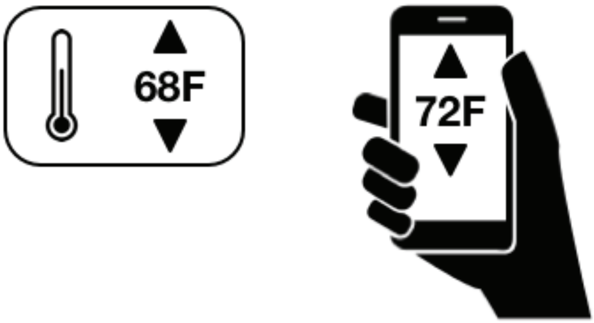

Figure 9.28: In some situations, devices may temporarily report conflicting information about the state of the system. (Hand/phone by Siddarth Dasari, thermometer by Saneef Ansari)

What can you do about this? You could fix this by making the controller check in more frequently. But that would run the battery down within days. Users don't expect to have to change batteries in heating controllers several times a week. So that's not practical.

Your next option is to consider how you can design the smartphone UI to account for this two minute period. There are two possible approaches.§

Firstly, you could show the updated settings the user wanted to apply: the temperature setting of 21C, even though it might (for a short time) give a misleading impression of the system state. If the instruction cannot be applied for some reason (e.g. temporary internet outage at the property), you can alert the user and then revert the UI to the old state. In essence, you pretend that it has worked while you wait for confirmation from the controller.

Instagram employ similar 'white lies' to make their mobile app feel more responsive. For example, Instagram registers likes and comments in the app UI while the request is still being sent to the service. The user is notified if the action fails. They call this 'performing actions optimistically'[18] (see figure 9.29).

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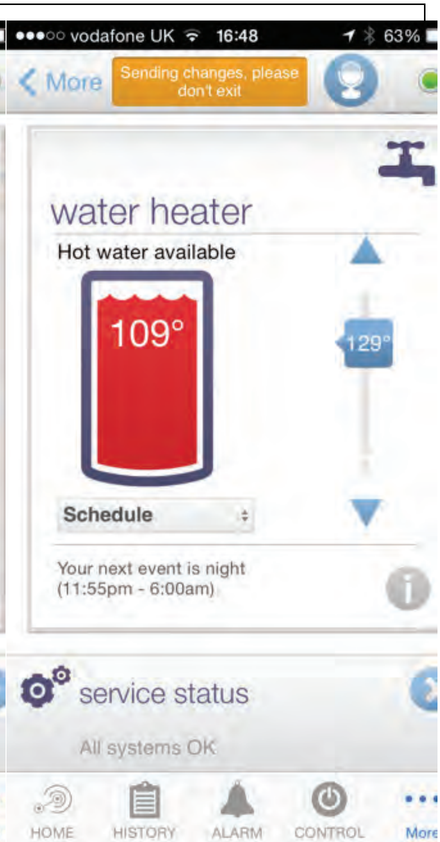
[18] Krieger, M 'Secrets to Lightning-Fast Mobile Design', Warm Gun conference 2011. https://speakerdeck.com/mikeyk/secrets-to-lightning-fast-mobile-design

Figure 9.29: Instagram registers likes or comments in the UI even while the status bar spinner shows the request is technically still being sent

When everything works OK with our heating example, the responsiveness allows the user to feel as if they are interacting with the *service*, not just the phone UI. They have direct control of the heating.

The second approach is to be more transparent about what is technically happening. You show the instruction as being in the process of being sent. This is the approach used by the Lowes Iris system (as also shown in chapter 3): a status message at the top of the screen is shown to indicate that an instruction is being sent. When confirmation is received that the controller received the instruction, a confirmation message is displayed (see figure 9.30).

	
The temperature is set to 109F. The user turns this up to 129F	*The system registers that the new temperature should be 129F, and that the current temperature is still 109F. A status message indicates that the instruction is still being sent.*

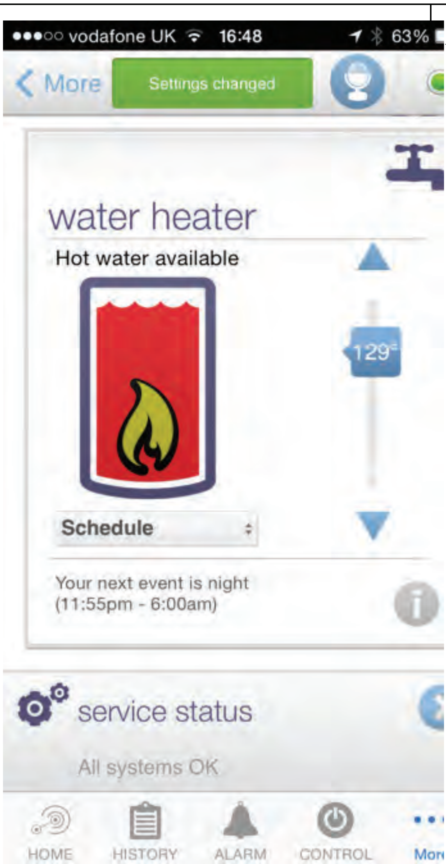


Image 1:

A status message confirms that the target temperature has been changed. The water heater has turned on to heat the water to 129F.

Figure 9.30: The Lowes Iris water heater UI, showing the status message

Here, the UI is showing the data as being in the process of being sent. In essence, the system is saying to the user: 'thanks for your instruction, let me see whether I can do that'. This requires the user to know a little more about how the system works in order to understand *why* the instruction isn't just acted upon. It also introduces the possibility of failure to every interaction, successful or not.

There are no standards here yet, and no right or wrong answer for every situation. In our first example, the primary use case for the system is to support remote access. If the user is out and about and turns the heating on remotely using the phone app, the 2 minute delay is not noticeable. The house will be warm when the user gets home. Even if the user is in, heating is the type of system that operates on a timescale of hours, so unlike a light switch, down to the second responsiveness isn't necessarily needed. If the user is standing in front of the heating controller with the smartphone app, it may be confusing, but the compromise may be acceptable.

In other situations, any delay or uncertainty about whether a command has been executed might be dangerous. For example, a person who presses an emergency alarm button must be absolutely confident their call for help has been sent and received. In this case, the UI should not make it appear that the system has received and acted on their command until it has definitely done so.

The frequency with which data is synchronized around the system can heavily shape the user value of the service. For example, dual fuel smart meters monitoring gas and electricity usage may report data at different frequencies for each fuel. The device monitoring electricity usage can run on mains power, so it can report data every few seconds. However, it would be dangerous to place a mains powered electrical device on a gas pipe. So the gas monitoring device will be battery powered. To maintain acceptable battery life, gas data will be reported less frequently than electricity data, perhaps only every 30 minutes.

With live electricity data, users can turn devices on and off and use a display (see figure 9.31) or smartphone to view almost immediately the energy impact each device had. The system can be used to understand the energy consumption of specific appliances and behaviors, such as boiling a kettle, or turning on a clothes dryer.

Figure 9.31: an in-home display

With gas data in half hour chunks, it's harder for the user to relate consumption to specific gas consuming activities in the home. You can't see the immediate impact of turning on a gas cooker. Was the last half hour's consumption high because the oven was on, or because the heating or hot water was in use? So the system data does not directly answer the question ‘how much gas does my oven consume’? As relatively few activities in the home run on gas as compared to electricity, it’s possible for users to make some rough guesses from the data. For example, if no one is at home but gas is being consumed, that might mean that the heating is on (and thus that the schedule should be changed). But for more detailed insights, the system would need to analyze longer-term patterns in gas consumption data and estimate likely usage by appliance.

When it’s not possible for all system data to be perfectly synchronized or ‘live’, it’s important to indicate how old data or status information may be. For example, you might show a timestamp for a sensor reading, or the time that the latest status information was received.

In the energy monitoring example above, it’s important that users understand that the two energy readings are not equally ‘live’. You could display a timestamp for each reading, but you might also choose to display information in a different format. You might use a line graph for electricity (because you have near continuous readings) but a bar chart for gas, where readings are only intermittent. (See e.g. figure 9.32).

Figure 9.32: gas vs electricity displays showing timestamps. (mock up)

It’s important to ensure that system status information is as accurate as it *needs* to be for the context of use. In a safety critical system, it should be clear when data may be out of date or an instruction may not yet have been received or acted on. A remote door locking system should not pretend that it has locked the door until proven otherwise! Perhaps the biggest challenge design-wise is how to design these behaviors for a system that needs to do multiple things with different responsiveness demands, such as heating, lighting and safety alarms. It’s safest to err on the side of communicating what is actually happening, but in some circumstances that may feel inelegant.

Handling cross-device interactions and task migration

Cross-device interactions require users to switch between devices in order to achieve a goal. Examples might include syncing data from a wearable fitness tracker to a smartphone, or connecting home sensors to a gateway.

Transitions between devices should be smooth and well-signposted. The word ‘seamless’ is often used in cross-platform UX, but it’s probably misleading.

Where a task requires the user to interact with more than one device, they *need* to be aware of the seams: the different role of each device, and the point at which the handover happens. This is especially important to help reinforce the user's mental model of the system, and what each part does. The less familiar they are with it (e.g. during setup when devices are new and unfamiliar), the more explanation is required. Below, we set out some key requirements for effective, usable cross-device interactions.

In the first place, the user needs to know that they *need* to switch to another device to complete their intended task. They may have to identify the correct device from amongst several: for example, there may be several identical light bulbs. Then they need to know what they're being asked to do, and any information that's needed to interact effectively with the other device. They also need to know why they're being asked to switch. For example, are they transferring data, or pairing the devices?

For example, the Misfit Shine syncing process tells the user to place or tap the Shine on the iPhone screen (see figure 9.33). (Data is transferred over Bluetooth LE but the sync is initiated by the phone recognizing the Shine on the touchscreen).

Figure 9.33: Misfit Shine syncing (https://www.youtube.com/watch?v=wmUOczrb9J4 - http://i.ytimg.com/vi/wmUOczrb9J4/maxresdefault.jpg)

The Bluetooth pairing process to connect a Jaguar car to a smartphone displays a 4 digit code on the dashboard that needs to be entered in the phone (if not already displayed) (see figure 9.34). (See chapter 12, Key interactions, for more on Bluetooth pairing interactions).

Figure 9.34: Jaguar syncing with Bluetooth device (low res grab from jaguar.com, get high res when Allan back from holiday).

The user also needs to know what reaction to expect from the other device. This is especially important if it has a very limited UI. For example, hitting a button on the web UI may make an LED flash for two seconds on a motion sensor to help you know which one it is, but you need to know where to look (see figure 9.35).

Figure 9.35: Identifying a sensor from the AlertMe web interface

If the interaction is not an integral part of a process (i.e. not something the user *has* to do), provide enough context/content to enable them to decide whether it’s important right now. For example, the Pebble Smartwatch can notify the user of new emails, texts and Twitter alerts, and shows some of the content (see figure 9.36) . The user might not be able to see the whole message, but there’s usually enough information to decide whether it’s important to get out the phone and read the whole thing there and then. A wearable that only tells you if you have a message, and not who it is from or what it might be, would not offer much over the phone’s audio alert or vibrate function.

Figure 9.36: A Pebble notification

With a multi-device interaction, it is very easy to lose track of your progress in a task, or for one or more devices to lose connectivity. Where possible, design for interrupted use. Try to avoid locking users into lengthy processes (such as setup) which must be completed in one sitting or in a specific order. Provide some flexibility: if the user has to break off and return later, don’t lose their progress - allow them to resume part way through. Guide them back to the parts that need to be completed when they return. For example, a home automation system setup process might require users to associate a gateway with an online account and then pair devices. If the user is interrupted after creating the online account but before pairing the devices, make sure that when they log in there is a clear route to resume and add devices, not just a blank screen! (See chapter 12, Supporting key interactions, for more information on designing effective setup experiences).

Broader contexts of interusability

This chapter has focused on cross-device digital interactions. However, these principles can also be applied to more holistic service design thinking across both on- and offline interactions. This broadens the focus of UX to include marketing and sales materials which set expectations of what the product does, packaging and setup guides which shape initial impressions of the UX, to customer support.

As with cross-device interaction design, the individual parts can be good, but if they don’t work together well the overall experience can still be unsatisfactory or confusing.

You might consider composition when figuring out which setup instructions to put onscreen and which in a print booklet. You would need to consider consistency of language, information graphics and aesthetics across online and print materials. And you might also need to consider the continuity of any processes that require users to refer between materials. Again, setup is a key example: if your instruction booklet says ‘now the LED will blink for 2 seconds’, that’s a pointer to look at the other device. (Setup is covered in more detail in chapter 10, Key interactions). Setting user expectations accurately is also a form of continuity: if your marketing materials highlight a feature, it should be easy to find the UI. If not, that’s a form of discontinuity.

The interusability model may not be complete for the broader service context, but I have found it useful for thinking about interactions than span digital and non-digital media.

Chapter summary

Conventional usability/UX is concerned with interactions between a user and a single UI. Interusability deals with interactions across multiple devices. The aim is to create a coherent UX across the whole system even when devices have very different characteristics.

Users need to form a clear mental model of the overall system, although it can be challenging for them to understand the interconnections between devices.

Designers need to distribute functionality between devices, to suit the capabilities of each and context of use (*composition*).

They also need to determine which elements of the design should be *consistent* across which parts of the system, for example terminology, platform conventions, aesthetic styling and interaction architecture.

Data and content can sometimes be out of sync around the system, causing *continuity* issues. Designers may need to find creative ways of dealing with this in the UI. When interactions begin on one device and switch to another, clear signposting is needed.

O'REILLY

Discussing Design

IMPROVING COMMUNICATION
& COLLABORATION THROUGH CRITIQUE

Adam Connor &
Aaron Irizarry

Discussing Design: Improving Communication and Collaboration through Critique

1

Understanding Critique

We've all been there…

Whether you're a developer, project manager, designer, business analyst, etc. it's more than likely that you've been in a meeting where the topic of "design" has come up explicitly or otherwise. If you're on a project that involves the creation of something – a tool, a service, a product, a brochure, a logo, whatever it may be – you're going to be involved in conversations about how it works, what it can do, what it contains, how it looks and so on.

Collaboration and coordination are critical elements in the success of projects in most (if not all) modern organizations. There isn't a single individual who will be responsible for coming up with an idea, designing it, building it, selling it and supporting it. Instead these responsibilities and the expertise that come with them are divided amongst a variety of contributors who each bring their knowledge to the team. So we need to work together, combining our skills and expertise. And to work together, we need to talk with each other. We need to discuss what it is we're creating, why we're creating it and how it will all come together.

But as many of us have witnessed, these conversations can turn painful. In most cases, as these discussions go wrong, the worst they do is delay progress. They seem to go nowhere as people disagree and argue and team members walk away not sure what to do next. And so measures need to be taken to plot next steps. While individual instances like this may not seem like a huge deal, it's the culmination of discussions that go this way that really impacts a team.

Over time as the delays grow and grow, the lack of momentum, the repeated questioning of what to do next and a sense that team members just can't seem to agree has a tremendous impact on people. They stop wanting to collaborate. They begin to care less and less about the project. And in some cases they begin to silo themselves, feeling that since they can only control their own output, that will be their sole focus without regard to the other team members and how it impacts them.

In some cases though, these conversations can become much, much worse. As people talk about what they think should or should not be a part of the design, it's not uncommon for their emotions to become engaged. And for some this can be difficult to control, which can lead to people getting defensive, tempers flaring, yelling, berating and lines being crossed.

The intent of this book is to help teams take a step back to look at the conversations that are happening in their projects and improve them. These discussions about what we're working on are always happening, whether it's because we called a meeting to discuss something specific or they happen casually as we're walking to grab a cup of coffee.

But we don't often take time to examine these conversations and understand what makes them good or bad. This book will look at the elements of these conversations and the patterns through which they arise and describe best practices for making them more productive to projects and toward strengthening a team's ability to collaborate through incorporation of critique, an often-overlooked component of the design process.

The problem with "feedback"

As we've described, conversations about what we're creating in our projects can come about through a number of ways. One of the most common ways design discussions are initiated is for a team member to ask for feedback on something they've created or an idea they have. They might just grab someone at a nearby desk because they want to take a break from putting something together and think about what they've done so far. Or it could be part of a planned milestone or date in the project's timeline, often called Design Reviews.

It's not that either of these is a bad time to get other's thoughts. Rather, the first real problem we encounter is from the word "feedback" itself. It's a word that's become engrained in our vocabulary. We use it all the time, a la "I'd love to get your feedback on something…"

What is feedback?

The issue with the term "feedback" lies in its broadness. Feedback itself is nothing more than a reaction or response. Designers talk about feedback and feedback loops all the time in their work. The user of a system or product interacts with it in some way, perhaps by clicking a button, and the system changes in one way or another. It could be that an animated loading bar appears while some new data is fetched and displayed, or maybe some elements in the interface move their position. See figure 1-1.

[Illustration of feedback in a UI]

That reaction by the system is the feedback. It is the system's response to what the user has done. Feedback is a reaction that occurs as a result of us doing something. In human-to-human interactions like the conversations we have in our projects, feedback can be nothing more than a gut reaction to whatever is being presented. And to be quite honest, even though we might not want to admit it, that's often all it is.

Reactions might tell us a bit about how someone feels about what has happened or been created, and that can be useful in some cases, but it also presents us with some challenges. As we'll discuss more in chapter 2, a reaction doesn't go far enough to be really helpful in allowing us to improve our creations and move forward in our projects. Not only that, the reaction itself is most likely built upon the biases and preferences of the individual doing the reacting, and in many cases that individual, whether it's a developer, designer, stakeholder, etc. is not a representative of the audience for our creation. There is a popular line in many design communities: "You are not the user." It's important to keep that in mind when we're discussing things we're creating and deciding what should or shouldn't be a part of them.

The problem with asking for feedback is that, most times, we aren't being specific enough in describing what we really want feedback on. Sometimes we might get a gut reaction. Sometimes we might get a list of instructions or suggestions on what to change. Sometime we might get comments that describe how what we've created doesn't match what the critic would have created, and so on. And weeding through all of that feedback to try to determine what's of use to us — what will help us identify the aspects of our design that we should iterate upon — can be a struggle.

Three kinds of feedback

As Aaron and I have seen in our own experiences and through watching and working with other teams, there are key characteristics that separate 3 forms of feedback, all of which vary in their level of usefulness to us in the design process. Understanding these three kinds of feedback can help us understand the conversations we have with our teams and improve our own ability to react to and use feedback to strengthen our creations.

The First 2 Types of Feedback

Reaction

> *Good lord! That's awful! An inebriated cocker spaniel could have done better!*

Reaction-based feedback tends to be emotional and/or visceral. It happens quickly, instinctively. Feedback of this type can often be the most passionate, as it's driven by an individual's own expectations, desires and values. Essentially, it's a gut reaction.

