The Needfinding Machine

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Abstract Interactive systems present new opportunities for creating devices that attempt to learn the needs of people. However, inferring from data alone may not always allow for a true understanding of user needs. We suggest a vision of Social IoT where designers interact with users *through* machines as a new method for needfinding. We present a framework using interactive systems as *Needfinding Machines*. Acting through a Needfinding Machine, the designer observes behavior, asks questions, and remotely performs the machine in order to understand the user within a situated context. To explore a Needfinding Machine in use, we created DJ Bot, an interactive music agent that allows designers to remotely control music and talk to users about why they are listening. We show three test sessions where designers used DJ Bot with people listening to music while driving. These sessions suggest how Needfinding Machines can be used by designers to help empathize with users, discover potential needs and explore future alternatives for Social Internet of Things products.

1 Introduction

The Internet of Things has expanded beyond industrial settings to encompass everyday products from toothbrushes to autonomous cars. Cheap microprocessors and wireless networking allow designers to make everyday objects "smart," with the capabilities to collect data, make decisions, and interact with people. But what is the best way to *design* these Internet of Things products so that they fit into the social context of people's lives? How can designers learn more about the environments these products will be deployed in, the uses people will want, and the problems people will encounter? During a human-centered design process, *needfinding* is an

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activity used by designers to explore and understand people in relation to the design of new products [32, 65]. Needfinding ideally occurs during the early stages of a design project where the designer's goal is to *design the right thing before designing the thing right* [43]. While discovered needs themselves do not present immediate solutions, they help to align the designer's perspective and empathy with the user. This subsequently helps the designer generate ideas that are more likely to satisfy the user.

As machines collect more data about their users, there have been efforts to develop ways for computers to observe and learn how to service the needs of their users. Some examples include the Lumière Project by Horvitz et al. [45], which aimed to automatically identify a user's goals and provide task support while using desktop office software; Chen and Cimino's [18] use of clinical information system logs to identify patient specific information needs; and Radhid et al.'s [68] "Getting to Know You" techniques for helping recommender systems learn about the preferences of new users. Though these systems can allow machines to automatically characterize users in limited settings, we argue for an alternative approach in which machine capabilities enable designers to perform needfinding in new ways. Central to this idea is the insight that data—and even needs—do not automatically lead to solutions; we still need designers to probe situations and synthesize the meaning of observations towards potential alternatives. While data-driven design may allow us a new lens, there is no replacement, as Dreyfus [29] suggests, for field research to educate the designer about the needs of people. With new capabilities though, we can explore how designers might augment their needfinding abilities.

This chapter explores how designers can use interactive technologies as a way to do needfinding with Internet of Things devices. We call this framework for doing needfinding the *Needfinding Machine*. Working with a Needfinding Machine allows designers to discover people's needs by allowing the designers to observe, communicate and interact with people *through* their products. While our work is similar to the idea of using things as co-ethnographers [41, 42], it differentiates itself by using things as a way of mediating direct interaction between the user and designer. The Needfinding Machine provides a "conversational infrastructure" [30] by which the designer can build their understanding of a person in an evolving fashion and in the user's real context. This means that the Needfinding Machine is not a machine that discovers needs on its own. Rather, the Needfinding Machine extends a designer's ability to preform traditional person-to-person needfinding by interacting with the user and observing the user experience *through* the machine. It is computer-mediated communication between the designer and user under the guise of the Internet of Things. This is shown in Fig. 1. The outer loop represents person-to-person needfinding, such as interviews and personal observations. The inner loop shows needfinding done through the machine.

In this chapter, we outline the concept of the Needfinding Machine and detail the motivations and prior work that have inspired the development of this concept. We then present a case study in which we built a Needfinding Machine, DJ Bot, that allows designers working with a streaming music service to act as a smart agent that talks to people to figure out what music to play. In the process of "being the

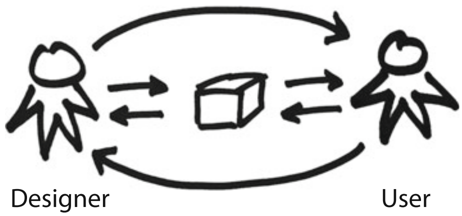

Fig. 1 The Needfinding Machine: a method for designers to interact *through* systems to understand user needs

machine," the designers are able to explore people's connection with their music and potential needs that would drive intelligent music recommendation agents. We conclude by discussing the implications that this Needfinding Machine framework has on how designers discover user needs in relation to the design of new products and experiences.

2 What Is a Needfinding Machine

Faste [32] defines needfinding as an active process of perceiving the hidden needs of specific groups of people. He has outlined a non-exhaustive list of needfinding methods that designers can use to better understand people, including market-based assessments, technology pushes and forecasting, and personal observations and analyses. Patnaik [65] further describes needfinding as an organized, qualitative research approach to support new product development that has been adopted within human-centered design processes [52]. Within human-computer interaction, needfinding is often focused on developing user requirements to guide product development and usability [10, 50] and to help designers develop empathy for their users [85].

A *Needfinding Machine*, then, is an instrument we intend to be used by designers to further their efforts to understand user needs in relation to a specific context. It is embedded in some product or device that itself is embedded in the user's environment and in their everyday life. This setup allows the designer to explore distant environments, interact over large time scales, see data, elicit information from the user, and prototype interaction in ways that overcome previous limitations of observational design research [49]. The information flows for a Needfinding Machine are shown in Fig. 2. Moreover, Needfinding Machines are inspired by Forlizzi and Battarbee's [33] framework for understanding the experience of interactive systems. Like Forlizzi and Battarbee, we center on user-product interaction as a way to understand user experience and focus on exploring situated interaction within the real-world.

During use, Needfinding Machines provide designers with real-time access to objective system data (sensor readings, system logs) and qualitative observational data (video, audio). Moreover, they allow the designer to actively converse with the user through Wizard-of-Oz [25] interfaces (voice, screens, tangible interfaces, etc.). This 'conversational infrastructure' [30] allows the designer, user, and the machine to interact in a situated manner [78] towards the goal of understanding the user's needs

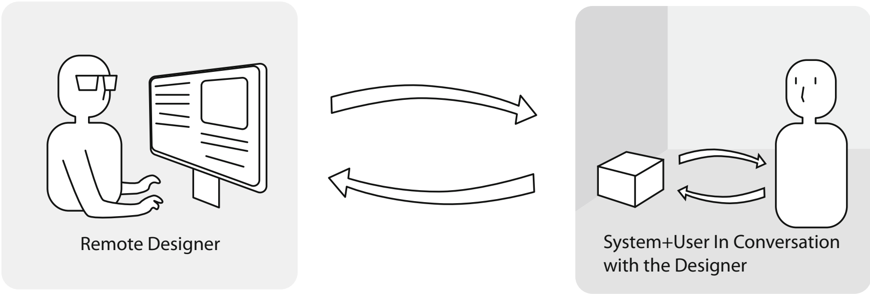

Fig. 2 Information flows in a Needfinding Machine. The remote designer interacts through and performs an interactive system situated in the user's environment. They can observe these interactions in real-time. This enables conversation between the designer and the user, mediated by the machine

in relation to a specific context. The Needfinding Machine uses an interactive device as a meeting point between the designer and the user [75]. By allowing observation and interaction, the designer can use a Needfinding Machine to understand the user and take preliminary action towards satisfying the user's needs [75].

