Usability Study of the Gauntlet Wearable Interface

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Abstract

This paper presents and discusses the results of a usability test of a wearable interface for ubiquitous gaming. Originating from a concept of interface that allows intuitive and immersive interaction in mobile applications, untethered from location-specific hardware and software frameworks, a first, fully functional prototype has been built and publicly demonstrated. Usability tests have allowed us to formally register and examine users' reactions to the device in order to determine if the concept is valid as well as to uproot usability and wearability issues. Analysis of test results determines the direction to follow in our next design iteration.

Keywords

Evaluation, usability, wearable, ubiquitous, gaming, gauntlet.

1. INTRODUCTION

Ubiquitous games have become a popular topic of research. The term "ubiquitous games", used interchangeably with "pervasive games", covers a wide array of gaming projects that explore different concerns and bring together sometimes seemingly heterogeneous technologies, frameworks and practices. As Benford *et al.* have pointed out, staging a ubiquitous game at different locations may require (and commonly does) hardware and software infrastructures to be installed and thoroughly configured for each new location [Benford05]. The majority of ubiquitous gaming projects have relied on common devices to provide user interfaces that can easily be integrated with widespread technologies. Such a solution tends to produce games which are more versatile and deployable on a large scale [Correia05][Flintham03] [Kratz07]. Other projects, however, rely on unique approaches that are restricted to a specific game-play mode and/or require a cumbersome supporting framework, but which provide much more engaging and immersive experiences for players [Lindt06][Stenros07].

In light of this we set out to develop an interface which would provide for both immersion and versatility, taking advantage of the physical world but all the while aimed at mobile use and as much as possible independent from sensor or communications frameworks or hardware of considerable size. Our first design iteration yielded a fully-functional prototype device which was then subject to assessment tests to determine how efficiently the concept had been implemented.

2. RELATED WORK

Data gloves and gesture-driven interfaces have been around for many years now, with the common goal of using such dexterous assets as are our hands in human-computer interaction [Sturman94]. A recent development of the same vision, the 3dID glove makes use of bend sensors, accelerometers and gyroscopes and transmits its data wirelessly [Sama06]. In gaming applications, gesture input seems to have become a recent trend, as proven by the success of commercial products such as the Sony EyeToy or the Nintendo Wii. Payne *et al.* have conducted a preliminary study of gesture input in gaming applications using a wireless device [Payne06]. A similar yet more detailed experiment using motion-sensing wireless game controllers is reported in [Lehtiniemi06]. Here, a usability test was conducted upon a population of eighteen subjects, using different configurations of the interface. A simple gesture recognition method intended for use in mobile applications is presented in [Kratz07], serving the base of a spell-casting game-play element in the REXplorer project.

Successful usage of RFID in game-related projects is illustrated by PAC-LAN, although in this case tags are used to identify locations rather than objects, using an RFID-enabled mobile phone [Rashid06]. A wearable RFID reader for play has been proposed in [Medynskiy07].

Intel's research on automatic recognition of human activities makes use of a bracer embedded with a plethora of different sensors, including an accelerometer and RFID reader, to capture data about a user's context [Smith05].

3. GAUNTLET WEARABLE INTERFACE

Terry Winograd suggests three main ways in which we interact with the world around us: manipulation, locomotion and conversation [Moggridge06]. It is already common to find mobile devices providing positioning services and voice command recognition. Using always-on connectivity they allow us to access data on the Web and interact with remote services, some of them able to recognize human speech. Following Winograd's view, the previous facilities would allow (to some degree at least) human-computer interaction through locomotion and conversation in mobile applications. We focused on complementing these with interaction through gestures and manipulation of physical objects.

Exploration and development of our concept resulted in a first prototype. Dubbed Gauntlet, the device takes the shape of an arm piece, which can be described as a mix between a long bracer and a fingerless glove (see Figure 1). At its core the Gauntlet is basically an array of sensors – an accelerometer, a digital compass, a pressure sensor and an RFID reader – designed in a way to be as unobtrusive as possible, if not even fashionable. The accelerometer allows for detection of specific gestures the wearer may perform or, when stationary, to roughly determine the position of the wearer's arm. The compass allows for interaction through pointing and can be combined with accelerometer data for increased reliability. The pressure sensor, located at the palm of the hand, is used to determine if the wearer's hand is closed as well as the amount of exerted pressure. Finally, the RFID reader is used to detect tagged objects in the proximity of the wearer's hand. Haptic output is also included, provided by a single vibration motor. The Gauntlet is battery-powered and transmits its data via Bluetooth, thus being completely wireless and apt to be used ubiquitously. In such a scenario, a mobile device paired to the Gauntlet is then responsible for processing the sensor data. The mobile device can also provide audiovisual output and even make use of other facilities such as video and sound capture, GPS positioning, network connectivity and even recognition of simple voice commands.