There is a second kind of reaction-based feedback that is driven by the individual's understanding of what they are expected to say, typically driven by a cultural understanding or what they think the presenter wants to hear. In this case, the reaction itself isn't in regard to what's being presented, but rather to the situation of simply being asked for feedback in the first place. Examples of this kind of feedback often take the form of:

> *That's wonderful! Great work!*
>
> *I love what you did with…*

Why it can be an issue: At best, this kind of feedback tells us about the subconscious reaction the viewer has to what you've created. These kinds of reactions are something we do want to understand when creating a product or service. It's not ideal to try to sell something potential customers or users cringe at or grumble about the second they see it. But are the people you've asked for feedback from reflective of your design's actual audience? Are they looking at it the same way your potential users would? Does this reaction tell you anything specific about any of the design decisions you've made so far or their effectiveness?

Direction

> *You should have made all of those radio buttons a drop down [because…]*

Direction-based feedback typically begins with an instruction or suggestion. In many cases that's also where it ends. In this form of feedback, the individual providing it is often looking for ways to bring the creation more in line with their own expectations of what the solution should be. You might also have encountered examples of this kind of feedback that start with phrasing similar to: *If I were to do this…* or *I would have…* or *I wish…*

In all of these, the individual giving the feedback is trying to communicate his or her own vision for the creation. It may be because they have their own detailed solution already in their mind, or it may be that they feel a problem they perceive is not adequately being solved. In some cases, the individual will go on to describe why they are making the suggestion, which can shed a bit more light on their thinking and motives.

Why it can be an issue: Similar to reaction-based feedback, direction-based feedback without any explanation tells you nothing about the effectiveness of your decisions in meeting the design's objectives. Sure, if the person giving you feedback is the one who will ultimately approve the design, it might supply you with a to-do list that you could act upon to get their approval, but getting that approval and creating an effective design are not necessarily the same thing.

In the situations where the individual also gives some explanation as to why they are making the suggestion, you at least begin to understand the impetus and perhaps the issue they're trying to address with it. But it still does not help you understand how or why the design you have is or is not effective at addressing that problem.

Additionally, when left unchecked, this type of feedback leads to problem solving which, while an important part of the design process, is counter-productive to the conversation you're trying to have. It's not that the direction itself that is being given is a bad idea, but at this point it's out of place. We'll talk more about problem solving and it's impact later on in Chapter 3.

We'll talk more about how to deal with these forms of feedback in chapters 4 and 5. For now what's most important is to understand what these forms lack in terms of their usefulness to us in helping us improve our creations.

What we really need is critical thinking

Critical thinking is the process of taking a statement and determining if it is true or false. When we're designing something, we're doing so to meet or achieve some set of objectives. When looking for feedback on our creations, what we should be working to understand is whether we think it's true or not that what has been created and the in which it's been created will work to achieve those objectives. We're looking for a form of analysis to take place.

And that's exactly what critique is.

Critique: The third form of feedback

> *If the objective is for users to seriously consider the impact to their bank balance before making a purchase, placing the balance at the bottom of the screen at the same size as all the other numbers isn't effective because it gets lost in all of the other information.*

It's this form of feedback that is most helpful to us in understanding the impact of our design decisions. Critique isn't about that instant reaction you might feel when seeing something, or about how you would change someone's creation to better solve an issue.

Critique is a form of analysis that uses critical thinking to determine whether a creation is expected to achieve its desired outcomes (and adhere to any pertinent bet practices/heuristics). Those outcomes can be any number of types of things. They can be about utility, for example giving someone the ability to complete a task. They can be about metrics and measurement, as in increasing the number of conversions for a particular call to action. Or they can be experiential, for example making someone feel excited or surprised by something.

For example, I once worked on a project for a financial services company whose goals for an update to their site's design included getting more visitors to spend time viewing their articles and commentary and more specifically to increase the average number of articles and commentary pieces viewed by a user within a visit. But the primary goal was an increased completion rate for a short contact form that helped generate leads. With these objectives agreed upon by the team we were able to focus our conversations on the aspects of the design ideas we came up with that we felt would or would not work to produce these results.

Good critique is comprised of 3 key details:

- It identifies a specific aspect of the idea or a design decision in the creation being analyzed.
- It relates that aspect or decision to an objective or best practice.
- It describes how and why the aspect or decision work to support or not support the objective or best practice.

We'll talk more later in chapter 3 about the role of these objectives in design projects and in setting the foundation for productive conversations, but hopefully this begins to give you a sense of how critique differs from the very broad and reactionary basis of feedback.

Knowing what we want and what we're asking for makes all the difference in how our conversations play out. It may seem like little more than semantics, and it's damn hard to let go of using the word "feedback" when asking to talk with people about an idea or creation (hell, we'll be using it over and over again in this book). But as you'll see as you read the coming chapters, what's important is to understand the difference and to use that understanding to inform how you ask people and facilitate the resulting conversations.

Critiquing Solo

This book centers on critique as a form of, and tool within, the conversations we have with our teams. But it's important to note that an individual alone can critique as well. While an individual critiquing another's work on their own (without the creator) can be challenging (more on this in [reference]) Individuals can, and should, critique their own work. When creating something, the brain operates as a toggle, switching between creative thinking – where individuals are generating ideas or assembling parts of ideas, and analytical thinking – where they are determining whether what they've created so far is inline with what they are trying to achieve. As experienced designers, artists, engineers, etc. they have learned how to be deliberate in controlling when to make this toggle.

Why critique is so important

Throughout this book we'll dive deeper into the various ways critique fits into the design process, but as we get started, it's important to identify these patterns and benefits in order to keep in mind the broader application of the concept.

Critique builds shared vocabularies

Ever noticed how, as people spend more and more time together, they begin to talk like one another? They begin to use the same phrasing of words and names for things. This is a natural occurrence in social groupings – part of a process called acculturation. Intuitively we seek out efficiency in communication with others. Communication between individuals grew out of a need of one individual to produce action by another. And it isn't very effective if we have to spend all of our time getting our point across. So as we come to build a shared understanding of what words and phrases mean amongst the group we instinctively use them over other words that may mean the same thing but that aren't as easily recognized by the others, streamlining and improving the quality of conversations.

One challenge project teams face in collaboration is the variety of language used by people in different roles. Members from IT, design and business may all have different ways of referring to the same thing. By bringing your project team together to critique on a recurring basis, you provide a venue for this shared vocabulary to be built within. And as that vocabulary is being built, it's happening across roles and silos, improving the ability of team members to communicate more efficiently with members of other roles.

Critique as consensus building

Design-by-committee and frankensteining are much-hated phenomena in the design community. Both are often used to imply the misguided amalgamation of ideas into a final creation without any attention paid to their disharmony or whether they really work to achieve the desired outcomes. In environments where this takes place, the driving force has become to get those involved, particularly stakeholders, all saying yes to what is being created without regard to whether what is being created is actually the best solution. And so bits and pieces are added to appease the various influencers of the project.

In these environments, critique may still be happening, but it's typically found happening in a small corner of the project team. A few people, maybe the designers and developers are doing it, but the entire team isn't doing it. Remember that the team includes stakeholders.

What Aaron and I have found in teams that carry a culture of critique is that at any time, these discussions may involve members of the team from all areas. It becomes a natural part of the way they talk with each other. And so, as the project progresses and decisions are made, members are consistently focused on and discussing the elements of the design that work best to achieve its goals. Consensus begins to be built around which ideas are stronger or weaker, and the design is strengthened as a result.

Years back, on a project that involved the creation of a new insurance application and processing platform, I got a call from one of the developers. She had been working on building out some of the functionality I had prototyped for the initial submission of an application. While doing so, she was stopped by a stakeholder who had an idea for a new piece of functionality that they were hoping could be added to the screens. In a few minutes, the developer had given me a call (I worked in another office), set up a screen share, and she, the stakeholder and I were discussing the new functionality and the ideas for its inclusion in the design.

As we did, we referred back to the task flows and scenarios we'd created for this particular set of functionally as well as the goals we had for individuals using it. In doing so, we quickly realized that the functionality itself didn't fit the objectives we were after. It would have created an awkward branch in the task flow and more work for the user. We also saw though, that the main point of this new functionality was to give the users, insurance agents; view of a key piece of data that had been missing from our designs. Once we realized that and agreed that being able to see that data was important to our objectives, we were able to generate a few ideas for adding the data value to the screen in an effective manner. The entire process took less than 30 minutes and afterwards, the stakeholder, developer and myself all walked away, confident that we had improved the design.

Critique as iteration driver

Critique is part and parcel of an iterative process. We'll talk more about iteration in chapter 3, but it can't be understated how closely these two are tied. If we're going to look at design as an iterative process, something that takes a creation and evolves it from idea to executed creation and further, then there need to be points in our process that drive that evolution and indicate what should change moving forward (i.e. the next iteration).

Many organizations use various testing and observation methods such as usability studies and beta releases to do this today, but depending on your market and audience, those can often take a lot of time. Sometimes you just need a quick step back. In the early stages of design my team at Mad*Pow might iterate 3 or 4 times on a design in a single day. All we do is make sure that after sketching and developing ideas for a period of time, maybe as short as 10-15 minutes, or as long as 1-2 hours, we stop and examine what we have so far against our objectives and best practices. Iterations don't always have to be huge readjustments of the entire creation. Sometimes they might be much smaller, focused on a handful or even just one interaction, or flow or design element.

In these cases, the drivers to our iterations are the critiques our teams regularly go through. Most are self-induced, as in not dictated by a date in someone's project plan, by the designer or design team when they feel like it's time to take a break from creating and look critically at what they have so far.

Critique as a life skill

By now, I hope that some of you are thinking about the processes your own organization goes through in projects. That's exactly what this book is about, but hopefully you've noticed that what we're really talking about here is something that applies beyond the boundaries of a business or organization. It applies to any time you want to improve on something. Whether it be a new recipe, your skills in Ultimate Frisbee, playing the ukulele, painting portraits of people's pets with macaroni, hot glue and food coloring, whatever it is, you can incorporate critique to help you improve upon it.

As mentioned above, critique is really about critical thinking. As we work toward doing or creating something with a set of objectives in mind, we always have the opportunity to stop and analyze what we've done so far in order to better inform how we might go forward. Critique is an act of reflection. It is part of the learning process. If Aaron and I might be so bold as to say, critique is a life skill, not a "design" skill.

Why critique is often overlooked

If critique is so important, why don't people pay more attention to it? Why don't teams take time to practice and talk about it?

When your team has a "post-mortem" for a project, what do you talk about? Most likely you talk about the decisions that were made, maybe a little about the process with regard to the kinds of meetings you had or when they happened. Have you ever talked about the language you use when talking to one another? Have you ever talked about how specific conversations were framed and facilitated?

When we think about our processes we tend to focus on a level higher than where the quality of critique is really influenced. Talking is something we take for granted and so the details of how we do it are often glossed over. But there is that obnoxious old cliché: the devil is in the details. Or more accurately, it should be that the devil is in ignoring the details.

Even when critique does come up in organizations, Aaron and I have watched it get dismissed or ignored for a number of reasons. The first being that in media today, the term "critique" has become almost meaningless. Media personalities, writers, pundits – anyone, really – can offer their "perspective" on a new product, service or policy and call it a "critique." It's come to mean nothing more than one person or group's thoughts on what another person or group has done. The aspects of critical thinking and of focusing on what the originating person or group's intents were have gone out the window.

Another thing we've seen happen is that critique can sometimes be thrown into the "creative professional" silo as something only artists, designers and their like do. It's not for everyone else.

Bullshit.

What these organizations fail to realize is that when a project is tasked with making something, no matter what it is, every single team member is a part of the creative process. The creating doesn't just happen in the design department. It happens with every decision about what will or won't be part of the final creation, whether that's a feature, a paragraph of content, a color pallet, a UI pattern, anything.

I'm ranting a bit here aren't I?

The point is, that if we truly want to improve our processes and improve the way our team members work together, we can't ignore the details and we can't silo our critical thinking. Yes, there are roles and responsibilities that each team member will carry based on their expertise and knowledge, but critical thinking about what we're creating and how we're creating it is a part of every member's role.

Incorporating critique and moving forward

The remainder of this book is about that role and the best practices and methods you have at your disposal for making sure it's fulfilled. As we dive deeper into the details, you'll start to see just how pervasive critique can be, how may places it can pop up and how many parts of your process it can help you improve upon.

The ultimate goal for teams that are interested in improving conversations and collaboration with critique is not to add one more tool or type of meeting to their ever growing toolbox. Instead it's to change the way we talk about what we've created regardless of the type of meeting or conversation we're in.

The quality that has stood out the most to Aaron and I amongst teams that have incorporated critique well is that critique itself becomes a natural part of how they talk to one another. Yes, they might, and often do, have critique meetings (or sessions, if you hate the "m" word), but outside of the meetings, whenever they begin to talk about what they're creating, their exchanges are framed around the objectives and goals they are working to achieve.

Critique itself is often referred to as a soft skill. Soft skills are often seen as personality traits that determine how people interact with others. Whereas "hard skills" tend to be applicable to a specific task, action or type of work, soft skills apply broadly across most activities and work. As we examine critique throughout the book, it's important to keep in mind two key aspects: critical thinking —the examination of what we're critiquing against the objectives for it's creation, and delivery — how we are presenting that critical thinking to the designer and others we're working with.

It should also be noted that critique isn't just about pictures. Often it can be seen as a process that only applies to a wireframe, or a visual design mockup or maybe a prototype, but in reality critique can be applied to just about anything. Any time you or your team construct something or make a decision about something in order to reach a specific goal or fulfill a certain objective, it is something that can be critiqued. For example, you're team may establish a set of design principles to help guide you in deciding between ideas for an interface. There are best practices for establishing and using design principles. For example, a good design principle should help you eliminate more ideas than you pursue and it should be specific and avoid overly subjective and ambiguous terms like “fun”. As such, with best practices like these, when your team creates principles for your next creation or project, you have an opportunity for critiquing your principles against them.

Chapter Summary

In order to work together, team members will have countless conversations throughout the course of a project. Many of those conversations will involve discussions about what they’re creating: its features, its content, its look and feel, etc. Often, these conversations can be unproductive or even painful and detrimental to the project and team.

Many of the reasons for these problems can stem from our understanding of “feedback” which is often how these conversations (or elements of them) are labeled. There are a few problems with “feedback”

- Use of “feedback” as a label is fairly ambiguous. It can be used to label any response to what someone has done or created.
- By definition feedback is nothing more than a reaction. And reactions themselves often aren’t helpful to helping us understand what is or isn’t working in what we’ve created.
- Feedback does not inherently include the two elements most important to helping us understand what is or isn’t working in what we’ve created: critical thinking and a focus on the creations objectives.
- Feedback itself can be categorized in 3 forms: reaction, direction and critique.

Critique is a form of analysis that uses critical thinking to ask whether what we’ve created will work to achieve the goals and objectives we are designing for. It can, and should, be a part of any formal or informal discussion we have about what we’re creating. It’s important that we learn about critique because it’s useful to us for a number of reasons:

- **It builds shared vocabularies:** by regularly having conversations focused on critical thinking and objectives for the product, teams will begin to use the same labels and language when describing things, leading to more efficient communication.

- **It builds consensus naturally around the strongest options**: when done by cross functional teams, including decision makers and stakeholders, attention is focused on which options are the strongest toward the product's objectives, and so consensus is built naturally around those options.
- **It informs and drives iteration:** critique allows us to use our expertise and understanding of a domain and an audience to iterate more frequently. It doesn't replace other methods we have for analyzing our design decisions, but rather augments them and adds to our options.
- **It's a life skill:** critique doesn't just apply to businesses and organizations creating products and services. It applies to any situation where we create or do something in order to reach a set of objectives.

Unfortunately, critique is often overlooked for a number of reasons, but by recognizing its value and spending a little time understanding what it is and how it fits within our teams and processes we can improve the quality of the conversations our team members have and make critique a natural part of our communication and process.

2

What Critique Looks Like

The Two Sides Of Critique And The Importance Of Intent

There are two sides, or roles, in any critique:

> **Recipient**: The individual(s) receiving the critique (i.e. the creator or presenter of whatever is being analyzed) who will take the perspectives and information raised during the critique, process it and act upon it in some way.
>
> **Giver**: The individual(s) giving the critique, who are being asked to think critically about the creation and provide their thoughts and perspectives.

Within both of these roles there is the discrete aspect of intention: why are we asking for/receiving/giving feedback. Intent is the initiator of the conversation and is often what separates successful critiques and feedback discussions from problematic ones.

For the best discussions, the intent of each participant, regardless of whether they are receiving or giving critique needs to be appropriate. If we aren't careful, critique with the wrong, or inappropriate, intent on either side can lead to problems not only in our designs, but also in our ability to work with our teammates.

Receiving critique with the appropriate intent is about wanting to understand whether the decisions you've made are working toward your product's (and its design's) established objectives.

Giving critique with the appropriate intent is about wanting to help the creator understand the impacts of their choices with regard to their effectiveness toward reaching the design's objectives.

Both acts are done with the intention of using the information and perspectives raised during the critique to iterate upon and strengthen the design. This is an important aspect of the discussion. Many of us have experienced meetings where we're asked to give our thoughts on something like a design, or a process, or maybe even a project (ex: a post-mortem) and over time, if these discussions repeatedly fail to produce action and changes, our desire to participate and provide our perspectives wanes.

Part of what makes for strong critiques is the desire to participate, to help. It isn't the case that everything said in a critique will produce a discrete modification to the design, but overall, participants should feel that the discussion, which they actively contributed to, played a role in improving the design, not just changing it, but strengthening its ability to produce the desired objectives.

Prior to beginning a critique, whether you're the giver or receiver, it's best to make sure that you're going in with the right intent.

Giving Critique

As mentioned, giving critique with the right intent is about wanting to contribute to the improvement of the creation by helping the creator understand the relative success their design choices have in working towards objectives. When we start our feedback discussions from this mindset we think critically not just about what we're saying but why we're saying it, which is important to productive dialogues.

To better understand what giving a good critique looks like, let's first look at some characteristics of bad critique. For more tips on handling and working with unhelpful feedback and unwanted critique, see Chapter 5: Critiquing with Difficult People and Challenging Situations.

Characteristics of Bad Critique

Selfish

The wrong intentions for giving critique are often selfish. They're focused on personal goals and desires for attention at the expense of the team or other individuals, specifically the creator of whatever is being discussed.

Selfish critique comes from the motivation of the giver to not only be heard and attract attention, but also to be recognized as smarter or superior, or further personal goals.

The most recognizable examples of this can be seen on social networks like Twitter or Facebook whenever there is a change to a popular app, device etc. A new feature is added or something is changed, and people immediately begin slamming decisions, calling them ridiculous and stupid and stating how things "should have been designed."

But in most of these situations, the commenters have only a cursory understanding of what the designer or team was working towards and the constraints they were working within. How is this helpful?

