Lessons Learned in the Design of Configurable Assistive Technology with Smart Devices

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Abstract. Assistive Technology (AT) aims at compensating for motor, sensory or cognitive functional limitations of its users. We report on a study with a single tetraplegic participant using AT that we have been developing for interaction with multiple devices in smart connected environments. We wanted to investigate a user's reaction during his first encounter with this technology and to verify if needs and opportunities for AT configuration would emerge from study activities and interviews. Results show implicit and explicit configuration needs and opportunities suggesting that we must address both hardware and software configuration, some to be done by the end user, others by assistants. At this initial stage our contribution is to propose a structure for organizing the AT configuration problem space in order to support the design of similar technologies.

Keywords: Assistive Technology · Configuration · Wearable Computers

1 Introduction

Assistive Technologies (AT) are resources that allow for compensating motor, sensory or cognitive functional limitations of their users [1]. One of the reasons AT are hard to design, produce and be used is the variability of kinds and degrees of disabilities and individual characteristics among users (physical, psychological, cultural, environmental, etc.). This variability can be addressed by means of configurations to improve production and adoption. However, before engaging in such endeavor we must answer questions like: what is configurable AT? What does AT mean to users (and to people around them)? There are, at least, two ways of defining AT: one is more technical, concerning the technology and its functions, as in the U.S. [2]; the other focuses on the disabled person, emphasizing the role of AT as equipment for social inclusion, which is the case in Brazil [1]. This work follows the second definition and explores issues beyond functionality and technology, but that can nevertheless influence the design of both. We conducted a case study with a single tetraplegic participant who controlled some devices using an AT platform operated simultaneously by gesture and voice interaction in a smart home environment. Based on our

adfa, p. 1, 2011.

findings, we propose a set of dimensions for AT configuration. We believe our contribution is to propose a structure for organizing the AT configuration problem space to support the design of similar technologies.

2 Related Work

Our work is currently investigating the intersection of three extensive research topics, depicted in **Fig. 1**. Of course, this section is not an exhaustive review of the research done in the three areas. We just want to point some work we think can show important approaches and advances, especially in the intersection between them. This might be useful to support the relevance of this research and to uncover its gaps. Our aim is to contribute to the design for user empowerment in the AT domain [3] towards an "ubiquitous accessibility" [4] to promote full social inclusion of disabled users.

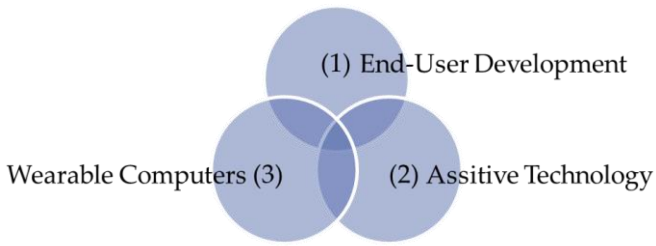

Fig. 1. A depiction of the research topics of our work.

The intersection of (1) and (2) was investigated by Carmien & Fischer [5] applying the meta-design framework in systems for people with cognitive disabilities. Lewis [6] has pointed at configurability needs and some aspects of design, also in the domain of cognitive disabilities. Between (1) and (3), there are investigations of configurability in tangible computing [7], end-user programming of hardware platforms [8] and alternative (even "physical") means and languages for programming [9], but in different applications and domains. Between (2) and (3), the use of wearable computers as AT has been studied in [10] and advanced work has been done in the rehabilitation field using robotics [11]. Most of these focus on engineering aspects. Closer to us, Kane et al. [12] make recommendations for increasing configurability in the design of mobile accessible devices for users with motor impairments, but more is needed to clarify what it is and how it could be done. To the best of our knowledge, there is no significant volume of research focusing on the intersection of all three areas.

3 Case Study

We are working with a single tetraplegic participant who has come to our lab looking for new technology that could help him in his everyday life. We anticipated that configurability would be an issue, but had little idea of what should be configured and how. We so decided to investigate his reaction in first encounter with a concrete instance of the technology he was looking for. We wanted to see if needs and opportunities for configuration would emerge and how this would come about.

3.1 An Assistive Technology Platform Prototype for the Smart Home

After observations and interviews with the participant and some market research, we proposed a solution composed by three parts, which can be seen in **Fig. 2**:

1. An electronic cap – a wearable computer – that detects head movements and simulates a mouse. The cap can be plugged to up to four exchangeable switches that are used to do the clicks. It communicates wirelessly to mobile phones via Bluetooth;
2. A dock station for Android™ mobile phones, which controls a lamp, a TV set and a wireless dual connection headset (switching between phone and computer);
3. An Android™ mobile phone, which is “the brain” of the system and connects with the dock station via USB. The phone is equipped with an app designed to control each device individually, besides the native features provided by Android™.

Fig. 2. Our AT prototype platform: on the left, a user wearing the cap to control a lamp, a TV and a computer; on the right, the dock station connected to a mobile phone with our app.

