Research Through Design in HCI

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Introduction

Many researchers have struggled to connect RESEARCH and DESIGN. Voices in the HCI research community coming from different disciplinary backgrounds have noted this challenge. Erik Stolterman stated that scientific research drives towards the *existing* and the *universal*, while design works in pursuit of the *non-existing* and in the creation of an *ultimate particular* (Stolterman, 2008). Design and scientific research, then, seem headed in opposite directions. Jane Fulton-Suri, reflecting on her training in social science followed by her experience working at a design consultancy, identified a gap between design with its focus on the future and social science research with its focus on the past and present. Alan Blackwell, discussing research from an engineering perspective, explained that research contributions must be *novel*, but not necessarily good. Design contributions, however, must be good but not necessarily novel (Blackwell, 2004). These observations reveal an uneasy tension between design and research within HCI. However, the repeated reflections and speculations on a connection hint at an underlying desire to discover a way to link these two together.

Research through Design (RtD) is an approach to conducting scholarly research that employs the methods, practices, and processes of design practice with the intention of generating new knowledge. People carrying out research using RtD generally reject the idea that research is synonymous with science. Instead, RtD frames design inquiry as a distinctly separate activity from engineering inquiry and scientific inquiry. RtD draws on design's strength as a reflective practice of continually reinterpreting and reframing a problematic situation through a process of making and critiquing artifacts that function as proposed solutions (Rittel & Webber, 1973;

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Schön, 1983). RtD asks researchers to investigate the speculative future, probing on what the world could and should be.

On the surface, RtD can look suspiciously like design practice. However, it is generally more systematic and more explicitly reflective in its process of interpreting and reinterpreting a conventional understanding of the world, and it generally requires more detailed documentation of the actions and rationale for actions taken during the design process. An RtD project gets documented such that other researchers can reproduce the process; however, there is no expectation that others following the same process would produce the same or even a similar final artifact. The most important distinction between RtD and design practice is the intention that design researchers bring to bear on a problematic situation. In the practice of RtD, design researchers focus on how design actions produce new and valuable knowledge. This knowledge can take many different forms including: novel perspectives that advances understanding of a problematic situation; insights and implications with respect to how specific theory can best be operationalized in a thing; new design methods that advance the ability of designers to handle new types of challenges; and artifacts that both sensitize the community and broaden the space for design action The focus on producing these types of knowledge make RtD quite different than commercial practice with its focus on making a commercially successful product.

We see RtD as one way to respond to an interesting challenge noted by Jack Carroll and Wendy Kellogg in the early days of HCI. They noted, with great frustration, that in HCI, the *thing* proceeds *theory* instead of theory driving the creation of new things (1989). They noted that the mouse needed to be invented before studies could be done that showed this was a good design. As another example, people developed many, many different direct manipulation interfaces, such as Sketchpad (Sutherland, 1963), long before Ben Shneiderman wrote about the value of direct manipulation (1983). The practice of RtD in HCI implores researchers to become more active and intentional constructors of the world they desire, constructors of the world that they believe to be better than the one that currently exists. In response to this challenge, we see RtD as a way for many new things to enter into HCI that can spawn new theory. At the same time, these new things can be informed by current theory, creating an ongoing dialog between what is and what might be. Building on Nigel Cross' observation that knowledge resides in designers, in their practices, and in the artifacts they produce (Cross, 1999), RtD provides a research approach for these types of knowledge to be generated and disseminated within HCI.

A recent book by Ilpo Koskinen, Zimmerman, Binder, Redstrom, and Wensveen (2011) provides a detailed investigation of current RtD practices in the interaction design research community. The authors provide a brief history of RtD's evolution in different design research communities, detailing how three distinct practices emerged that they refer to as Lab, Field, and Showroom. The *Lab* practice comes mainly from the Netherlands. It combines design action with experimental evaluation processes traditionally used in psychology. It focuses on creating novel and much more aesthetically appealing ways for people to interact with things. The *Field* practice comes out of the Scandinavian tradition of participatory design and out of user centered-design practices in the USA. It merges research practices from

sociology and anthropology with design action. In this practice, design researchers map out a problematic situation and offer design ideas to improve the state of the world. The *Showroom* practice borrows methods from art, fashion, and design. Here, researchers design provocative things that challenge the status quo. Critical designs force people to reconsider the world they inhabit and to notice aspects too often overlooked. The knowledge produced includes the characterization of the issue being critiqued, the approach used to draw the viewer's attention to the underlying issue, and the process used to arrive at the problem framing and the final artifact form.

History of RtD and Its Connection to HCI

The histories of RtD and of RtD in HCI are strongly connected to events in the design research community and to the emergence of interaction design as a design discipline distinct from architecture, industrial design, and communication design. The term "research through design" comes from Christopher Frayling (1993). He provided a descriptive framework for research in the arts as being:

1. *Research into design*—research into the human activity of design. Well-known examples include Herbert Simon's work on design as an artificial science (Simon, 1996), Harold Nelson and Erik Stolterman's work on the "way" of design (Nelson & Stolterman, 2012), and Donald Schön's work on design as a reflective practice (Schön & Bennett, 1996).
2. *Research for design*—research intended to advance the practice of design. This includes almost all design research including any work that proposes new methods, tools, or approaches; or any work that uses exemplars, design implications, or problem framings to discuss improving the practice of design.
3. *Research through design*—a type of research practice focused on improving the world by making new things that disrupt, complicate or transform the current state of the world. This research approach speculates on what the future could and should be based on an empathic understanding of the stakeholders, a synthesis of behavioral theory, and the application of current and near current technology. The knowledge produced functions as a proposal, not a prediction (Zimmerman, Stolterman, & Forlizzi, 2010).