2.1 Considerations for Needfinding Machines

Remotely accessing a user's environment through an interactive device can provide a designer with many potential ways of collecting data about the user. With this in mind, we actively steer the Needfinding Machine away for certain kinds of data collection in order to respect the user and obtain honest feedback on a design concept. Specifically, we do not advise that Needfinding Machines be:

Spybots—Needfinding Machines help the designer build understanding through *interaction* rather than *surveillance*. This interaction is intended to be an overt conversation that builds a relationship between the designer and the user and is conducted with respect toward the user. To that end, Needfinding Machines should not be solely observation devices. Rather, they allow for observation, action, and analyses simultaneously as a way for designers to explore unknown needs around a product [46]. By interacting with users through an artifact and by engaging the user in conversation, the Needfinding Machine can "amplify designer understanding of the intended purpose(s) of the artifact and may provide information that does not come out of initial interviews, observations, and needs analysis" [1].

Machines that ask "How am I doing?"—Though a Needfinding Machine enables remote user observation, the goal of a Needfinding Machine is to aid the designer in developing an understanding of the user in context, not to justify the existence or usability of the machine in that context. A machine that asks "Do you like this?" or "How am I doing?" can lead to overly polite responses from users [63]. Just as a designer should not lead off needfinding by telling users what they plan to build or asking if the user likes a prototype, Needfinding Machines should focus on how the user feels and experiences the interaction rather than on confirming how well they are functioning.

3 What Is in a Needfinding Machine

In this section, we describe what elements are required to make an interactive device into a Needfinding Machine. We use a hypothetical Internet of Things coffee maker as an example device that designers can use to do needfinding work in a home environment. Specifically, we can imagine a design team tasked with understanding the user experience of a smart coffee maker as well as understanding that broader relationship that a user has with coffee and the kitchen.

The essential elements of a Needfinding Machine are functional blocks which support the user-machine interaction and the designer-machine interaction. These elements are show in relation to the interaction loop in Fig. 3. For the user-machine interaction, we build on Eric Dishman's formulation of design research [26] where designers *observe*, *ask*, and *perform* in order to understand users. A Needfinding Machine should allow the designer to *observe* the user in context, *ask* about the user's experience, and *perform* the machine's interactions with the user. We extend Dishman's elements of design research to include functions required in a Needfinding Machine for the designer-machine interaction. A Needfinding Machine should provide ways to *display* data about the machine and user, *control* the performance of the machine's interaction with the user, and *document* the observations that occur during the interaction. We now describe each element in more detail and suggest how it can be realized in our Internet of Things coffee maker.

3.1 Observe

Observation allows the designer to see how users behave within a specific context and respond to different events. These observations can include both qualitative and quantitative information streams, depending on what the designer is looking to perceive.

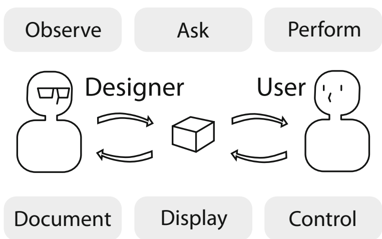

Fig. 3 Functional elements of a Needfinding Machine in relations to the user and to the designer

Cameras and microphones can provide a high bandwidth picture of the user's environment and actions. Sensor and system data can show the designer information about the user's context that is often not directly observable in-situ. This information is streamed back to the designer using a high-speed internet connection and displayed through various indicators and data visualizations.

The placement of the cameras and the selection of the data to be monitored by the designers is critical to consider; these decisions about what to instrument in the user's environment embody hypotheses on the part of the designer about what sort of information they might be looking for or need to support their interaction. For our Internet of Things coffee maker, we might put a camera facing into the kitchen that can see the user as they approach the machine and interact with any physical interfaces. This camera can also give the designer a view into the kitchen, allowing them to observe people's morning rituals and interactions with other kitchen objects. A microphone lets the remote designer hear the participant as they answer questions and talk about their morning experience. Buttons and knobs can be instrumented so that the remote designer can see how the user interacts with the machine and what settings the user changes.

3.2 Ask

Asking questions though the machine allows designers to elicit information that cannot be observed, such as what the user thinks and feels. By asking the user questions, the designer establishes the interaction as a conversation, inviting the user to engage and participate in the needfinding process. These questions can be planned before an interaction with some goal in mind. However, just as with any conversation, the appropriate questions for each situation are often revealed over the course of interaction with the user.

To enable question asking, a Needfinding Machine needs a communication interface. We use speech based communication to ask users questions. Perhaps there are ways that questions can be asked without speech, such as through physical movement of the device, but for our work, speech offers the easiest way to ask the user questions about their experience. In our work, we use text-to-speech on the interactive device to ask questions through the machine. In the case of our Internet of Things coffee maker, we can use a text-to-speech system on the machine to ask the user questions about their coffee making experience such as "What is important in a coffee machine?" and "How much customization would you like in a coffee machine?" We can also ask broader questions about the user's relationship with coffee, such as "What is the best part about drinking coffee?", "When did you first start drinking coffee?", and "What would life be like without coffee?" Furthermore, the designer can also ask about the rest of the user experience in the kitchen. For example, asking questions about the microwave and fridge, or what type of cooking the user likes to do. Using text-to-speech allows a Needfinding Machine to maintain its machine alibi, and aids in creating a consistent voice and persona around the user's interaction with the machine over time. Using machine voice also keeps the interaction situated in an Internet of Things context, making discussion about other things in the kitchen somewhat plausible.

3.3 Perform

Interacting through the machine allows the designer to *perform* as the machine. This allows the designer to explore potential interaction opportunities and use physical or digital interactions as a means of eliciting needs from the user. In addition, the designer can also explore the machine interfaces themselves, giving them a sense of the machine's needs and limitations in relation to potential design ideas.

Depending on the specific context, the designer can perform as the machine in various ways. This performance may include tangible, graphical, or auditory interfaces. It may also include interactions with other devices in the environment such as phones or Internet of Things products. Each interaction that the remote designer can preform represents a degree of freedom that the designer can experiment with throughout their interaction. This may require the designer to build functional rapid prototypes of an interactive system. However, commercially available products could also be re-purposed for needfinding. For example, technology such as VNC or TeamViewer can enable remote control of GUIs.

In our coffee maker example, the designer might augment a commercially available coffee maker with smart capabilities. The designer can perform various functions of the coffee maker, such as setting the coffee preference of each user or controlling when the coffee is made each morning. The designer can also explore new functionalities that a future coffee maker might have, such as providing the user with their morning news update, adding coffee to the user's shopping list when they run out, or even starting up the user's car once their coffee is ready to go. By preforming as the machine, the designer can explore functionality that is not yet available. The designer can also test new interaction dynamics between the user and the machine, helping them determine how the machine ought to interact and what technology may be required to enable new machine behaviors.

3.4 Document

By capturing interactions with a Needfinding Machine, we can preform post-analysis and revisit our observations made during the live interaction. Actions that occur in the user's context and within the remote designer's environment should be recorded. It is critical to document what happened on the user end of the interaction. Documenting the designer's environment can also help the designer to reflect upon their actions during the session.

Documentation can include recording video, audio, and data streams from the session. By recording the designer's control interface and any conversation they may be having with other designers, the Needfinding Machine can capture important moments that reveal the designer's thinking during the interaction. Special interfaces such as pass-through audio/video recording devices, web-based data logs, and devices with built-in logging all contribute to the documentation of Needfinding Machine interactions. Our Internet of Things coffee maker can record video and audio from the user's kitchen during the interaction and log button presses, coffee levels, or voice commands from the user. On the remote designer's side, we can keep a log of every question that was asked and each interface that was controlled. We can also record what the designer sees on their screen and any conversation they might have with other designers participating in the session. After the session, these data streams can be synchronized for later viewing and analysis by the design team.

