Designing Adaptive Robotic Services

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Abstract: Our research group is designing robotic products and services that will adapt to people's changing behavior through repeated interactions. Through the process of creating these products and services, we have found that there are many dynamic issues to account for in the design: the behavior of customers, the capabilities of the robot, and what the robot knows about people and their preferences. Current service design blueprints are not sufficient for capturing these dynamic relationships among elements of the service. Therefore, we explored the activity of designing a dynamic robot-assisted snacking service. Based on the results of a contextual inquiry, we created a service design blueprint which incorporated three main components: a delivery robot, a website, and human assistants. Using this blueprint, we mapped out how the snacking service will evolve over time. Our contribution is an addition to the service blueprint process, which can represent services that change over time.

Key words: Service Design, Robotic Service, Design Method, Human-Robot Interaction

1. Introduction

Service design has been of interest to the business and marketing community for nearly three decades [2]. Recently, designers have begun to apply human-centered design methods to the design of services in the retail, entertainment, and health care domains, and others [4][16][28].

Designers conceive of how a service will work through the use of a service blueprint [23]. This diagram models the process of delivering services, identifying the components of the service and mapping the flow of events for each component. The blueprint functions effectively in describing how intangible parts of service might be orchestrated during a *journey*, or the experience of interacting with a service.

However, most services involve more than a one-time journey. In fact, the success of most services can be measured by how many users return to use the service again [11]. Nevertheless, little attention has given to understanding people's experiences of a service over time, and designing a service that can adapt to and support these changing experiences. These changes are critical because they can alter users' experience with existing products and services and even lead users to stop using certain products and services. Creating a dynamic, adaptive service that supports these changing experiences will create the ability to sustain users' engagement with the service and strengthen their relationships with the service over time.

In this paper, we take a first step towards providing a blueprint for designing adaptive services. We do so using the design of a robotic snack delivery service. In the next section of our paper, we describe the context of our research. We then present relevant related work on service design, studies of new technology at home and in the workplace, and experience design. We articulate important factors to consider in the design of an adaptive service, and illustrate how factors work in the design of our snacking service.

2. Context of our research

Our chosen service domain is snack delivery. In developed countries, the majority of people eat snacks at least once a day [20]. Snacking, particularly high caloric snacks, also contributes to obesity, one of the major health problems in the United States and parts of Europe. To date, very few services or design efforts have been made to assist and improve people's snacking practices. Our research showed that people have a variety of unmet needs when choosing snacks [15]. For example, people desire to eat healthy snacks, yet they tend to choose unhealthy, fattening snacks due to stress and convenience.

In response to these problems, we designed a robotic snacking service using the Snackbot robot, a four and half foot tall, human-like robot that navigates the hallways semi-autonomously and delivers snacks to people (Figure 1) [14]. The Snackbot interacts with people in a social way using natural human language, sound, and head/body movement. To order snacks from the robot, people use a website to specify the types of snacks that they want and the delivery location and time (Figure 2). Our design challenge is to design a service that satisfies changing human needs, and to sustain people's engagement with the service over time, but also, to account for changing technology capabilities, since the robot will learn people's preferences over time. Some of our research questions include: What are the factors that the service should be sensitive to? How might people's experience with a service change over time? How can a service evolve to maximize people's satisfaction with it? To answer these questions, we began by reviewing the literature on service design, orientation to new technology products at home and in the workplace, and experience design.

Figure 1. The Snackbot robot, around which the dynamic snack delivery service is based.

