Experience Design in Ubiquitous Computing

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The technologies underlying ubiquitous computing are beginning to move from research laboratories into the real world. As they do so, the value to users of this new paradigm will begin to emerge. We believe that one potentially valuable area of application of ubiquitous computing will be in the delivery of *Situated Digital Experiences*, i.e. compelling consumer experiences delivered by digital technology that reflect and enhance their physical locations. In this paper, we outline a research program in the design of such experiences and describe two case studies involving experimental deployments. We also describe a provisional model of consumer experience that is emerging from the research and indicate some aspects of future work.

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1 Introduction

There is a growing sense that ubiquitous computing may be about to emerge from research laboratories into the real world. Processor speeds and memory capacity continue to increase and the size, cost and power consumption of devices keep on falling. At present, the benefits of these changes are seen in the growing ubiquity of mobile phones, and in the growth of the laptop and handheld computers markets. However, we may be on the cusp of a significant paradigm shift in which the familiar computing devices of today mutate into wearable accessories or disappear into the fabric of everyday life.

One trigger for this shift is the emergence of low-cost wireless connectivity. Mobile phone operators around the world are investing billions of dollars in third generation (3G) networks that promise to deliver low latency and high bandwidth data channels over the next few years. In the meantime, free 802.11b wireless LAN access is spreading rapidly as companies and individuals deploy base stations open to all comers. Ubiquitous wireless connectivity will greatly increase the potential of portable (and soon, wearable) devices, and ease the incorporation of computing devices into bus stops, park benches, road signs and the myriad other objects that would benefit from added intelligence.

Of course, this is a fairly conventional view of the future, at least in the community that attends UbiComp. Many research groups, including those at Hewlett-Packard Laboratories [1, 2], are working to bring this future about. But it may be worth pausing briefly to test the value of this new paradigm. In other words, to ask: What will ubiquitous computing be for?

The usual answer to this question seems to be that the value of ubiquitous computing will derive from the greater utility expected from always-connected mobile devices and an intelligent environment. For example, we need never again pass a supermarket without being reminded of the groceries that we intended to buy, or meet an acquaintance without remembering their name, or passing on some important message [1]. While the benefits of such applications may be easy to grasp, we suspect that they may be of limited appeal to ordinary consumers who would be expected to make a significant personal investment in an appropriate product or service tariff, or in taxation to fund public works.

As a result, we are increasingly focussing our research effort on applications that we believe will appeal enough to consumers to warrant such expense. In particular, we are exploring what we have termed *Situated Digital Experiences* in which ubiquitous computing is used to enhance the user's everyday experience of place. Examples might include digital art interventions that reflect and modulate their locations, physically distributed digital games in which your position and those of other players condition what you can do at any point, and context-sensitive local history (or tourist) guides that can bring a historic part of a city to life through narrative, drama, sound, image and video. In this our interests overlap with those of researchers at Columbia, Lancaster, The Play Research Studio and elsewhere [3-5].

Our research program boils down to two key questions:

- What constitutes a compelling consumer experience?
- How can we deliver such experiences through ubiquitous computing?

In the rest of this paper, we will begin to give partial answers to each of these questions. In a later section, we will describe a recent case study in which an art installation in a traditional, physical exhibition space has been augmented with a location-sensitive digital soundscape. But first, we will outline our current thoughts on the nature of digitally mediated experience.

2 Unpacking Experience

From a commercial perspective, we can identify two reasons for a focus on delivering compelling experience. The first, hinted at in the introduction, is that the experience delivered by a product (or service) is a crucial factor in a consumer's choice of that product. Most consumer offerings are not differentiated by their functionality but by what they say about their owners, what they feel like to use, and where they take you. These last two elements are both aspects of the user experience.

Traditionally, the computing industry has focussed on what a system is like to use, and whether it allows the user to achieve some task efficiently and without frustration. The emphasis has been on ease of use. However, while acknowledging the importance of getting this right, we believe that the experience gained *through* a product is of even greater significance. Consider a musical instrument, for example. Its owner may enjoy its appearance and the way it sits just right under the fingers, but the real pleasure lies in the challenge of mastering the instrument, or in the fun of playing with others, or in those occasional, sublime moments when one is lost in the resulting music. These are the experiences that motivated the acquisition of the instrument in the first place, and they are the kind of experiences that, in the consumer world, can demand significant price premiums [6].