Research *into design* and research *for design* both refer to the outcome of a research project; the type of knowledge that is produced. Research *through design* differs in that it is an approach to doing research. It can result in knowledge *for design* and *into design*.

Many design researchers have produced valuable frameworks for discussing what research is with respect to design (i.e., Buchanan, 2001; Cross, 1999); however, Frayling's framework, particularly his description of RtD, has been increasingly important in interaction design research (Basballe & Halskov, 2012). While Frayling coined the term "research through design," he is not the practice's point of

origin. In fact, looking over the history of this research approach, it is possible to see it emerge from several different places. Here we tell three different origin stories: Rich Interaction, Participatory Design, and Critical Design. These are based on Koskinen et al.'s (2011) framework of Lab, Field, and Showroom.

Rich Interaction Design (Lab)

In the 1990s, researchers at the Technical Universities in the Netherlands drew a clear distinction between design, which was taught to students in the industrial design programs, and the scientific research performed by the faculty to investigate human perception, consumer preferences, emotional reactions, and the design process. A small group of researchers and designers at the Technical University in Delft observed that with the transition from mechanical interaction to electronic interaction, interaction possibilities should increase with the freedom from mechanical constraints. Yet almost all new products reduce interaction to pushing a labeled button. They viewed this trend as a failure to account for people as sensual beings; a failure to focus on perceptual motor skills as a source of interaction inspiration, due to an overreliance on cognition as a singular theoretical stance in interaction design, and a failure to consider aesthetics as a critical component of interaction. Drawing on theories from perceptual psychology, ecological psychology, and phenomenology, they worked from the perspective that interaction design should engage all of the senses, not just the visual. Following this theoretical stance, they created a new approach to interaction research with the goal of designing systems that would more fully engage people's bodies to richly express themselves and people's full range of senses as channels for input and feedback from interactive systems, a new research space they dubbed Rich Interaction (Frens, 2006a, 2006b).

These Dutch design researchers wanted to invent entirely new methods for people to interact with things. To do so, they combined aspects of experimental psychology and aspects of design practice. In general, they would start from a psychological theory with the goal of making it actionable through design. They would then conduct a series of design workshops to understand how to do it. These workshops brought together many designers who, working with rough materials, would rapidly invent new ways for people to interact with systems. Workshops investigated things like how consumer products like alarm clocks might function differently if they took into account the user's emotional state (Djajadiningrat et al., 2002), or how a vending machine might behave if it were polite or unfriendly (Ross et al., 2008). Outcomes of the workshops functioned as semi-articulated hypotheses of potentially better forms for interaction. Following the workshops, the researchers would select and refine an idea into a more detailed hypothesis. In order to validate these hypotheses, researchers make several slightly different versions of a single product and conduct controlled lab studies around the interaction.

Philip Ross' dissertation work at the Technical University in Eindhoven provides a good example. He carried out design workshops where design teams created

Fig. 1 Adaptive, interactive lamp by Philip Ross

candy vending machines based on different ethical stances including Confucianism, Kantian rationalism, vitalism, romanticism, and Nietzschean ethics (Koskinen et al., 2011). The workshop revealed that an ethical stance could drive design inspiration, and it revealed many aspects of Kantian rationalism embedded in the machines people interacted with everyday. Based on this finding, Ross hypothesized that ethics could be imbued into the design of interactive products by using a specific perspective to drive a design process. Over the course of his PhD studies, he developed many different lamp forms and interactive behaviors that explored subtle aspects of ethical stances.

This RtD practice grew out of academia through the collocation of psychologists and designers. Unlike more user-centered design processes popular at this time, this approach allowed the designer to brainstorm freely to create new innovations. This approach blends design methods to envision the unimagined and both analytic and experimental methods to evaluate the novel design offerings and to generate frameworks that described how rich interaction works. This approach is still practiced today by researchers in the Designing Quality in Interaction group at the Technical University in Eindhoven.

Figure 1 shows an image of Ross' final lamp (Ross & Wensveen, 2010). The lamp reacts by changing the intensity and direction of the light based on the way a person touches and strokes it. The lamp also uses an understanding of the situation at hand, such as the fact the user wants to read, to augment its behavior. This can range from helpful, where it provides light for the reading material, to playful, where it moves the light to draw the user's attention away from reading towards the lamp. The work investigates how designers can use ethics as a lens for investigating aesthetics in the behavior of adaptive products, broadening the space for innovation and creativity in the design process.

Fig. 2 Still from Maypole project showing a child using a working prototype of a digital camera designed for children

Participatory Design and User-Centered Design (Field)

The participatory design movement began in Scandinavia as a reaction to the disruptive force of information technology as it entered the workplace and caused breakdowns in traditional roles and responsibilities. Workers believed that IT systems often reduced their voice and diminished their craft skills. In addition, companies and software developers noted that many of these systems, while designed to increase productivity, often resulted in productivity losses because the people designing the systems lacked a detailed understanding of how the work was really performed (i.e., Kuhn, 1997; Orr, 1986).

