User Perceptions of Adaptivity in Ubiquitous Systems: A Critical Exploration

Karen Tanenbaum
School of Interactive Arts & Technology
Simon Fraser University
250-13450 102nd Ave
Surrey, BC V3T0A3 Canada
ktanenba@sfu.ca

Abstract

My research addresses a gap in the field of adaptivity for ubiquitous systems by taking a critical look at the notion of "adaptivity" and how users experience it. Through a set of detailed case studies of the design of several different systems, I develop a theoretical understanding of the experience of adaptivity that is useful for designers of intelligent systems, particularly those with ubiquitous and tangible forms of interaction.

1. Introduction

The goal of this dissertation is to turn a critical eye on the notion of adaptivity, specifically within the realm of tangible and ubiquitous systems. In educational and workplace applications, adaptivity is typically task oriented and aimed at helping users achieve a particular learning or productivity related goal. This means that the adaptive mechanisms can be much more explicit, intervening directly with the user to offer them assistance or advice. In ubiquitous environments, however, the nature of the interaction with technology shifts. Computational elements are embedded in the environment or in smaller, handheld devices. Users may not be paying explicit attention to the system, and the activities taking place are less task oriented. Some of the most common uses of adaptivity in ubiquitous spaces are for leisure activities, such as museum guide systems that combine entertainment with education, or domestic systems that automate or anticipate common user behaviours. Since users of these systems are less focused on interacting with the technology itself, the goal of the system is to unobtrusively monitor the users and adapt itself to suit them in some way. The novelty of this kind of interaction is a significant issue in constructing adaptive components that work as intended.

The term “reality-based computing” was proposed recently as a catchall term for the large amount of work being done in fields such as virtual, mixed and augmented reality, wearable, tangible, mobile and ubiquitous interaction, context-aware computing, and other areas that build on “user’s pre-existing knowledge of the everyday, non-digital world” [5]. Many of these research areas examine novel forms of physical, embodied interaction with embedded computation as opposed to more focused and familiar interactions with keyboard, mouse and screen.

2. Literature Review

The vision of ubiquitous computing, first established by Weiser in 1991, is for information technology to become "invisible" and to vanish into the background when people become sufficiently used to computation embedded throughout the environment [9]. In an imagined ubiquitous future scenario, he describes the daily life of Sue, a woman surrounded by embedded systems that unobtrusively prepare her coffee and newspaper, track and display information about her environment and family members, log her in and out of work, and facilitate her collaboration with office mates [9]. Each of these elements requires the computational systems around Sue to know something about her: where she is, what her preferences are, who she is connected to, or what she is working on. This knowledge of Sue as a specific individual rather than a generic user allows the technological systems surrounding her to adapt and personalize their functionality to suit her.

Most interactive systems, such as the laptops, desktop computers and smartphones that people use on an everyday basis, respond to their users in a reliable and repeatable manner, treating each user the same. Adaptive systems hold the promise of responding to each user as a unique individual [1]. The appeal of this vision has sparked numerous research projects looking at how to imbue computational systems with enough intelligence and awareness to be able to learn about and adapt to their users.

Designing these intelligent, ubiquitous systems is not a straightforward task, however. When the technology is designed to be obscured, as is the case with many distributed, ubiquitous systems, intelligent components can cause unexpected or unpredictable behaviours that make it difficult for users to understand what the system is doing [4]. Williams et al phrase it well when they say that the embedding of computation into everyday environments will "reconfigure the relationship between people, objects, and space: first, by making spaces responsive to activities in ways not previously possible, and second, by presenting new challenge for the interpretation of actions and objects in space. In other words, how will people be able to make sense of computationally enhanced spaces and how will

they be able to make sense of each other in those spaces?" [10]. Such spaces often involve new methods of interacting with technology, such as via tangible interfaces or ambient feedback systems, so users in the space must both learn a new form of interaction as well as interpret a new level of adaptive response. How we design for these situations, as well as how users make sense of these novel systems, is an open and active research area.