The textile bracer was crafted as to provide comfort for the wearer, protection of the hardware and visual appeal. Most hardware has been encased in silicon rubber, granting improved mechanical resistance to shifting and impact. Together with the use of neoprene as material for the inner layer it improves adaptation to the shape of a wearer's body and size variations between wearers. The outer layer of the wearable is fashioned out of leather and fastened with three buckled straps, conferring a distinct, slightly medieval look to the finished piece, as can be seen in Figure 1.

Figure 1 – The Gauntlet wearable interface.

4. EXAMPLE APPLICATION

As a way to publicly demonstrate the Gauntlet and illustrate the different modes of interaction it may allow, we developed an example application, suitable to be presented in an exhibition setting and later in usability testing. Best described as a mix of interactive narrative and mystery game, "Noon – A Secret Told by Objects" prompts the player to conduct an investigation by tapping into the memories of real objects. On a table surrounded by five candles, lay six objects (see Figure 2). As the (fictional) background story goes, a fire of unknown origin claimed the lives of a family, but those objects managed somehow to survive unscathed. The player dons the Gauntlet to probe the objects, which are visibly marked with RFID tags. To provide for data processing and audiovisual output, the Gauntlet is wirelessly connected to a PDA encased inside a book – an object we shall refer to as Tome.

Five of the objects – the snow globe, the picture, the cup, the schoolbook and the hammer – hide memories which can be accessed by holding each object in a way that the RFID tag is recognized by the Gauntlet. Whenever a tag is read the device's haptic actuator is triggered, suggesting a flow of information between object and player, and a memory is displayed on the Tome as a page from a book. A sixth object – the table clock – allows the player to shift the memories of all other objects between five distinct time periods. This is achieved by touching the clock (as in Figure 1) and then pointing at one of the can-

Figure 2 – The six objects whose memories the player must explore.

dles (as in Figure 3) until a chime rings from the Tome. Some memories contain a hint to further use the object through very simple motions: shaking, striking or pouring. When adequately used, an object will yield a second and more revealing page of memories. Finally, probing of the most important memories will unleash a *poltergeist*, which manifests by producing audible white noise and burning the Tome's pages. To deal with this, the player must scan all around her using the Gauntlet until the noise becomes really loud, in order to pinpoint the *poltergeist*'s general location. The player can then dispel the ghost by closing her hand, and proceed with the investigation. The game ends when the player wants it to, generally because the Tome is rendered unreadable by *poltergeist* attacks or because the player has formed her own theory on the origin of the fire.

The installation uses four distinct game-play modes: touching objects, gesturing with objects, pointing at the candles and scanning for *poltergeist*. These illustrate the Gauntlet's core interaction modes: object detection, gesture recognition and arm direction/orientation recognition.

Figure 3 – A view of the installation. A player points to a candle to change the time of the memories.

5. USABILITY TESTING

Having produced a fully-functional prototype of the interface and an example application which revealed itself interesting for users – this we observed during public exhibition of the Noon installation – we set on to conduct a usability test so that we could formally quantify and analyze user experience with the Gauntlet.

5.1 Methodology

The study was carried out during daytime in an office by two investigators, playing the roles of the facilitator and the observer. Users were invited to don the device prototype with the help of the test facilitator. They were then briefed about the objectives of the test, introduced to the synopsis of Noon's story and explained the game-play rules and interaction, all the while being encouraged to explore the system and "think aloud". The tests were carried out individually for each user.

Tests lasted for a minimum of 20 minutes and a maximum of 30 minutes each, depending on each user's strategy to explore the installation. Although there was an application goal (finding out how the fire started) and a clear method to achieve that goal which kept the users' attention in using the device, it wasn't relevant if the users came out with the right conclusion, since we weren't testing the application but rather the wearable device itself.

