INTERNATIONAL CONFERENCE ON HUMAN BEHAVIOR IN DESIGN
14-17 OCTOBER 2014, ASCONA, SWITZERLAND

USING EMBODIED DESIGN IMPROVISATION AS A DESIGN RESEARCH TOOL

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ABSTRACT
Embodied design improvisation is a generative and evaluative technique to elicit tacit knowledge about embodied experience. It incorporates storyboarding, Wizard of Oz prototyping, domain expert improvisation, video prototyping and crowdsourced experimentation. We have been developing this technique to design physical interactions with expressive, robotic everyday devices, eliciting the tacit rules and behavior patterns that comport with the social expectations established by human-human interactions. By codifying and providing an example of this technique, we hope to encourage its adoption in other design domains.

Keywords: Improvisation, prototyping, Wizard-of-Oz, crowdsourcing, experimentation

1 INTRODUCTION

> *Design, by definition, is...mostly tacit knowledge. It has to do with people's intuitions and harnessing the subconscious part of the mind rather than just the conscious...If you think about the structure of the mind, there just seems to be a small amount that is above the water—equivalent to an iceberg—which is the explicit part...If you can find a way to harness, towards a productive goal, the rest of it, the subconscious [understanding], the tacit knowledge, the behavior—just doing it and the intuition—all those, then you can bring in the rest of the iceberg. And that is hugely valuable.*
>
> *–Bill Moggridge*
> *Co-founder of IDEO, Director of Cooper-Hewitt National Design Museum*
> *Ambidextrous Magazine interview, 2007*

1.1 Embodying Design Thinking

One of the key challenges facing designers is to unlock the tacit understanding of how they believe things should be, so that these ideas can be shared, discussed, critiqued and eventually operationalized. Nowhere is this more difficult than in the design of physical interactions, where critical aspects of a design are often neither verbalized nor materialized. And yet, physical movement, behaviors and gestures can be critically important in the design of everyday objects—of cars, of robots, of doors and drawers—where autonomous motion is increasingly being incorporated, and where inexpensive controllers and batteries enable products that can lock and unlock, open and close, move around, wave, hide—*act* on their own.

We propose that, on some level, designers intuit what should be designed, but at the same time, they need ways to elicit that knowledge in ways that are actionable. How, then, can we help designers to understand, think through and evaluate interactions during their design process? We have been developing an approach to *embodied design improvisation* that combines storyboarding, physical and video prototyping, Wizard of Oz techniques, and crowdsourced experimentation to both reveal and evaluate appropriate interactions. Our use of improvisation has been particularly crucial in designing machines and robots that employ physical action, because a) we are drawing upon motions, gestures and interaction patterns that are most often implicitly, rather than explicitly, understood, and b) the time and expense to build real functional systems to evaluate is high.

In exploring and integrating these methods for physical interaction design, we believe that we are also taking first steps towards a more generalizable technique for drawing out the intuitive and tacit aspects of design thought and action, which need to be articulated, recorded, codified, transmitted and reused in order to reach their full potential.

2 DESIGN RESEARCH SETTING

Our use of design improvisation has evolved over several projects the last two years. We are currently developing everyday objects that can sense and physically respond to users' needs, and express their own intentions and emotions. The *mechanical ottoman* is a robotic footstool that interacts with users by offering or responding to request cues to place itself under their feet (Figure 1a). It can roll along the floor from across the room, rotate around itself to change direction, and lift itself up several centimeters as if poised to act. The *emotive robotic drawers* [1] is intended to anticipate when users need to stow or retrieve small desktop items, and open or close in expressive ways that react to their emotional states (Figure 1b). It can open or close a specific drawer swiftly or lazily, synchronize the movement of several drawers, or even shudder as if frightened. These prototypes represent initial forays into understanding and designing interactions between humans and *ubiquitous robotics* [2].

Figure 1: On the left (a) is an actor and designer improvising with the robotic ottoman. Its movement mechanism is concealed just below the frame. On the right (b) is a video prototype of the emotive robotic drawers responding to being tickled by a confederate actor.

3 DESIGN RESEARCH PROCESS

The following sections detail elements of our design research process in the context of these two ongoing interaction studies. The activities are presented separately for clarity, although in practice, they overlap and may occur in some other sequence, depending on the project's design arc.

3.1 Identify a Research Question

When starting a design research program, it is important to identify one or more research questions to guide and focus efforts, even if the questions are only broadly defined at first. Research questions inform the selection of relevant interactions, participants, and the contexts in which these interactions occur. These circumstances, in turn, inform the types of research protocols to follow, the type of data that can be collected and analyzed, and the scope and validity of findings.