Participatory design embraced a Marxist philosophy. It focused on developing a new approach to the design of work automation that increased democracy and protected workers. Design work was performed by interdisciplinary teams consisting of behavioral scientists, technologists, and designers, who brought a theoretical understanding of people and work, knowledge about the capabilities of technology, and skills at conceiving an improved future state. In addition, the design teams included workers selected by their peers, who brought domain expertise on work practices within an organization. Working together, these teams followed a rapid prototyping approach, iteratively conceiving of new work and workplace designs by starting with low-fidelity prototypes and working towards higher fidelity until a final concept emerged. These design teams socially prototyped the new work practices before committing to the technology that could bring about this future. Figure 2 shows an image from the Maypole project (Giller et al., 1999). Maypole was a

2-year European research project funded by i3net, the European Network for Intelligent Information Interfaces. One goal of the project was to develop communication concepts for children aged 8–12 and others in their social networks. The methods in this project extended the legacy of participatory design, and focused on interaction with users in real world settings. The image shows a child using a digital camera. Mobile technology to do what designers envisioned did not exist at that time, so researchers cobbled together a camera and output screen, tethered together and carried in a backpack. Making working prototypes like this camera, and giving them to users in the field allowed researchers to begin to investigate how new technology might create new practices around image making and messaging. Insights on what these new practices might be were then used to inform the design of new mobile technologies.

This new approach to the design of technical systems was intended to result in commercial products. What made this research and not design practice was the focus on developing a new design methodology that borrowed research practices from anthropology and sociology and combined them with design. Over time, researchers began to also see the artifacts they produced as a research contribution. For example, in the Maypole project, researchers made advances on how to conduct participatory design with children, which advanced this method over previous work that focused on workers. In addition, the user intentions for using a digital camera as well as the interactive behaviors created during the design of the camera could be generalize and applied to future cameras, once the technology allowed a digital camera of an appropriate size. Thi observation, that insights from making and the resulting artifact were also research contributions, helped refocused this research practice from being method specific to being more an investigation of the speculative and desirable future.

Critical Design (Showroom)

In RtD that follows a critical design approach (Dunne & Raby, 2001), design researchers make provocative artifacts that force people to think, to notice, and to reconsider some aspect of the world. The term "critical design" was first used by Tony Dunne to describe a philosophy about design that refutes the status quo (Dunne, 1999). However, the idea of designs that critique the current state of the world is much older and can be found in many design and art movements such as in the work of the Pre-Raphaelites or the Memphis Design Group. The approach emphasizes that design has other objectives than to help people and to improve the world.

This research approach draws from historical design practice. In the 1990s, in many design schools, a movement towards conceptual design rather than finished artifacts began to take place. It is possible to characterize much of the work done in fashion, conceptual architecture, and conceptual design as a type of critical design. Critical design offers a research approach that allows designers to draw on the strengths and traditions of design. The research involves a process of problem

Fig. 3 The prayer companion by the Interaction Research Studio at Goldsmiths, University of London

selection, exploration through the generation of many possible forms, and iterative refinement of a final form that approaches showroom quality. Knowledge is captured as the designer or design team engages in reflective writing that describes the process, the artifact, and the intended influence. While popularized at the Royal College of Art in the UK, this RtD approach has been taken up at a number of design schools.

Figure 3 shows the Prayer Companion. This design from the Interaction Research Studio at Goldsmiths University provided a well-known example of critical design in HCI. The device displays electronic news feeds in a convent of cloister nuns, providing a connection from the outside world as a source of prayer topics. The design raises interesting questions on many topics including the role of computation as a material embedded in sacred artifacts. The project mixed in elements of participatory and user centered design by installing the device into a convent and reflecting on how the nuns came to view and understand it.

Authors' Connections to RtD in HCI

The authors both participated in the development and growth of RtD as a research practice in HCI. Their interest in this topic was pragmatic. Both worked as practicing interaction designers in industry before becoming professors at Carnegie Mellon. Jodi worked at the design consultancy e-Lab in Chicago, performing fieldwork to inform the design of a variety of products and services. John worked at Philips Research. He collaborated with technical researchers to give more commercial forms to their research; forms intended to help product managers better understand what the technology could and should be. In accepting joint appointments at Carnegie Mellon's HCI Institute and at the School of Design (Jodi in 2000 and John in 2002), they were two of the first interaction design researchers working directly in the space of HCI research. However, what it meant to be an academic interaction

design researcher at this time was still largely undefined. Carnegie Mellon had hired them both to help define the role of design research within HCI and to help develop new ways for interdisciplinary researchers in HCI to integrate design thinking into HCI research and education.

In the early 2000s, the term design research within the HCI research community generally meant the upfront research done in the practice of design. Daniel Fallman described this as *research-oriented design*; design work in HCI that is informed by upfront research as opposed to designers working in isolation in a studio (Fallman, 2003). At this time the term "design" within the HCI research community was synonymous with the term "practice." Design was not viewed as a discipline that could produce knowledge, but was instead used as a term to help distinguish research from practice.

To better understand how design might best fit into HCI research, the authors, along with other collaborators, held a workshop at CHI 2004 with the intention of bringing researchers from a variety of disciplines together to discuss and advance the role of design (Zimmerman, Evenson, Baumann, & Purgathofer, 2004). Out of this workshop came a desire to move design thinking into HCI research by making a place for RtD. To do this, design researchers in HCI needed to convince the HCI research community to accept RtD research contributions as both valid and valuable. They needed the community to see the speculative artifacts designed in this process as more than an integration of known technologies. They needed this research community to see these things as rigorous speculations on the possible future that reveal new and important insights on how people understand and engage with new technology and the appropriate roles technology might play as it continues to move into more and more aspects of people's lives.