When we do this (and Aaron and I are guilty of it too, as do most people) are we really trying to help someone improve their design? Or are we more interested in showing others in our community or organization how smart we are on a certain topic?

This type of feedback happens on project teams as well. Maybe you've encountered it at work, are thinking of a colleague who's done it to you, or maybe you've done it yourself.

Sometimes, this kind of feedback comes from having our own ideas of what we think the design should be but not having had a chance to share it with the team. So we set about to use feedback as a way to diminish the design being presented and (in some cases) propose our own alternative. While Aaron and I are firm believers that a great idea can come from anywhere, and team members in any role should be given an opportunity to share their ideas, this path to doing so is detrimental to a critique.

As we'll discuss more in Chapter 4, critique is not the place for exploring new ideas. Its purpose is to analyze the design as it has been created so far. Shifting a group from an analytical mindset to an explorative one is best done with deliberate facilitation.

Untimely

Despite what we may think, and what some people may even say, people aren't always looking to hear feedback on their work. Unless someone has specifically told you they'd like your feedback, it's unwise to think your conversation is a great opportunity to share your analysis with them. If someone is telling people about their creation, it may just be to get the word out or simply that they're excited about what they're working on.

In order for the receiver to really listen, process and make use of critique, they need to be in the proper mindset. Whether at a team member's desk, in a meeting, or on social channels, when critique is uninvited it can lead to defensiveness, communication breakdowns, and often paints the person giving it as a "know it all".

Incomplete

For critique to be useful, the creator(s) need to understand not just the potential outcome or reaction to an element of their creation, but the "why" behind it. We often see feedback in the form of things like:

> *"I think the button is better than the link."*
> *"Nobody is going to click on that."*

Or, even worse:

> *"This is terrible…"*

This type of feedback typically comes from the reactive form of feedback we discussed in Chapter 1. It lacks the extended critical thinking that allows those working on the design to understand what they might need to change in their next iteration. In order for these critiques to become valuable they need to be followed by an explanation as to "why" the giver is having that reaction or foresees a certain outcome. For example:

> *"Nobody is going to click on that because the current page design leads the eye down the left side of the screen away from the call-to-action."*

Good critique is actionable. When the "why" behind the feedback is included, the comment can now be fully understood and the creator can take action. That is to say that the creator has enough of an understanding of what is/isn't working and why that they can explore alternatives or make other adjustments.

Note though that this is different from prescription or direction. It is not the case that critique should tell the creator how to act on something or specifically what changes they should make (i.e. the directive form of feedback). Good critique tries to avoid problem solving as it can detract and distract from the analytical focus of the discussion. For more on this, check out Chapter 4.

Preferential

Another common characteristic of bad critique is feedback that is justified by the giver from purely preferential thinking. We've all heard horror stories about this kind of feedback: designs are torn apart, not because a particular aspect isn't working toward its objective, but rather it doesn't match exactly what the feedback giver "likes", for example: a website design gets canned because the color scheme reminds a stakeholder of a Christmas sweater his ex-wife had given him.

Though it might seem ridiculous, this kind of feedback is common, though maybe not always so extreme. It usually feels like it's coming out of nowhere and has no relevance to the work we're doing, but sometimes, it really just boils down to a personal preference.

This kind of feedback is not only unhelpful, as it does nothing to analyze a creation with regard to objectives, it can be distracting and counterproductive. This is especially the case when it comes from team members or stakeholders who are in a position of approval. In these situations, the team begins, consciously or subconsciously, to prioritize that individual's tastes alongside or above project and user goals even if they conflict.

Best Practices For Giving Critique

Where critique with the wrong intent (done knowingly or not) is harmful, damaging teams, processes, and most importantly the product. Useful, productive critique has the ability to strengthen relationships and collaboration, improve productivity and lead to better designs. In order give the best critique possible, think about the following best practices when giving feedback.

Lead with questions. Get more information to base your feedback on and show an interest in their thinking.

Chances are, before being asked for your feedback, the creator(s) will give a brief explanation of what they've put together so far and how it would work. This gives you some context and understanding of the objectives they have and the elements of the design they've put in place to achieve them. But chances are they haven't explained everything. Actually, as we'll talk about shortly, HOPEFULLY they haven't explained everything.

This is your chance to open up the dialogue. By asking questions you give yourself more information on which to base your analysis and give stronger, actionable feedback. And if done in a non-interrogative way, it shows the creator that you're genuinely interested in, not only their work, but their thinking behind it, which can make discussing it and listening to feedback a bit easier for them.

Examples of questions you might ask:

- Can you tell me more about what your objectives were for [specific aspect or element of the creation]?
- What other options did you consider for [aspect/element]?
- Why did you choose this approach for [aspect/element]?
- Were there any influencers or constraints that affected your choices?

Remember though, the dual purpose of asking these questions of the creator:

1. to get you more information and…
2. to get them more comfortable talking about their thought process and decisions.

To that extent, how you ask these questions can have a huge impact? Asking every question beginning with "Why…" can feel abrasive or like an attack. Use lighter, more inviting phrasing such as, "tell me more about…"

Use a filter. Hold on to your initial reactions, investigate them and discuss them in the proper context as appropriate.

You're going to have reactions. As the work is being presented to you there will be things that make you think "huh?" or "that's cool" or "I don't get it" or maybe something worse. Hold onto those reactions and remember that reactions don't typically make for useful feedback. Ask yourself why you're reacting in that way. Ask the presenters additional questions if necessary.

Once you understand your reaction and what caused it, think about whether it makes sense to discuss. Does it relate to the objectives of the product, the audience for it or any particular best practices that should be followed? Or is it more about your personal preference or wishes for how you'd like to have seen it designed?

If your feedback is related to the product's objectives or best practices, and not about your personal reaction or preferences, then it definitely has a place in the conversation. Sometimes though, you may find yourself with feedback that, while not a best practice or preference, is also not specific to a best practice or a stated objective. Maybe it's something new that you think should be considered. What should you do in those situations?

In these cases it may still be useful to bring your feedback into the conversation. These kinds of thoughts can be useful in determining additional objectives or constraints for the project that need to be exposed. It may be something you can discuss quickly and then continue on with the critique, or it may prove to be something sizeable that needs a separate, dedicated discussion so that the critique isn't derailed.

Don’t assume. Find out the thinking or constraints behind choices.

“To assume makes an ass out of you and me.” Most of us have probably heard that line a few times in our lives. It’s one of my father’s favorites, and it’s stuck with me.

Assumptions can be one of the worst things to happen in a discussion that is meant to be productive. When we make assumptions we begin to form our thoughts, questions and statements around them, without ever knowing if they’re true or not. And before you know it, the participants of the discussion go on their way to do their work based on very different ideas and producing work that doesn’t align with each other or reality.

When you make assumptions in a critique about what an objective or constraint might have been, or maybe that there were no constraints and the designer could have done anything, you begin to offer feedback that can be less useful because it isn’t based on the real situation.

To get around this is simple. The quickest way to eliminate assumptions is to ask about them.

Yup. More questions. Put your assumption out there and ask if it’s accurate. If it is, continue on with your insights. If it isn’t, you may find that you need to adjust your thinking a little.

Don’t invite yourself. Get in touch and ask to talk about the design.

Recall in the previous section that we talked about untimely feedback as one of the types of unhelpful critique. If the recipient of the critique isn’t in a mindset where they want and are ready to listen to the feedback and use it, chances are it’ll be ignored or potentially cause a rift in your working relationship with them.

If you have thoughts about someone’s creation and they haven’t explicitly asked for your feedback or critique, get in touch with them first and let them know. Tell them that, when they’re at a point when your thoughts might be helpful to them, you’d be happy to share them. Give them the opportunity to get themselves ready to listen.

Talk about strengths. Critique isn’t just about what’s not working.

As a culture and society, we have a tendency to focus on negatives, the things that cause us problems, get in our way and that we’d like to see changed. We often take the positive for granted. In our project meeting and design discussions it’s often no different, we spend the vast majority of time talking about what isn’t working. But that can be harmful. Remember that critique in about honest analysis. It’s balanced focusing on the design and it’s objectives, regardless of their success. It’s just as important to talk about what is working as why, as it is what isn’t working.

Often when talking about the role of "positive feedback" in critique, we see discussions center on the importance of discussing strengths as a mechanism for making critical feedback easier the receiver to take. There is a common structure often discussed called the "OREO" or "sandwich" method in which you begin by offering a positive piece of feedback, followed by a negative one, followed by another positive one. It's a fairly useful technique, which we'll talk more about in Chapter 5, and there have been studies showing its effectiveness.

But there are other reasons for making sure that critiques include discussion on what aspects of the design are working toward objectives and why/how.

Part of the creative process involves the decomposition and abstraction of ideas and then recombining them in different ways or with ideas from somewhere else. It's a common way in which we take a familiar concept where there is room for improvement or added value and innovate. When we talk about aspects of a product or design that are working, there is the potential for the creators to examine those areas and abstract concepts or elements from them that could be used to strengthen other areas of the design that might not be working as well.

Additionally, with the understanding that the creator(s) will iterate upon their design after a critique, how much would it suck if at the next critique you noticed that an aspect of the design that seemed great previously had now been changed and wasn't quite as effective, all because it hadn't been talked about and so the team didn't see a reason not to change it.

Think about perspective. From whose "angle" are you analyzing the design?

In the previous section we talked about preferential critique, or feedback that's based on personal preferences rather than being tied to objectives for what we're creating. When we're analyzing a product, it can be easy to forget that we most likely aren't representative of the product's target audience. Even if we are a potential user, we know far more about it than the average user.

As you analyze a design it's important for you to try to balance your expertise with the user's perspective. It can be a difficult balance to strike, but by simply asking yourself "how am I looking at this" when you examine an aspect of the design and making compare your perspective to what you think the user's might be, you've got a good start. From there you may find that one is clearly more appropriate than the other, (ie your visceral hatred of the shade of green being used probably doesn't matter) or perhaps it might be best to bring both up in the discussion. For example:

"From the user's perspective, I think all of the steps in this flow make sense and are understandable and useable. But from an interaction design perspective I think there may be some redundancy and opportunities to simplify…"

A Simple Framework For Critique

It's helpful to have a sense of what the structure of a good critique sounds or looks like. As we shared in Chapter 1, critique contains 3 important details:

- It identifies a specific aspect of the idea or a design decision in the creation being analyzed.
- It relates that aspect or decision to an objective or best practice.
- It describes how and why the aspect or decision work to support or not support the objective or best practice.

To make sure that, uncover and include all of these details there is a simple framework of four questions that we can ask ourselves, or the other individuals participating in the critique.

What was the creator trying to achieve?

↓

How did they try to achieve it?

↓

How effective were their choices?

↓

Why is, or isn't, what they did effective?

These four questions flow together to generate feedback in the form of critique. By asking these questions we collect the necessary information that allows us to think critically about the creation we're examining. Lets take a look at these questions individually.

> **What was the creator trying to achieve?**
>
> We want to understand what we're to be analyzing the creation against so that we can focus our attention on things that are pertinent to the conversation and the improvement and success of the creation. So we try to identify the objectives that they creator was aiming to accomplish through the choices they made. What are the objectives of the project or creation that have been agreed upon by the team?

How did they try to achieve it?

Next we identify the choices that the creator made to try to reach the objectives they have and produce the work we're looking at. Whether the creator spent time going back and forth between options to determine which was better, or something was done just based on instinct or given little conscious thought at all, everything being looked at is the result of a choice.

How effective were their choices?

Now that you are thinking about specific objectives and choices that the creator made it's time to ask whether you think the choices they made will work to achieve the objective they set? This is the crux of critical thinking.

Why is, or isn't, what they did effective?

Finally, think about the result that you think the choice will actually produce. How close is it to the actual objective? Is it completely different? Does it work counter to the objective. Maybe it won't work to achieve the objective on it's own but it contributes, in conjunction with other elements of the design, to the objective.

Note that the first two questions can be reversed in order depending on how the design is being presented. These questions form the foundation for the critical thinking that comprises good critique. As such, these questions can be asked and answered internally by individuals giving feedback, or they can be exposed and asked directly of the creator. As mentioned in the section on best practices for giving critique it's great to lead with questions, and questions that ask about what choices were made and what objectives those choices were intended to achieve make a great way to start the conversation.

Other questions to think about

The four questions above will help you formulate feedback that a creator can use to better understand the effectiveness of their choices in regards to their objectives, but what about other aspects of the design, what about other questions that come up. For example:

- What new problems, complications, or successes might arise from the choices being proposed?
- What other objectives should the creator have been considering, but didn't?

Raising these kinds of questions can be important. Ignoring them may mean missing something that becomes problematic later on down the project's timeline, or it might give rise to a new objective for the team to discuss and agree to (or discuss and agree isn't an objective).

With additional questions like these however, it's important to keep in mind scope – both the scope of the project/creation and the scope of the feedback discussion. These questions may lead to spending too much time discussing things that are outside the scope of the project or creation itself, like perhaps a known issue that the creation isn't intended to solve. Or questions like these may take the focus off of the aspects of this design that the presenter is looking for feedback on and instead use up valuable time on elements of the design that haven't been fully thought out yet and are likely to change anyway.

This means that the group, both the recipient and the givers need to be conscious of this and be prepared to end, or parking-lot, a discussion when it begins to moves out of scope. More on this in Chapter 4: Facilitating Critique.

Receiving Critique

Listening to people comment on something you've created can be scary. It can be difficult enough to present something to a group of people, never mind the possibility that they then might start to pick it apart.

When I was in film school, at the end of my each year we were required to present our final film to an audience of classmates, instructors, family and friends. At the end of my first year, I presented my work, a short film that debated which was the better superhero: Batman or Superman (the answer is Batman, of course). Following the credits, I walked to the front of the room, talked for a few minutes about it and waited for the comments. I didn't wait long, one of the professors began to tear into it, commenting on how pointless it was, how little depth it had, how the actors didn't move enough yet we're working in a medium called "movies".

Those 12 minutes still haunt me. And for a very long time after that, I was terrified of showing my work – any work. I've had multiple instances over the years where that fear has gotten so significant that I've thrown out everything I created. Even when I moved into the business world, the prospect of standing there and listening to feedback terrified me. And I had numerous encounters with co-workers that reaffirmed that fear.

Many of you may have had similar experiences, or have hear enough horror stories that you've feel like it's happened to you too. All of this fear and trepidation can lead to patterns in our behaviors and expectations when presenting work that cause us to ask for feedback and critique with less than genuine intentions.

Just like giving critique, receiving it in a way that is useful and productive requires the recipient(s) to have the right intentions. Recipients of critique should be in a mindset of stepping back from their creative thinking to examine the choices they've made so far in order to better understand how to proceed and take their creation further. And they should value the expertise and perspectives of their teammates in doing so.

Often though, we see individuals and teams go through the process for the wrong reasons. And whether it's done consciously or not, it leads to issues down the road as the project progresses, both for the product and the team's relationships.

Critique Anti-patterns

Asking For Feedback Without Listening

Sometimes we ask for feedback because we feel like it's the right thing to do, or because we feel like we have to. While Aaron and I believe that stepping back and forth between creative thinking and analytical thinking is a key component of a successful design process, it isn't the case that you are always in a position mentally or tactically, to listen, consider and utilize feedback to improve your designs.

Asking for critique at these times leads to unproductive discussions. By not listening to our teammates we miss valuable insights that can help us improve our designs. The people critiquing our work are likely to pick up on our disinterest and as a result will feel uninterested in sharing their thoughts. And over time they'll be less likely to participate in these kinds of conversations at all.

Depending on the process your organization follows, you may have specific times when you're required to present your work and collect feedback. Sometimes, these sessions might be useful to the design, but you're brain just isn't ready to make the switch to analysis, and so you aren't ready to listen to critique.

In these situations, it's important to recognize where your own thoughts are at and understand why the meeting is being held. Make the most of it by focusing your presentation and the discussion on aspects of your design that are more fleshed-out. If conversation turns toward things you haven't had the chance to explore yet, make note of people's questions or comments and either facilitate the discussion back toward aspects that can be analyzed.

Remember the importance of being able to switch between creative and analytical thought. While it might not always feel comfortable, getting yourself used to making this switch and how to use it effectively, by making critiques a scheduled part of your process, can go a long way to strengthening you and your team's skills as designers.

For more on formal critiques and the design process, see Chapter 3.

Asking for Feedback For Praise or Validation

Creating something can feel awesome. Whether we do it alone or as part of a team it's not unusual to want to be recognized for our creations. But when it's our motivation for asking for feedback, it can bite us in the ass.

And yet we do it often. We share our work with statements like "Hey! Check out this thing I just made! I'd love your thoughts on it." When really, the only thoughts we want to hear are: "Way to go!" Looks awesome!" and "Congratulations!"

So we wait for the cheers. Some come, and it feels great. But then we get some feedback about things that aren't so great, things we could have done better, and it hurts. No matter how valid the points may be, we aren't in a mindset where we want to hear them. So we get defensive. Maybe we argue and try to discredit the feedback. Maybe we ignore the comments. But either way, we haven't done a very good job at receiving critique even though we've asked for it.

Best Practices For Receiving Critique

As we've described, receiving critique in a way that's productive goes beyond just asking for it and then sitting back to let others give you their thoughts. When receiving critique, keep the following best practices in mind:

Remember the purpose. Critique is about understanding and improvement, not judgment.

There is no such thing as a perfect solution. There is always room for improvement. A goal of a critique is to help identify where those opportunities are. The conversations we have during critique act as road-signs along the evolution of our ideas and creations, helping us to understand which paths might take us closer to our end goals. Critique isn't about pass or fail, approval or rejection. They are a reflection used to inform a next step.

Listen and think before responding.

Many of us have a bad habit of not really listening when someone is speaking to us. Instead we hear the first few words they say, and then instead of listening to them continue to speak, we begin to formulate a response and wait for the first opportunity to start talking.

What this means is that while the person we should be paying attention to is explaining their thought, instead of listening to and processing that explanation we've essentially ignored it. It's not that we've done so maliciously, this is a common occurrence and most of us do it. Obviously though, this is counterproductive to what we're trying to do in a critique. When receiving critique it's important for you to consciously work toward preventing any natural tendencies to form rebuttals and instead focus on listening to people's entire thoughts. To help make sure you understand what people are telling you ask them follow up questions or repeat what they've told you as you've understood it and ask them if your interpretation is accurate. This is called active listening.

Return to the foundation.

As people share their thoughts with you, you may encounter feedback that seems out of place, as though it has little to do with what you're trying to create or the objectives you have. It may be that the person you're hearing from is just having difficulty connecting their thoughts, or it may be that they've started to offer feedback that is based more on their own preferences or goals.

To help you find out you can use previously agreed upon objectives. If you can't determine for yourself how the feedback relates to the product or project's objectives, try to work with them on relating it back by asking them follow up questions related to the objectives.