3. Case Study

This dissertation research takes the form of an exploratory, collective case study. A case study is both a process of inquiry and the outcome of that inquiry [7]. It is an in-depth study of a specific, bounded phenomenon through multiple sources of data [3]. A case study looks at a social phenomenon, focusing on detailed descriptions, interpretations and explanations that participants attach to the phenomenon [8]. This method is ideally suited to complex, real-world phenomena where it is difficult to isolate specific variables or dependencies and when the boundary between the phenomenon and its context is not clear [11]. The phenomenon under study in this dissertation is the design of tangible and/or ubiquitous computing systems with adaptive components. Adaptivity, and most particularly the user experience of adaptivity, is an undertheorized and underexamined facet of computing systems. The cases I analyze here are not strictly real-world phenomena, but rather explicitly designed research studies with recruited participants. However, each case is a system of sufficient complexity that it would be impossible to perform controlled experiments on isolated elements. The adaptive components are interwoven with other aspects of ubiquity and tangibility in a manner that would be challenging to disentangle, thus making it an ideal situation for the holistic approach of the case study methodology [8].

3.1 Research Questions

To investigate the phenomenon of adaptive systems, I start with the following research questions:

RQ1: What are the elements of user experience found in different ubiquitous adaptive systems?

RQ2: What is the relationship between the ubiquitous and tangible system elements and the adaptive components, from the user's perspective?

RQ3: How do the goals and intentions of the designers of adaptive and ubiquitous systems compare to the actual experience that users have of the designed system?

4. Cases

Each of the cases to be studied is a specific design project, with two embedded units of analysis, the system designers and the participants who experienced the system [11].

4.1 Case 1: Reading Glove

The Reading Glove is an interactive storytelling system centered around a wearable interface and a set of narratively rich objects. "Readers" of the story wear a glove containing an RFID reader and pick up tagged objects to trigger audio playback of story fragments. A tabletop display provides adaptive recommendations on which object to select next.

Figure 1. A reader using the Reading Glove

Unit of Analysis: Designers: The designers of the system were myself and my collaborator, Joshua Tanenbaum. Our design process was documented via an online blog as well as through paper prototyping and notes.

Unit of Analysis: Participants: The participants in the Reading Glove study were graduate level students at Simon Fraser University's School of Interactive Arts & Technology program and Great Northern Way's Masters of Digital Media program; 20 participants were working on their Masters degrees and 10 on PhDs. They ranged in age from 23 to 55 years old, with the median at 31 years. Of the 30 participants run through the study, 19 were men and 11 were women.

4.2 Case 2: Kurio

The Kurio system was an adaptive museum guide system that invited family groups to play an educational game as a way of exploring a museum space. In Kurio, a family imagined themselves as time travelers from the future whose time map had broken, stranding them in the present. They had to complete a series of challenges that encouraged them to learn certain concepts from the museum in order to fix the map and continue their time travels. The interactive guide itself was comprised of a tangible user interface that was distributed over several tangibles with different functions, a tabletop display, and a PDA. An adaptive user model component attempted to gauge the appropriate challenge level for each user and determined the optimum length of rounds for the group as a whole.

Figure 2. A family using the Kurio system

Unit of Analysis: Designers: The designers of the Kurio system were a group of SFU researchers that included myself, two professors, and two other graduate students. The project began with an ethnographic study of the museum that the system was to be placed in, which resulted in a design requirements document. The design process was documented in an ongoing way via storyboards, wireframes, and other design artifacts.

Unit of Analysis: Participants: The Kurio participants were families recruited from SFU and the local Surrey community. The number of participants was 58 parents and children, or 18 families. The family sizes ranged from 2 to 4 people and in a few cases a family friend joined the group. In most cases, a single parent accompanied one or more children, but in one case two parents participated. There were 35 children between the ages of 7–12: 20 boys, 15 girls. There were 4 children between the ages of 13-17: 2 boys, 2 girls. And there were 19 parents (15 mothers, 4 fathers) ranging in age from 24 to 57.

4.3 Case 3: Socio-ec(h)o

The socio-ec(h)o project involved a group game played with a responsive, ambiently intelligent environment. Groups of four players had to complete game levels by arranging their bodies and movements in a particular configuration, guided by riddle-like hints projected onto the walls. Ambient sound and lighting cues provided continuous, real-time feedback as to whether or not the group was moving closer to the correct solution. Since one of the main tasks of the game was to figure out what elements of player interactions and movements were important to solving the puzzle, there was a great deal of in-situ discussion between the participants about how the system worked and how to interact with it. These discussions are a valuable resource for beginning to understand how users make sense of the behaviour of an adaptive system. One of the original goals of the project was to use personality types to determine the adaptive response, but difficulties encountered in the design and implementation of the system prevented this mechanism from being fully developed.