Interestingly, Bill Gaver presented a paper describing the Drift Table (Gaver et al., 2004) at the same CHI conference. Both the artifact and the paper describing its design and evaluation challenged the HCI community's institutionalized belief that interaction designs must require an explicit user intention; that everything should have a "right" way to be used. The design opened a new research space, which Gaver and his team called "ludic interaction." In addition, it provided a great example of how design and design thinking can expand the scope and role of HCI. The paper was presented as an "Experience Report," a track within CHI designed for practitioners to share their design cases. While clearly intended as a research contribution, the paper was not a part of the peer-reviewed technical papers section of the conference. Nevertheless, the Drift Table has been held up as one of the earliest and best examples of RtD published within HCI.

Following the workshop, the authors, working with their colleague Shelley Evenson, began a project focused on bringing RtD to HCI. We began by first detailing how knowledge is produced in the design of commercial products and services (Zimmerman, Evenson, & Forlizzi, 2004). The work explicitly noted the different kinds of knowledge produced at different points in typical design process (Fig. 4). Based on this map from commercial practice, we embarked on a project to create a model of RtD that could work for the HCI research community. The intention of this model was not to define a singular type of design research in HCI. Instead, it was

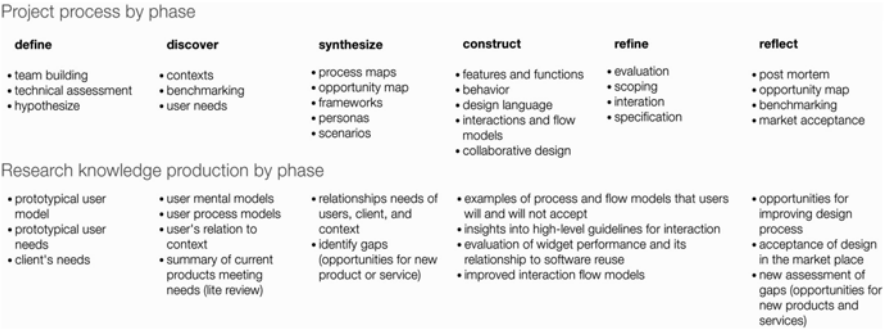

Fig. 4 Knowledge opportunities in the design process

intended to open a door to create an initial foothold for RtD research contributions to gain entry into HCI research venues.

We began by interviewing leading HCI researchers and leading HCI designers, probing to understand how they define design, on how they see design producing knowledge, and on how design might or might not fit into HCI research. One of our favorite comments came from a psychologist who shared that: "designers make things, not knowledge." Another, also from a psychologist, asked: "Why do you want to make the right thing? Why not conduct a two-by-two experiment?" This comment in particular helped us see a critical disconnect between design thinking with its focus actively constructing a subjectively preferred future and scientific thinking with its focus on universal truth that remains true through time. Following the interviews, the team created a model of RtD in HCI, evaluating and iteratively refining it through many presentations and individual meetings with HCI researchers, design researchers working in HCI, and design researchers working in the design research community. The results of this work came to the HCI research community as a paper and presentation at CHI 2007 (Zimmerman, Forlizzi, & Evenson, 2007) and to the design research community through an article in a special issue of the journal *Design Issues* on design research, edited by this team (Forlizzi, Zimmerman, & Evenson, 2008).

In this model (Fig. 5), interaction design researchers following an RtD approach work to integrate three types of knowledge in the design of new things: how, true, and real (Zimmerman et al., 2007). The types of knowledge build on the definitions of "real, true and ideal" knowledge introduced by Nelson and Stolterman in the *Design Way* (2012). From engineers, design researchers take "how" knowledge; the latest technical possibilities. From behavioral scientists, they take "true" knowledge, models and theories of human behavior. From anthropologists they take "real" knowledge; thick descriptions of how the world currently works. Based on these three types of inputs—how, true and real knowledge—design researchers ideate many possible visions of a preferred future state by imagining new products, services, systems, and environments that address challenges and opportunities and that advance the current state of the world to a preferred state. In a sense, the design

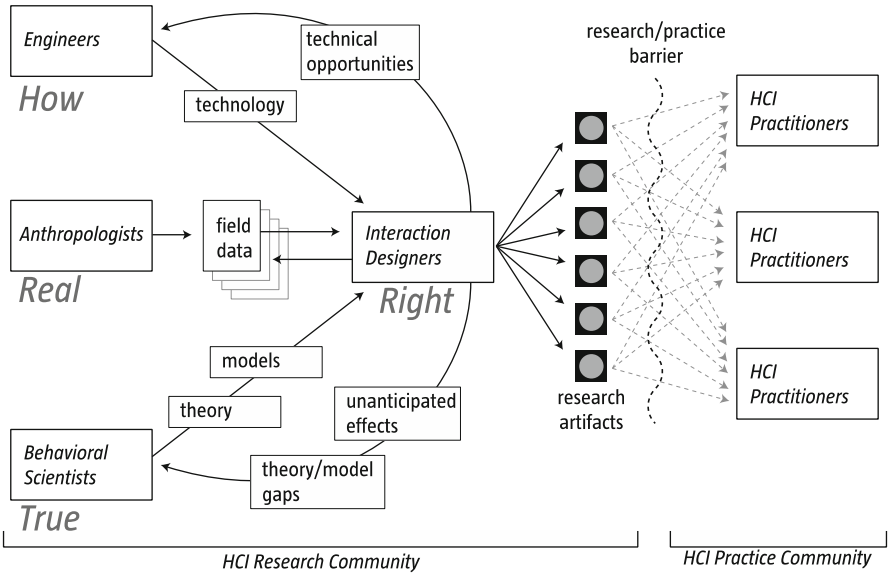

Fig. 5 Our model of research through design within HCI

researchers attempt to make the "right thing," an artifact that can improve the state of the world. This model builds on the idea of design as a process of repeatedly reframing a problem through a process of proposing possible solutions (Buchanan, 1995; Rittel & Webber, 1973; Schön, 1983; Simon, 1996).