If over time you're able to determine a connection, then you'll better understand the feedback and can use it moving forward. If not, then you know that the feedback likely isn't valuable to your next iteration.

Participate

One of the best things a creator can do during a critique is to become a critic themselves. Being able to shift our mindset from thinking creatively to being analytical about what we're creating is a key creative skill. Participating in a critique of our own work has multiple benefits.

First, the more we exercise intentionally switching our mindset like this the easier it becomes to control this mindset "toggle." Switching from creative thinking to analytical will be easier, faster and something we can do whenever we feel like it's helpful, whether we're alone at our desks, or we grab the person sitting next to us, or we're in a meeting.

Second, one of the common challenges people have with giving critique is a fear of hurting the creator's feelings. By participating in the analysis and openly talking about the aspects of our product that could be improved upon, we can make others feel more comfortable participating in these discussions.

Aim for dialogue

One of the worst mechanisms for meaningful critique is email, yet it's also one of the most often used. The problem with email is that it isn't conducive to dialogue. Instead of an in-time back and forth of questions and answers between the presenter and critic, email tends to push people to generate longer lists of comments, each of which might spur it's own conversation.

It's almost always true that the best method for critique is a real conversation, but that isn't to say that you can't collect useful critique through email or other digital means. Just make sure that when you do, you pick platforms, or structure your requests in ways that maximize the opportunities for back-and-forth discussion of discrete aspects or elements in your creation. Products and services that allow you to annotate documents with comments are often a good start for this.

Critique, Conversation and Questions

Our hope, as you've read this chapter is that it's become clear that good critique, critiques that are productive for the entire team, are the result of dialogue. The giver and receiver request and exchange information back and forth, and from those exchanges come useful, actionable insights. This means that, in a productive critique, there are often a lot of questions asked by both parties.

In fact, great critiques are often more about questions asked than statements made. Questions being asked means that assumptions can be validated, eliminated or further examined collaboratively. Which means that the feedback being collected is based upon a mutually understood foundation rather than individual's different interpretations. It's also useful for the recipient to pay attention to the questions being asked as they can be signs as to what elements of the creation may be clear or confusing to others.

This should also tell you something about how best to ask for feedback and which communication platforms make the most sense. It's common for designers or teams to send their creations to other members of the team via email and ask for feedback. It's also common for these kinds of exchanges to become problematic. Email isn't a great conduit for anything resembling real time conversations. It isn't designed to work that way, but being able to quickly ask questions and get back responses that allow you to further your thinking and either ask additional questions, or provide insights is key. When dealing with multiple people giving feedback, these deficiencies become even more pronounced as now you need to manage threads, keep track of who gets what information via replies and reply-alls, etc. We've all likely experienced situations where feedback was originally solicited by email, and after one or two replies, a conference call or in-person meeting was called because it just seemed easier than trying to make sense of the lists of questions and comments coming back.

Online feedback tools like inVision app and others do their best to try to work around this, by allowing people to comment on specific aspects of a design and keeping those threads together. This works better, but the non-real-time nature can prove challenging as well as individuals try to give their comments but have to do so based on assumptions that they haven't been able to validate or eliminate yet.

That isn't to say that critique isn't possible through these mechanisms. It very much is, but, if we're going to use tools like this, perhaps because we're in a situation where we have no other choice, we need to make sure we're doing our best to make them as conversational and focused as possible. When requesting feedback through a mechanism like this, be specific about what you want feedback on in your request, and specify what the objectives for your creation were. Allow for as many questions back and forth as you can. When making assumptions in order to offer an insight, make sure to state that assumption so that the recipient can see it and verify that it's true or let you know that it isn't. It takes more work, and can often take a bit longer, but it can be done. We do recommend though that, when you can, it's best to use a platform in which everyone can talk in real-time and look at the creation together. With some good facilitation (see Chapter 4) you'll find that sessions like this, whether their in-person or through a conferencing tool like WebEx or Google Hangouts, you'll do much better at collecting useful feedback, keeping the team in sync and building a sense of collaboration.

Chapter Summary

The intention of individual(s) in both roles of a critique discussion, giving feedback and receiving it, has a direct impact on not only the quality and usefulness of feedback shared in a design discussion, but also on the relationships of team members and their ability to collaborate.

Proper intention is about wanting to understand the impacts of choices made in order to better determine what to keep, change, eliminate and strengthen as we iterate on our creations and move them forward.

Whether done intentionally or not, characteristics that make feedback unhelpful are:

- It's derived from personal goals: The individual giving the critique is doing so because they are looking to be recognized or because they have their own ideas on how or what should have been created.
- It's untimely: It's given without regard to whether the recipient(s) are in a mindset or position to listen and make use of the insights.
- It's incomplete: It's a reaction or prediction without a description of what has caused it.

- It's based on preference: It's based on what the individual giving the feedback personally likes rather than being based on context of use and the product's audience.

To help ensure your feedback is useful and works toward improving the product:

- Lead with questions. Get more information to base your feedback on and show an interest in their thinking.
- Use a filter. Hold on to your initial reactions, investigate them and discuss them in the proper context as appropriate.
- Don't assume. Find out the thinking or constraints behind choices.
- Don't invite yourself. Get in touch and ask to talk about the design.
- Talk about strengths. Critique isn't just about what's not working.
- Think about perspective. From whose "angle" are you analyzing the design?

Similarly when asking for feedback, be sure that you aren't:

- Asking with no intention of listening.
- Asking when you're really just looking for validation or praise.

When asking for critique, keep the following in mind:

- Remember the purpose. Critique is about understanding and improvement, not judgment.
- Listen and think before responding. Do you understand what the critics are saying and why?
- Return to the foundation. Use agreed upon objectives as a tool to make sure feedback stays focused on objectives.
- Participate. Critique the work alongside everyone else.

If we understand the best practices for giving and receiving critique, we also notice a few things about how we collect feedback through various platforms. The more we're able to facilitate real-time asking and answering of questions across the group, the better the exchange is likely to be. This is why in-person and teleconferences with visual capabilities tend to be best. However, feedback tools and email can still be used, they just take more planning and careful facilitation.

O'REILLY®

Understanding Industrial Design

PRINCIPLES FOR UX AND INTERACTION DESIGN

Simon King & Kuen Chang

Understanding Industrial Design: Principles for UX and Interaction Design

Chapter 1
Introduction

Historical background on Industrial and Interaction Design

Throughout the last century, the discipline of Industrial Design has refined an understanding of how to design physical products for people. More recently, as computation and network connectivity extend beyond the screen, Interaction Designers and UX professionals also find themselves addressing design problems in the physical world. Although the context is new, much can be learned by looking to the long-standing principles of Industrial Design. Technology evolves rapidly, but the underlying qualities that define the products we love have not changed.

In this book, we will look at ten principles of Industrial Design that can inspire new ways of approaching UX challenges, both on-screen and in the physical world. Each principle will be explored through numerous product examples, both historical and contemporary, and related to present or near-future Interaction Design challenges.

This chapter will provide a brief grounding in the history of Industrial and Interaction Design. We will cover key people and moments in each discipline, highlighting pivotal events and noting points of divergence and convergence. The history of personal computing will be used to trace advances in Interaction Design, with particular attention given to the virtual or physical nature of different computing platforms. Additional background on Industrial Design is interspersed throughout the book in conjunction with the examples that illuminate each principle.

Industrial Revolution

For most of history, when people needed a particular object, they either created it themselves or found someone to make it for them. Individuals may have specialized in their production, such as shoemakers or carpenters, but their output was still largely a unique creation.

There is evidence that generalized fabrication was used to standardize crossbows and other weaponry as early as the 4th century BC in China.[1] However, it was the rapid improvement of manufacturing capabilities during the Industrial Revolutions of the 18th and 19th centuries that signaled the radical shift to mass production of identical goods. For the first time, the act of design became separated from the act of making.

Driven by this change in technology, the field of Industrial Design emerged to specialize in the design of commercial products that appealed to a broad audience and could be manufactured at scale. In contrast to the craftsmen of the past, these designers were challenged with meeting the needs of a large population, balancing functionality, aesthetics, ergonomics, durability, cost, manufacturability, and marketability.

The Industrial Designers Society of America (IDSA) describes Industrial Design as a professional service that optimizes "function, value, and appearance for the mutual benefit of both user and manufacturer."[2] It is the study of form and function, designing the relationship between objects, humans, and spaces. Most commonly, Industrial Designers work on smaller scale physical products, the kind you buy and use every day,

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[1] Needham, Joseph. 1954. Science and Civilisation in China: Volume 1, Introductory Orientations. United Kingdom: Cambridge University Press.

[2] 2015. What Is Industrial Design? Accessed January 22. http://www.idsa.org/education/what-is-id.

rather than larger scale complex environments like buildings or ships.

Whether you realize it or not, Industrial Design is all around you, supporting and shaping your everyday life. You are likely to recognize numerous examples cited throughout this book, perhaps from your childhood, your office, or even sitting next to you as you read this. The mobile phone you are fidgeting with, the clock on your wall, the coffee maker brewing in your kitchen, and the chair you are sitting on. Everything you see, touch, and are surrounded by was designed by someone, and thus influenced by Industrial Design.

Throughout the 20th century, along with balancing the needs of the user and manufacturer, differences in politics and culture were evident in the design of objects. A rising consumer culture in the post-WWII period meant that manufactured goods doubled as a cultural proxy, intertwining national pride and economic reinvention. Along with regional differences, numerous philosophical and stylistic periods created distinct and recognizable eras within Industrial Design, including the Bauhaus school, Art Deco, Modernism, and Postmodernism.

Design for Business

On a more individual level, there are many famous Industrial Designers who have had an outsized influence on the history of the discipline. Raymond Loewy, a French-born American, is often referred to as the “Father of Industrial Design.”[3] Loewy is widely considered to have revolutionized the field by pioneering the role of designer as consultant, working for a wide variety of industries and mediums.

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[3] ‘Raymond Loewy’. 2015. The Official Site of Raymond Loewy. Accessed January 22. http://www.raymondloewy.com/.

Loewy designed everything from streamlined pencil sharpeners, Coca-Cola vending machines, Studebaker automobiles, and NASA spacecraft interiors. He brought design into the mainstream business spotlight, gracing the cover of Time magazine in October of 1949, where they noted that he "made products irresistible at a time when nobody really wanted to pay for anything."[4] Loewy intertwined culture, capitalism, and style, establishing a template for how design and business could be mutually beneficial.

Design for People

Henry Dreyfuss is another famous American Industrial Designer whose work and influence from the mid-20th century are still felt today. Among his iconic designs are the Honeywell T87 thermostat, the Big Ben alarm clock, the Western Electric 500 desk telephone, and the Polaroid SX-70 camera.[5]

Figure 1.x Henry Dreyfuss measurement image

Dreyfuss was renowned not only for his attention to formal details, but his focus on the user's needs. He founded the field of ergonomics and pioneered research into how human factors should be considered and incorporated into Industrial Design. After retiring, this focus on anthropometry and usability led him to author two seminal books: *Designing for People* in 1955 and *The Measure of Man* in 1960. His interest in universal accessibility extended to graphics as well, as evidenced by *Symbol Sourcebook: An Authoritative Guide to International Graphic Symbols*, in which Dreyfuss catalogs and promotes the use of internationally recognizable symbols over written words.

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[4] 'Google Doodle Honors Raymond Loewy, the "Father of Industrial Design".' 2015. TIME.com. Accessed January 22. http://newsfeed.time.com/2013/11/05/google-doodle-honors-raymond-loewy-the-father-of-industrial-design/.

[5] 'Henry Dreyfuss, FIDSA'. 2015. IDSA. Accessed January 22. http://www.idsa.org/content/henry-dreyfuss-fidsa.

Dreyfuss felt that “well-designed, mass-produced goods constitute a new American art form and are responsible for the creation of a new American culture.”[6] But he emphasized that good design was for everyone, that “these products of the applied arts are a part of everyday American living and working, not merely museum pieces to be seen on a Sunday afternoon.”[7] He promoted this approach through his own work, but also more broadly in his role as a founding member of the American Society of Industrial Design. In 1965 he became the first president of the IDSA.

Design for Technology

Along with the needs of business and users, the history of Industrial Design has been strongly shaped by the introduction of new technologies, which present an opportunity to redesign and improve products. Industrial Design has always been a conduit for innovation, translating the latest discoveries of science to meet the needs of everyday people.

Figure 1.x Composite image of chairs highlighted in text below

Take for an example the humble chair, a ubiquitous object that has become a laboratory for variation in form and materials. Figure 1.x shows four chairs, each highlighting a shift in the possibilities of material use and manufacturing capability.

The No. 18 Thonet chair (1876), was an evolution of experimentation begun by Michael Thonet, with this variation released after his death in 1971.[8] Thonet pioneered a new process of bending beech wood to reduce the number of parts involved, simplifying and strengthening the chair while increasing

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[6] Dreyfuss, Henry. Designing for People. New York: Simon and Schuster, 1955. 82-83.
[7] Ibid.
[8] ‘History - Thonet’. 2015. Accessed January 22. http://www.thonet.com.au/history/.

efficiency in shipping and assembly. The aesthetic was influenced by the technology, with generous curves honestly reflecting the bent wood process.

The Eames Molded Fiberglass chair (1950) features a smooth and continuous organic form, unique in appearance and extremely comfortable. It was originally designed in stamped metal, which proved too costly and prone to rust. Instead, a new manufacturing technique was utilized that allowed fiberglass to cure at room temperature. A boat builder, who was familiar with fiberglass, helped build early prototypes to prove out the concept.[9]

Jasper Morrison's Air chair (1999) takes reduction of parts to the extreme, since it is constructed out of a single piece of injection-molded polypropylene. Inert gas is pumped into the center of molten plastic, resulting in a solid, light, and economical product that comes off the assembly line fully formed.

Konstantin Grcic's Chair_One (2004) uses a die-cast aluminum process to achieve an original form that is at once full of voids, yet very solid; angular and sculptural at a glance, yet surprisingly more comfortable than it looks. Grcic says that "a bad chair is one that performs all the requirements, but remains just a chair. One that I use to sit on, but then I get up and it didn't mean anything to me."[10] He believes that what makes good design is something hidden in the relationship you have with the object.

Design for Context

Of the chairs mentioned above, the fiberglass model by the husband and wife design team of Charles and Ray Eames

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[9] 'Molded Plastic Chairs | Eames Designs'. 2015. Accessed January 22. http://eamesdesigns.com/library-entry/molded-plastic-chairs/.

[10] NOWNESS'. 2015. Accessed January 22. https://www.nowness.com/series/on-design/on-design-konstantin-grcic.

deserves further attention. The Eames are known for their enduringly popular classic furniture designs, most of which are still being manufactured by Herman Miller. Their work often utilized new materials such as molded plywood, wire mesh, and the aforementioned fiberglass.

The Eames Molded Fiberglass chair won second prize in the 1949 International Low-Cost Furniture Competition, primarily for its innovative base that allows it to adapt to different uses and environments such as nursery, office, home, or school. This notion of adaptability to context is a theme that runs through much of Eames' multidisciplinary work, which spanned products, photography, film, and architecture.

Figure 1.x Powers of Ten image

In 1977, Charles and Ray made *Powers of Ten,* a short documentary film that explores context by examining the effect of scale. The film begins at the level of human perception, with a couple having a picnic on the Chicago lakeshore, and then zooms out by consecutive factors of ten to reveal the entire universe before zooming inward to the scale of a single atom. The film has been influential in encouraging designers to consider adjacent levels of context — the details of how a design relates to the next level of scale, whether that's a room or a body part. These details are often overlooked, but as Charles once explained, "The details are not the details, they make the product."[11]

Designing for Behavior

Continuous evolution of manufacturing capabilities, business needs, human factors, materials, and contexts created a wide spectrum of ways in which Industrial Designers could express a

[11] 'Designers Charles and Ray Eames - Herman Miller'. 2015. Accessed January 22. http://www.hermanmiller.com/designers/eames.html.

particular product. However, it was the embedding of electronics into products that resulted in the most radical shift in both design possibilities and people's relationships with objects. For the first time, the potential behavior and functionality of a product was disconnected from its physical form.

Consider the difference between a chair and a radio. Although chairs vary widely in form and materials, the way that a person uses them is largely self-evident, without instruction or confusion. With a radio, the functionality is more abstract. The shape of a knob may communicate its ability to turn, but not necessarily what it controls.

A designer of electronic products uses a mix of different controls, displays, colors, and words to communicate the purpose of various components and provide clarity in how they work together. Done poorly, a user can be overwhelmed and confused by the possibilities and interrelationships, requiring them to read a manual before operating a product.

Figure 1.x Dieter Rams image (*TBD)*

German Industrial Designer Dieter Rams is a master at simplifying these complex electronic products to their essential form. Rams designed simple, iconic products for German household appliance company Braun for over 40 years, where he served as the Chief Design Officer until his retirement in 1995. His understated approach and principle of “less but better” resulted in products with a timeless and universal nature. He was restrained in the amount of language used to label knobs and switches, relying on color and information graphics to communicate a product’s underlying behavior in an intuitive manner.

In a similar spirit to this book, Dieter Rams has compiled a list of "Ten Principles of Good Design"[12] that is rooted in his Industrial Design experience, but relevant to designers of any discipline. Our principles overlap with Rams' choices, emphasizing those that best relate to UX and Interaction Design challenges. Much has been written about Rams' ten principles, and we encourage you to review it as a jumping off point for further learning and inspiration.

Rams' has influenced many contemporary designers, and between 2008 and 2012 the *Less and More* retrospective of his work travelled around the world, showcasing over 200 examples of his landmark designs for Braun.[13] During an interview with Gary Hustwit for his 2009 film *Objectified,* Dieter Rams said that Apple is one of the few companies today that consistently creates products in accordance with his principles of good design.

Figure 1.x Apple / Jonathan Ive example *(TBD)*

It's no surprise that Jonathan Ive, Apple's Senior Vice President of Design, is a fan of Rams' work and ethos. Since joining Apple in the early 1990s, the British industrial designer has overseen the launch of radical new product lines with unique and groundbreaking designs, including the iMac, iPod, and iPhone. Regarding these disruptive innovations, he emphasizes that being different does not equate to being better. In reference to the first iMac design, Ive has said that "the goal wasn't to look different, but to build the best integrated consumer computer we

[12] 'Dieter Rams: Ten Principles for Good Design'. 2015. Vitsoe. Accessed January 22. https://www.vitsoe.com/gb/about/good-design.

[13] 'Less and More: The Design Ethos of Dieter Rams'. 2015. SFMOMA. Accessed January 22. http://www.sfmoma.org/exhib_events/exhibitions/434.

could. If as a consequence the shape is different, then that's how it is."[14]

Ive’s approach seems to echo and build upon Rams’ motto of “less but better,” although the products that Apple makes are significantly more complex than the ones that Rams’ designed for Braun. The physical enclosure and input controls of a computing device are similar to legacy electronics, but the mutable functionality of software on a screen is its own world of complexity. The introduction of the personal computer significantly widened the separation of form and function.