With a design agenda in hand, benchmarking enabling technologies, observing individuals and environments, and brainstorming behaviors of interest can all be particularly helpful in generating ideas for what interaction scenarios to focus on. Such ideation methods should generally be considered team activities, whose value increases with several researchers involved per activity. It is important to document and record this process and its artifacts, as rich descriptions, sketches and recordings are often used in reports, and as pointers to when and where ideas initially emerged.

3.2 Storyboard People, Activities and Environments

Especially during the early stages of a design oriented research project, it can be valuable to find or create scenarios to explore and understand people, technologies and the interactions between them. The goal is to help reveal implicitly known, unstated, behaviors and understanding. We typically start as a group huddled around a whiteboard with Post-It notes in hand, creating one or more storyboards [3, 4], and blocking out the interactions that we want to explore (Figures 2 and 3). At first, these storyboards serve as guides for how to enact scenarios or design prototypes. Later, they become archives of our initial thinking and indicators of how that thinking has evolved.

By sketching as a group, we raise and challenge alternatives, acting out interactions or device usage scenarios. This process unearths what individuals on the team implicitly know or anticipate about the interaction scenarios, so that others can reflect upon, and then extend or redirect, those ideas. By working at a rapid pace, at large visual and physical scale, in a situated environment, the team develops an embodied understanding of the problem [5, 6] and alternative approaches to explore it.

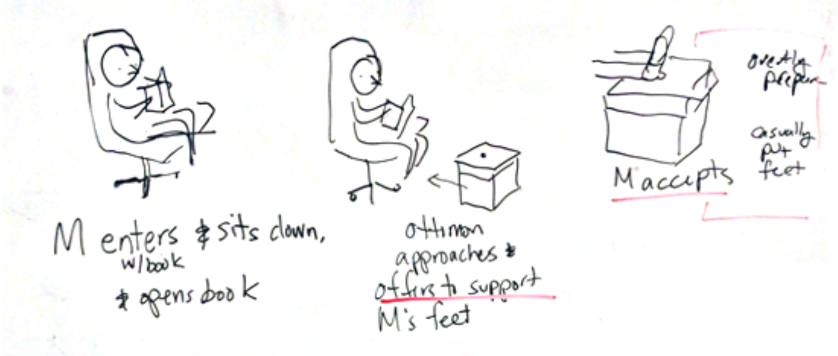

Figure 2: Excerpt of a storyboard for the mechanical ottoman. The scene shows our initial ideas about how the ottoman would offer to interact and the person would accept.

Figure 3: Excerpt of a storyboard for the robotic drawers. The storyline shown anticipates the viewing angle and action that we used in subsequent video prototypes (shown above).

3.3 Prototype Technologies for People and Situations

As we discuss how interactions should unfold—usually concurrent with storyboarding—we prototype devices, technologies and situations. Prototyping and storyboarding inform each other, and alternating between them builds a deeper understanding of the design questions at hand [7].

At first, prototypes are hastily constructed: we recruit lamps, hand tools, cardboard boxes, furniture, or whatever else may be at hand as stand-ins for the features and functions that we need. This keeps initial costs low and permits quick testing. For example, the first prototype of the mechanical ottoman was a half-meter square foam cube, while the first prototype of the robotic drawers was an IKEA mobile drawer set borrowed from a nearby office. We animate these prototypes through motion: steering objects around the floor by hand using parallel linkages made from broomsticks, lifting and lowering lids by tugging on barely-visible clear monofilament, or opening and closing drawers from behind using makeshift handles made of rolled-up gaffer's tape.

By improvising usage scenarios with these prototypes, we develop an initial set of functional requirements (such as *"the drawers should be able to open/close with variable speed"*) and design principles (*"objects should 'sit down' when they stop moving"*), which we use to purchase or construct more robust, useful prototypes, and thus iterate our way to improved designs. Over the course of iterating, these prototypes *should* begin to resemble useful devices, rather than rough-and-ready prototypes, to make sure that users or observers can focus on their designed features and functions rather than the artificial aspects of their construction.

3.4 Improvise Usage Scenarios with Experts

In a break with traditional research methods, we recruit domain experts to help improvise these scenarios and enact our storyboards. Interactions depend strongly on context and use, so these improvisation sessions help us maintain a focus on prototyping interactions rather than devices [8, 9]. In particular, we seek professionals from outside of our design context—actors, dancers, puppeteers, interface designers and roboticists—who offer diverse, yet deeply experienced and informed, perspectives. During any project, we conduct several such improvisation sessions, each with one or (preferably) more artists and engineers present, as engaging several participants at once can raise questions and answers that might otherwise have gone unspoken. One example is whether the mechanical ottoman should be treated, or behave, as a trusted servant, or as an obedient pet.