The model illustrates four types of research outputs to different disciplines within HCI.

1. RtD can produce *technical opportunities* that feed back to engineers. These are places where if a nearly possible technical advance existed, it would benefit the world. For example, the fieldwork, concept generation, and speed dating studies by Davidoff et al. revealed that parents would benefit from computational systems that learned routine pick-up and drop-offs in order to help parents to not forget their children (Davidoff, Lee, Dey, & Zimmerman, 2007; Davidoff, Lee, Yiu, Zimmerman, & Dey, 2006; Davidoff, Zeibart, Zimmerman, & Dey, 2011; Davidoff, Zimmerman, & Dey, 2010).
2. RtD can expose gaps in current behavioral theory. For example, theory on product attachment explains why parents grow to cherish some of the books they read to their children. This theory, however, fails to explain why this attachment does not seem to develop when parents read these same stories to their children using an eReader. Something in the digital quality of this material possession makes it different (Odom, Zimmerman, & Forlizzi, 2011).
3. By making things and placing them into the world, RtD can change the current state, creating new situations and new practices for anthropologists and design researchers to investigate. For example, the Tiramisu project produced a mobile

service so transit riders could coproduce a real-time arrival system by sharing location traces from their smart phones. Use of this service changed transit riders' sense of engagement, causing them to report issues, concerns, and compliments with the service (Zimmerman et al., 2011).

4. Finally, by making many different things intended to address the same problematic situation, RtD can reveal design patterns (Alexander et al., 1977) around problem framings, around specific interactions, and around how theory can be operationalized. For example, the analysis of six artifacts created with the intention of helping users become the person they "desired to be," revealed several problem framing perspectives other designers can use in their own practices of user experience design (Zimmerman, 2009).

Since the presentation of this model at the CHI conference, the use of RtD in HCI and the participation of design researchers in publishing at HCI venues have grown significantly. Today the CHI conference has organized two technical papers committees devoted to design research in order to address the ever-increasing number of submissions.

Following the introduction of this model, the authors have continued to conduct research on and with RtD. They have both conducted a number of research projects following this approach and published those at both HCI and interaction design research venues. In addition, they have worked to formalize this research approach. Specifically, they have investigated how RtD can lead to theory and how researchers can better evaluate what makes a better or worse RtD contribution (Forlizzi, Zimmerman, & Stolterman, 2009; Zimmerman et al., 2010; Zimmerman & Forlizzi, 2008).

RtD's Contributions to HCI

RtD offers many contributions to HCI. Two that we focus on here are

1. the reflective practice of *reframing* the underlying situation and goal of the project during the design process and
2. a shift to investigating the future as a way of *understanding the world that should be brought into being*.

Below we provide an overview of two design cases. The first talks about the design of the Reverse Alarm Clock, and describes how the process of reframing helped to advance the understanding of what domestic technology should do and how it might be best situated in the home. The second addresses the design and investigations of Snackbot, a snack delivery robot. This RtD investigation of a speculative future where robots bring workers snacks addresses both the need for guidelines on how robots should socially engage with people and the complex issues surrounding the sedentary work practices of today's office workers and the growing obesity problem.

Reverse Alarm Clock

The reverse alarm clock project provides an RtD research example of how problems and project goals are continually questioned and reframed during the research process. This project began with a fieldwork observation that busy parents in dual-income families sometimes yell at their children in the morning. The goal of getting everyone out of the home on time is important to parents, but it is not often important to young children. In the stress of the morning rush, a lost shoe or a slow eater can push parents beyond the edge of their patience. When they yell at their children, they feel they are failing as a parent by starting their child's day off with such a negative tone. Parents who have their sleep disrupted, by small children who wake at night, have even less emotional reserve to maintain their patience during the morning rush.

Based on this observation, the project team was motivated to design a system that could help small children to stay in bed at night. The result of this effort was the reverse alarm clock (Fig. 6). In its final form, the clock consisted of four parts:

Display: The display expresses time as three states, each associated with a rule: When the moon is up, the child must be in bed; when the moon sets, the child can get out of bed if they wish; and when the sun rises, the child must get up.

Treasure box: This box goes next to the child's bed. At night the child places a token into the box, selecting the music to play at wakeup, when the sun rises. After placing the token in the box, the child presses a button on the top of the box, causing the moon to rise.

Controller: A circular dial, called the controller, hangs on the wall near the light switch at the entry to the child's room. It has two levers: one to set the moonset time and one to set the sunrise time.

Bed sensor: A sensor mat goes under the mattress to detect if the child climbs out of bed. If a child leaves the bed while the moon is up, nothing happened. If the child leaves the bed after the moon has set, the sun instantly rises and the wake up music starts to play.