3.5 Display

The video, audio, and data streams coming from the user's environment should be displayed in real-time to the remote designer. The display supports the designer's observation and allows them take action on any data that may be relevant during their interaction session. These include video and audio from the user's environment, state changes in the system, and time series information of certain product features. Often, the designer is presented with more information than they would naturally be able to see during an in-session interaction, such as multiple camera views and data from the machine that is usually hidden to the user. When creating the display interface, the designer should take into account what they need to see and what aspects of the data may be interesting.

The display interface for our coffee maker might include a video window and a data dashboard. We have found that designers should set up their display to facilitate easy viewing of the data. In this case, the designer might have one screen dedicated to the live video feed from the user's kitchen and another screen with the data dashboard. The dashboard might include live displays of the system settings such as supply levels or coffee temperature. If the designer is testing voice interaction, there could also be a running text log of what the coffee maker hears and interprets from the user. When laying out the display, the designer should consider what information they will need in real-time and how best to show the information in order to support their performance as the machine. Just as important, the designer should also consider what information they should hide from live display so that they are not overwhelmed with data.

3.6 Control

The control interface that allows the designer to preform as the machine should be considered with similar care as the display interface. Message boxes for asking questions should be prominent in the interface so that the designer can easily send custom messages for the machine to speak. Any scripted speech should have easily accessible "play" buttons. For each element that the designer wishes to preform, there should a corresponding controller on the designer's remote interface.

For our coffee maker, the interface can have a list of questions or news stories that have been scripted for the interaction and a message box for sending custom messages that the designers create in the moment. Graphical toggle switches can turn elements of the coffee maker's graphical display on an off. Buttons can be used to send messages to another device in the environment, such as the users phone or to control something on the user's Internet of Things enabled car.

With the high number of degrees-of-freedom in a Needfinding Machine, the job of observing and interacting can become overwhelming. Depending on the rate of interaction, controlling the machine may require two or more people. With our coffee maker, it may be best for one remote wizard to control the speech, while another controls the physical interfaces on the machine or helps look up information like news to tell the user. In order to facilitate collaboration between multiple designers controlling the machine, control interfaces should be easy replicated in different locations and allow for split control of different interfaces. We use web-based technologies to create display and control interfaces so that all members of a design session can participant from any location. This reduces the load for each designer and supports collaboration among a design team.

4 Why Needfinding Machines

The purpose of the Needfinding Machine is to extend the designer's gaze and reach [49] by allowing them to see and understand user interaction in real-world contexts. Working through a Needfinding Machine can let designers engage people beyond themselves and their local technology community when working on the design of new technology products. Consideration and awareness of people who are different from the design team gives designers a more informed position about the technology they are developing. While needfinding, understanding the experience of more people who are further from the design team can lead to designs with further reach and more impact on people's everyday lives. Furthermore, understanding and designing for more people provides an economical benefit by addressing a broader customer base.

A Needfinding Machine also helps designers explore new technologies as tools for crafting new interaction design and as way to better connect with their users in the real world. The Needfinding Machine framework takes advantage of several concurrent trends in technology:

- **Embedded computing**: Imbues everyday objects with computation, sensors, and network communications [83]. Allows for devices to communicate with the Internet of Things and provides a way for designers to collect data remotely.
- **Cloud services**: Allow software and hardware to communicate across the internet, store data on remote servers, and enable new interaction capabilities such as machine vision and speech.
- **Online machine learning**: Allows systems to continually learn and update their models of users from streaming data. Can be used to support intelligent interaction between the machine and user.
- **Conversational agents**: Lets users use natural language to interact with their devices. Provides a way for designers to capture their user's thoughts and feelings about a product or interaction.
- **Adaptive interfaces**: Attempt to change based on the users preferences. Designers can explore what personalizations may be useful and what information is needed from the user to enable this adaptivity.

By utilizing and considering these technologies, a Needfinding Machine works as a tool to help designers understand their users better. A Needfinding Machine also allows designers to understand the needs of the machine better. By interacting through the machine, the designer can assess what it is the machine will need to understand and what data to collect in order to adapt to the user. This interaction helps to expose the designer to the new material of interaction data and allows them to play with potential interaction possibilities that consider this information.

5 Related Methods

In this section, we review methods that have been used by designers to help them understand users. Each of these methods inspire some of the elements of the Needfinding Machine. For each method, we provide a brief overview of its use in design and discuss which functional components from Sect. 3 are incorporated into the Needfinding Machine.

5.1 Ethnography

Ethnographic research is the foundation for much of what is considered design research in practice. Within many design contexts, practitioners act as participant observers, embedding themselves within a context to understand people. This tradition arises from Geertz's "thick description" of people and their behaviors and situates the observer as having a specific point of view that allows for specific interpretation of people's actions and motivations [39]. For example, when users quickly change a song on the radio, are they interested in listening to something else or does that song harbor undesired meaning and emotion?

This process of interpretive, contextually situated ethnography has translated well to design work and allows the designer to observe the lives and experiences of their users. However, most companies do not preform academic ethnography [54], which can often take months or years of intensive study. Rather, designers have adapted ethnographic methods into short, focused participant observations often lasting on the order of hours or days [61, 67]. Even with short observations, ethnography-inspired methods have become staples for finding user needs and supporting generative design activities [52, 55, 71].

Within human-computer interaction, ethnographies are often required to report on some *implications for design*. Though Dourish argues that requiring design implications of academic ethnographies can undermine the richness of these studies [27], interactions through a Needfinding Machine are specifically situated to support design work and thus help designers generate implications for future design. Additionally, Needfinding Machines are interested in understanding user needs in relation to a specific product or context. While designers can learn about the broad aspects of user's lives, the designer's performance as the machine grounds needfinding around the user-product interaction.

5.2 Things as Co-ethnographers

As the Internet of Things becomes an everyday reality within people's homes, there is growing interest in how designers can use information from the viewpoint of things to understand and empathize with people in context. Projects such as Comber et al.'s BinCam [20] and Ganglbauer et al.'s FridgeCam [36] used cameras attached to products to collect pictures of everyday interactions. By collecting images and video from the point of view of the objects, the research teams could observe aspects of user lives that would usually be out of view during interviews and short observations. After using similar methods of collecting pictures from cameras placed onto everyday objects, Giaccardi et al. [42] have suggested that the software and sensors of Internet of Things objects can give designers access to "fields, data and perspectives that we as human ethnographers do not have, and therefore may help us to 'see' what was previously invisible to humans." By providing a different viewpoint, the things become "co-ethnographers," working in conversation with the designer to help them understand the user from a different and situated perspective [41, 42]. Wakkary et al. [81] extend this idea of thing-centered understanding of people to focus primarily on the relationship between things rather than focusing on direct observation of people. Their work explores how focusing design inquiry on things and their interactions can inform the relationship that people have with internet connected products. For example, during interactions with "Morse Things" [81] people attributed human-like qualities and an ability to identify people in the home to a set of plates and bowls that communicated with each other and on Twitter.

The Needfinding Machine is related to the use of things as co-ethnographers. However, human designers remain in the interaction loop with users with a Needfinding Machine. While things as co-ethnographers allow designers to observe and document people's interactions with things, they do not provide the designer the ability to control the machine's performance or view real-time data about an interaction. Moreover, by acting as the machine, the designer can gain an understanding of interaction challenges the machine will face. By mediating their interactions through the machine, the designer can reveal both the needs of the people as they interact with the technology and the needs of the machine as it interacts with a person.