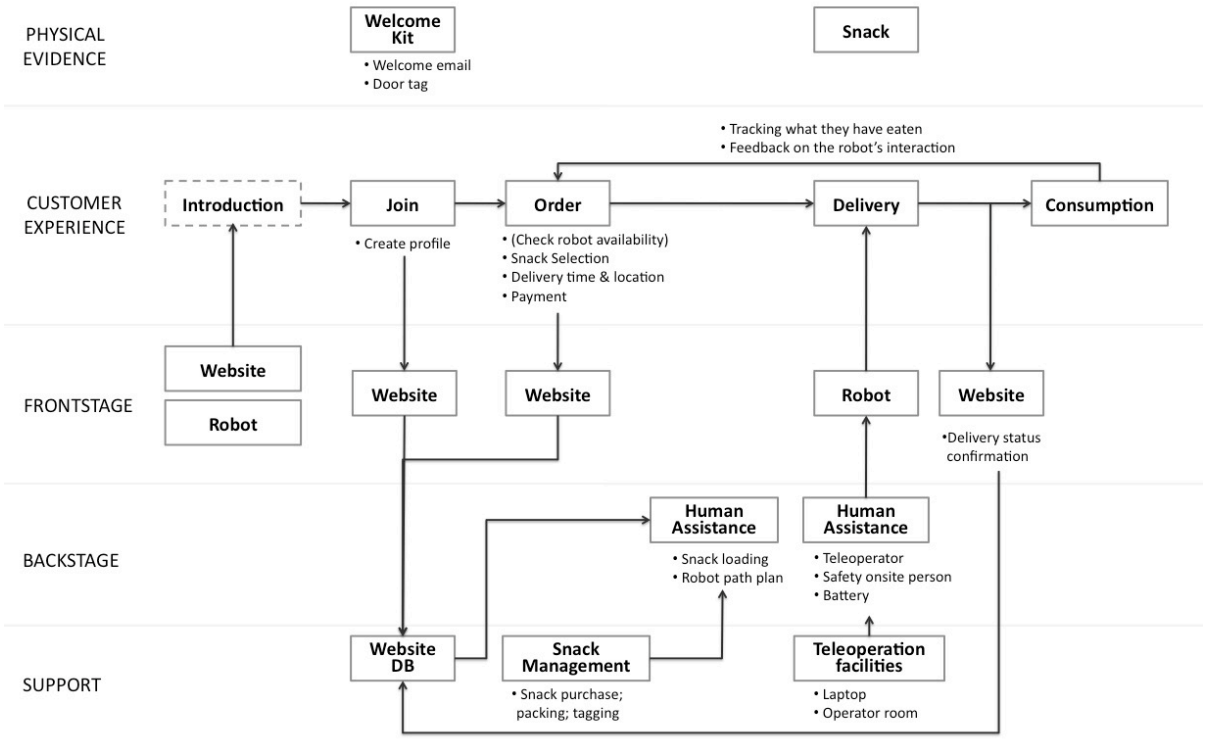

Figure 2. A blueprint of the Snackbot snack delivery service, describing a one-time journey of the snack order and delivery process.

3. Related Work

To begin the process of designing a snacking service using the Snackbot robot, we looked at three overlapping areas of context: service design, adoption of technology products, particularly assistive robots, at home and in the workplace, and experience design over time. Based on this literature review, we identified factors that are important when considering the use of a service over time. The service design literature shows existing approaches to designing services and a need for ways to depict service changes over time. The experience design literature gives insight on how people's experiences with products are formed and evolve. Finally, the literature on adoption of robotic technology elaborates the sensemaking and incorporation processes of robotic technology, which is central to our service design.

3.1. Service design

In marketing and operations science, the concept of service has traditionally been articulated through the use of a service blueprint [3][23]. These diagrams map out the processes that constitute the service and serve both as a sketching tool for service designers in the development phase and as a guide for service providers in the operation phase. A service blueprint is well suited for representing a linear flow of service components such as user and service actions, or *touchpoints*. Our literature review showed that the service design blueprint technique has been sufficient for several decades of service design.

Recently, a few changes have been made to service blueprints to better support user-centered design. Morelli illustrated how a service blueprint can be used in combination with other design methods such as personas or use cases [18]. These methods add more contextual information about different types of users and scenarios of how each step of the service will take place. In addition, more representations were added to the service blueprint that distinguish different places where the service takes place (e.g., virtual vs. physical), various actors who perform the functions, and whether tasks are automated or not.

Other research proposed a visualization method to represent changes in users' emotion during a service journey [25]. More recent work attempted to incorporate improvisational aspects of art, music, dance, and drama into the service blueprint [16]. Pinhanez proposed a new representation for a service blueprint, where all phases of the service revolve around a customer in order to emphasize that a service is a customer-intensive system [21]. In our review, we did not find a service blueprint method that provided a way to visualize and express how services (and correspondingly, user behavior) can change over time.

3.2. Adapting to robotic technology

A growing body of research examines how people adapt to robotic technology in the home and workplace. This work is largely based on Weick's process of *sensemaking*, which plays an important role in technology adaptation [29]. Sensemaking is triggered when a new technology interrupts or changes a process or routine that currently exists within a home or workplace. In a study of a hospital delivery robot, Siino and Hinds illustrated how sensemaking occurred before and after a delivery robot was introduced into the setting [24]. Factors such as occupation, hierarchical status, and gender roles in the organization affected hospital workers' sensemaking process. Other researchers have studied vacuuming robots in domestic settings [8][9][26][27]. Their results also describe the sensemaking process, including change in routine, adaptation of role in the household, and socialization of technology. These studies of adoption of robotic technology show that robotic technology interrupts people's existing practices more as it is novel technology, and evokes greater sensemaking activities. When sensemaking fails — for example, when a robot does not meet people's expectations — the technology can be rejected.