Figure 3. Participants interacting with socio-ec(h)o

Unit of Analysis: Designers: The designers of the socio-ec(h)o system consisted of two professors and four graduate students.

Unit of Analysis: Participants: The participants in the socio-ec(h)o study consisted of 56 people total, in 14 groups of 4 per study session. The participants were primarily undergraduate students at the School of Interactive Arts & Technology at Simon Fraser University.

5. Data Sources

5.1 Semi-structured Interviews

Each of the three cases contains data from semi-structured interviews conducted with participants following their interaction with the systems. Interviews were recorded and the dialogue transcribed for analysis. The interview data was analyzed for information about the experience participants had of the systems: what kind of sense they made out of it and how they arrived at that understanding.

5.2 Observation of System Interaction

Video recordings of participants interacting with the systems were collected in all three cases. While a full coding of the video was not undertaken, the videos were annotated with broad categories of behaviour and ways of interacting with the system. In Kurio and socio-ec(h)o, multiple people used the system together and the dialogue between participants was transcribed and analyzed to see how an understanding of the system was constructed collaboratively over time.

5.3 Questionnaires

All three cases had pre and/or post interaction questionnaires involving mostly Likert-scale questions on different topics. Pre-interaction surveys tended to ask basic demographic questions and probe for certain key characteristics, such as experience with similar systems, familiarity with museums, or personality types. Post-interaction surveys gathered quantitative data about the experience of using the system, asking participants to rate how much fun it was, how easy it was to use, and so forth.

5.4 System Logs

System logs provide valuable details about specific features of the experience. They allow me to extract information about how long the interaction lasted, how many game challenges each person completed, and so forth. Details about the adaptive system are also recoverable from the system log, so specific system behaviours can be interrogated to see what triggered them.

5.5 Design Documentation

Design documentation, including wireframes, interactions models, design scenarios and technical reports, has been collected. Published papers on the projects also provide insight into the motive of the design. Interviews with the designers will be undertaken as necessary.

6. Analytic Strategies

This is a mixed method study with a predominately qualitative focus.

6.1 Exploring the Nature of the Experience

To answer my first two research questions, my primary analytic strategy will be a qualitative analysis of the participant's descriptions of the system and their experience with it, taken from the interviews and conversations held while interacting with the system (data sources 1 and 2). These transcripts will be coded and then categorized into themes to allow for a deep understanding of the experience from the participant's point of view [2, 6]. The results from this analysis will be supported by survey data, system logs, and video data of the participants interacting with the system (data sources 2-4). Some of these supporting results will be quantitative in nature, including descriptive and correlational statistics. Others will take the form of data displays, following the representational techniques of Miles and Huberman [6, 8]. Once all of the individual case analyses are complete, I will also compare across the cases and see where the similarities and differences lie and whether these differences can be connected to the differences in case characteristics.

6.2 Comparing the Intended and Actual Experience

To answer the third research question, I will combine the participant-focused analysis from above with a qualitative analysis of the design documentation, written papers, and interviews with the designers. This designer-focused analysis will be aimed at developing an understanding of the goal of each system, the designers' intended participant experience, and the theoretical commitments underlying it (data source 5). These intentions will be compared to the actual experience of the system (data sources 1-4).

7. Contribution

The analysis work is currently ongoing, but the intended end result of the research takes two basic forms. One is a set of individual case studies focusing on the design of adaptive, ubiquitous systems. These individual case studies will each consist of a deep understanding of the experience of the system from the perspective of the user, and a comparison of how that experience stacks up to what the designer's intent was. The second result is a cross-case analysis that explores the similarities and differences across the three cases and connects these variations to elements of the system design.

7.1 Preliminary Results

The Reading Glove analysis is partially completed, enough to be able to present some preliminary results here. A qualitative analysis of the post-interaction interviews yielded four broad themes related to the experience of using the Reading Glove. In each of the thematic descriptions below, the italics indicate codes developed based on the interview data. The full analysis includes quotes from the participants and a deeper investigation of what each code means.