The initial problem framing viewed children getting up at night as a contributing factor for why parents might yell in the morning. Guided by this framing, the team investigated why children get up at night. Through literature and interviews with sleep specialists they learned that young children have no sense of duration. In viewing the situation from the child's perspective the team began to see parents as inconsistent. Sometimes a child would wake and visit their parents, and their parents would be glad to see them. Other times the child would wake and visit their parents, and the parents would be upset and insist they go back to bed. Taking the child's view, the problem became one of usability. The child needed better feedback that could help them predict how their parents might react to their action. This new framing motivated many of the initial designs for the display.

The design team then expanded their scope from the wakeup and began looking at bedtime. While often viewed by busy parents as a stressful time, the team also

Fig. 6 (*Clockwise from top*) Experience prototyping of an early version of the display with a 3-year-old child. Experience prototyping of the treasure box. Final design showing the sun after it has risen. Final design showing the moon before it sets. Early prototype of the controller. (*Center*) Screen based version of controller used for the field trial, which ran on a laptop in the child's room

observed a sweet and intimate interaction between parent and child when parents would read bedtime stories. The team members noted how their own parents kept and cherished specific books they had read together at bedtime. In watching these bedtime routines unfold, the team noted that when reading to children, parents stopped multicontexting—a term introduced by Darrah, English-Lueck, and

Freeman (2001) to describe how busy parents inhabit both work and home roles simultaneously—and fully engaged in their role as parent. These observations helped to shift the focus away from this simply being a problem of parenting consistency. The team expanded their scope, looking for opportunities to connect the intimate ritual of bedtime with the design. This perspective eventually led the team to add the treasure box as a way of connecting the product with this intimate, nightly routine.

The team advanced the design through a process of scenario building, body storming (Buchenau & Suri, 2000), and rough prototyping. Through critique and reflection on the many sketches and prototypes created, the team began to play with the complex issue of control. Smart home research shows that busy parents are much more interested in gaining control over their life than gaining increased control of their stuff (Davidoff, Lee, Yiu, Zimmerman, & Dey, 2006). Other smart home research showed that parents did not want new technology that automated parenting; that took over parenting responsibilities (Davidoff, Lee, Dey, & Zimmerman, 2007). These insights helped to reframe the project goal. The team began to look for ideas where parents gained control of a situation and for opportunities to support parents in parenting as opposed to automating parenting tasks.

This new framing led to the controller and to the design of the display as a set of rules. The controller provides a type of relative control for parents. They can set a very different moonset time for a Tuesday and for a Saturday while the child's experience with the display remains consistent. In terms of supporting parenting, the linking of the display to a set of rules framed the clock as a tool parents use to help teach their children to make good decisions, a long-term goal of parenting. When the child has a bad dream or feels sick and seeks comfort in their parent's bed, the parents' reaction to the situation helps shape the child's understanding of when rules must be followed and when they might be suspended. From this new framing, the clock's role is to provide information a child can understand, and the parent provides the guidance to the child, helping them interpret the meaning of this information in different situations.

Once the team arrived at a final form, they continued the design process by making three versions of the clock and conducting a field trial with three families. They recruited families who had problem sleepers; children that repeatedly got up at night and woke their parents. In early discussions with parents, one mother described moving her three-year-old from the crib to a toddler bed as the "worst three weeks" of her life. The clock functioned well, helping to reduce the frequency with which children woke their parents at night and reducing the length of time it took to get children back into bed. More importantly, however, discussions with parents both before and after the installation help change the team's idea of how the product should situate in a family's life. Up to this point the design had been focused on solving a problem for families that were experiencing disrupted sleep. It was seen as a solution once the problem had occurred. In talking to these parents about the transition from crib sleeping and co-sleeping to having a child sleep in a toddler bed, the team was struck by the sense of celebration and achievement bound up in this transition. These new beds were presented to children as a sign of achievement; a sort of

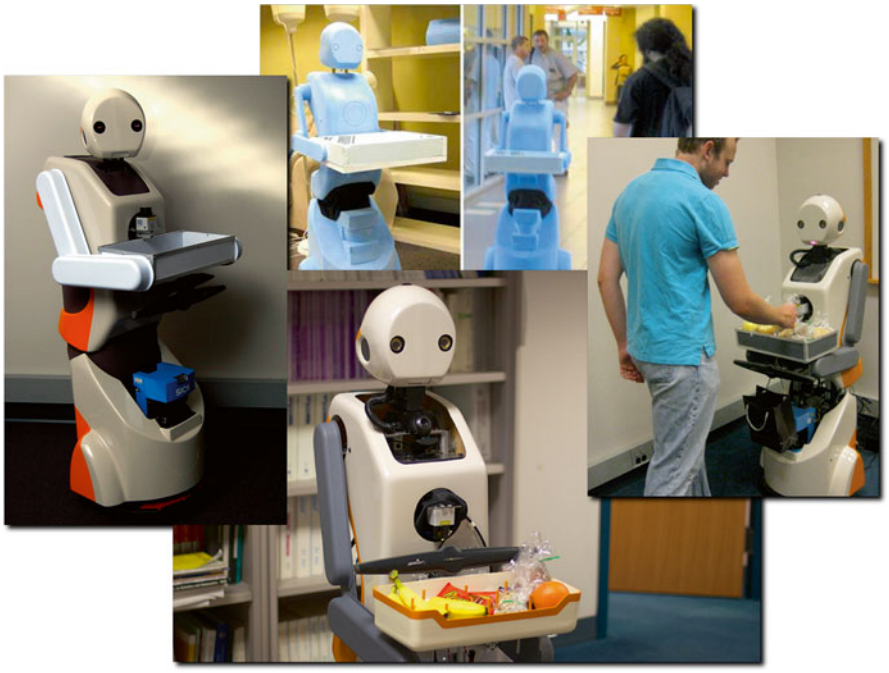

Fig. 7 (*Clockwise from top*) Exploring different physical forms in the context of use. person collecting the snack they ordered from Snackbot. Final design showing robot holding a tray of healthy and less healthy snacks. Nearly final version of Snackbot investigating color, arms, and tray