During the tests, while participants were "thinking aloud", an observer took notes, recording their verbalizations and providing us with a record of any problems with the system that they explicitly mention. The facilitator answered any questions users might have regarding the application and, when needed, provided users with hints about the correct usage of objects in order to maintain the flow of game-play interaction.

After the test, users were asked to answer a questionnaire. We were mainly interested in finding out if the users:

1. felt comfortable wearing the device;
2. easily learned how to use the wearable device;
3. easily manipulated objects using the wearable device;
4. interacted naturally with physical objects performing operations such as "pour" or "shake";
5. would be willing to wear such a device in the future;
6. were able to perform typical tasks (for example, writing) while wearing the device.

We were also interested in studying how subjects' interaction with the system evolved over the course of the test. The information was gathered with the ultimate goal of further refining the Gauntlet.

5.2 Participants

The tests were performed on a population of sixteen voluntary participants, twelve of them college students and six of them female. The subjects for this experiment ranged in age from 22 to 49 years old with a mean age of 28.6. Although two of the participants were left-handed all participants wore the device on their right-hand, since both its form factor and gesture-recognition algorithm require so for now. Twelve of the participants reported they usually play digital games. All participants had their first contact with the wearable device during the test and used it under similar conditions.

5.3 Questionnaire

The questionnaire captured personal data, experimental feedback and raised several open-ended questions. Besides age and gender, personal data included digital game playing frequency as well as which gaming platforms and interfaces the users were familiar with.

The experimental feedback was measured through 9 statements, 4 classification questions related to the user's performance in each game-play mode and two queries based on the Microsoft "Product Reaction Cards" [Benedek02].

Each participant was presented with nine statements related to their experience with the wearable device during the test. Each one of them then indicated his or her level of agreement with each statement by circling a response on a 5-point Likert-type scale. On this scale a response of 1 (one) means disagreement and a response of 5 (five) means agreement. In the same way, participants were also required to classify how easy it was to perform each one of the game-play modes (selecting an object, manipulating an object, changing the time and capturing a *poltergeist*) during the test. On the scale used a response of 1 (one) means "easy" and a response of 5 (five) means "difficult".

Two queries based on the Microsoft "Product Reaction Cards" were also used to capture the users' reaction to the wearable device, since they facilitate the measuring of intangible aspects of the user experience [Benedek02]. Users were asked to choose the words that best described their experience with the wearable device and then the device itself. They could select as many words as they wished from a list of 21 words and 37 words, respectively. Each list consists of about 60% of words considered positive and 40% of words considered negative.

The questionnaire also included four open answer questions in order to gather recommendations regarding future developments of features, collect positive and negative aspects of the device, and obtain general evaluation of the system.

5.4 Results

Regarding the first part of the questionnaire, which included the user's evaluation of the 9 statements concerning the use of the wearable device and the 4 classification questions related to the user's performance in each interaction procedure, we examined average scores of the users' responses to see if there were general trends in agreement or disagreement with the statements (strong feelings one way or the other showing up as mean scores closer to 1 or 5) and to see how broad the consensus about the issue was (represented by the standard deviation of the mean score). In general, the users' feedback was very positive.

Most participants agreed that "it was easy to learn how to use the device" (Mean = 4.56, SD = 0.61) and that "it was easy to use the device" (Mean = 4.63, SD = 0.60). The majority of the participants also stated that they would like to use the device in the future (Mean = 4.44, SD = 0.70), and assented that they liked the experience of using the device (Mean = 4.38, SD = 0.60) as well as its aesthetics (Mean = 4.19, SD = 0.73).

Although still very positive, feelings concerning the comfort in using the wearable device were not so strong, since for the statement "I feel comfortable while using the device" the scores are closer to the middle scale value (Mean = 3.88, SD = 0.86).

The willingness to use the wearable device in an everyday basis in public spaces proved weak, since the opinions were very heterogeneous (Mean = 3.00, SD = 1.06). While some of the users agreed with the statement "I would use a similar device in an everyday basis in public spaces", two of them totally disagreed. This can be due to the physical characteristics of the device, which is perceptibly unusual both for the person wearing it and for the others around.

Some participants agreed with the statement "The device interferes with the execution of other activities that do not require the device", however that was also not a very consensual issue (Mean = 3.81, SD = 1.07). We considered it a very subjective matter, since the participants could only use the device while executing one extra activity – writing. The purpose of this question was to capture the users' general feeling towards the use of the device in their daily life.