By physically engaging these experts with specific design challenges *("shoo the ottoman away in as many ways as you can"*), and purposefully creating a playful environment (*"how would a silly, or hungry, or timid drawer open?"*), we hope to invite serendipity, and encourage them to open up, challenge our expectations, and reveal their own implicit understandings. Improvisation sessions are quite informal, although at times we may employ more structured warm-up exercises or techniques. These include a) focusing on the obvious or immediate needs of the situation, b) failing cheerfully by encouraging exaggeration, c) telling stories about real or fictional characters and situations, and d) asking whether more or less detail is needed to understand the situation [10].

3.5 Video Record to Demonstrate Usage

Video prototypes are brief clips of how an interaction might take place. Much like storyboards, only with greater audio and visual fidelity, video prototypes help designers and researchers communicate—to others as well as themselves—the interplay between humans and novel technologies, within a specific context, over time. When combined with rapid prototyping and Wizard of Oz techniques [11, 12], video prototypes [13] allow design researchers to a) explore and evaluate potential technologies—their roles, appearance and functions—without incurring the time and expense of building fully realized systems, and b) distribute meaningful representations of these technologies to a much broader and more diverse population than the actual, physical prototypes and environments would allow. This is not to say that more fully realized systems are never built, just that their design extends across exploratory stages that help to get the *right design* [14].

By video recording improvisation sessions, we create a record of our expert interactions as well as (potential) initial video prototypes of these interactions. But most often, we recreate these scenarios more deliberately during one or more dedicated recording sessions, for which we recruit colleagues as onscreen actors and employ established videography techniques. Among these are use of an establishing shot (so the viewer understands the interaction context), multiple camera angles (typically one wide and another narrow), and framing scenes to conceal our Wizard of Oz manipulations (including linkages, cables, and humans-in-the-loop).

To help scenes convey the designed interactions, we create simple sets that include lighting, furnishings and props appropriate to that situation. At the same time, we are careful not to over-populate scenes in ways that distract from the important action. For example, scenes of the mechanical ottoman were shot in a lab corner with a lounge chair, floor lamp, cushions and houseplants, while scenes of the robotic drawers were shot in an office with a work chair, desk, shelf and computer (Figure 2). We then edit this footage into several alternative clips, where each clip demonstrates a different device, behavior or scenario for observers to evaluate. Since these clips will serve as conditions in an online experiment [15], it is important to craft them so that only one of these variables of interest changes between conditions [16].

3.6 Crowdsource Studies to Understand Broad Perceptions

We deploy video prototypes using Amazon's Mechanical Turk, a crowdsourcing platform that matches requesters having small online tasks to be performed with qualified workers. Each video is embedded within an online questionnaire that asks participants about aspects of the scenario before them (Figure 4). We find sets of questions by searching prior literature, or we develop our own, to address research and design questions raised during prototyping and improvisation sessions. Finding measures within existing work has the advantage of drawing upon validated scales and analyses that have already been vetted by the community.

For the robotic drawers, more than just understanding whether one type of action/response was perceived as more appropriate than another, we wanted to understand whether the interaction between person and drawers would be perceived as a dialogue, and to what extent the drawers could project an emotional affect. This led us to a body of work on robotic conversational analysis [17], which we adapted for our research context, and included in the online questionnaire. The resulting set of questions included, for example: *"how appropriate was the dialogue between person and drawers," "did the drawers show empathy toward the person," "are the drawers and person similar,"* and *"did the drawers and person get to know each other during the interaction?"*

The use of Mechanical Turk—especially when combined with an online survey and analytics service such as Qualtrics—allows rapid iteration of study design: typically within a few hours [18]. Often, before a study is complete, a cursory review of initial responses reveals how well participants understand the questions asked and the scenarios depicted, and suggests whether the study should proceed as it is, or be revised and redeployed. This revision might include re-recording video prototypes, altering the set of questions asked, or even revisiting the motivating research questions.

Please respond to the following statements:

	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
The dialogue between the drawer and the person felt natural.	○	○	○	○	○	○	○
I thought the dialogue was appropriate.	○	○	○	○	○	○	○
The person liked the behavior of the drawer	○	○	○	○	○	○	○
Over time, I think the person would build up a relationship with the drawer.	○	○	○	○	○	○	○
The drawer showed empathy towards the person.	○	○	○	○	○	○	○
The drawer demonstrated emotion at times.	○	○	○	○	○	○	○
The drawer was compassionate.	○	○	○	○	○	○	○
I felt the person could correct the drawer when necessary.	○	○	○	○	○	○	○
The drawer got to know the person during the interaction.	○	○	○	○	○	○	○
The drawer is rather like the person.	○	○	○	○	○	○	○
The drawer was polite.	○	○	○	○	○	○	○
The drawer surprised the person at times.	○	○	○	○	○	○	○
The drawer anticipated the person's needs.	○	○	○	○	○	○	○

Figure 4: Excerpt from the online study on the emotive robotic drawers. Participants viewed alternative video prototype clips using Amazon's Mechanical Turk crowdsourcing platform.