In 2012, Ive was knighted by Queen Elizabeth for his landmark achievements. In the same year Sir Jonathan Ive’s role at Apple expanded, from leading Industrial Design to providing direction for all Human Interface design across the company.[15] This consolidation of design leadership across physical and digital products speaks to the increasing overlap between these two mediums. The best user experience relies on a harmonious integration of hardware and software, an ongoing challenge throughout the history of computing.

Computing Revolution

Interaction with the first personal computers was entirely text-based. Users typed commands and the computer displayed the result, acting as little more than an advanced calculator. Computers had shrunk in size, but this direct input and output echoed the older mainframe technology. Even the common screen width of 80 characters per line was a reference to the

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[14] Kahney, Leander. 2013. Jony Ive: The Genius Behind Apple’s Greatest Products. United States: Penguin Putnam Inc.

[15] ‘Apple Announces Changes to Increase Collaboration Across Hardware, Software & Services’. 2015. Apple Inc. Accessed January 22. https://www.apple.com/pr/library/2012/10/29Apple-Announces-Changes-to-Increase-Collaboration-Across-Hardware-Software-Services.html.

number of holes in a punch card. In the relationship between people and technology, these early computers favored the machine, prioritizing efficient use of the small amount of available processing power.

This early personal computing era can be likened to the time before the Industrial Revolution, with digital craftsmen making machines primarily for themselves or their friends. These computers were the domain of hobbyists, built from kits or custom assembled by enthusiasts who shared their knowledge in local computer clubs.

In 1968, at the Fall Joint Computer Conference in San Francisco, Douglas Engelbart held what became known as “The Mother of All Demos,” in which he introduced the oN-Line System, or NLS. This 90-minute demonstration was a shockingly prescient display of computing innovation, introducing for the first time modern staples such as realtime manipulation of a graphical user interface, hypertext, and the computer mouse.

Early computing pioneer David Liddle talks about the three stages of technology adoption: enthusiasts, professionals, and consumers. It was the introduction of the graphical user interface, or GUI, that allowed the personal computer to begin its advancement through these phases.

The GUI was the key catalyst in bringing design to software. Even in its earliest incarnations, it signaled what computers could be if they prioritized people, increasing usability and accessibility despite the incredible amount of processing power required. But making software visual did not automatically make computers usable by ordinary people. That would require designers to focus their efforts on the world behind the screen.

In his book *Designing Interactions*, IDEO co-founder Bill Moggridge relates a story about designing the first laptop computer, the GRiD Compass, in 1979.[16] The industrial design of the Compass had numerous innovations, including the first clamshell keyboard cover. It ran a custom operating system called GRiD-OS, which featured an early graphical user interface, but with no pointing device. Using this GUI prompted him to realize for the first time that his role as a designer shouldn't stop at the physical form, but include the experiences that people have with software as well.

Years later, Bill Moggridge, along with Bill Verplank, would coin the term "Interaction Design" as a way of distinguishing designers who focus on digital and interactive experiences from traditional Industrial Design.

Pioneering computer scientist and HCI researcher Terry Winograd has said that he thinks "Interaction Design overlaps with [Industrial Design], because they both take a very strong user-oriented view. Both are concerned with finding a user group, understanding their needs, then using that understanding to come up with new ideas."[17] Today we take for granted this approach of designing software by focusing on people, but in Silicon Valley of the 1980s the seeds of human-centered computing were only just being planted.

The Bifurcation of Physical and Digital

In the 1970's, influenced by Douglas Engelbart's NLS demonstration, numerous research projects at Xerox PARC explored similar topics. The Xerox Star, released in 1981, was the first commercially available computer with a GUI that utilized the now familiar desktop metaphor. This structure of a virtual office correlated well with the transition that computing was attempting to make from enthusiasts to professional users.

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[16] Moggridge, Bill. *Designing Interactions*. Cambridge, Mass.: MIT, 2007.

[17] Preece, Jenny, Yvonne Rogers, and Helen Sharp. *Interaction Design: Beyond Human-computer Interaction*. New York, NY: J. Wiley & Sons, 2002.

The graphical desktop of the Star featured windows, folders, and icons, along with a “What You See Is What You Get” (WYSIWYG) approach that allowed users to visually see and manipulate text and images in a manner that represented how they would be printed. These features, amongst others, were a direct influence on both Apple and Windows as they developed their own GUI-based operating systems.

In 1983 Apple released the Lisa, their first computer to utilize a GUI. A year later they launched the Mac, which became the first GUI-based computer to gain wide commercial success. Microsoft debuted Windows 1.0 in 1985 as a GUI overlay on its DOS operating system, but adoption was slow until 1990 with the release of the much-improved Windows 3.0.

Although their operating systems had many similarities, the business models of Apple and Microsoft could not have been more different. Apple was a product company, and made money by selling computers as complete packages of hardware and software. Microsoft made no hardware at all. Instead, they licensed Windows to run on compatible computers made by third-party hardware manufacturers that competed on both features and price.

As businesses embraced computers in every office they overwhelmingly chose Windows as a more cost effective and flexible option than the Mac. This majority market share in turn created an incentive for software developers to write programs for Windows. Bill Gates had found a way to create a business model for software that was completely disconnected from the hardware it ran on. In the mid-1990s even Apple briefly succumbed to pressure and licensed their Mac OS to officially run on Macintosh “clones.”

The potential for design integration that Bill Moggridge had seen between hardware and software was difficult within this business reality. The platform approach of the Windows operating system had bifurcated the physical and digital parts of the personal computer. Companies tended to focus on hardware or software exclusively, and designers could make few assumptions about how they were combined by end users.

Although the GUI used a spatial metaphor, the variety of monitor sizes and resolutions made it difficult to know how the on-screen graphics would be physically represented. The mouse and the standard 102-key keyboard acted as a generic duo of input devices, dependable but limited. Software emerged as a distinct and autonomous market, which contributed to the largely separate evolution of Interaction and Industrial Design.

As software took on new and varied tasks, Interaction Designers sought inspiration and expertise not only from traditional design fields but from psychology, sociology, communication, and computer science. Meanwhile, Industrial Designers continued to focus primarily on the physical enclosures of computers and input devices. After all, computing was only one of the full range of industries within Industrial Design's purview.

Information Revolution

In 1982 the Association for Computing Machinery (ACM) recognized the growing need to consider users in the design of software by creating the Special Interest Group on Computer–Human Interaction (SIGCHI). Shortly after, the field of Human-Computer Interaction (HCI) emerged as a recognized sub-discipline of computer science.

Because designing how people use digital systems was so new, and because the task required integrating so many fields of knowledge, it became a vibrant research area within multiple

fields of study (psychology, cognitive science, architecture, library science, etc.).
However, at the end of the day, making software always required the skills of a software engineer. That changed in 1993 with the launch of the Mosaic web browser, which brought to life Tim Berners-Lee's vision for the World Wide Web.

The web was an entirely new medium, designed from the ground up around networks and virtuality. It presented a clean slate of possibility, open to new forms of interaction, new interface metaphors, and new possibilities for interactive visual expression. More importantly, it was accessible to anyone who wanted to create their own corner of the web, using nothing more than the simple HyperText Markup Language (HTML).

From the beginning, web browsers always came with a "View Source" capability that allowed anyone to see how a page was constructed. This openness, combined with the low-learning curve of HTML, meant a flood of new people with no background in computer science or design began shaping how we interact with the web.

The web hastened the information revolution and accelerated the idea that "information wants to be free." Free to share, free to copy, and free of physicality. Microsoft Windows had distanced software from the machine it ran on, but the web pushed interactive environments into an entirely virtual realm. A website could be accessed from any computer, regardless of size, type, or brand.

By the mid-1990s Wired Magazine described web users as Netizens, socializing in virtual reality was an aspiration, and there was growing excitement that e-commerce could replace brick-and-mortar stores. The narrative of progress in the late 20th century was tied to this triumph of the virtual over the physical. The future of communication, culture, and economics increasingly looked like it would play out in front of a keyboard, in the world on the other side of the screen.

Standing on the shoulders of previous pioneers, the flood of designers native to the web used the very medium they were building to define new interaction patterns and best practices. The web had brought about the consumer phase of computing, expanding the scope and influence of Interaction Design to a level approaching its older, Industrial cousin.

Smartphones

Early mobile phones had limited functionality, primarily centered on making voice calls and sending SMS messages. The introduction of the Wireless Application Protocol (WAP) brought a primitive browser to phones so they could access limited information services like stocks, sports scores, and news headlines. But WAP was not a full web experience, and its limited capabilities, combined with additional usage charges, led to low adoption.

Even as mobile phones began accumulating additional features such as color screens and high-quality ringtones, their software interactions remained primitive. One contributing factor was the restrictive environment imposed by the carriers. The dominant wireless networks (AT&T, Sprint, T-Mobile, and Verizon) didn’t make the operating systems that powered their phones, but they controlled how they were configured and dictated what software was pre-installed.

Decisions about which applications to include were often tied to business deals and marketing packages, not consumer need or desire. The limited capabilities and difficult installation process for third-party apps meant that they were not widely used. This restrictive environment was the opposite of the openness on the web, a discrepancy that was strikingly clear by 2007 when Apple launched the iPhone and disrupted the mobile phone market.

Just as Microsoft's Windows OS created a platform for desktop software to evolve, it was Apple's turn to wield a new business model that would dramatically shift the landscape of software and interaction.

Although the original iPhone was restricted to the AT&T network, the design of the hardware and software was entirely controlled by Apple. This freedom from the shackles of the carrier's business decisions gave the iPhone an unprecedented openness.

For the original release, that openness was focused on the web. Mobile Safari was the first web browser on a phone to render the full web, not a limited WAP experience. A year later, an update to iOS allowed third-party applications to be installed. This was the beginning of yet another new era for Interaction Design, as the focus shifted not only to a mobile context but to the reintroduction of physicality as an important constraint and design opportunity.

The interaction paradigm on the iPhone, and the wave of smartphones that have since emerged, uses direct touch manipulation to select, swipe, and pinch as you navigate between and within apps. Touchscreens had existed for decades, but this mass standardization on one particular screen size awoke Interaction Designers to consider the physical world in a way that desktop software and the web never did. Respecting the physical dimensions of the screen became critically important to ensure that on-screen elements were large enough for the range of hands that would interact with them.

Knowing the physical dimensions of the touchscreen also led to new opportunities, allowing designers to craft pixel-perfect interface layouts with confidence in how they would be displayed to the end user. This ability to map screen graphics to physical dimensions was concurrent with the rise of a new graphical interface style that directly mimicked the physical world. This visual style, often called skeuomorphism, presents software interfaces as a mimic of physical objects, using simulated textures and shadow to invoke rich materials such as leather and metal.

Although often heavy-handed and occasionally in bad taste, these graphical references to physical objects, combined with direct touch manipulation, reduced the learning curve for this new platform. Katherine Hayles, in her book *How We Became Posthuman* describes skeuomorphs as "threshold devices, smoothing the transition between one conceptual constellation and another."[18] The skeuomorphic user interface helped smartphones become the most rapidly adopted new computing platform ever.[19]

Today, skeuomorphic interface styles have fallen out of favor. One reason is that we no longer need their strong metaphors to understand how touchscreens work; we have become comfortable with the medium. Another factor is that touchscreen devices now come in such a wide variety of sizes that designers can no longer rely on their design rendering with the kind of physical exactness that the early years of the iPhone afforded.

The iPhone was also a bellwether of change for Industrial Design. Smartphones are convergence devices, embedding disparate functions that render a variety of single-purpose devices redundant. Examples of separate, physical devices that

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[18] Hayles, Katherine. How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics. Chicago, IL: University of Chicago Press, 1999. 17.

[19] DeGusta, Michael. "Are Smart Phones Spreading Faster than Any Technology in Human History?" Accessed January 20, 2015. http://www.technologyreview.com/news/427787/are-smart-phones-spreading-faster-than-any-technology-in-human-history/.

are commonly replaced with apps include the calculator, alarm clock, audio recorder, and camera. Products that traditionally relied on Industrial Designers to provide a unique physical form were being dematerialized, a phenomena that investor Marc Andreessen refers to as “software eating the world.”[20]

At the same time, the physical form of the smartphone was very neutral, designed to disappear as much as possible, with a fullscreen app providing the device’s momentary purpose and identity. This was a shift from the earlier mobile phones, where the carriers differentiated their models primarily through physical innovation such as the way a phone flipped open or slid out to reveal the keypad.

Even as Interaction Designers introduced physical constraints and metaphors into their work, Industrial Designers saw their expertise underutilized. The rise of the smartphone made inventor and entrepreneur Benny Landa’s prediction that “everything that can become digital, will become digital” seem truer than ever. For Industrial Design, which throughout the 20th century had always defined the latest product innovations, this was a moment of potential identity crisis.

Smart Everything

The general purpose smartphone continues to thrive, but today these convergence devices are being complemented by an array of single-use “smart” devices. Sometimes referred to as the Internet of Things, these devices use embedded sensors and network connectivity to enhance and profoundly change our interactions with the physical world.

This introduces design challenges and possibilities well beyond a new screen size. Smart devices can augment our natural

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[20] "The Man Who Makes the Future: Wired Icon Marc Andreessen | WIRED." Wired.com. Accessed December 17, 2014. http://www.wired.com/2012/04/ff_andreessen/5/.

interactions that are already happening in the world, recording them as data or interpreting them as input and taking action. For example:

- The Fitbit activity tracker is worn on your wrist, turning every step into data.
- The Nest Protect lets you wave away a smoke alarm caused by a faulty detection, like when it's accidently set off while cooking.
- The August Smart Lock senses your approach and automatically unlocks the door.
- The Apple Watch lets you pay for goods by simply raising your wrist to a checkout reader.

The smartphone required designers to consider the physicality of users in terms of their fingertips. These new connected devices require a broader consideration of a person's full body and presence in space.

Over the last few decades, opinions have oscillated on the superiority of general purpose technology platforms versus self-contained "information appliances." Today's "smart devices" represent a middle ground, since these highly specialized objects often work in conjunction with a smartphone or web server that provides access to configuration, information display, and remote interactions.

Open APIs allow devices to connect to and affect each other, using output from one as the input to another. Services such as IFTTT (IF This Then That) make automating tasks between connected devices trivial. For example, one IFTTT recipe turns on a Philips Hue light bulb in the morning when your Jawbone UP wristband detects that you have woken up.

Unfortunately, seamless experiences between connected devices are rare and too often the smartphone is treated as the primary point of interaction. This makes sense when you want to change your home's temperature while at the office, or check the status of your garage door while on vacation. But if adjusting your bedroom lighting requires opening an app, it certainly doesn't deserve the label "smart."

We find ourselves in yet another transitional technology period, where physical and digital blur together in compelling but incomplete ways. There is potential for connected devices to enhance our lives, giving us greater control, flexibility, and security in our interactions with everyday objects and environments. There is promise that we can seamlessly combine our digital and physical lives, reducing the need for constant engagement with a glowing screen in favor of more ambient and natural interactions within our surroundings. But there is also a danger that connecting all of our things simply amplifies and extends the complexity, frustration, and security concerns of the digital world.

The technical hurdles for the Internet of Things are being rapidly overturned. The primary challenge today lies in designing a great user experience.

Industrial Design Principles for UX and Interaction Design

Connected devices represent a new era for both Industrial and Interaction Design. Because this new paradigm intertwines physical and digital, designing a good experience will require the two disciplines to overlap like never before. Industrial Designers will need new sensitivities towards complex system states, remote interactions, privacy considerations, and the open-ended potential of how input can map to output. Interaction Designers will need to embrace physical and spatial possibilities, consider a person's whole body, and use new forms of feedback less reliant on a screen.

In the past, we could often draw a clean line between hardware and software. As that line blurs, both Industrial and Interaction Design will need to combine their expertise. In the 1990s the emergence of the web led designers to develop new interaction patterns for an entirely new medium. A similar definition of best practices for connected devices will need to occur, but this time the process can be more integrative, drawing from knowledge embedded in both disciplines. The principles that have informed and defined Industrial Design for the last century are a good starting point for Interaction Designers to find new ways of approaching, framing, and evaluating their work.

The ten principles in this book represent ways that Industrial Designers have approached design problems across a diverse array of industries and eras. Each principle is explained and situated within Industrial Design history, and then reframed for a modern Interaction Design context. The chapters can be read in any order, so you can return to and review relevant principles when starting a new project.

The goal is not that Interaction Designers should all become Industrial Designers, or vise versa, but that these two design disciplines should find an overlap of skills and approaches appropriate to a world where the traditional distinctions between physical and virtual are increasingly blurred.

Chapter 2
Sensorial

Engage as many senses as possible

We connect with the world around us through our senses, and describe the process of understanding something new as "making sense of it." The pervasiveness of sensing makes it easy to take for granted, as we integrate our five common senses of touch, hearing, sight, smell, and taste without conscious thought or effort. Similarly, as designers create objects and interactions, it can be easy for them to overlook the richness of human sensorial capabilities. By primarily considering the unavoidable senses of sight and touch, many designers seem to treat humans as little more than eyeballs and fingers.

Industrial Designers, because of the physicality of their work, have historically been able to engage a broader range of senses than Interaction Designers. We obviously see and touch objects, but we also hear something when we place an object on a surface, or even smell certain materials when we hold them closely. We generally don't eat our objects, but increasingly designers are collaborating with chefs and food companies to support the smell and taste of our eating experiences.

Beyond the traditional five senses, we perceive our presence in the physical world through non-traditional and combinatorial senses as well. We have a sense of balance that helps us walk and carry objects, a sense of pain that keeps us from over damaging our body, and a sense of temperature that is finely tuned to our human tolerances. Our kinesthetic sense tells us the position of our body parts relative to each other, and helps us detect weight and tension when we grasp and hold an object.

All of these senses are commonly used with intention by Industrial Designers. The weight of a fountain pen, the balance of a snow shovel, the smell of a leather wallet, and the warm welcome of a heated car seat are all purposefully designed. In this chapter, we will demonstrate how sensoriality is central to Industrial Design by looking at the core foundations of the discipline such as formgiving, color, materials, and finish. We'll look at products that transition between multiple states, where engaging the senses through action feels good enough to be addictive. We'll look at ways that products can delight us through sensorial reaction to our input, and how designers may even influence the smell and taste of food.

As digital systems escape the screen, the sensorial methods that Interaction Designers can utilize for both input and output will expand. Engaging this full range of human senses, in ways both obvious and subtle, is one of the most important things that Interaction Designers and UX professionals can learn from Industrial Design.