5.3 Remote Usability Testing

With the rise of high-speed internet and mobile devices, designers are now able to remotely explore user experience. More traditional usability testing methods have been modified to be performed remotely so that the designer does not need to physically "be there" in order to build understanding about the user and the product [11]. Waterson et al. [82] and Burzacca et al. [16] each test the usability of mobile web sites by collecting data from people using the website on devices outside the lab. Often, these methods have been created to explore the use of mobile devices beyond traditional lab studies. English et al. conducted remote contextual inquiry to improve enterprise software [31] and Dray and Siegel used remote usability testing to explore international use cases for their software [28]. Depending on the study setup, remote usability testing can be done synchronously, where the researcher is observing the remote activity as it is happening and interacting with the user, or asynchronously, where the researcher is analyzing data logs or recordings at a different time [11].

Although being out of the lab can reduce study control and be more challenging for data recording, Andreasen et al. [5] and Brush et al. [15] have found that synchronous remote methods can be just as good for designer understanding as being present with the user. In addition, remote interaction and observation can reduce the pressure participant's may feel from having a researcher constantly looking over their shoulder [5].

The Needfinding Machine is inspired by the kinds of observation and documentation that remote usability testing provides designers. Similar to remote usability testing, a Needfinding Machine enables designers to synchronously observe and engage with remote users. The Needfinding Machine also documents data from the interaction in a similar way to remote usability testing. However, Needfinding Machines differ from remote usability testing as designers engage with the user by performing as the machine rather than being on a phone call with the user as they are trying an application. The ability for a designer to perform the machine moves a Needfinding Machine ahead of usability testing and focuses the designer on learning through interacting with the user, not just through data collection. Furthermore, the intent of a Needfinding Machine is to help designers understand the broader needs of users, rather than only test how usable a product is.

5.4 *Data-Driven Design Validation*

As devices generate more data, there is a growing interest in using this data for the purposes of understanding users. Christian outlines how web sites have tested and refined new designs using A/B testing [19] and Geiger and Ribes use system logs to conduct 'digital ethnography' about users of online blogs and wikis [40]. These methods provide a way for designers to observe how users engage with a product based on objective data measures. The use of objective data can help designers avoid some of the challenges with direct observation such as researcher interpretation of events and participant bias due to the researcher's presence [66]. Data-driven methods also allow for designers and researchers to observe at a much larger scale, helping designers see a range of interactions that users have with an interactive system.

Still, many methods that rely solely on data logs can only show what a user is doing and only can see data from what is instrumented. Attempting to understand users only from interaction logs can run the risk of being too granular (if the data is too noisy) or too high-level (if too many data points are aggregated).

Some projects bring qualitative experience in by bringing experience surveys into the physical world, such as Cadotte's Push-Button Questionnaire for understanding hotel experiences [17]. A modern version which simplifies a questionnaire into four simple smiley face emotions is Happy-or-Not's (https://www.happy-or-not.com) customer satisfaction kiosks seen in airports and sport complexes [64]. These systems allows for businesses to quickly gather some level of satisfaction data. Often, when many customers rate things negatively, a member of the business can go to the site an figure out what is wrong. This shows how small bits of focused emotion data can be used to understand some aspects of customer experience. Still, data-driven approaches often prove more appropriate for design validation and optimization rather than generating new design ideas. While data-driven design can be useful for beta testing usability or optimizing the experience of a particular location, designers are often interested in *why* users are behaving in a certain way; what are their motivations, their goals, challenges, and thoughts?

5.5 *Experience Sampling in the Wild*

To help understand both the *what* and *why* during mobile-based user experience studies, Consolvo and Walker [21] and Froehlich et al. [34] blend interaction logs with randomly timed text message based questions about the user's experience based on Csikszentmihalyi and Larson's Experience Sampling Method [24]. Aldaz et al. used similar experience sampling questions through a phone app designed to help hearing aid users tune their hearing aid's settings [2]. Through collecting user experiences while tuning their hearing aids, Aldaz et al. suggest that blending interaction data and the user's in-the-moment experience can allow for new forms of needfinding beyond in-person interviewing and observation [2].

While the projects above aim to elicit the user's experience with a product, they focus on text based descriptions of experience. Froehlich et al.'s My Experience system did allow researchers to see images and video that people captured on their phones, helping researchers to better understand the user's context [34]. However, these media clips were captured when the user took them rather than when the researcher may have wanted to see an interaction. Crabtree et al. captured video clips from third person cameras while exploring ubicomp games blending online and real-world tasks [23]. They then synchronized these clips with sensor readings and device logs to "make the invisible visible and reconcile the fragments to permit coherent description" of the player's experience. The Needfinding Machine builds upon Crabtree et al.'s insight of mixing video and data to provide designers with a high-fidelity view of the user's experience. What is critical for a Needfinding Machine is the real-time *video* of the user's environment. This not only allows the designer to observe the user's experience but also allows them to inquire about the user's experience at the moment of interaction, rather than after post analysis of data or through a random experience sample. Live video also allows the remote designer to control the interactive device rather than only observe preprogrammed interaction, letting the designer explore a wider range of interactions. Finally, video provides a rich context for the data logs that are captured from the interactive device providing documentation beyond click-streams and system logs.

5.6 Probes

The Needfinding Machine concept takes many inspirations from the development and use of probes in design and HCI. Gaver, Dunne, and Penceti's Cultural Probes [37] provide designers with a means to understand and empathize with geographically distant peoples. Cultural Probes, often consisting of postcards, cameras, and guided activities, help to elicit contextual information from people and help designers build a textured and rich understanding of people's lives. Hutchinson et al.'s Technology Probes [47] extend Cultural Probes to include the use of technology as an eliciting agent. These probes allow technologists to understand how new devices may fit into everyday life and inspire new potentials for computational products. Originally, probes were intended to be provocations for collecting stories about user's lives that would lead designers to reflect on their users and their role in the design process [37]. Even when technology is used, Hutchinson et al. suggest that probes are not prototypes to be iteratively developed over time, but should focus on eliciting user engagement and open up design spaces [47]. This being said, Boehner et al. describe how HCI researchers have expanded the use of probes to include diary studies, photo journals, longitudinal studies, and participatory design prototypes [12]. Boehner et al. also discuss how probes have expanded beyond their original goals of promoting reflection to also help designers collect data and generate user requirements for future design ideas. Amin et al. [3] used a probe during a participatory group exercise to help develop a set of four design requirements for mobile phone messaging. Kuiper-Hoyng and Beusmans [53] and Gaye and Holmquist [38] each use probes along with interviews to help users discuss their experiences in their home and city, respectively. The use of probes helped each group to refine and iterate on more specific design projects.

Needfinding Machines build from using probes as a way to understand user needs but still focus the designer on considering implications for more specific product ideas. Thus, Needfinding Machines exist somewhere in a space between probes and prototypes. While probes can help to document user experiences asynchronously, Needfinding Machines are focused on helping designers observe and interact with users in real-time. Needfinding Machines also aim to collect data from the remote environment and display this to the designer so that they can continuously change how they control the machine's behavior. By preforming as the interactive device, designers can test specific interactions with users; however, these interactions are not intended solely for usability testing. Needfinding Machines retain the goals of probes to help designers understand the user's experience and life more broadly. Furthermore, Needfinding Machines build upon the ability for probes to elicit textually rich information from people in contexts that would be otherwise unobservable. Information collected from these interactions is intended to be analyzed in holistic and interpretative manners but will also include more actionable data about the user's experience with the interactive product. By allowing the designer to ask the user questions and perform the interactive product's behavior with the user in real-time, Needfinding Machines aim to collect what Mattelmäki and Battarbee call "inspiring signals" for developing empathy with the user [59] and develop what Boehner et al. state is a "holistic understanding" of the user's experience with a product [12].