graduation. Seeing families use the clock and listening to the transition stories again reframed the goal of this project. Instead of a focus on solving a problem, the design team noted that the transition point, where the child moves to a toddler bed was the ideal time to introduce the clock into a child's life. It should be part of the transition in the same way as the toddler bed, as a celebrated artifact of this transition. In stepping back, the team saw that many technologies designed for the home could also follow a similar path, of being introduced during life stage transitions as opposed to being introduced in reaction to a breakdown in the family.

Snackbot

Snackbot (Fig. 7) is an example of how prototyping a future state, which is core to RtD research, can open up new ideas for how future technology products can benefit people's lives.

This project began with the desire to develop a robot so that the research team could study human–robot interaction (HRI) over time. Many questions about long-term HRI are unanswered. How do people's perception and attitudes towards a robot

evolve over time? What interaction design strategies will reinforce a positive long-term relationship between people and a robot? Will employees engage with a robot as the design team intends, or will they appropriate the robot in new ways, as have happened with other technologies? Could robots deliver services that are beneficial to people over the long term? How should robotic products and services be designed?

As designers, we had three design goals for development of the Snackbot robot. The first was to *develop the robot holistically*. Rather than advancing technology *per se* or focusing on one aspect of design or interaction, such as a dialog system, we took a design approach that considered the robot at a human–robot–context systems level. The second goal was to *simultaneously develop a robotic product and service*. By this we mean that the robot as a product would have to be more than sociable and attractive; it would need to deliver something useful to people. The third goal was to *develop interaction designs that would help to evoke social behavior*. Because the robot was meant to serve as a research platform that would be used by people over time, decisions about functions and features were made supporting the interest of promoting sociability. In its final form, the Snackbot delivery service (Fig. 7) consisted of the following components:

Robot. Snackbot (Lee et al., 2009) is a 4.5-foot tall, anthropomorphic wheeled robot. The robot can make head movements to each side, and up and down, and can animate its LED mouth display to smile, frown, or show a neutral expression, and employ speech output.

Snack ordering Web site. Participants could order snacks using a custom designed snack ordering Web site and database. Customers specified the snack type, delivery day, and their office number. Only those registered in the study could order snacks through the Web site.

Snacks. Snackbot delivered six different snacks—apples, bananas, oranges, Reese's peanut butter cups, Snickers candy bars, and chocolate chip cookies. We chose a mixture of snacks that were not always available in the workplace.

Robot control interface. A GUI allowed an operator to control the robot's navigation, nonverbal movements, and dialog system remotely. The interface showed the video feed from the robot, the robot's location on the building map, its head position, and a number of dialog scripts. The operator could see a participant's actions through the video/audio feed on the interface.

Operator. An operator transformed the orders on the Web site to a delivery schedule, loaded the snacks on the robot's tray, initialized the robot at the start of each delivery run, and localized it.

The development of the robot, Web site, and GUI was an iterative, user-centered design process, and was guided by frequent meetings of our interdisciplinary research and design team. Once the system was complete, we could begin to systematically explore what aspects of the design could be modified to increase trust and rapport with the robot, increase the likelihood that customers would use the service again, and inspire customers to make healthy snack choices or to converse about personal topics with Snackbot.

For example, in one study, we focused on operationalizing behavioral economics theories to help people make healthy snack choices by varying the design and location of how the snacks were presented on the Web site and on the robot (Lee, Kiesler, & Forlizzi, 2011). We learned that some strategies are more persuasive than others, especially for those with less healthy lifestyles. We can design to support convenience or minimize it, and to support choice influence by making healthy choices look good and unhealthy choices look stale or unappetizing. We learned that we can even leverage social influence in helping people to make better decisions.

In another study, we varied the robot's behavior to offer a set of customers personalized snack delivery service (Lee, Kiesler, Forlizzi, & Rybski, 2012). Customers receiving personalized service were offered the option of a special mystery snack in lieu of their order, or an opportunity to do a neck stretch with the robot. The robot also chatted with customers about things it remembered about them, such as what snacks they had ordered in the past, and what kind of work they did. Customers in the control condition received typical social chat and did not have the option to receive a mystery snack as their order. Despite the knowledge of Snackbot as a machine, participants receiving snacks delivered by the robot developed a variety of social relationships with the robot. Beyond one-on-one interaction, the robot created a ripple effect in the workplace, triggering new behaviors among employees, including politeness, protection of the robot, mimicry, social comparison, and even jealousy. The design implications of this work will assist in development of many kinds of future technology for the workplace.

Snackbot as an RtD effort continues to explore many questions about the social use of robotic technology within an organization. However, additionally, the robot and the service it provides create a rich context for understanding and advancing research in the design of technology services. In this work, we are creating new understanding of how people will adopt technology over time, and will develop rapport, trust, and liking of assistive robots and technology services. Without this research platform, we would make far less educated judgments about an improved future state.