Formgiving

Fundamental to Industrial Design is idea of formgiving, the process of determining the best shape, proportion, and physical architecture for a three-dimensional object. This additional dimension, beyond the flat 2D world of a screen, presents a multitude of new challenges and sensorial possibilities. This is why Industrial Designers often start sketching physically first, shaving foam or wood with their hands to craft the basic depth, dimensionality, and proportions of an object before modeling it on a computer. Should an object be thick and narrow, or thin and wide? Feeling the difference in your hand is often the only way to know.

In giving an object form, a designer is trying to both meet a human need and create a product with character, something that is unique, differentiated, and better in the marketplace. As the form evolves through the design process it must be evaluated holistically, seeing how each change affects the front, back, and sides from every angle. Additional constraints might be informed by the way an object will be held, or what function it performs. Certain challenges, such as accommodating bulky embedded electronics, might be addressed by prioritizing particular viewing angles, creating the illusion of an object being thicker or thinner when viewed from particular sightlines. A good example of this is the wedged-shaped side profile of the MacBook Air.

On-screen elements in a user interface tend to default to rectangular shapes: windows, buttons, bars, and lists. Obviously, it is possible to make interfaces with other shapes, but the very idea that there is a default can influence and limit Interaction Designers. Even if less conventional shapes are used within an interface they are framed within a larger system of rectangles that a designer has little control over, not least of which is the screen itself. While some physical objects are part of a branded family, most are standalone forms that free Industrial Designers to consider a much wider range of shapes. This allows shape to become a defining personality for an object, whether round, square, sharp, soft, or organic. A product's shape is the first thing you see.

Rarely is a product constructed from a single shape, so formgiving usually includes a process of composition as well, shaping various individual elements and then arranging them into a greater form. Consider a simple FM radio with a frequency dial, volume knob, screen, and speaker grill. The overall shape of the radio may be a starting point, but the form is not complete until all of the elements are composed in relationship to the whole.

Similar to composition, the way that elements connect to each other is a key consideration in more complex formgiving. The joint on a chair, the hinge on a laptop, the clamshell or slider on a mobile phone. For products with moving parts, these connections and architectures are fundamental to the overall form and act as a bridge between multiple states of the product. A laptop can be open or closed, and both of those states should feel related and work together.

Color, Materials, Finish (CMF)

Along with formgiving, Industrial Designers craft sensorial experiences by utilizing the building blocks of color, materials, and finish, or CMF. Combining these three in an acronym makes sense since they are often chosen and used in combination with each other to create a perception of quality, indicate affordances for use, and communicate brand identity.

All three elements involve consideration for the sense of vision, but materials and finishes provide designers with the additional opportunity to purposefully engage the sense of touch. Should an object feel hard or soft when you touch it? Should it be cold or warm against your skin? Should it be glossy or matte? Light or heavy? These are all carefully considered and often combined to create a desired product experience.

The unique properties of a material can be the catalyst for a design idea, even before explorations of formgiving have begun. However, this inspiration requires that designers have physical access to new materials so they can feel and experiment with them. In 1999, IDEO started their Tech Box project,[1] which collects examples of interesting materials and mechanisms from a range of products and industries and distributes them to all the company's offices. Designers can rummage through the

[1] "Tech Box." IDEO. Accessed January 25, 2015. http://www.ideo.com/work/tech-box/.

collection for inspiration when starting a new project. This kind of reference library is an important tool in allowing materials to spark new design ideas.

Like formgiving, CMF is a balancing act between the desired sensorial experience, feasibility of manufacturing at scale, and overall cost of the product. To achieve that balance, designers must maximize the impact of every CMF choice. An example of a company that has made the most from simple materials and color is Fiskars, whose classic orange-handled scissors have sold more than 1 billion units since their introduction in 1967.

Figure 2.x: Fiskars "Classic" orange-handled scissors

Fiskars has been making scissors since the 1830s,[2] originally for professional use, with wrought iron handles that matched the material of the blades, and later with brass to increase comfort. In the 1960s, new manufacturing capabilities made it possible to create scissors with ground metal blades that could outperform their forged counterparts. These lightweight blades were paired with another mid-century innovation, the molded plastic handle. The combination of these two materials allowed Fiskars to offer higher quality, more comfortable scissors at a price that was affordable to everyone, not just tailors and seamstresses.

The recognizable orange color of the scissor's handle has a serendipitous origin story. At the time that the first plastic-handled scissor prototypes were made, Fiskars also had a line of juicers in production. The injection molding machine had leftover orange dye in it, so the initial handles were produced in orange. Other colors were tried as well, including red, green, and black, but orange was selected by the Fiskars board in a final vote of 9 to 7. That decision has had a profound influence on the company.

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[2] Kulvik, Barbro, and Antti Siltavuori. The DNA of a Design: 40 Years, 1967-2007. Helskinki: Fiskars, 2007.

Today, the Fiskars Orange® color is an essential part of the company's brand. It was registered as a trademark in the USA in 2007, following its Finish trademark in 2003.[3] The color has successfully extended beyond the scissor line to other Fiskars products, making their garden tools and crafting supplies instantly recognizable, even at a distance. In recognition of their simple appeal and design legacy the Classic orange-handled scissors are part of the permanent collection of the Museum of Modern Art (MoMA) in New York.[4]

Another company whose innovative handle design can be found in the MoMA collection is OXO,[5] whose soft rubber grips with ribbed finishes transformed the commodity utensil category and launched an entire product portfolio built around the sense of touch.

Figure 2.x: OXO Good Grips Peeler

The origin story of OXO comes not from the introduction of new manufacturing capabilities like Fiskars, but with observation of an unmet need in the marketplace. Founder Sam Farber, who was ostensibly retired from a career in the kitchenware business, was inspired by seeing his wife Betsy struggle when using a standard metal vegetable peeler. Betsy was suffering from arthritis in her hands, and the design of the all-metal implement was optimized not for comfort or support, but to be manufactured as cheaply and easily as possible.

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[3] "Orange-Handled Scissors: Superior Cutting Since 1967." Fiskars. Accessed January 25, 2015. http://www2.fiskars.com/content/download/22952/394664/file/OHS Backgrounder.pdf.

[4] "Olof Backstrom. Scissors (1960)." MoMA.org. Accessed January 25, 2015. http://www.moma.org/collection/object.php?object_id=3250.

[5] "Smart Design, New York. Good Grips Peeler (1989)." MoMA.org. Accessed January 25, 2015. http://www.moma.org/collection/object.php?object_id=3758.

Farber worked with Smart Design in New York to make a better handle based on the principles of Universal Design, a philosophy that prioritizes designing for the broadest group of people possible, including those with special or marginalized needs.[6] Smart Design prototyped forms that would be easy to hold, regardless of hand size, and explored materials that would support varying levels of physical capability.

The final design is a handle made of a soft rubber called Santoprene,[7] in an oval shape that evenly distributes the user's force during use. The non-slip material provides comfort and grip, even when wet, while withstanding exposure to kitchen oils and dishwashers. On the sides, small ribs or "fins" are cut into the rubber, providing an affordance for where to hold. These tactile elements make the OXO brand recognizable at first touch, even without looking.

The Good Grips handle design has been applied to 100s of products since its introduction 1990. But unlike Fiskars, which used materials innovation to reduce the cost of the scissors, OXO products are often more expensive than their traditional counterparts.[8] It's a compelling demonstration that people are willing to pay for good design, and that taking a Universal Design approach can lead to products with broad appeal.

The stories of both Fiskars and OXO show how simple and disciplined use of colors, materials, and finishes can define a brand that extends across an entire product line. This might remind Interaction Designers of the consistency that permeates an operating system, where signature elements such as menu bars or drop-down lists are presented in a consistent manner so

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[6] "About OXO." About Us. Accessed January 25, 2015. http://www.oxo.com/AboutOXO.aspx.

[7] "FAQs." OXO. Accessed January 25, 2015. http://www.oxouk.com/faq.aspx.

[8] "Identifying New Ideas for Breakthrough Products." Accessed January 25, 2015. http://www.ftpress.com/articles/article.aspx?p=24132&seqNum=4.

that users know immediately what to expect and how to perform similar actions.

Beyond consistency though, it is often the CMF of a product that draws us to it. As objects become increasingly connected and computational, it's important not to lose these positive, tactile qualities that makes us want to have them in our lives. For example, instead of a raw LED providing feedback, a light might be placed under a frosted glass surface. Or, instead of a touchscreen for input, sensors might be placed under a thin veneer of wood. This is not about hiding technology, but finding ways to integrate it with the same rigor that goes into all CMF selections.

Multi-sensorial and Luxury Products

Straightforward use of color or a single material can be an innovative advancement for simple tools, but just as most digital products require multiple interconnected states to result in a good experience, a more complex physical product requires bringing together a mix of sensorial moments. By engaging multiple senses, at every scale and detail, the overall experience can transcend its parts.

Figure 2.x: Leica Camera

“Shooting with a Leica is like a long tender kiss, like firing an automatic pistol, like an hour on the analyst's couch.” —Henri Cartier-Bresson

Cameras can inspire intense loyalty from photographers based not only on how they perform, but also how they feel. A good camera becomes an extension of the photographer's sense of vision, capturing what they see with minimal interruption. Few brands have spawned as much obsession amongst photographers as the German manufacturer Leica.

Leica has been making cameras since the mid-1800s, and even though today's models are digital, they feature tactile, analog controls similar to the earliest models. This decision is driven by more than nostalgia, since familiar physical controls allow a photographer to keep their eye looking through the viewfinder while they adjust the dials for shutter speed, aperture, and focus. Unlike selecting on-screen menu items, twisting an aperture control can be done without looking, and the reassuring click of each demarcation on the dial can be felt and heard.

A Leica is a triumph of engineering, but also of form and finish, the feel of each dial and marking on the camera body building muscle memory through use, avoiding a fumble that could lead to a missed shot. It's the integration of these tiny details, along with the build quality and craftsmanship that fosters such passion and commands a premium price.

Leica craftsmanship is celebrated to the point of fetish. For example, the Leica T camera body is machined out of a solid block of aluminum.[9] The marketing materials for the camera boast that the body is hand polished, and a video ad[10] released on their website showcases the entire 45 minute process in closely cropped shots of gloved hands at work. The ad's voiceover boasts that it takes "around 4,700 strokes to finish each body," asking the viewer in the end if they can see the difference, and reassuring them that "you can most certainly *feel* it."

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[9] "Leica T Camera System." Accessed January 25, 2015. http://us.leica-camera.com/Photography/Leica-T/Leica-T-Camera-System.

[10] "The Most Boring Ad Ever Made?" Vimeo. Accessed January 25, 2015. http://vimeo.com/92073118.

The Leica M9-P, Edition Hermès[11] is an example of how detailed finishes and subtle sensorial experiences can elevate a product to the level of luxury. In collaboration with the eponymous Parisian fashion house, this limited edition camera is wrapped in a soft, ochre-colored calfskin leather. The metal body underneath was redesigned for this special edition by the automotive designer Walter de'Silva, and the exposed portions of the metal are even smoother than the well polished standard edition. The contrast of materials heightens the user's awareness of each as their fingers shift from holding the warm, soft, natural leather to adjusting the cold, hard aluminum controls.

The sensorial experience extends beyond the camera itself though, with a strap made of matching calfskin, an Hermes designed camera bag, and a two-volume book of photographs from Jean-Louis Dumas, shot with a Leica M. These items are packaged alongside the camera lenses, in a fabric-coated custom display box that includes a set of white gloves, further emphasizing the museum-like quality of the overall package. All of this can be yours for only $25,000 or $50,000, depending on which limited edition package you choose.

As we've seen, there are examples of CMF choices that can make a product more affordable, or push it well out of reach for all but the most wealthy. The more senses that a product engages, through high-quality materials or finishes, the more luxurious it can appear.

Lightweight scissors that still cut well are desirable, but a lightweight luxury item might appear "cheap." Even with the use of aluminum bodies, Leica cameras are known for their significant heft. It's well documented that people perceive weight

[11] "Leica Creates M9-P Hermès 18MP Rangefinder Special Editions." DPRreview. Accessed January 25, 2015. http://www.dpreview.com/articles/5424047475/leica-creates-m9-hermes-edition-18mp-full-frame-rangefinder-camera.

as a signifier of quality. One of the studies documenting this phenomena can be found in 2009 issue of the journal Psychological Science,[12] where researchers published a paper entitled “Weight as an Embodiment of Importance.” In their study, they found that varying the weight of a clipboard used by participants altered their behavior and influenced their opinions. Designers wishing to capitalize on this kind of psychological influence can make the appropriate materials decisions, though care should be taken that these choices are still authentic to the purpose of the product. This topic is explored in more depth within the *Honesty* chapter.

On top of high-quality design, scarcity is often utilized to further differentiate a standard and luxurious product. This invocation of luxury is something that has traditionally been very difficult for Interaction Designers to achieve. After all, what is a luxurious interaction? For purely digital products, the ability to create unlimited copies of digital resources makes scarcity too artificial to resonate as luxurious. Offering a limited edition with an improved user experience also comes off as more unfair than special. Digital experiences seem to be evaluated through a more egalitarian lens.

However, for the increasing number of products that integrate digital and physical, there are many untapped opportunities to explore and define luxurious interactions. For all of its fine materials and finishes the Leica M9-P, Edition Hermès uses the same firmware, on-screen graphics, and interactions on its digital screen as the less luxurious standard edition. How might the on-screen interactions better match the overall feel of the camera? How might digital and physical be integrated in a way that seems inherent and specific to this particular camera? At what point will luxury consumer’s changing perception of quality require

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[12] Jostmann, Nils B., Daniël Lakens, and Thomas W. Schubert. "Weight as an Embodiment of Importance." Psychological Science: 1169-174.

stronger digital and physical integration to command a premium price?

Addictive Action

Many products reveal their full set of sensorial qualities only through use. For physical products with multiple states, such as open/closed or on/off, the transition between those states can itself be sensorially satisfying, something more than a means to an end.

The opening and closing of a Zippo lighter feels good. Zippo has used the same design throughout its 80-year history and the "click" of a Zippo flipping open is recognizable enough to serve as a dramatic moment in over 1,500 television shows and films.[13] Smokers who use Zippo lighters find themselves addicted to more than their cigarettes, absentmindedly flipping their lighter open and closed repeatedly. It would be hard to estimate the ratio of Zippo clicks to lit cigarettes, but it's safe to say that it is far from 1:1.

What fosters this kind of delightfully addictive feeling? What triggers us to do something repeatedly with no apparent purpose? Is this kind of enjoyable transition something that happens by accident, or can it be intentionally designed for? In 1933, the differentiating characteristic in the design of the Zippo lighter was not its resistance to wind, but the ease of opening and lighting it with one hand. It was a success because of the experience it provided, including that distinctive click. It's not surprising that the company founder, George G. Blaisdell, made up the word "Zippo" primarily because he liked the way it sounded.

[13] "Zippo : Then and Now." Zippo. Accessed January 25, 2015. http://www.zippo.com/about/article.aspx?id=1574.

Figure 2.x MonAmi 153 ballpoint pen (composite image with two states, open and closed)

Another addictive transition with a satisfying sound is the repeated clicking of a ballpoint pen, the metronome for office workers everywhere. With each repeated click, the ink reservoir protrudes or retracts from the body of the pen, not always to ready the pen for writing, but simply because it feels and sounds good. The most common addictive clicker is a toggle at the top of the pen, although the classic Korean design of the MonAmi 153 ballpoint pen is even more satisfying and sensorial.

The MonAmi, which means "my friend" in French, is one of the most common items ever produced in Korea,[14] with over 3.3 billion in sales since its introduction in 1963.[15] The ballpoint tip of the MonAmi is revealed by pressing down on the top of the pen, but its retraction back into the body is triggered with a sliding control on the side. These two separate mechanisms create a more natural mapping between the force of the action and the direction of the ink cartridge; the shape of the spring-loaded slider seems like it's just asking to be triggered. Each control results in a unique sound, and the possibility of alternating between single- and two-finger operation adds to the addictive cadence.

A more high-tech product category where satisfying transitions played a differentiating role is the mobile phone market of the early 21st century. The first mobile phones are often referred to as "bricks," in reference to their bulky size as well as their horizontal shape. As phones miniaturized, this basic "bar" form was maintained for many phones, with keyboard and screen always exposed and at the ready.

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[14] "Prominent Designs Symbolize Generations of Korean Lives." Korea.net. Accessed January 25, 2015. http://www.korea.net/NewsFocus/Culture/view?articleId=74101.

[15] "[□□□□ □□□] '□□ □□' □□□ 153." Chosun.com. Accessed January 25, 2015. http://www.chosun.com/site/data/html_dir/2009/02/15/2009021500723.html.

The Motorola StarTAC, released in 1996, was the first phone with a clamshell or “flip” design that protected the keyboard while significantly reducing the overall height. Motorola not only invented the flip phone, but 8 years later designed perhaps its most iconic representation, the Motorola RAZR V3. The thin design, innovative use of materials, and durable flip action helped the V3 model become the best selling flip phone of all time.[16]

The flip design made mobile phones more sensorial. Answering a call with a bar shaped phone was a matter of pressing a button, but on a flip phone the conversation could begin with a physical action, a satisfying flick of the wrist to split the clamshell as you lifted the handset to your ear. Given that people carry their mobile phones with them everywhere, it’s no surprise that this flipping action became an addictive transition that people repeatedly performed even when not answering a call.

Mobile phone manufacturers, keen to capitalize on the success of the flip phone, began a rapid exploration to patent and release phones with unique and innovative form factors. By the time that touchscreen devices eclipsed the market there was a nearly exhaustive set of possible transition types available. Phones could flip, slide, and swivel, but also half-swivel, flip both ways, and bottom pivot.[17]

Figure 2.x Motorola RIZR Z3 slider phone (composite image with two states, open and closed)

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[16] "The 20 Bestselling Mobile Phones of All Time." The Telegraph. Accessed January 25, 2015. http://www.telegraph.co.uk/technology/picture-galleries/9818080/The-20-bestselling-mobile-phones-of-all-time.html?frame=2458999.

[17] "Mobile Phone Evolution: Story of Shapes and Sizes." GSMArena.com. Accessed January 25, 2015. http://www.gsmarena.com/mobile_phone_evolution-review-493.php.

All of these transitions were physical, but not all felt good enough to foster repeated, non-functional fiddling. Perhaps most successful by this metric were the slider phones, such as the Motorola RIZR Z3. In this form factor, the numeric keypad was hidden underneath the slider mechanism, with a 5-way directional pad available in a closed state. This allowed many actions to be performed without actually sliding open the phone. In practice though, it wasn't functional necessity that caused people to slide the phone open and closed repeatedly throughout the day. They did it because it felt and sounded good.

Why does this mechanism feel good enough to invite repeated non-functional triggering? For one, the sliding movement is dampened, with a spring providing slight resistance until it reaches a catch point where the force is reversed and the cover is accelerated to its final open state. This avoids accidental opening, but also results in a satisfying "pop" sound as the mechanism takes over and amplifies your action. Sliding is also easy to perform discreetly with one hand, without requiring wrist or arm movements.