5.7 Wizard-of-Oz

Wizard-of-Oz methods have often been used in design to simulate technologies that are currently unavailable. This method uses the "wizard behind the curtain" metaphor as a way to control prototypes when the product's technology is unavailable or intractable at the time of experimentation. Prototypes such as Kelly et al.'s exploration of natural language understanding [51] and Maulsby et al.'s simulation of multimodal interfaces [60] show how designers can learn a great deal about their proposed designs before allocating significant resources to technical development [25]. When performed early in the design process, Molin et al. suggest that Wizard-of-Oz experimentation can help to define user requirements and promote collaboration between designers and users [62].

Along with prototyping new interactions, designers can also use Wizard-of-Oz experiences to gain insight into what a user is feeling and thinking during the moment of interaction. For example, Sirkn et al. used Wizard-of-Oz to control a simulator based autonomous car while asking a driver questions about their experience [76]. The improvisational style of these interactions allowed the driver to experience a potential future for autonomous vehicles and allowed the designers to gain insight into how drivers would react and respond to the car's behavior. This playful style of Wizard-of-Oz interaction prototyping and inquiry provides a foundation for how designers can collaboratively work with people to explore new interaction potentials and reflect upon their current and future needs. Furthermore, Maulsby, Greenberg and Mander found that one of the most important aspects of Wizard-of-Oz prototyping is that designers benefit by acting as wizards; seeing uncomfortable users and finding product limitations while acting as the machine can help motivate further prototype iterations [60].

The Needfinding Machine extends the capabilities of lab-based and controlled Wizard-of-Oz for use in real-world contexts. Designers interacting remotely keeps many of the same aspects of control, performance, and documentation of lab-based Wizard-of-Oz studies. Needfinding Machines also use Sirkin et al.'s use of improvisational interviewing through the machine with the goal of helping the designer understand a user's lived experience and potential needs around the specific interaction that is being designed.

5.8 Conversational Agents

Conversation around the experience of products is a powerful tool for understanding and moving forward with design ideas. Dubberly and Pangaro [30] describe how conversation between project stakeholders allows for design teams to co-construct meaning, evolve their thinking, and ultimately take an agreed upon action in the world. This echoes Schön's [73] conceptualization of design as a conversation between the designer and the situation. With this in mind, designers can use machines that converse with users, or conversational agents, as tools for understanding user experience.

Although human conversations can be quite complicated, even simple questioning from a machine can elicit meaningful responses from people. By the mid 1960's, systems such as Weizenbaum's [84] ELIZA teletype Rogerian psycho-therapist could use simple rules to engage people in deep conversation about themselves. As conversational agent technology is becoming more popular within contemporary product design, design teams are exploring how to use chatbots to inquire about user experience in the real-world. For example, Boardman and Koo of IDEO have used Wizard-of-Oz controlled chatbots to prototype a fitness tracker application, a text-based call center for public benefits, and a mobile application for healthcare workers tracking Zika [14]. Using chatbots to engage people in conversation, the designers on these product teams were able to continually engage people and develop empathy for the everyday lives of their users. The chatbot conversations helped the designers uncover needs around the services they were designing. For example, the need for users to track healthy and unhealthy activities in their day and the need for users to feel safe while asking health related questions. Additionally, by acting as the chatbots, the design team engaged other project stakeholders in controlling the bots. This led to debate and reflection on what the product ought to do and how it ought to interact, helping the team to better understand their own designer values and the needs of their stakeholders.

The Needfinding Machine builds upon the work of Broadman and Koo at IDEO to use conversational agents as a way for designers to understand user experience with interactive systems. While using a Needfinding Machine, the designer can have a rich conversation with the user as the user is interacting with the product. Additionally, using people's innate ability to converse allows more members of the design team, even those without special training in interaction design or user research, to engage a user while acting through the machine. In our work on Needfinding Machines, we have used voice-based conversation rather than text messaging. This allows for more fluid communication and lets users describe their experience and answer questions during the interaction instead of needing to switch to a mobile phone messaging app. By using voice instead of messaging, designers can explore experiences in environments where a user might be preoccupied with other tasks, such as cooking in their kitchen or driving in their car. The Needfinding Machine also differs from using chatbots alone by providing live video and data feeds from the user's environment. Having live video and data allows designers to use context as a basis for their conversation with the user and frees the designer from relying only on what the user is saying to understand the user's experience.

6 Case Study: DJ Bot

To illustrate a concrete example of a Needfinding Machine within a specific context, we present the design and test deployment of *DJ Bot*, a smart agent that talks with people to figure out what music to play as they are driving. *DJ Bot* is a functional system prototype that allows designers acting as remote wizards to play songs and to converse with people about their musical whims and preferences as people listen to music while driving in a car. We piloted the system ourselves and with researchers at a commercial music streaming company exploring future interaction design modalities for music services. These tests show the design research possibilities, benefits, and challenges of using a Needfinding Machine in context. In the process of "performing DJ Bot," the designer/wizards were able to explore people's connection with their music and potential needs that might drive future intelligent music recommendation agents and services.

6.1 Design Motivation

The DJ Bot project began as a way to test the ideas of the Needfinding Machine in relation to real-world interactive systems. We chose the space of interactive music services because these services are heavily data driven and powered by recommender systems [72] but provide a product that is laden with personal meaning and contextual importance [44]. Digital streaming music services allow people to access huge amounts of music and have changed the way listeners discover, share, and curate their music collections [56]. The music recommendation systems behind these services can help listeners discover new music or suggest just the right song to play in the moment. In essence, these systems attempt to know the user in order to make predictions about what music they will enjoy [68].

Music presents a rich and open test platform for our needfinding explorations. Everyone has both a biological and social connection to music [79], allowing for almost anyone to be involved as a user in the development of new music interfaces. Music has been used for therapy to improve one's sense of purpose and is used as a way to convey personal meaning to others [4, 8], suggesting it as a useful mechanism for allowing designers to explore who the user is as a person. Cook [22] states that deciding what music to listen to is a way of signaling who you are. Music is also linked to time and space and is used similarly to personal photo organization as a way of reminiscing and storytelling [9] and creating a personal "musical panorama" of one's life [35].

As we consume more music, interaction design around music listening is becoming more data-driven and focused on recommender systems. This is enabled by previously unseen patterns emerging from analyses of large data collections on listener behavior. For example, Zhang et al. [86] analyzed Spotify listener data to determine when the most popular times during the day for listening were and what devices (mobile, desktop, web) were being used. In an analysis of six years of data from 310 user profiles from Last.fm, Baur et al. [7] were able to determine that seasons had a large impact on listening habits. Still, vast stores of listener behavior data do not provide all of the rich information that makes individuals passionate about their music. While these studies highlight *how* users listen, they do not provide the richness of *why* users listen. Streaming services are now exploring alternate ways of categorizing music to get at this meaningful information. For example, Spotify's "Line-In" interface aims to collect more meaningful tags about music directly from users and plans to use these tags as meta-data in their recommendation system [70]. Building on the desire for users to talk about their music, DJ Bot uses an interactive music agent as a platform to let the designer connect with a listener around music in-context. While situated in the listener's environment and performing as the machine, designers can explore new speech-based music service interactions and build their understanding of individual music listeners.

6.2 Music on the Road—A First Context

For our first context, we explore music listening while driving. The car provides a number of interesting opportunities for exploring the needs of music listeners, as it is a semi-private, semi-controlled environment where people often enjoy music or other audio-based media. From a logistical perspective, the car is readily instrumented with cameras, computers, and interactive devices. With the use of high-speed mobile routers, cars can be fully connected to the remote designer. Finally, while music listening is one of the few safe secondary activities drivers can engage with, current smart-phone based streaming services may be distracting or challenging to use, and present open design opportunities for new music applications.