3.3. Experience design

Research on user experience has informed the design community about how people interact with products and make sense of products and the experience that results. McCarthy and Wright described six phases in an experience, and articulated how people make sense of products as they experience them over time [17]. Ford, Forlizzi, and Battarbee described how experience moves from an unconscious, unarticulated state to a cognitive and social state, finally becoming an experience that is schematized in memory and shared through social interaction [6][7]. Battarbee and Koskinen described how aspects of an experience are "lifted up" or shared with others, and become memorable social moments [1]. Karapanos and his colleagues studied the stability of experiences, finding that an initial experience of a product differs greatly from the quality of experience over the long term [12][13]. Some of the qualities they found to be important include stimulation and beauty as people orient to the product, usability as people incorporate a product in their lives, and emotional attachment as a product becomes meaningful. These trajectories of experience with products are most likely applicable to

people's experiences with services. We believe that as in experience design, when interacting with a service, *orientation* will matter during initial service encounters, when people understand and make sense of a service, and rely on its usability and consistency; later on, *incorporation* of a service in daily life, making meaning, and having a concern for social and emotional benefits of the service becomes important.

4. Designing An Adaptive Robotic Snack Service

Our literature review on experience design and technology adoption highlighted several ways in which the behaviors and attitudes of customers might change over time as they orient to adaptive services and incorporate them into their lives. Changes in human behavior influence how people use product and service; but in the case of our snack delivery service, the products and services can change, too. With the advent of context-aware, intelligent technology, services can be designed to adapt to these changes to better support users' behavior. For example, with a traditional snack delivery service, daily interactions might change once a delivery person begins to learn the preferences and habits of customers served on the route. Our snacking service, which uses robotic technology, can record user preferences and behaviors, allowing for daily interactions to change as user preferences are learned and automated, and as new technologies are brought onboard the robot.

With this in mind, we sought to find a way to understand how a service blueprint can represent and visualize how products and services adapt to changing behavior over time. In the next section of the paper, we describe our initial blueprint for adaptive service design and the new factors within the *Line of Adaptivity* that need to be considered.

4.1. A Blueprint for Adaptive Service Design

To represent adaptive services, we augmented a traditional service blueprint to depict *repeated service encounters* over time. We added a *Line of Adaptivity* to a traditional service blueprint, and allowed for *orientation, incorporation, streamlining,* and *personalization* in the design.

The *Line of Adaptivity* represents how people and services change with iterative use (Figure 3). In each encounter, people go through the process described in the one-time journey blueprint represented in Figure 2, making subtle adaptations in their behavior in response to the product and service, which are also changing in response to interacting with people over time.

We categorize changes in people using two factors: *orientation* and *incorporation*. In the orientation phase, users frequently engage in sensemaking activities in order to understand how a service functions. When people make sense of services, they understand the functional aspects of the service, evaluate their utility and desirability, and form initial attitudes towards the services. In traditional static services, products and services contain a fixed *spirit*, or schema of use, in their design [5]. These are feature sets that assume a particular physical and social context of use. People need to make sense of this schema, and either modify their own schema to fit the schema of the products and services, or reject the use of the service [19].

In the incorporation phase, users begin to integrate products and services into their daily lives, building trust and emotional attachment. Sensemaking becomes a peripheral activity in this phase, and only takes place when aspects of the service that do not fit into their worldview are experienced.

The concept of *cultural models* can be used to describe interpretive strategies that people use to incorporate particular services into their lives [22]. Cultural models are used to confirm existing belief systems, and to discount contradicting evidence. Three cultural models have been described for how people respond to services: relational, oppositional and utilitarian models [22]. The relational cultural model is applied by people who desire and value emotional ties with a service provider. The oppositional model is applied by people who perceive themselves as the vulnerable, weak player in the consumer-provider relationship and easily take an aggressive stance toward the service provider. The utilitarian cultural model is applied by people who rationally weigh benefits from a service against costs. Depending on these models, the same service can be incorporated in different ways and evoke either pleasant or dissonant experiences.