Figure 2.x iOS list view scrolled upwards beyond its final list item

Purely digital products can also exhibit moments that cause delight in repetition. One example is the "bounce" animation at the bottom of a scroll view in Apple's iOS. As the user swipes their finger upward the list scrolls up and off the screen, but when the user reaches the bottom it doesn't just stop abruptly. There is a subtle animation, where the whole list pulls up slightly farther than the last item, before easing back to let the final entry sit at the bottom of the screen.

The functional reason for the scroll view bounce is to act as feedback that the user has reached the bottom of the list. However, even though the animation is purely visual, it "feels" good enough that one can find themselves scrolling again and again to watch the list bounce back. Some apps have built upon this expectation to provide unique and equally addictive animations. For example, Yahoo! News Digest has a large image at the top of each story that zooms in and then snaps back to normal size as the user scrolls upward and lets go.

In many mobile apps, a downward pulling gesture at the top of a list triggers a refresh of content from the server, usually accompanied by an animation. Although done for functional reasons, this action can be addictive as well, leading to repeated pulling well before any realistic expectation of new content being available. A client with a mobile app that has millions of users once told us that repeated pull-to-refresh was so pervasive they had to limit the actual server request to only once every 30 seconds, faking the animated feedback for repeated requests within that time period. It’s a good reminder that addictive actions can bring delight and appeal to a product, but one should be careful of their unintended consequences, whether it’s the need for a physical hinge that’s rated for a much high number of openings or avoiding a server overload.

Delightful Reaction

Lids, switches, and sliders can be satisfying to use, providing direct sensorial feedback that confirms an action and, in the best instances, feel good in the process. However, direct feedback is only one way a product can engage our senses. By reacting to our presence, intention, and continued engagement, a product can be inviting and delightful, coming to life in unique and surprising ways.

Figure 2.x Beosystem 2500

The Danish high-end audio manufacturer Bang & Olufsen (B&O), is known for their unique product designs that push the limits of technology to explore new form factors and interaction paradigms. In 1991, as popular music was shifting from analog to digital formats, B&O released the Beosystem 2500, designed by the late David Lewis. The Beosystem 2500 is an all-in-one stereo featuring a CD-player, cassette deck, and AM/FM radio in an extremely flat vertical design, flanked by a pair of equally flat speakers.

Doors made of smoked glass cover the front of the Beosystem 2500, further emphasizing the flatness of the design. Raising your hand within 10 centimeters of the doors causes them to automatically glide open and turns on an interior light, illuminating the now accessible audio controls. Upon retracting your hand, the doors closes automatically after a 15 second delay, with the lights remaining on to accompany the audio, or turning off if no music is playing.[18]

The use of automatic motion to signal readiness and recognition of intention gives the Beosystem 2500 a sense of life and personality. It lends the stereo a magical quality, and reframes the doors as the "face" of the product, giving them a character beyond their merely functional purpose. The detection of presence and corresponding motion is fairly limited and crude in comparison to today's advanced capabilities, and yet it is enough to provide a sense of animation and lifelike personality.

Another design element that contributes to the sensorial quality of the Beosystem 2500 is the transparent cover on the vertically oriented compact disc holder. As the CD plays, the spinning artwork can be seen through the glass doors, providing a unique visual reference to accompany the audio experience. This celebration of the disc itself is a departure from the popular CD tray mechanisms of the time, which completely enclosed the disc, treating it as a hidden key to unlock the audio.

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[18] "Beosystem 2500." BeoPhile.com. Accessed January 25, 2015. http://beophile.com/?page_id=1122.

Figure 2.x Axor Stark V

The Axor Starck V faucet by Hansgrohe also uses transparency to bring an experience to life, but in a more natural and analog way. Created in collaboration with the French designer Philippe Starck, this clear faucet is made of crystal glass that showcases a unique water vortex created by its base. The faucet design is minimal, acting as a platform to support and celebrate the natural beauty of the swirling water, the texture of its motion, and the sound it creates as the vortex moves upwards and flows into the basin.

Turning on the faucet is a delightful experience because of the way it engages your senses unexpectedly. You assume that water will begin flowing, but are caught off guard by the richness of what is normally a mundane experience of liquid moving silently through an opaque pipe. The Axor Starck V highlights the notion of design as an amplification of what is already there, recognizing the potential of water to engage the senses more than it normally does, and providing the support for that unique experience to happen.

Reaction vs. Feedback

These two very different products instill delight through their reaction to a person’s presence and actions, which goes beyond mapping input to output. They foster more of a conversation, where a person signals intent and the product takes over to enable or perform a multi-part sensorial experience. Whether it’s the choreographed movement of doors and lighting, or the swirling vortex of water with its dramatic beginning and ending scenes, the response takes place over time and relies heavily on motion to engage and communicate with us. It is a conversation, and the speaking role has briefly passed to the product, while still feeling under our control.

In a purely digital product a change of state can be done instantaneously, but it has become common for interaction designers to utilize physics-based motion algorithms to design transitions that feel more “natural.” One example is Tweetbot 3.0 for iPhone, which allows a user to close out of an image detail view by flicking the photo in any direction, causing it to animate off screen in proportion to the speed, direction, and angle of the user’s gesture. The result feels much richer than a simple close button, although ultimately this animated reaction is an abstraction that relates only generically to physical forces, with no intrinsic relationship to the content being acted upon.

As physical products become increasingly embedded with computation and network connectivity they are able to react not only to a user’s direct physical presence, but to changes in remote data as well. Designers of such products should hew towards reactions with an innate connection to the specific material or subject they are working with, resisting the full abstraction that the digital world makes possible.

It’s great that our products can keep track of changes in remote data, but when the object reacts to that change, and starts a conversation with us, it should be done in a manner that strongly communicates the meaning of the data itself. Otherwise our environments will be full of objects trying to engage our senses without us knowing how to interpret their message. An instructive comparison can be found in two of the simplest and earliest explorations of physical objects representing remote data: Ambient Orb and Availabot.

Figure 2.x Ambient Orb

Ambient Orb, created in 2002 as the first product by the company Ambient Objects, is a frosted glass orb with a glowing programmable light inside of it. The color of the light can be associated with variable data sources, and the value of the data is mapped to the glowing hue of the orb. The concept behind the design is to provide glanceable information without a screen, which the Ambient Orb achieves, but only through abstraction that requires a person to have a clear mental model of the programmed ruleset. It works well as an early demonstration of what might be possible with networked objects, but scales poorly in a world full of such objects. Imagine everyone in your family having to remember why the orb on the kitchen counter is now glowing green when it used to be blue. Does it mean the same thing as the green orb in the bedroom?

Figure 2.x Availabot

On the other side of the spectrum, moving from abstract to concrete representation, is the Availabot,[19] a physical representation of your friend's instant messenger presence. Created by Schulze & Webb in 2007, Availabot is a bendy, plastic avatar customized to look similar to a specific person. This hinged likeness unambiguously communicates your friend's availability, standing straight at attention when they are online, or collapsing in a heap when they go away. The idea was that Availabot could utilize rapid prototyping capabilities to economically create one-off representations that were truly unique for each person they represented, though unfortunately the product was never brought to market after initial talks with a toy company.[20] Regardless, it is instructive as an example of a delightful physical reaction to remote data, though of course it has the opposite problem of the Ambient Orb in that it can only ever represent one thing.

Somewhere between these poles is the sweet spot for Internet of Things devices that react to remote data. Too much abstraction,

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[19] "Availabot." BERG. Accessed January 20, 2015. http://berglondon.com/projects/availabot.

[20] "OFF=ON, Or, Whatever Happened to Availabot?" BERG. Accessed January 14, 2015. http://berglondon.com/blog/2008/09/02/whatever-happened-to-availabot/.

and the device is speaking in hidden codes that feel too machine-like and mysterious. Too concrete and the device is too limited to find commercial success or justify space in a person's home.

New Frontiers: Designing for Smell and Taste

Two of our richest senses, smell and taste, are not often associated with design. However, the creation of objects that support these senses is an ancient practice, embodied best by the tea set, where rituals of assembly and service lead to hints of the aroma. Holding the tea cup warms your hand without burning it, and the slow sipping of the tea forms a communal bond with other participants. Outside of classic and common serving items, designers today are increasingly finding new ways to collaborate with chefs and food companies to design with smell and taste in mind, forging a new frontier for sensorial design.

Martin Kastner is the founder and principal of Crucial Detail, a studio in Chicago that specializes in custom pieces to support unique culinary experiences. Martin is best known for his work designing serviceware concepts for Alinea, the 3-star Michelin restaurant founded by chef Grant Achatz. That collaboration has extended to other restaurants owned by Achatz, including The Aviary, a cocktail bar that prides itself on serving drinks with the same level of attention as a fine dinner.

Figure 2.x Porthole Infuser

At The Aviary, one of the most popular creations by Crucial Studio is the Porthole Infuser,[21] a round vessel that presents the ingredients of a patron's cocktail between two flat panes of glass,

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[21] "The Porthole Infuser by Crucial Detail." Accessed January 25, 2015. http://www.theportholeinfuser.com/.

emphasizing the transformative action of the steeping process and building anticipation for the cocktail's taste. The Porthole Infuser takes a part of the preparation process that is normally hidden and brings it directly to the person's table, providing time for the drinker to contemplate the ingredients on display, creating a mental checklist for their tongue to seek out when they take their first sip.

The popularity of the Porthole Infuser at the Aviary led Kastner to create a Kickstarter campaign[22] to fund the additional design and manufacturing required to release it as a commercial product. Support for the project was dramatic, achieving 25 times more funding than originally asked. This backing set the course for a redesign that allowed the infuser to be manufactured at scale and sold for $100, down from the several hundred dollars that each custom constructed Aviary version cost.

The Porthole Infuser is marketed as more than a cocktail tool, working equally well to support the smell and taste of oils, teas, or any other infusion recipe. It's an example of how designers can enhance the dining experience, not by crafting the smell or taste of the food itself, but working in collaboration with a chef to heighten our awareness of those senses.

Figure 2.x “Haptic” Juice Skin

Much of what we eat today comes in a package, rectangular boxes that homogenize our food into the same shapes and textures without regard to their smell or taste. Japanese designer Naoto Fukasaswa explored how food packaging could more fully engage our senses in his “Haptic” Juice Skin submission to the Takeo Paper Show 2014.

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[22] "The Porthole." Kickstarter. Accessed January 25, 2015. https://www.kickstarter.com/projects/692213374/the-porthole.

Fukasaswa created various juice boxes, each with a covering and structure that invokes the skin of the relevant fruit. The banana milk package has the rubbery texture of a real banana skin, along with faceted edges and the ubiquitous oval sticker on the side. The strawberry juice box is square in shape, but richly textured using real seeds. The kiwifruit juice box, as you might expect, is brown and fuzzy to emulate the unique feeling of that fruit's natural shell.

In simulating the color and texture of the fruit's skin, Fukasawa hoped to reproduce the feeling of real skin, invoking a more holistic sensory moment as the juice was consumed.[23] Although designed as a concept for an exhibition, the banana packaging was actually produced commercially for a limited time by the TaKaRa company. The production run looked quite similar to the exhibition version, but unfortunately without the simulated texture.[24]

How might Interaction Designers support smell and taste? This is truly a new and underexplored territory, but there are signs of interest and one-off experiments happening that point towards a potential role. One of the most engaging speakers at the IxDA Interaction 2014 conference in Amsterdam was Bernard Lahousse, who gave a talk entitled "Food = Interaction."[25] Lahousse, who has a bio-engineering background, works at the intersection of food and science to truly design for taste itself. He founded the The Foodpairing Company,[26] which provides an online tool and API for chefs, mixologists, and foodies to explore

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[23] Fukasawa, Naoto. Naoto Fukasawa. London: Phaidon, 2007. 112-113.

[24] "Naoto Fukasawa JUICEPEEL Packaging (revisited)." Box Vox. September 16, 2014. Accessed January 25, 2015. http://www.beachpackagingdesign.com/wp/2014/09/naoto-fukasawa-juicepeel-revisited.html.

[25] "Food Interaction - Thursday - Program." Interaction14. Accessed January 25, 2015. http://interaction14.ixda.org/program/thursday/528-food-interaction.

[26] "Homepage." Foodpairing. Accessed January 25, 2015. http://www.foodpairing.be.

and be inspired by potential food combinations through a science-based recommendation engine.

In Lahousse’s Interaction ‘14 presentation, he shared how it’s not only the flavor pairings themselves that contribute to the smell and taste, but that the environment and manner in which we eat can have a dramatic effect. The design of packaging and utensils is one part of this, but he also gave examples of chefs who are creating interactive, even game-like eating experiences. One restaurant he highlighted uses room temperature, sound, and projections to design an environment that alters and enhances the smell and taste of the food. These augmented dining environments are one area in which Interaction Designers could contribute their expertise to support the full range of human senses.

An Orchestration of the Senses

Interaction Designers have always tried to engage people’s senses but in comparison to the tangible output of Industrial Design, the options to do so have historically been limited. When designing for the screen, the best option has often been simulation, using metaphor and connotation to invoke a sensorial experience beyond what can truly be offered.

The introduction of the graphical user interface was the first major advancement in engaging the senses through a screen. The next leap forward was the “multimedia” era, bringing sound, motion, and interactivity together in unique and immersive environments. Multimedia was initially made possible through cheap CD-ROM storage, which offered access to large graphics and video files that were impractical to store on small hard drives or download over slow internet connections.

Interaction Designers of the multimedia era often utilized the new capabilities of CD-ROMs to break away from standard interface conventions and mimic as many sensorial, real world elements as possible. Map interfaces looked like faded and stained treasure maps, deep drop-shadows created virtual depth, and richly textured environments launched users into immersive 3D worlds. This was a time of widely variable interface experimentation, as designers combined text, graphics, audio, video and animation in unique ways to make encyclopedias, video games, and educational programs that simply weren't practical before CD-ROMs.

Figure 2.x Brushed metal UI example

The invocation of physical materials and properties also found its way into standard programs and operating systems. Apple first introduced a brushed metal interface style with Quicktime 4.0, which later became a dominant feature of their OS X operating system. By 2004, Apple had canonized the brushed metal in their Human Interface Guidelines (HIG), encouraging designers to use the visual treatment if their program "strives to recreate a familiar physical device — Calculator or DVD player, for example."[27] This visual reference to a physical material was less sensorial than metaphorical, acting as a bridge to ostensibly enhance usability and understanding as behaviors transitioned from physical to digital devices. This was the same rationale employed for the early versions of Apple's iOS and, over time, both operating systems evolved to use simpler UI styles once users became familiar with the platforms.

Referencing physical materials through a visual treatment obviously cannot engage our senses in the same way as their physical counterparts. Graphics that look like leather, felt, steel, or linen are often little more than interface decoration. The sensorial limitations of these graphic treatments highlight the distinction between Interface and Interaction Design. Static

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[27] "Brushed Metal and The HIG." Daring Fireball. Accessed January 25, 2015. http://daringfireball.net/2004/10/brushedmetal.

pixels on a screen can only engage us visually, and in most instances should avoid invoking additional senses they can't deliver on. But Interaction Design goes beyond the interface to encompass all the moments of interaction that a person has with a system over time.

This is why Interaction Designers tend to think of their work in terms of "flows," focusing equally or more on the connections between states, the various inputs and outputs that are possible at that moment. This focus on the in-between makes time itself a kind of design material. It is not so much that Interaction Designers are manipulating a user's sense of time, though sometimes elements like progress bars do try to ease waiting, but that they are using this fourth dimension as a connective platform to combine information, choices, and responses.[28] Time is a kind of stage from which to orchestrate sensorial engagement into a set of dynamic movements.

On a computer, or mobile device, this orchestration of interaction possibilities and system feedback can utilize animation, translucency, figure/ground relationships, color, sound, and standardized notifications to facilitate engagement with the system over time. But how does this work when we move beyond the screen? When a physical product is embedded with computation and network connectivity it transforms from an object to a system. A traditional product has discrete and predictable interactions that take place within a defined session, but once it becomes a system the sequence of interactions are less predictable and take place over a longer period of time.

Consider the previously discussed Beosystem 2500, where the opening and closing of the stereo's doors represents three clear states to form a beginning, middle, and end to the experience. Compare that to the range of possible states and behaviors that

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[28] "Defining Interaction Design." LukeW. Accessed January 25, 2015. http://www.lukew.com/ff/entry.asp?327.

a connected, computationally controlled stereo might have. Beyond reacting to your raised hand, it could detect your presence in the room as a specific individual. It could respond to your gestures or voice, highlight or hide relevant modes based on nearby media or subscription status, allow for use of remote speakers, adapt the volume based on time of day, offer you new music by your favorite bands, start music playing just before you enter the house — it is almost limitless to consider the possibilities.

How should this hypothetical stereo enable and allow for this expanded set of interaction possibilities? One approach is to put the majority of interactions on a screen, a tablet on a stand in the living room. However, as David Rose of the MIT Media Lab refers to it, the next era of computing is more likely to be full of "enchanted objects,"[29] where interactions with our products and environment are more natural, physical, and less reliant on a glowing rectangle to control everything.

As physical products become increasingly integrated with digital systems, Interaction Designers should avoid defaulting to a screen for everything. Computational sensors can be used as richer and more natural inputs, detecting and making inferences from changes in light, temperature, motion, location, proximity, and touch. Output can move beyond a screen with voice feedback, haptic actuators, light arrays, and projection.

In utilizing this mix of inputs and outputs, screen-based interaction patterns should not always be translated directly into the physical environment. Getting a notification on your phone might be unobtrusive, but having it spoken aloud in your living room might be less desirable. In the same way, there is a danger in assuming that a gesture or sensor-based input is necessarily more natural. If a user needs to develop a new mental model of

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[29] Rose, David. Enchanted Objects: What They Are, How to Create Them, and How They Will Improve Our Lives. New York: Scribner, 2014.

how a product “sees” them, or detects their presence, then the illusion has broken down. An example of this can be found in many airport or hotel bathrooms, where people wave their hands in frustration near unfamiliar sink fixtures in an attempt to discover how the sensor is triggered.

The technology may be new, but designers need not start from scratch as they wrestle with orchestrating good experiences that span digital and physical. As more complex behaviors move off the screen, Interaction Designers should augment their knowledge of digital systems with over a century’s worth of Industrial Design lessons on how to engage the full range of human senses.