3.2 Study Scenario

We designed a study split in two steps. First, we presented the platform to the participant, taught him the basic operation and allowed some time for him to play with it. Second, we proposed a task scenario specifically designed to include multitasking: he would be working on the computer doing some generic activity (e.g., reading e-mail, the news, etc.) when a friend (a role played by another researcher) would call him unexpectedly to discuss a spread sheet in his computer. Study session took place in the participant’s home and lasted approximately three hours, including the interviews. Each step was video-recorded using the CAS (Capture & Access System) infrastructure, which allows for a complete capture and subsequent analysis of the scene observed from different angles [13]. The first author of this paper conducted and supported the participant during the session. At the beginning and at the end of each step we made oral open-question interviews about his expectations about what was coming next and about his impressions on what he has just experienced, respectively.

4 Results and Discussion

Our findings are based on two kinds of evidence: the participant's actions and behavior during study activity; and his utterances, during actions and when answering our questions. In the first step (technology introduction), we placed the cap on the participant's head, adjusted fit and position properly and tried out the different switches we could use. We quickly discarded two of them, because we noticed instability on the control and the participant's emerging fatigue, discomfort and frustration when testing them. The other two were placed and adjusted in such a way they could be activated comfortably, which we could notice and the participant verbally confirmed. We connected all the parts, taught the basics and then let him explore the equipment for some time on his own.

In the second step (task scenario), many things happened (mostly triggered by us as part of the scenario) to promote task switching and interleaving. They brought about interaction challenges that we saw and were also verbalized by the participant in the interview. Switching the voice from the computer to the mobile phone and answering the phone doing a "swipe" with his head was the greatest issue. It took our participant several attempts to accomplish that, because of failure in one or another intermediary stage and confusion about moving the mouse pointer up and down. We observed some tension and anxiety, which was later confirmed by him in the final interview. The participant, however, persisted in the task, not asking to abandon it (which he could easily do).

This study revealed many configuration needs and opportunities. First, there were **physical form and hardware options**, like the size of the cap, the switches to be used, their positioning and fit to allow for comfortable use. Then, there were **behavior configuration opportunities**. In the interview, the participant spontaneously suggested the creation of shortcut buttons (hardware switches) to allow for quick switching voice channeling from the computer to the phone. He also mentioned options for changing the behavior of the mouse pointer, like going up when he pitches down and vice-versa (the equipment worked opposite to his expectations). He even suggested the possibility to use the head gestures like keyboard arrow keys, he referred to it as being a "more primitive" kind of control that could be easier for him.

One may argue that a better design for our AT prototype might improve his experience, which is true. However, the desired actions for any given task are subject to change according to the situation (for example, if he receives a call while watching TV at high volume) and the contingent access conditions to control buttons (limited by range of physical movements the user can do). A configurable mechanism could provide means for defining shortcut actions using the available buttons (and combinations) that can be reconfigured according to context and task. Along this line, in the interview the participant referred to tetraplegic friends that he believes may act and think differently from him, for example, in the up-down head control preferences and in the ability to move the shoulders. A flexible system can effectively adapt to a broader population of users, especially when we consider that our participant represents a "best case", with high motivation levels, since he had anticipated the benefits of technology when he first contacted us on our lab.

As a result from our study, we propose three dimensions with which to organize the analysis of needs and opportunities of AT configuration:

- **The psycho-social dimension**, concerning the different form and behaviors factors that may be desired in different situations in a context-dependent way and determined by individual motivations and social environment. That includes: appearance and mobility, devices to be controlled, shortcuts for quick performing functions, and end-user definitions of contexts, tasks or situations of use. For example, the equipment to be used at home may be different from that to be used at school or work due to its appearance, portable abilities and devices to interact with. In the same way, the functions to be performed and how they will be achieved can be totally different in each context: there will probably be no TV at work, but the user may need to control a projector; using voice can be more convenient and practical alone at home, but not possible at a classroom or meetings;
- **The carrier dimension**, concerning the means by which a configuration can be done and the *substratum* where it will reside: whether it is a hardware, software or hybrid configuration and if is to be changed by the user himself or by somebody else helping him. That includes the fit of the cap, the switches to be used and their position, that will have to be put on him by somebody else helping him; at the same time, the outcome of a switch activation and the connections to other devices have the potential to be done by himself on the platform software;
- **The persistence dimension**, concerning the duration of a configuration, its timeliness and volatility: some configurations will be temporary, and some will last for a long time or be for ever. For example, a user's size and abilities to move his head and shoulders are unique, and will probably not change significantly over time, allowing for a persistent setup; however a task or context of use may begin and end making sense once the user changes activity, uses different devices, and so on.

Design features will often have to be considered from the perspective of more than one dimension. For example, the "look" (appearance) feature may vary between "discreet" and "impressive" in the psycho-social dimension (depending if the user is going to school or to a date with his girlfriend), whose effective configuration requires hardware changes, which in turn may entail changes in the carrier dimension. From the persistence dimension perspective, configurations might be kept only for a short time (say, the duration of a date outing or a class). The user might probably want to save it for use in similar situations. So, these dimensions play complementary roles that are all closely linked to each other and we cannot consider them separately during the design. All of them contribute for the achievement of specific goals. We find it useful to think about AT configuration in terms of these dimensions, as a way to clarify the options to be considered and the ways to set them.

5 Conclusion and Future Steps

In this work we proposed three dimensions to support the design of AT configuration options. This characterization of the problem space hasn't been proposed to date and we believe it can be a starting point for the incorporation of configuration features into most AT systems. We plan for a subsequent research cycle, where we will use these findings in a new design and then evaluate it with the same participant to investigate techniques, technologies and approaches that may suit each configuration need.

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