6.3 Implementation

Functionally, DJ Bot in the car allows a designer to control a streaming music service on the listener's mobile device, communicate with the driver using real-time synthesized speech, and view multiple channels of live video and audio from the car. We modeled the DJ Bot system on a system we previously designed system for conducting real-time, remote interaction prototyping and observation in cars [58]. We use the Spotify streaming service which allows for "remote control" from any device where the user is logged in. This allows the designer to use a desktop version of the application to control the music on the user's mobile device.

Figure 4 shows a system diagram outlining the remote designer locations, the communication streams, and the in-car interactions that occur with DJ Bot. Within the car, the listener connects their mobile device running the Spotify app to the car's audio system. Video cameras and microphones are placed around the car, allowing the remote designer to see both the driver and the road from multiple angles. Having multiple views allows the designer to better experience the driving context. The road facing camera also helps the designer have a sense of the driving conditions, allowing them to better plan interactions and avoid distracting the driver. A computer in the car streams the live video and audio via a video chat client back to the remote designer. The computer also runs a text-to-speech engine and speaks messages sent from the remote designer through a separate portable speaker.

The designer, acting as a wizard, controls DJ Bot through an interface that displays video from the car, the desktop Spotify app with "remote control" enabled, and a custom web-based interface for sending speech messages to the car, shown in Fig. 5. The designer can view information such as the audio level and current song in the Spotify app and can control music using the app's audio player controls. The speech control interface includes a text input area to send custom messages and a list of pre-scripted questions such as: "*What do you want to listen to next?*," "*Why did you choose that song?*," "*What does this song remind you of?*," and "*Can you tell me more?*"

In order to support documentation and analysis, video and audio is recorded using cameras mounted in the car. Because both sides of the interaction are required to reconstruct the dialogue, the designer's control interfaces are also recorded. All speech messages are logged and the music selections stored in the user's listening history.

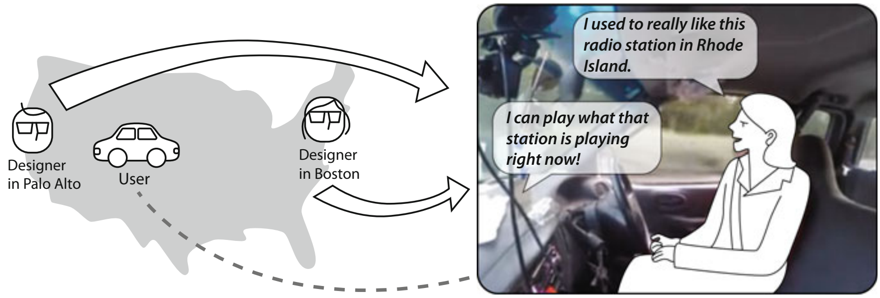

Fig. 4 DJ Bot implementation with distributed designers. Designers can remotely interact with users from anywhere in the world, allowing situated, real-time needfinding through a machine

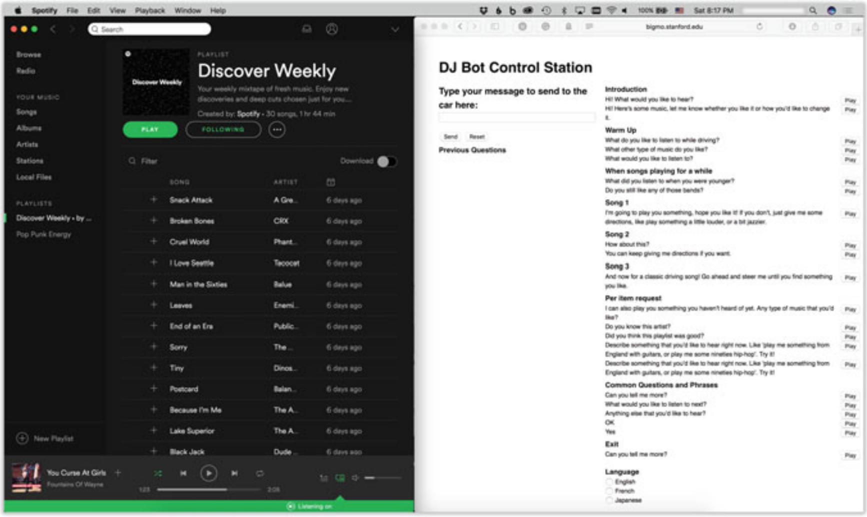

Fig. 5 An example control interface from the DJ Bot project. The designer can remotely control music and synthesized speech with planned or improvised questions

6.4 On-Road Sessions

We conducted three interaction sessions for our initial exploration.

1. A 1-h session where Nik acted as the DJ/wizard for a user driving her pickup truck on the freeway
2. A 1-h session where a colleague and interaction design practitioner acted as a DJ/wizard for Wendy as a user driving to visit a friend
3. A 30-min session where two interaction researchers from a music streaming company acted as DJ/wizards for a commuter driving from home to school at 5:30

AM PST. One researcher connected from California while the other connected from Massachusetts, as shown in Fig. 4.

After each session, we conducted an interview with the wizards and drivers, asking questions about the interaction experience and the use of the Needfinding Machine. Our goal in describing these sessions is to present a working example of how a Needfinding Machine can be used and to reflect on the opportunities a Needfinding Machine can have for professional design work. The following sections provide excerpts and commentary from the sessions as a means to give the reader a feeling of the conversations that occurred between the designer preforming as DJ Bot and the listener/driver.

6.4.1 Session 1

During the first session, Nik controlled the DJ Bot for a user who drove her pickup truck on the freeway for about one hour. Prior to the session, Nik setup cameras and the data streaming computer in the user's truck. Nik had little prior information about the listener's musical preferences before starting the music. He began the session by simply asking "What would you like to listen to?" through the DJ Bot. This lead to a back and forth interaction to determine if the listener wanted to hear the song that was selected. At one point in the interaction, the driver remembered a song that they liked and requested it to be played. Nik ended up playing an alternative remixed version of the song, leading to the following conversation:

♫ *I would walk 500 miles - remix* ♫

[DJ Bot] What do you like about this song?

[Driver] This isn't the original, is it? You said it was a remix. But it's just fun and it has a good beat and it's like easy to sing along to.

[DJ Bot] Do you sing along to music often?

[Driver] Yeah! It's pretty weird to sing along to music when I know I'm being recorded.

[DJ Bot] Do you sing along with others?

[Driver] Yes.

[DJ Bot] What songs you do you normally like to sing?

[Driver] Lots of songs. Like Disney songs.

This interaction elicited that the driver liked to sing along to music, enjoyed Disney music, and associated Disney music as music the user would sing with others.

While thinking of other music to listen to, the driver remembered a radio station they liked from a time when they lived in Rhode Island:

[Driver] I can give you a radio station in Rhode Island that I really like.

[Bot voice] Okay.

[Driver] So it's 95.5 WBRU in Rhode Island. It's the Brown radio station, it's alternative rock. The stuff that they play is pretty great. When it's not overplayed songs.

[Bot voice] Okay, let me see what I can find. Did you find this while you lived in Rhode Island?

[Driver] Correct. They introduced me to a lot of music.

[Bot voice] Here's what they are playing now.

♫ *Green Day - Holiday* ♫

During the interaction, Nik switched windows from the control interface to a web browser and searched for the radio station's website. This quick thinking gave him a new source of potential music to recommend. It also presented an interesting example of the listener's relationship between place and music, providing future opportunities for further exploration.