7.1.1 Experience of the Adaptive Components

People *made sense of the intelligent recommender* in a variety of ways, although overall they paid less attention to it than I had initially expected. This theme looks at what they thought was the *purpose of the recommender* and *how the recommender worked*. Connected to this is the issue of whether they tended to be *following or not following the recommender* and whether they were *trusting or distrusting the system.*

7.1.1.1 Purpose of the Recommender

At the start of interacting with the system, participants were given minimal information on how to understand the recommender system, in order to provoke their own interpretations. They were told that the tabletop display would "help guide you through the story", but given no details about how that guidance was generated. One of the most common ways participants described the recommender was as a system that gave "hints" or "clues", as when participant 3 said: "And you get some hints on the map of which objects would be useful to try next....The ones that got bigger were sort of your clues for, if you touch one of these objects, something useful will happen." Similarly, participant 7 said identified the recommender images as being "kind of like wayfinding or navigational devices". Four participants had a negative or dismissive take on the recommender, saying that sometimes they thought it was simply a "trick" or intended to confuse or distract them.

7.1.1.2 How the Recommender Worked

Participants were often hesitant to make guesses about how the recommender worked, and gave fairly vague and hedged responses when asked directly. The most common guess put forth was that the recommender was responding in some way to the last object touched, but exactly what that response consisted up was unspecified, as when

participant 2 suggested that “it was probably responding to what was the last object that I touched before I touched the new one." When pressed to generate more specific guesses about what determined the objects that were recommended, most participants guessed that it was based on the linear order of the story, with the recommended objects being those that were immediately before or after the last object selected. Participant 27 said “I think they were trying to relate in terms of the order. So you pick up one, and these are three things that would happen in relation to it or after it." Two participants ventured that the system might use more information than just what they picked up last, speculating that the recommender might be looking at a sequence of items that they had selected. Participant 20 said “I was thinking maybe it is depending on the sequence of the object that you pick up, it's capturing my patterns to figure out whether I understand the story behind the first action or not. Something like that." When starting this project, I had thought that the recommender would be the locus of people’s efforts to “figure the system out”. While some people clearly did try and puzzle out the recommender workings, this aspect of the system was not as salient or as cognitively engaging for the participants as the non-lineary delivery of the story.

7.1.1.3 System Trust and Intelligence

Seven people talked in implicit or explicit ways about whether or not they trusted the system, and most of this discussion had to do with the recommender. Participant 10 said that she considered not following the recommended objects, but was too interested in the story to take that risk, implying that she trusted the system to tell the story "correctly" or well and did not want to interfere. Thus her desires were subsumed in the desire to have a coherent story and a belief that she could trust the system to supply that. Participant 12 affirmed that he mostly followed the recommendations because he was "not inclined to challenge the authority" of the recommender. Other participants had the opposite reaction, saying that they felt the recommender's goal was simply to "add to the confusion" and reporting that they could not figure out why it was recommending what it was. Related to the issue of trust, three participants made explicit reference to whether or not they perceived the system as intelligent. Participant 1 said "I think there’s some kind of really complicated algorithm in the background that’s figuring out what to display" while participant 11 said "I had more a sense that the system knew more than I did." On the flip side, participant 21 said "I make a general rule not to think that systems make choices" when asked whether or not the system produced sensible recommendations to pick from.

7.1.2 Choosing and Controlling

A second theme arising from the Reading Glove data examines the difficulty of dealing with the non-linear story and how that affected participants’ sense of control and choice. The biggest challenge when using the system was *grappling with non-linearity* and attempting to reassemble the story fragments into a coherent narrative. Participants discussed various strategies they used in *figuring out how story delivery worked*. This grappling often lead to participants *experiencing cognitive load* and even *distrusting themselves* and their interpretation of the story. All of these factors lead to an interesting tension between *experiencing control/lack of control* and *getting to choose*.