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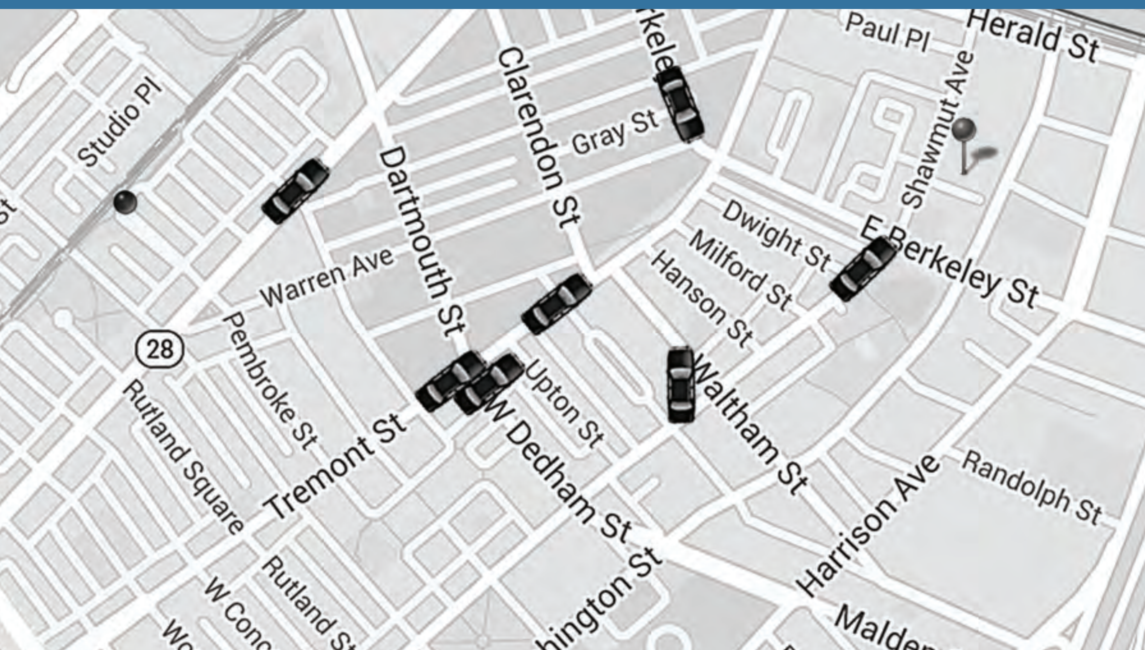
Software Above the Level of a Single Device

The Implications



Tim O'Reilly

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by Tim O'Reilly

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Software Above the Level of a Single Device: The Implications

The following document is adapted from the keynote address by Tim O'Reilly, Software Above the Level of a Single Device: The Implications, given at the Solid 2014 conference. Follow along to learn how you can best take advantage of new technology known as the Internet of Things.

Highlights

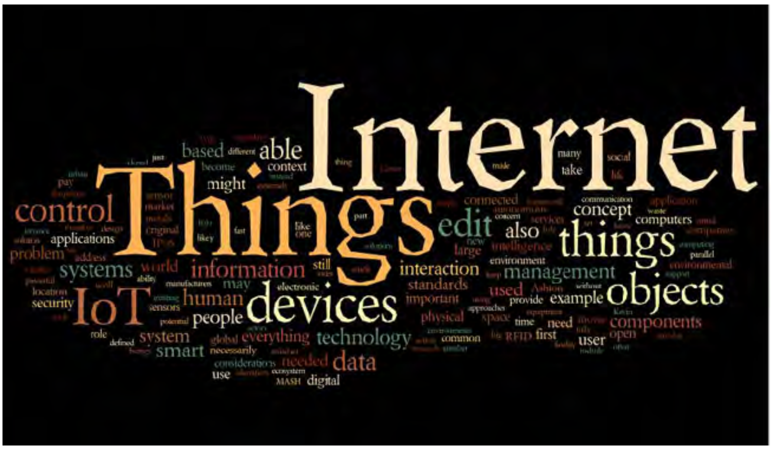
- Humans and machines work together in a complex pattern, where data is captured through human activity, stored in the cloud, pre-processed, and then used by a robot in the Internet of Things.
- If we really want it to be an Internet, as opposed to a set of Intranets, we have to think about interoperability.
- The smartphone that we carry in our pockets is filled with sensors, and it's filled with capabilities, which is the key component to so many of these things.

There is some pretty amazing stuff we are seeing here at the Solid 2014 Conference. I want to give you a little bit of perspective, though.

One of my favorite quotes is this one from Edwin Schlossberg. If you've heard me talk, you've heard it before: "The skill of writing is to create a context in which other people can think."

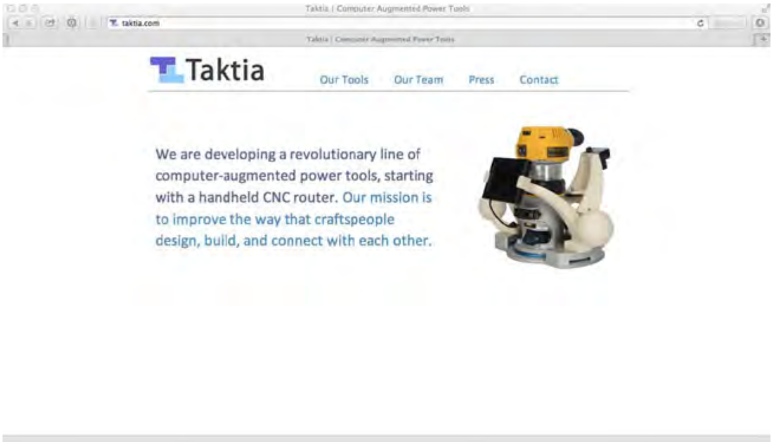
And that means that the way we talk about things is a kind of map. And like any map, it can either take us to the right place, or it can lead us astray. I want to talk a little bit about some of the words that we use in the current context and start thinking about what we might be missing.

I did a word cloud of the Internet of Things article on Wikipedia and as you can see, *things* is a really big word in the cloud, and not only that but *devices* and *objects* also appear a lot. And sure enough, there are some pretty amazing smart things. That word, *smart*, also shows up in the word cloud.

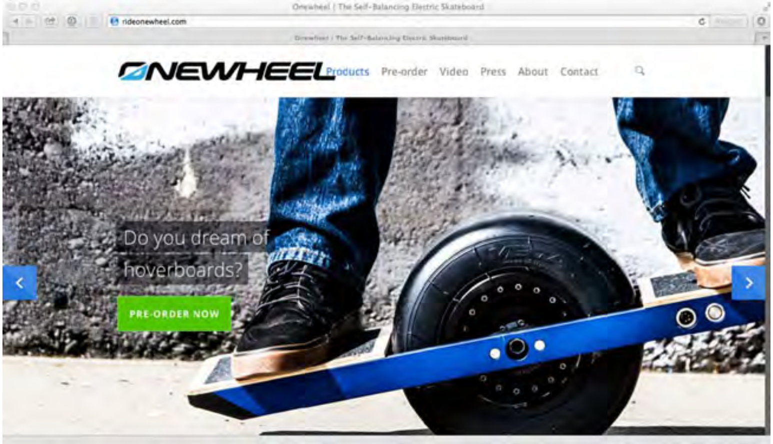


Multiple Smart Things

Out front in the demo hall of the building, you probably saw the Taktia smart router. I'm a home craftsman, and I want one of these. I'm not as good as I'd like to be, and this thing would make me better. It's a human augmentation, and it is super awesome.



The Onewheel: I tried it yesterday, not very well, but it is also pretty awesome.



And of course the Makani airborne wind turbines use incredible smart control to generate power. This is an invention originally made by my son-in-law, Saul Griffith, so I'm very proud of that.

Importance of Human Input

There is something missing in this word cloud, because we shouldn't just be talking about smart things. *People* and *time* are also concepts in there. But they are way, way too small. I think one of the things I'd like to have as an outcome of this talk is that the people in this room go read that Wikipedia entry and make it better, because I really don't think it actually captures so many of the concepts that we need to be thinking about today.

I want to talk a little bit about these aspects of people and time that are too small in that graph.

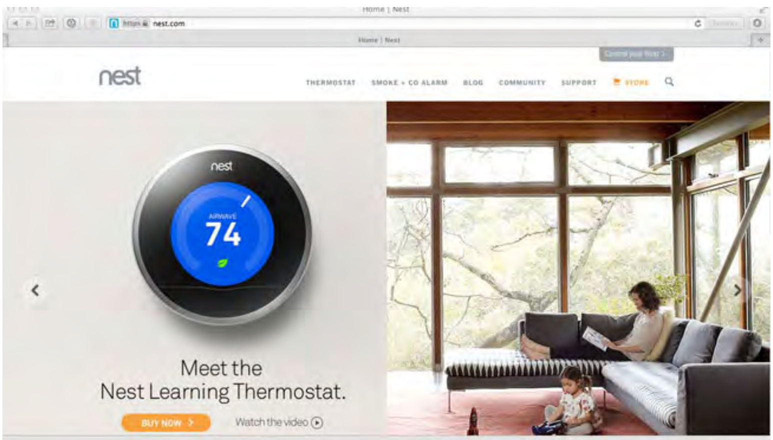
When we think of the Internet of Smart Things, we tend to imagine that these things—the Nest thermostat or the Google self-driving car—they're sensor and data driven, they are autonomous, not really needing human input, and they are operating in real time. That is really our first blush imagination.

But in fact, one of the super interesting things about the Google self-driving car is its connection to the human-driven Google street view vehicle that did all of the initial mapping. What you see here is actually humans and machines operating together in a complex pattern in which data is captured through human activity, stored in the cloud, pre-processed, and then used by a robot.

And I think that pattern is a really, really important one to pay attention to as you design applications. Think about how data, generated by humans, is captured over time and is stored and acted upon later by a device. It is not all real time.

Implicit Versus Explicit Input

The human input is critical, and it may also be implicit rather than explicit. So, when you see the web page for the Nest learning thermostat, the whole pitch is that it learns implicitly from you, but it also learns explicitly: you set the temperature. (By the way, Nest, you really need to use energy-friendly temperatures in your advertisements!)



The Nest auto-detects when you've been away for awhile and turns off the heat or air conditioning. Okay, that's sort of our image of the smart thing, but we have to remember that we are still giving that input, it's just through a different kind of interface. We are so used to talking about how we give input through a keyboard. Then we are giving input through a mouse and now we are giving it through a touch screen. And now, we say "Wow! When we don't show up in the room, that is user input to this device." It is still user input!

Think of this as a user experience problem and not an autonomous device problem. And of course you have multiple input modalities, since you have a Nest app. And one of the things I've noticed is that once I set the schedule using this app, the device doesn't seem to learn any more. The interaction between the explicit, the implicit, and what modes of implicit really matter.

Types of Sensors

Think a little bit more broadly about the kinds of sensors that you have. When sensors first appear, we don't use them that often, and as a result they still seem magical. And then we take them for granted, until someone figures out a new way to make them more powerful. Some of the most important sensors that we have that are now entering this rediscovery phase are the camera and the microphone in our phones. Both Siri and Google Now are using the microphone as the key to very, very powerful new interfaces, and ones that are going to get better very rapidly. They are going to be a big part of the user interface mix for this Internet of Things.

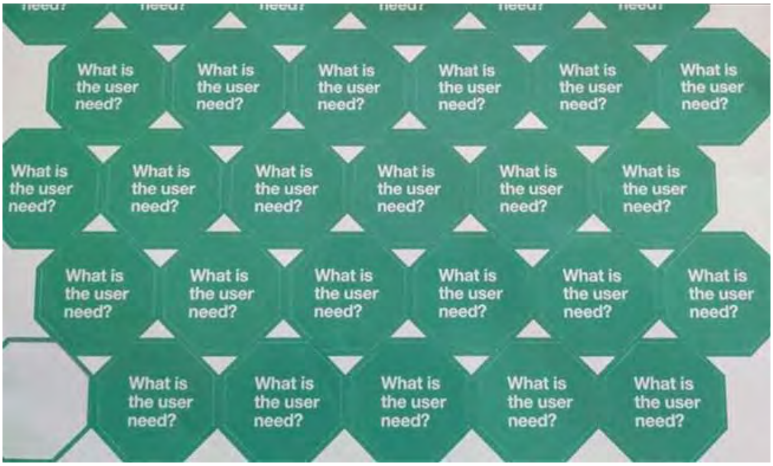
The point is that sensors allow us to create new kinds of user interfaces. But you still need to remember that it is a user interface.

The System as a User Interface

I do have an example of a bad user interface. And that is this wonderful smart key for my Tesla. And it does wonderful things. I walk up to my car and the car automatically opens. I don't have to stick it in a tiny slot or turn it, or any of those things we were so used to in the mechanical age.

But it's got one really bad flaw, which is all over the forums, which is you can't hang it on a key ring. That's actually a stupid device, because it didn't think about how I might want to use it. And any time I leave my car in valet at the airport it comes back in a little plastic bag because they can't hang it on the hook. Sometimes they lose it. The entire system in which we operate is the user interface.

There's this great sticker that was given to me by Liam Maxwell, who is the CTO of the British government.



They've really focused hard on this idea: what is the user need? And, they made that the first of their design principles, to start with needs.

As we design this new world we need to think about user needs first.

A Network of Devices

Coming back to this Internet of Things word cloud, I want to move on and pick out one of the big words that we use, and that is *Internet*. And the Internet really matters. When you look at that smart device, it's not a standalone device. Yes, it's controlled by its smartphone, and yes, Nest now offers other devices connected to the network with the thermostat as its hub, and they talk to each other. In fact, all of these things are connected to satellites and data centers, and potentially to other similar devices or other smart devices.

And, by the way, even in that data center, you actually have smart networks of things. The cooling is actually controlled semi-autonomously. So there is this big network all over. There's a network of data centers all over the world, so the Internet is clearly very involved. But let's remember the original ground rules of the Internet.

The Robustness Principle

We used to call the Internet "The Network of Networks," because it was this magical thing that connected all of these incompatible networks. And interoperability was the focus. One of the things I worry about as we move into this new world is that we may have forgotten that interoperability. We have vendors who are trying to own it all, building systems that talk to their devices, but not to everyone else's. We have to think a lot about interoperability.

And we have to think about this wonderful principle that was put out by one of the saints of the early Internet, Jon Postel. (I wonder sometimes what would have happened if he hadn't died too young of a heart attack.) He wrote in the TCP RFC, "Be conservative in what you send, be liberal in what you accept from others." It's become known as the Robustness Principle.

That is such an important principle, and I want those of you who are designing devices or systems to think about interoperability and to remember if we really want it to be an Internet, as opposed to a set of Intranets, you have to think about interoperability.

Software Above the Level of a Single Device

The next thing I want to cover briefly is the notion of software above the level of a single device. This is a phrase that I got from Dave Stutz, who wrote a fabulous letter when he left Microsoft back in 2003. It was his parting advice. And it ended with the line, "Useful software written above the level of the single device will command high margins for a long time to come."

This was very, very prescient, because a lot of focus was still on the PC and even on the network; it was very small thinking. And his notion of software above the level of a single device stuck in my head. I've used it for years. It was part of my core Web 2.0 principles. But I want to bring it out in the example of the Uber app.

System of Interaction

Let's not get too taken up with new wearables. Uber is a smart things app. We forget that the phone is our most widely used smart thing. This thing that we carry in our pockets is filled with sensors, and it's filled with capabilities.

But what's really interesting about Uber is, of course, that it doesn't work in isolation. There's an app for the passenger, but there's also an app for the driver. And those two things are coordinating in real time using a kind of Internet operating system. There are various types of functions for communication, and for GPS to locate everybody, and to track progress. There is a payment and a rating system.

All of these things are part of a "system of interaction." That's a wonderful phrase that was coined by someone at IBM.

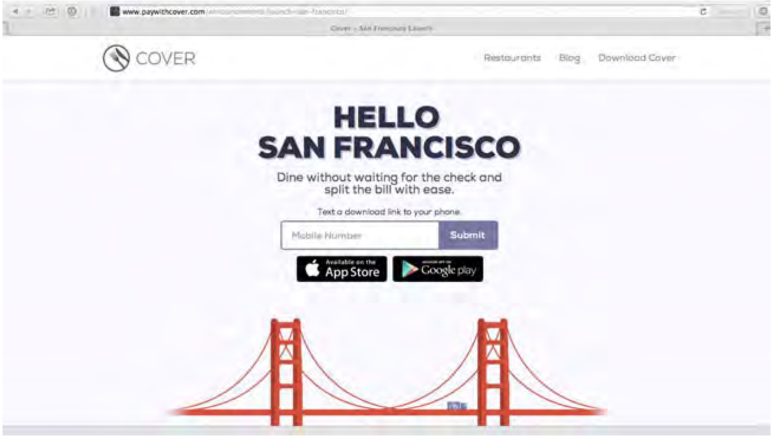
What I want you to think about here is that once you have new UI capabilities and new augmentations of humans via sensors, you can actually start to think about things differently.

There's a wonderful quote from Aaron Levie at Box that I saw on Twitter. He said, "Uber is the lesson in building for how the world should work, instead of optimizing for how the world does work." That's our opportunity with this new technology that we've been given.

How the World "Should" Work

We can start thinking about how the world *should* work, instead of optimizing how the world does work. So, back to the Makani wind turbine out there. The idea is that, instead of having a turbine sitting on the ground like we've had since the Dutch windmills, you could actually put one in the sky using this incredible control technology. Now, they are still working on it, but the notion that this thing has to be able to fly autonomously for thousands of hours, and has to be able to take off and land by itself, and it's generating power up high where there is always wind. That's thinking about how the world should work, rather than how the world does work.

This notion is critical and the sensors let us do new things. A company that we are invested in at O'Reilly Alpha Tech Ventures is Cover.



Because you are registered with the cloud, and because the application is able to tell where you are, you can walk into a restaurant and sit down. You are identified, fed, and when you are done with the meal you walk out and your credit card is charged. It's kind of magic. Because of sensors, we can rethink the way things work.

Another great example is Makespace: your closet in the cloud. This is an example of how sensors don't have to be complicated. These guys have realized that if you can actually take pictures of what you put in the boxes when you put stuff in storage, and you can identify what's in that box, you can put this stuff away in a warehouse where space is cheap. They can then bring you just the box you want. You don't have to go rooting through your storage closet, because you can effectively go into a robotic warehouse. Once again, they are rethinking a familiar process, because we now have new capabilities.

Think About Things That Seem Hard

Where I want to go with this is a final piece of advice, which is don't just try to re-create the experiences and the technologies that we have today. Try to think about new things, and in particular, think about things that seem hard—things that might have seemed impossible before you had these new capabilities.

One of the things I'm most excited about in this technology revolution is how it is giving us amazing new capabilities to affect the physical world. And the physical world, in the end, is where we all live, and where the biggest problems that we face as a society are to be found.

We have to feed the world. We have to generate energy. We have to deal with climate change. We have to deal with the problems of our society. And there are amazing new capabilities, and I want you to not just make cute, cool, and amazing consumer devices. I want you to think about hard problems that you can solve. Take this technology and make the world a better place.

Thank you.