While the system did function, this session was not entirely smooth, highlighting challenges for the designer and the user during the interaction. For example, Nik had trouble choosing songs since he was biased by his own musical tastes and did not have a baseline for what the driver liked. He stated in after the interview:

> [Nik (as wizard)] Actually it's really challenging. I have really strong opinions about music and I kept seeing all these bands and was like "I like this song! Let me play this song." But then I was trying to figure out "How am I supposed to tease out of you what you like?" And the thing is, I have such a limited knowledge of what I could even go off of.

Though this made the interaction more challenging, it pushed the driver to actively steer the music selection. This revealed information about the driver's preferences and kept them conversing rather than simply sitting back and listening.

The driver's comment about being recorded suggests that they were not always comfortable opening up to the machine. After the session, the driver stated:

> [Driver] Yeah, it was weird. It's also weird because I know I'm being recorded and I'm trying to drive and I am telling someone who I don't know very well all about my musical tastes. Which is pretty intimate and so yeah, it was just weird on a lot of levels for me.

This suggests some limitations of the Needfinding Machine method. In this particular case, the driver knew that a person was on the other end of the machine. Though this may have biased their answers during the session, the conversation afterward suggests even when the intentions of the designer are known, eliciting and recording personal information may prove challenging. Still, much of the conversation went smoothly and provided ample information about the listener and their preferences. Moments of discomfort from the user may help designers to identify potential "off-limit" areas early in the design process.

6.4.2 Session 2

Wendy acted as a driver in the second interaction. A colleague who is an interaction design practitioner acted as the wizard. Wendy spent about 45 min driving one of our research vehicles on a freeway and scenic road on her way to visit a friend. This session occurred after a recent and fierce presidential election. When the designer asked why Wendy chose a particular song, Wendy responded as follows:

♫ *Public Enemy - Public Enemy No. 1* ♫

[DJ Bot] This one?

[Driver] Yeah, I love this one.

[DJ Bot] Why this right now?

[Driver] Maybe like a post election thing and it has a lot of energy.

Although the question "Why this song?" was simple, it elicited a response with information about the song and about the context. In this case, the wizard built on the contextual information about the political times. This lead into a longer discussion of the relationship between current affairs and the driver's music.

After a while, however, Wendy was not interested in talking about politics and asked to change the subject.

[Driver] Let's not listen to any more Trump songs.

[DJ Bot] Okay.

[Driver] Like, let's play something by Missy Elliott.

[DJ Bot] How is this song?

♫ *Missy Elliot - Work It* ♫

[Driver] This is good.

[DJ Bot] Why Missy?

[Driver] I really like the way that she plays with words, I feel like she's like really really creative and like breaks rules. In like really interesting ways and, I don't know, it's like one of these things like, is so unlikely and then when you listen to it it's kind of amazing and then it's very upbeat and I have difficulty understanding what's being said and I think it's like fun to figure it out, like a puzzle. And maybe a little bit like Devo, it just seems like she's having such a good time, such a good time singing, you know, and I love that.

Later in the session, Wendy spoke about bands from college and her connection with the artist *Fountains of Wayne*.

♫ *Fountains of Wayne* ♫

[DJ Bot] What do you like about this band?

[Driver] You know what, actually the thing I like about this band is it makes me think about college and it's a little bit funny because it's not something I actually listened to when I was in college, but when I went to grad school...

...a lot of my thoughts about undergrad are colored by this soundtrack even though like I said I never listened to Fountains of Wayne in college. And I had like this homesickness for college...

This then lead to the wizard to ask "What other bands did you like in college?," which prompted Wendy to list off 14 other bands, helping to log a number of songs and genres that the driver enjoyed. This interaction showed the rich storytelling that can occur when thinking back on the music people enjoy. The story about college, in particular, paints a textured picture about the driver's life, helping the designer develop empathy for the driver and a sense of the meaning behind the 14 bands that were listed.

6.4.3 Session 3

The third session highlighted a number of strengths that a Needfinding Machine can have for remote needfinding. This session was conducted in a distributed manner with one designer at home in California and one at work in Massachusetts. To split the interaction load, one designer controlled the bot voice and one controlled the song selection. During this session, the designers communicated on a separate voice channel and coordinated their actions between music control and the bot voice. The session was done at 5:30 AM PST (8:30 AM EST), during the driver's 30-min commute from their home in the city to school. While interacting through the machine, these researchers were able to experience the user's local context, despite the geographical, temporal and logistical challenges.[1]

Early in the session, the designers asked about what the driver listened to when they were younger.

[DJ Bot] What did you listen to when you were younger?

[Driver] Classical music. And a lot of Christian rock.

[DJ Bot] Do you still listen to that music anymore?

[Driver] I'm not really religious anymore.

After this comment from the driver, the remote designer controlling the DJ Bot voice moved on to another subject. However, after the session, she remarked that there was a tension in her own interest as a researcher and the role of performing the machine.

> [Wizard 1] When he said things for example about religion, I was like "Oh!" but then "no, I probably shouldn't go" you know the car goes digging around into your personal history. It wouldn't be on brand for the car or music service to go digging into your childhood.

This interaction further shows that even simple questions about one's music can lead to meaningful answers. However, in this case, the designers chose not to follow the topic. Being confronted with such an unique situation during conversation prompted the designers to reflect on how the machine ought to interact and what the machine should and should not talk about. The designers' in-the-moment and post-session reflection can be useful for understanding their own designer values and brings to light potential issues to consider for future design ideas.

7 Discussion

The Needfinding Machine is a method to allow designers to explore people's needs by interacting with the user through an interactive system. It enables the designer to observe and act in real-time, allowing for in-the-moment design inquiry with data elicited from the user. This lets designers explore potential design ideas *by*, *with*

[1]The driver's car was instrumented the evening before by the research team.

and *for* new types of social data [77]. Designers engaging with users through a Needfinding Machine can also explore the *why* behind the user's behaviors. These aspects of the Needfinding Machine present a number of benefits to the designer.

7.1 Designing By, With and for Data

By interacting through a Needfinding Machine, designers actively engage with and elicit data about people in order to understand their potential needs. When considering how designers should approach this data, Speed and Oberlander [77] ask three questions around how we can design *by, with* and *for* data. Specifically, they consider:

1. How might designers develop new methods to capture data that reveals people's values in a respectful way?
2. How might designers capture how data influences people and machines in a system and intervene in the system?
3. How might designers mediate systems developed by other machines while considering people's values?

The Needfinding Machine is one method to address these three questions. By framing the interaction through the machine as needfinding, designers act and observe so that they can understand, empathize, and learn about the user's life and the user's values. Active interaction with the user, rather than covert surveillance of the user's behavior, allows the designer to explore useful data features while being sensitive to the user's values. During the first session with the driver who spoke about singing along to her music, the driver was acutely aware they were being recorded and interacting with a person through the machine. While the user's awareness may seem to inhibit needfinding, it engages the user in a participatory way, allowing them to better consider and control what they share with the designer. For example, in our second session with Wendy, we saw that Wendy would explicitly ask to change subjects of discussion. Though this cut off some avenues of conversation, it helped to guide the interaction in directions aligned with what Wendy would be comfortable discussing.

From the designer's perspective, we saw that by interacting through the machine, designers actively confront the implication of machines that elicit data from people. Interaction ideas and questions that feel okay in the abstract may turn out to be creepy or weird when implemented. In our third session with the driver on their morning commute, the interaction researchers explicitly refrained from discussing the user's religion or childhood because they questioned if a machine *ought* to engage such discussions. The in-the-moment setup caused designers to consider what information can and should be used for the design of new music services. As the Internet of Things enables more data about users to be collected, designers will need to confront whether this data should be collected or used at all. This need for designer reflection around Internet of Things data has been seen in other work such as Berger et al.'s Sensing Home [6], seen in this volume.