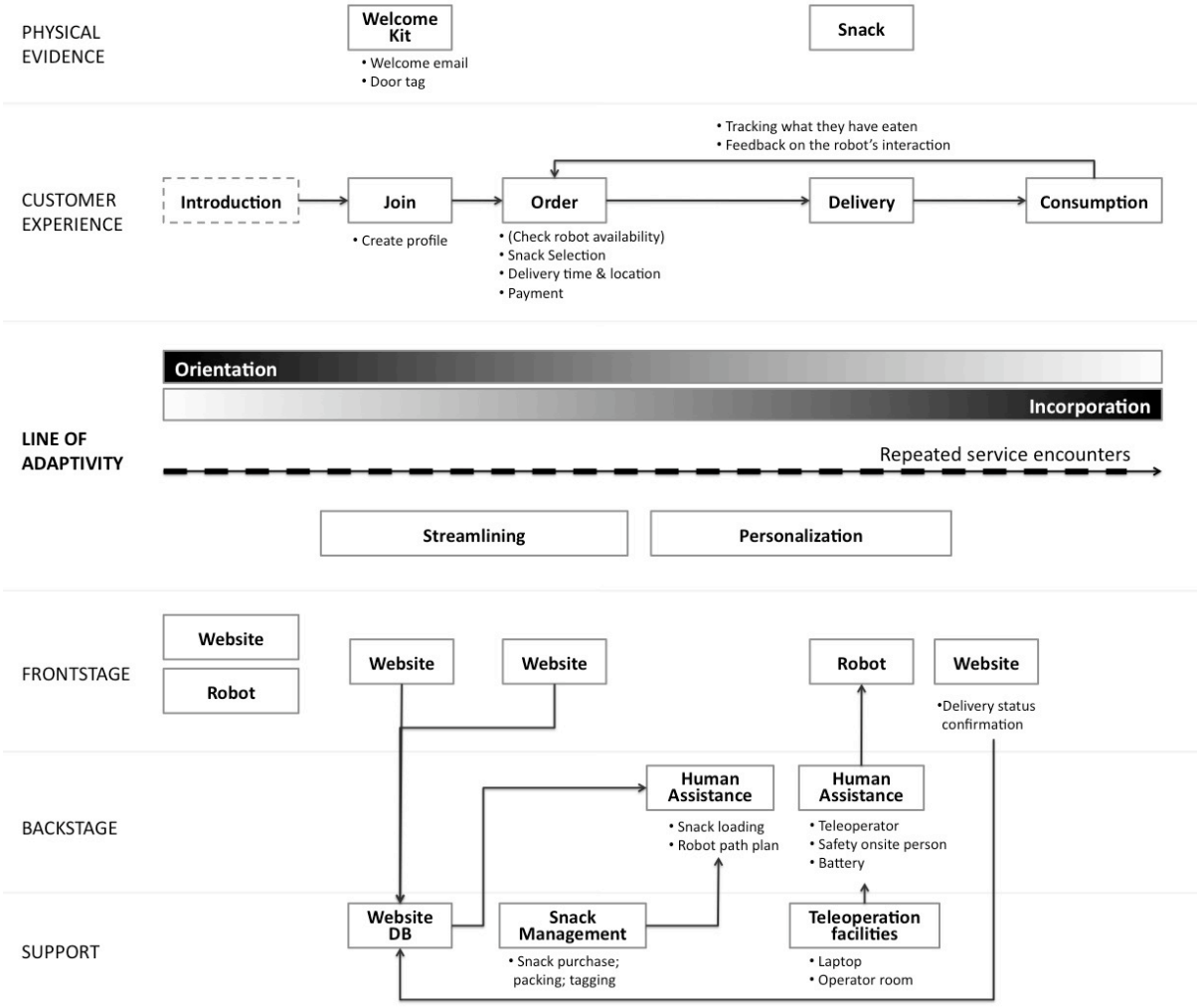

Figure 3. A service blueprint that describes how products and service can be adapted to users' changing experiences.

We categorize changes in the components of a service over time using two factors: *streamlining* and *personalization.* These changes are designed to support changes in users' behaviors over time. Service offerings will evolve as users' routines and preferences are learned. Some of the touchpoints in the journey may become unnecessary, requiring streamlining to continue to offer a beneficial service. Additionally, services may be personalized to better fit the needs of users, once their patterns of service purchase and service use have been learned.

To exemplify these ideas, in the next section, we describe how the Line of Adaptivity is designed in our robotic snack delivery service.