How to Do It

To carry out an RtD research project, we suggest a team follow five simple steps:

1. Select
2. Design
3. Evaluate
4. Reflect and disseminate
5. Repeat

Select involves choosing a research problem worthy of investigation. Teams should first decide if they want to focus on a problem or a design opportunity. They need to select a new material to play with, a context and target population to

understand and empathize with, a societal issue or insight, and/or a theoretical framing they wish to apply to interaction. Selecting is an iterative process of trying many different things until the team agrees. Other important factors in terms of selecting include if the research problem lends itself to investigation via RtD. Is this a wicked, messy problem space that can best be addressed through the application of design thinking? For example, does it have multiple agendas driven by different stakeholders and entrenched interests that prevent an optimal solution? Finally, the teams will want to consider the skills the research team possesses, as well as the desires and concerns of the people or institutions that are funding the research project.

Next, the team should consider which RtD practice to follow (Lab, Field, or Showroom) or if they wish to mix two of the practices together. Once they make a selection, we suggest a literature review to discover examplars of this kind of RtD research. One or two exemplars can provide scaffolding to guide the process.

After choosing the exemplar(s), the team can begin *design* activities. They should conduct a literature review to understand the state of the art and the questions and concerns of other researchers working in this space. They can then continue by conducting fieldwork, by holding a design workshop, by playing with a new material, or by exploring ideas in the studio. In these early stages of the project, the team is searching to understand what the state of the world is and how they might offer a new perspective, a new problem framing, which provides a path to a preferred future.

Once they have an initial framing, the team can explore by creating new product/service ideas and then select and iteratively evolve and refine an idea into a completed form. Through their process of making and critiquing, the team should *evaluate* and continually challenge their initial framing. In a sense, each new concept they generate will offer a different framing through its embodiment of a solution, and part of the critique is to explicate the proposal that is embedded in the designer and in their solution. Throughout this process, the team should document their design moves, the rationale (Moran & Carroll, 1996) for these moves, and how different hunches did and did not work out. In addition, the team should reflect on how their framing of the situation evolves and work to capture the reasons their framing changes.

When the team has an artifact they like, they should evaluate it based on the concerns of the specific RtD practice they selected (Lab, Field, or Showroom) and on concerns specific to their research question. Work following a Lab practice will most likely result in several similar artifacts that can be assessed in a lab study. Work following the Field practice will most likely place a working prototype into the field and assess if it produces the intended behaviors and outcomes (See "Field Deployments: Knowing from Using in Context"). In addition, the researchers will look for the creation of new practices as people attempt to incorporate this new thing into their lives. Finally, work following the Showroom practice will likely involve the installation of a working system in a gallery or in some other place where people outside of the research team can experience the design and can begin to question the world around them.

Following the evaluations, the team should reflect on what they have learned and then work to disseminate the research. Dissemination can happen in terms of publication in peer-reviewed venues such as conferences or journals. It might also take the form of a video or demonstration. Finally, for some RtD projects, the work may result in a working system that remains in use by people long after the research project has ended, provoking designers to think about the next problematic situation and solution.

The final step in the process is to repeat. Koskinen et al. (2011) note that RtD researchers who produce the best research results do so by repeatedly investigating the same situation. It is through the development of research programs much more than through individual projects that the best results emerge (See Koskinen et al., 2011: Chap. 10: Building Research Programs).

Exemplars we recommend looking at include:

Rich Interaction Design (Lab)

1. Joep Frens' investigation of rich interaction through the design of camera that rejects the convention of buttons with labels. (Frens, 2006a, 2006b).
2. Philip Ross' work on ethics and aesthetics through the design of a lamp. (Ross, 2008; Ross & Wensveen, 2010).
3. Camille Mousette's investigation of sketching with haptics (Although this lacks the formal lab studies of these other examples, it does have workshops run with designers to see if the methods of sketching could be transferred to these designers) (Moussette, 2012).

Participatory Design and User-centered Design (Field)

1. Hutchinson et al.'s work on technology probes produced a fascinating design method where researchers design and implement a working system which they then place into the hands of users for long periods of time in order to observe appropriation (Hutchinson et al., 2003).
2. Scott Davidoff et al.'s work on a smart home system that helps busy parents with the logistics around picking up and dropping off children (Davidoff, Lee, Dey, & Zimmerman, 2007; Davidoff, Lee, Yiu, Zimmerman, & Dey, 2006; Davidoff, Zeibart, Zimmerman, & Dey, 2011; Davidoff, Zimmerman, & Dey, 2010)
3. John Zimmerman et al.'s work on Tiramisu, a service design project that allows transit riders to coproduce real-time arrival information with their transit service (Yoo, Zimmerman, & Hirsch, 2013; Yoo, Zimmerman, Steinfeld, & Tomasic, 2010; Zimmerman et al., 2011).
4. Sara Ljungblad's work on connecting people's marginal practices to design innovation and how she integrated lomography into camera phones (2007). The work does seem to foreshadow commercial products like Instagram.

Critical Design (Showroom)

1. Bill Gaver et al.'s Drift Table, which challenges the HCI assumption that interaction design must have a clear intention for how it should be used (Gaver et al., 2004).

2. Bill Gaver et al.'s Prayer Companion, which pushed digital information into sacred places (Gaver et al., 2010).
3. Eric Paulos et al.'s work on Jetsam, a system that publically displayed items people threw into public trashcans (Paulos & Jenkins, 2005).
4. James Pierce et al.'s work to get people to rethink their ability to produce, store, and share energy (Pierce & Paulos, 2010).

Exercises

1. Generate three questions that can be answered by RtD. How would you characterize them?
2. How does research through design compare with design?

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