Instrumenting and documenting user interactions in context allows designers to see and understand how data flows through the context. The Needfinding Machine's functional elements allow for data to be captured and viewed in-the-moment and reviewed later during post-analysis. Capturing the data live allows designers to see how the information that is collected about the user is representative of the user's values. The live interaction allows designers to explore interventions that can enhance the user' experience and engage with the user's values. For example, the interaction during Wendy's drive indicated a political dimension to her music tastes. This in turn reveals aspects of Wendy's values to the designer. The designer can then work from this understanding of the user's values to assess what information is useful for the design. The designer can also consider how systems that collect data on their own or generate data, such as a music recommendation engines, might become better aligned with the user's values.

7.2 Understanding the Person and the User

Bill Verplank argues that there are three key questions when designing interaction: *How do you feel?*, *How do you know?*, and *How do you do?* [80]. By conducting needfinding through a contextually situated system and by explicitly asking the user questions during the interaction, the designer can answer all of these questions. The designer can ask how the user feels about the interaction and how the user knows what is happening during the interaction. The designer can also see what the user does during the interaction.

For example, during the second session, Wendy discussed a long list of bands she liked in college. This interaction helped the designers collect data about what music could be included in Wendy's listener profile. Additionally though, the conversation allowed the designers to see how Wendy felt about the bands she listed and how she developed the feelings for the music. By getting the list of bands along with the personal meaning behind the bands, the designer could gather a set of meaningful information from the interaction. Information such as this could be directly used to design new features into a product, such as ways to seed new playlists or potential new voice commands. Furthermore, seeing this meaningful information allows the designer to feel a connection to the interaction participant as a person rather than just another member of a user group.

The relationship between the designer and user does have some asymmetries due to the Needfinding Machine setup. The interaction designers who participated in the third session during the morning commute noted that they felt that they learned a lot about the driver, who they did not previously know, through the interaction. However, to the driver, the designers were still complete strangers. The interaction researchers stated "Oh, I should introduce myself!" during the post interview. This suggests that there are unresolved questions about how designers should frame these interactions, and how much reciprocity is expected from a Needfinding Machine. Should the user know that they are interacting with a designer? Should they know who that designer is? And, how should the designer utilize the information gained to benefit the user? Interacting through the machine may give the designer an opportunity to reflect on these questions and on their own practices and values. Designers performing as the machine and eliciting meaningful information should consider how they want to engage with the user as they can understand both functional aspects of the interaction and personal details about the user.

7.3 Implications of Real-Time Interaction

Situated, real-time interaction supports designers in developing a rich view of the user's life in context. For example, one of the interaction researchers from the morning commute session noted that (virtually) being in the car at 5:30 AM was an eye opening experience. The time of day painted a picture for the designer of a an everyday user experience that they had not considered before. It was a departure from the designer's previous work with stationary voice interfaces and their experience as a remote wizard identified previously unknown needs around how people might listen to music as a means to wake up or ease into the day. The experience suggested that the interaction needs of the user might differ as the day goes on. This ultimately changed the interaction researcher's thinking about how often a music agent might interact based on the user's context.

Real-time interaction puts designers in an improvisational theater, where designers need to treat each utterance from the user as a gift to be responded to in kind [48]. While planning is required for the logistics of the session, designers need to be very awake to the unplanned opportunities that open up in the course of an engagement. Reacting to moments as they happen can give the designer the opportunity to understand experience right as it happens. Designers can also improvise the machine's behavior as they are performing in order to quickly explore different ideas and to elicit different types of information. One readily improvised characteristic which can lead the designer to elicit different information is conversational style [13]. For example, the wizards interacting with the woman driving her pickup truck in the first session and with Wendy in the second session used more human-like conversation. This lead them to focus on having deeper conversations about the music. During the morning commute session, the interaction researchers focused on a more machine-like interaction. Being more machine-like allowed them to shape the interaction to be closer to a what a product might be, but still allowed them to explore some of the more meaningful aspects of the user's music preferences.

We can liken the way interaction designers employ their intuitive and embodied sense of context and timing during in-the-moment dialogue to construct interaction with the way industrial designers and architects prototype and design in-the-moment with pliable materials. The industrial designer Henry Dreyfuss describes how using clay as a material allows the designer to explore form beyond what is possible with sketches [29]. Working in three dimensions allows the designer to experience a model in a form closer to what the everyday experience would be. It also allows the designer to alter a design as they build, similar to how designers can alter as they sketch, but with less thought devoted to simulating what something may be like. The architect Eero Saarinen, for example, created “huge models that you could put your head into and really look around the architectural space and surfaces” [69] as a means to experience the architectural design in one moment, and then rework them in the next.

The real-time interaction enabled by the Needfinding Machine parallels the designer’s need for a tactile and embodied way to prototype a design in-situ. Using a Needfinding Machine, the designer can get their head into the action and converse directly though the machine, shaping the interaction over time. The conversation with the user through the machine acts as the pliable material with which interaction designers can form new alternatives for future designs.

8 Limitations and Future Work

Although we have discussed a number of benefits that a Needfinding Machine can have for interaction designers, we have also identified some limitations in their usage. During our sessions, we recognized that some people were uncomfortable with being recorded, given the intimacy around the discussion of music. In some cases, users did not want to engage beyond a certain point during the interaction, closing themselves off and reducing the amount that a designer can learn. The tension that these moments cause for both the user and for the designer can be useful during early phases of design as a potential way to identify both user and designer values.

We also noticed that there can be issues on the designer’s end when considering what information they have been given and how they should proceed along with the conversation. The designer may question if they should act as a person or if they should perform the machine, potentially muddling their needfinding efforts. This being said, we found these moments to be interesting points of reflection for the designer, potentially working as a way to help the designer consider their own values during the design process [74].

From a systems perspective, it is tempting to fall into the trap of adding “bells and whistles” that enable higher and higher fidelity prototyping and realism. We feel instead that it is important to develop the system so that it maintains focus on the actual needs of the user [43, 57]. At present, the Needfinding Machine depends upon having environments with easy network access, power, and the ability to host cameras, microphones, and the interactive system itself. Adaptations to remove these types of requirements will enable us to better perform needfinding in less-resourced environments, where better longitudinal needfinding is direly needed. Developments in embedded computing and global network connectivity, as well as carefully budgeting bandwidth needs, might open Needfinding Machines to these new arenas.

Finally, the practicing interaction researchers noted that documenting and sharing the data from Needfinding Machine sessions is challenging within the corporate environment. Aside from the technical knowledge required to set up a Needfinding Machine, instrumenting and recording the live interaction is beyond what many designers can easily perform today. There are opportunities for finding out methods to communicate the results of the multidimensional data and in-the-moment learning that is collected during a Needfinding Machine session. Synchronized data from the user interactions, system logs, and designer reflections should be turned into easily shareable and interpretable artifacts so that this information can more meaningfully guide product discussions.

9 Conclusion

As interactive Internet of Things become more embedded in everyday life, there will be an even higher need for interaction designers to find and understand unmet user needs. The Needfinding Machine presents a method for using the devices themselves to allow designers anywhere in the world to interact with users in situated contexts. This provides opportunities for designers to extend their needfinding capabilities.

As machine learning enabled adaptive systems change the nature of products, designers will play a large role in defining how these systems interact and learn from users. Needfinding Machines can help designers to understand what data may be relevant to new interaction experiences and can help them simulate and communicate what interactions are most valuable to a user. Moreover, they present a vision for a future where designers can use interactive systems to understand and impact the lives of people.

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