7.1.2.1 Grappling with Non-Linearity

The biggest stumbling point for most people was the non-linear nature of the story and figuring out how to reassemble the narrative. Participants reported having a hard time *figuring out how the story delivery worked*. A number of people believed there was some sort of branching going on, so that choices they made early on affected the paths that the story took or the ways in which the plot was resolved. Others seemed to think that the story was fixed, but were unsure how many clips were on each object or thought the associations between object and story changed throughout the interaction, with the system shuffling the clips around to different objects. A handful of people seemed to realize that each object was associated with only 2 clips, that those clips could be cycled through systematically, and that the story content was fixed and did not change based on participant choices. Half of the participants discussed experiencing some variety of cognitive load or difficulty dealing with the non-linear and fragmentary nature of the story. This increase in cognition was sometimes listed as a positive result of the experience, with participants claiming it increasing immersion by forcing one really pay attention and to make connections between the story fragments. Several people talked about not trusting themselves or their interpretations of the story because of the difficulty of piecing together the non-linear story. . Participant 10 said "I don’t know if I know everything. So that’s hard to judge, if you know everything." Participants worried that they had not uncovered all the story fragments, or that they had failed to remember and piece it together correctly. They were unsure whether they did it "right", as with participant 17 who said: "I was probably navigating the story in a different sort of way than was intended". This self doubt led to a complex relationship with the concepts of “control” and “choice” with regard to the system.

7.1.2.2 Experiencing Control

The issue of control within the Reading Glove is complex and interesting. Several people complained about the lack of control and noted that they would have liked to be able to easily and quickly revisit previously heard material. Other participants noted that there was a lack of direct control over the system in this manner, but did not see this as a strictly negative characteristic; it contributed to the ability to explore the system and discover or uncover the story there. Although they did not know what the results of their choices would be (i.e. what fragment they would

hear and how it would connect to the previous ones), the fact that they got to choose gave them a feeling of control. In one of the more intriguing quotes, participant 30 describes the Reading Glove as an “Interactive story based on objects that you can touch and discover. Again, but you don’t have control. If I want to go back or listen back, I want to go back to the chapter where I missed something, there is no definite way. In the end, because it is short story, the third time you touched the same object, obviously you got the first version.” That is, just after asserting that there was no way to “control” the system, he affirms that he knows exactly how to control the system to move back and forth between fragments at will. So what makes up the feeling of control? It seems like there are several different ways of understanding control interwoven here: 1) Control as freedom of choice: since interacters can choose any object at any time, they are directing or controlling the story. 2) Control as knowledge of what will happen, i.e. what story fragment they will get. When interacting with an object for the first time, the reader doesn't know what story fragment they will get. On the second time around, they may remember or they may not, as the story is sufficiently long and complex as to not be perfectly memorable the first time through. 3) Control as technical understanding: Knowing for sure that there are two pieces on each object and that they flip back and forth. Not all participants achieve this understanding, but even those that do complain about the lack of "control". Most people experience the first kind of control, but few experienced the second or third form of control.

7.1.2.3 Getting to Choose

Two thirds of participants talked about the idea of choice. Choose Your Own Adventure stories were frequently mentioned as an experience that was similar to the Reading Glove, but the notion of choice was deeper and more complex than that. When asked to describe the system, the responses often centered on the key role of choice in the interaction. Participant 3 said "I would say that there’s a story that’s happening and depending on which objects you choose to touch, you hear different parts of the story." What choice meant to participants varied. Some participants figured out that the story was static and that the fragments heard flipped back and forth. For them, choice was more navigational and less exploratory. As we saw in the previous section, most participants were uncertain how the story delivery worked and thought their choices might have an effect on the story content. For them, choice of objects was therefore more loaded than the people who viewed it more as a navigational method through a fixed and determinate set of options. The recommender may also have had an effect on the feeling of choice. Participant 1 sums up the difference between choice and control nicely: "I guess picking up all the objects and the tangible…getting to sort of choose what you heard next kind of…although you didn’t really know what you were going to exactly hear...It’s a lot harder to figure out what’s going on than just if you knew what you could listen to next, if I could choose specifically." While the participants had full freedom of choice, they did not know what those choices meant.

The relationship between feeling a sense of control and the ability to choice, combined with way the technological system of the Reading Glove mediates those feelings is hard to untangle. These preliminary results grounded in the participant’s description of their experience with the system highlight the challenge and opportunity inherent in designing and evaluating adaptive, ubiquitous systems.

Acknowledgments

This research was undertaken with the support of my advisors, Marek Hatala, Ron Wakkary, and Alissa Antle, as well as my collaborator Joshua Tanenbaum. Funding for this research was provided by NSERC and the Play-PR project of the GRAND NCE.

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