This part of the questionnaire included one more statement – "I can't accurately control the actions I want to execute". Only 15 participants expressed their opinions and the scores revealed their general disagreement although without strong beliefs (Mean = 2.67, SD = 1.30).

The first part of the questionnaire also included four classification questions related to the user's performance in each interaction procedure. We intended to assess how easy users found each of the four game-play modes (described in Section 4) and also which was considered the easiest. According to the results, the interactions were generally deemed reasonably easy to perform and the easiest was selecting an object, followed by capturing a *poltergeist*.

From the analysis of the two queries based on the Microsoft "Product Reaction Cards" we concluded that all participants gave a positive score when classifying their experience using the wearable device and the wearable device itself. Considering the users' experience while using the device, the maximum score was obtained by the word "innovative", followed by the word "fun". 50% of the participants also considered their experience "stimulating", "pleasant" and "simple".

When asked to choose the words that best describe their feelings about the wearable device, most participants chose "easy to use" (10), innovative (9), fun (9), intuitive (8) and light (8). We would also like to point out that only six participants found the device big and only two said it was heavy. On the other hand, seven participants reported the device as being warm; five of these considered it comfortable, while only two said it was uncomfortable. None classified the device has being discreet.

In the second part of the questionnaire, using open answer questions, participants were also asked to comment on the overall system usability. We summarized their main statements classifying them as either positive or negative, followed by the number of participants who made similar statements, in brackets.

Positive: easy to use (6), stimulating (5), intuitive (3), potential applications (3).

Negative: warm (5), big (4), writing becomes difficult while using the device (2), not suitable for precise movements (2).

As seen during the analysis of the second part of the questionnaire, contradictions arose in the evaluation of the physical characteristics of the device. Some participants found it light, while others found it big and a few found it heavy.

One of the participants mentioned how interesting it was to "communicate" with everyday objects. This means he really felt he was exchanging information with the objects. The device feedback when it detects an object (slight vibration) was pointed out by one of the participants as a positive aspect, since it was not disturbing and it reveals that something had happened.

Several other comments were more closely related with the application than with the device itself, so they were not considered in the study.

6. DISCUSSION AND FUTURE WORK

Overall the usability test results are quite positive and indicate a successful first iteration of our concept.

In what regards the interaction experience, users have consensually found it pleasurable and easy to learn. Gesture-based interaction and tangible interfaces are not completely new; however our challenge was to achieve a positive degree of intuitiveness and engagement with a fully mobile interface and in this we have been successful. The example application uses very simple types of gestures – shake, strike and pour. The gesture recognition algorithm upon which it is based is very primitive and needs to be tuned or altogether replaced, since some users found it difficult to successfully perform some of the object usage gestures even after being shown how to execute them.

In what concerns wearability, the results were by far less positive. Although not outright uncomfortable or cumbersome, several aspects seemed to cause discomfort. The bracer quickly becomes too warm when worn due to the materials used, the bracer's thickness and the fact that it covers most of the forearm all around. The hand module is a focus of concern since it is pointed out as being too big and thick. The location of the batteries (which can be seen in Figure 1) became an obvious problem for a few users when trying to write while wearing the Gauntlet. Weight was not pointed out as an issue, however. The choice of materials needs to be reviewed and smaller electronic modules can be used, so that the device not only becomes altogether smaller but also provides several apertures through which the skin can breathe. It is also possible to design a lower voltage circuit for the device so that it requires only two AAA batteries instead of four. These can then be relocated to a more favourable position. The hand module is present in the current design as a way to house both the RFID antenna and a pressure sensor. It is unlikely that it may be removed from further iterations instead of redesigned to be more ergonomic, since the antenna should be located near the palm of the hand.

Although left-handed users made no complaints, an additional aim for the next iteration is to achieve an ambidextrous design, so that the device can be equally used by left-handed and right-handed people.

7. CONCLUSION

We have briefly introduced our concept for a wearable, mobile gaming interface which allows the use of gestures and manipulation of real objects as game-play elements – the Gauntlet. We then presented our first prototype, together with an example application which has been used to publicly demonstrate the device and also to conduct usability tests. The test results have, on one hand, validated our concept as an intuitive and highly engaging; and, on the other hand, highlighted deficiencies in wearability. The knowledge obtained will allow us to focus on overcoming specific challenges in order to achieve a truly comfortable and satisfying interface which users will hopefully want to both wear and use.

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