4.2. Adaptive Service Design: A robotic snack delivery service

The Line of Adaptivity for our robotic snack delivery service focuses on people interacting with a robot, a website, and a delivery service. Changes in human behavior are described through orientation and incorporation, and service adaptation is captured through streamlining and personalization.

4.2.1 Orientation and Adaptive Services

In the orientation phase, people use products and services for the first time, comparing them to prior product and service experiences. When engaging with our robotic snack delivery service, the process of sensemaking will be iterative. Our snacking service will be sensitive to users' sensemaking process, thereby reducing the likelihood that users reject the service early on. The design feature that we employ to do this is a *two-way interaction between users and the product and service*. The robot uses simple speech recognition, and a series of cameras and lasers to capture human behaviors and respond to interaction breakdowns. The second design feature employed during orientation is *incorporating human social cues into the robot's design* to allow people to draw on their experience with familiar services. This can be manifested through any design feature ranging from the structure of the dialogue, for example following an interaction sequence that a human vendor employs, to humanoid cues in the robot design.

4.2.2. Incorporation and Adaptive Services

Our snacking service *adapts to relational and utilitarian cultural models* to help people incorporate the service into their lives. For people who rely on the relational cultural model when interacting with the robot, the Snackbot follows a human-human interaction model, mimicking a human vendor's interactions and using interpersonal relational strategies when delivering snacks. For example, applying the rule of reciprocity, the robot can give a free snack as a gift on a special day, which can result in feelings of thankfulness and indebtedness toward the robot. The robot can also build on what the users said in their previous meeting, or use self-disclosure strategies to create the feeling of closeness as users and the robot interact each other repeatedly. For people who rely on the utilitarian model, the robot follows a more machine-like interaction sequence without trying to engage users in social conversation with the goal of delivering an efficient, minimal transaction.

To assess how to design and dynamically respond to different cultural models, we can rely on technology to understand users' cultural models. For example, we can record and track how people talk to the robot.

Automatically sensing the structure and form of this dialogue would allow us to infer the cultural model that is being employed at any given time. Alternatively, when a snack is ordered, users could specify the type of interaction they desire at the time of a snack delivery.

4.2.3 Streamlining and Adaptive Services

As users repeatedly engage with a service, they may gain a greater understanding of the service, and want to speed the process of ordering and using the service. Some of the touchpoints within might become unnecessary. Our snacking service will *combine or automate some steps in the service journey for expert users*. For example, speech-based instructions about how to complete the transaction with the robot might eventually become unnecessary. Instead, a simple sound that indicates the robot's actions (i.e., its arrival or an approval for taking a snack) might be informative enough and will not interrupt or distract those on the delivery route. In addition, if users exhibit same usage patterns over time, the service could automate some steps to facilitate the process. For example, a robot may automate the order process and begin to deliver snacks regularly to those who order cookies every Friday, or support one click ordering.

4.2.4 Personalization and Adaptive Service

In the incorporation phase, people begin to use products and services fluently, incorporate them into their daily lives, form trust and emotional attachment, and find meaning from repeated experience with the service. As users repeatedly engage with a service, the opportunity exists to personalize the service to better suit their needs. Our snacking service customizes its offerings by *tracking users' preferences and customizing responses*. For example, for customers who prioritize utility, the robot never engages in social conversation as it delivers snacks. Healthy snacks are suggested for those looking to increase options for a healthy lifestyle. The service can also provide proactive recommendations based on what it has learned, by asking users if they want information about new and greater varieties of snacks. Eventually, the robot and service will be able to scrape information from users' calendars and deliver snacks for birthdays and special events.

After people make sense of services and incorporate them into their daily lives, they discover greater personal and social meaning relate to the products and services. Here, the meaning arises not from the products and services themselves, but from how they support what people value. Adaptive services can better respond to the subtle reprioritization of people's values. Our robotic snack delivery service can do more than just carry snacks from point A to point B. The service can attempt to understand diverse motivations behind why people order snacks and customize the service in response. For example, for those who use the service to enjoy a social snack break, the service can facilitate coordination of multiple people in support of these values.

5. Conclusions and Future Work

In the process of creating a robotic snack delivery service, we found that the current service design blueprint technique was not sufficient for capturing the dynamic nature of the adaptive service, and the human experience that results. In this paper, we take an initial step towards creating a service blueprint technique for designing adaptive services. The blueprint can be used to understand how products and services should change over time as users' experiences with the service change. In future work, we will evaluate the proposed framework through

long-term user studies and investigate the reciprocal influence between changing user experiences and adaptive services.

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