3.7 Conduct a Lab/Field Study to Confirm or Extend Findings

The use of video prototypes is but one tool in conducting robot interaction research [19, 20]. To confirm how well the perceptions of online observers agree with the experiences of physically co-present participants, we recreate, to the extent possible, the online study in our lab or a nearby environment [21]. Alternatively, we may bring prototypes into the field to extend the findings from web-based studies. In either case, live interactions with functional robots requires much more robust construction than recorded interactions with Wizard of Oz prototypes, so we only begin lab or field studies once we build in to our devices the ability to move on their own. If we are able to do so early enough, field trials may begin before we have even recorded the video prototypes. For example, the robotic ottoman prototype is built upon an iRobot Create platform, so after only a few hours of software and network configuration, we could teleoperate the ottoman at a local coffee house.

For such impromptu field studies, we prefer to have in mind a detailed set of questions to answer, or tasks to perform, as this focuses our activity during the session and provides specific, actionable takeaways. For the coffee house study, these questions included the following: *"how many ways can the ottoman get someone to rest his/her feet (or drink) on it," "can the ottoman start a conversation* *between two strangers," "how would the ottoman calm someone,"* and *"how would the ottoman get someone to speak to it?"*

4 CROWDSOURCED DESIGN IMPROVISATION

We are currently expanding the role of crowdsourcing into the earlier stages of design improvisation. In this variation, online study participants assume the role that domain experts filled previously, in providing early-stage feedback of potential usage scenarios and rough prototypes. Implementing tools such as Legion [22], which enable real-time interactive teleoperation among crowd workers through a shared interface [23, 24], allows these distant design process participants to interact with each other, and build upon one another's recommendations. As a result, they can collaboratively decide how scenarios should be setup, and how objects should behave within them. Our current explorations center on understanding proper social relations between humans and a *roving trashcan* and *chair* (Figure 5).

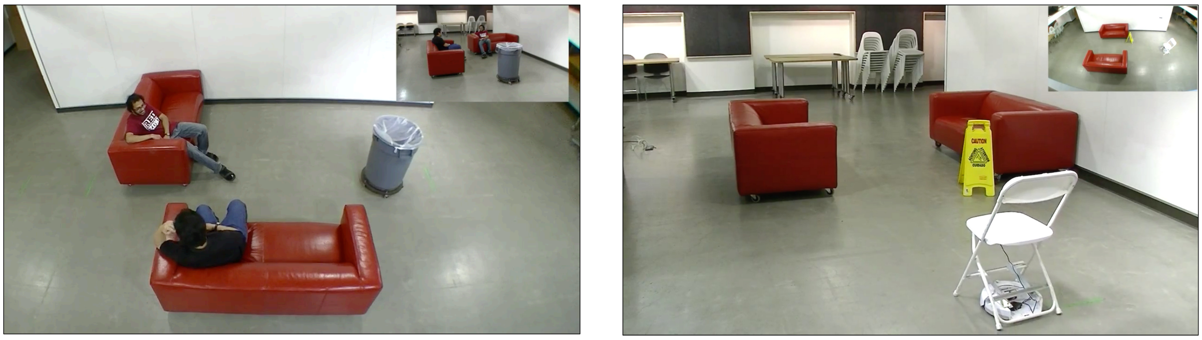

Figure 5: On the left (a) is a roving trashcan setup, which online participants help situate, and then steer. On the right (b), participants' recommendations combine to form a consensus of how the chair should navigate the wet area between/around the sofas.

5 DESIGN DOMAINS AND IMPACT

While the immediate application domain of our research is that of physical interaction design, the techniques we are using address the challenge of making tacit design knowledge explicit. As such, the approach can be employed by the broader design research community.

Many of our techniques are, and have been, in use in pockets of design practice and research. However, the potential synergies between embodied action, improvisation, video prototyping and crowdsourced experimentation as yet remain unrealized. By adopting this method, designers begin to make explicit things that are known, but are difficult to articulate. They expose these understandings to open discourse, allowing them to operationalize the resulting insights into practices that can then be employed by others. They incorporate divergent and convergent thinking into their design research process: to help refine thinking, answer questions, test approaches and resolve questions.

The impacts of this work lie in a) developing and systematizing our approach to design research, b) making the approach actionable and available to the research community, and c) exposing embodied design improvisation and video prototyping as valid and integral elements of the design research process. We expect that this work will provide a roadmap for researchers in other design domains to follow in their own explorations of embodied design thinking.

ACKNOWLEDGMENTS

The authors thank the Hasso Plattner Institute—Stanford Design Thinking Research Program for funding the work, colleagues Aleta Hayes, Jofish Kaye and Matteo Vignoli for their expertise, and research assistants Brian Mok, Ashley Mills and Daniel O'Shea.

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