Of course, those comments apply to any kind of consumer product, but there is a second issue that is more specific to ubiquitous computing. That is that the applications of ubiquitous computing will inevitably, even deliberately, be encountered while the user is already engaged in some ongoing experience or activity. Ubiquitous computing applications are usually intended to be deployed in contexts – in the street, in restaurants, malls, workplaces, etc - where the user is already likely to be doing something, for example talking to friends, or choosing new clothes, or dealing with email. It is vital that such applications do not detract from or diminish these ongoing activities, or they will simply be rejected. More ambitiously, we should look to enhance those activities, or to offer alternatives that are at least as compelling. To do so, we need to understand better how experiences work.

One question that begins to emerge from these considerations is whether it is possible to deliver compelling experiences through computing technology. Computer games, chat rooms, and high-tech theme park rides can give us some confidence of a positive response, and we have begun a series of prototyping exercises in an attempt to develop a better understanding of why they appeal and how other types of experience might be provided.

2.1 Zap Scan

Our first experiment involved the development of Zap Scan, an exhibit for the Explore@Bristol hands-on science museum in Bristol, UK [7]. This project was a deliberate attempt to develop something fun and engaging from mainstream technologies - scanning, display and printing - that are sometimes considered dull and uninspiring [8].

Functionally, Zap Scan is very simple. Users can draw a picture with supplied paper and crayons, scan that picture (or anything else) through a one-button interface, and see the scanned image appear on digital picture frames on either side of the exhibit. Separately, if they wish, they can move to a nearby print station, select their image on a touchscreen, enter their name, insert a pound coin, and produce a glossy greetings card with their image on the front and their name on the back. Figure 1 gives a feel for the equipment and its use.

Fig. 1. Images of Zap Scan

Described like this, Zap Scan may sound rather boring, and it certainly does little more than most visitors are able to do at home with their PCs. But Zap Scan has turned out to be a very popular exhibit with both visitors and staff. For example, in the period between April and October 2001, 29551 images were scanned and 1918 cards were printed. Throughout the summer school vacations, the number of cards printed per day ranged between 17 and 37, despite the pound cost being equivalent to a soft drink, ice cream or a couple of chocolate bars! Initially installed for a six-month period in April last year, Zap Scan is still in place in Explore, and we have received enquiries for a further installation elsewhere. Examples of the images produced on Zap Scan can be found by following the appropriate link on the Explore website at http://www.at-bristol.org.uk/explore/default.htm.

So, the anecdotal evidence from Zap Scan is encouraging. Compelling consumer experiences *can* be delivered by mainstream computer technology. To go beyond an anecdotal understanding, we carried out a series of observational studies, discussion groups and interviews to try to discover exactly why Zap Scan appealed to visitors.

2.2 Experience Model

The result of these studies is the provisional model of consumer experience shown in figure 2. The model represents three key dimensions of the kinds of experiences enjoyed at Explore:

Challenge /Achievement

This dimension is highly personal – it is either about *testing* your skills (mental or physical) or *expressing* your skills, creativity, views or personality, or simply *learning* something new about yourself that you didn't know before. The 'buzz' comes from achieving something you didn't know you could do or from expressing something original about yourself. There is an emphasis on individuality, uniqueness, and self-development.

Many compelling experiences, particularly at an interactive science museum such as Explore, have an element of challenge and self expression. An example of a physical challenge is provided by an exhibit in which visitors haul themselves up in the air in a cage using a pulley system. This is quite strenuous and if the user manages to reach the target height, a bell rings

to signal their success. When asked why such challenges were enjoyable, visitors responded with quotes such as:

> *"it was really like you had to put all your muscle into it – it showed you how much strength you had – I rang the bell TWICE!"*

Though Zap Scan had little of the element of challenge, it did encourage some physical engagement through drawing. Moreover, it did encourage self-expression, as did other exhibits such as a television studio. Such exhibits tended to evoke responses such as:

> *"I liked making my own show"*

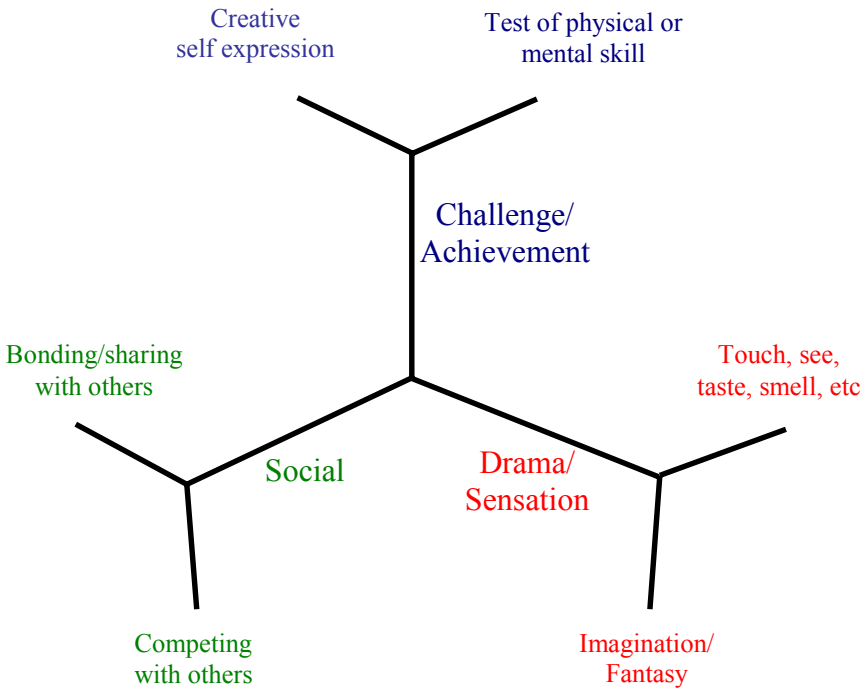

Fig. 2. A provisional model of consumer experience

Social

This dimension is about our relationship with others. The 'buzz' arises either from the intense sense of bonding arising from a moment of shared achievement or shared emotion, or from the sense of superiority over others which comes from out-performing them in a competitive exercise. The latter was particularly powerful for boys visiting Explore with their siblings or classmates. Typical comments expressing why social interaction is enjoyable included:

> *"when you see the fathers enjoying the same thing as the smallest"*

and

> *"you can really get into it and really annoyed, really competitive – it's good fun!"*

Drama/Sensation

This dimension is about experiencing in the more common-sense use of the word, i.e. the 'buzz' comes either the bombardment of our *physical senses*: sight, sound, touch, smell and/or the grabbing of our *imagination, emotions* and *dreams.* Comments typical of this dimension include:

> *"where there's noise and movement and lights and bells ringing"*

and

> *"I always dreamed of being inside a computer game and now you can!"*

It is reasonable to ask whether a model derived from studies at a hands-on science museum has more general applicability. In reality, we do not yet know. Much of our ongoing research can be seen as attempting to validate, correct and refine the model. However, informally, we believe that it may indeed have some generality. Consider the example of experiences associated with a musical instrument given earlier; mastering the instrument, playing with others, and enjoying the resulting music correspond fairly well to the challenge/achievement, social, and drama/sensation dimensions respectively.

Another issue concerns the relative balance of the three dimensions. For example, must experiences exhibit all three dimensions in some measure to be compelling? In the Explore context, the challenge/achievement dimension dominated the responses of visitors when asked about their experiences of the exhibits. This dominance may well be specific to that context and may not be found in, say, an art gallery or a café. However, it also reflects Csikzentmihalyi's findings on the desirable state of *flow* experienced when people engage in a challenging activity with clear goals, a chance of completion, the opportunity to concentrate whole-heartedly, immediate feedback, and control over actions [9].

To explore some of these issues further, and to move more directly into the area of ubiquitous computing, we have developed a second technology mediated experience in the form of a digitally augmented art installation with a particular emphasis on the drama/sensation dimension. Before describing that work, however, we will outline the general context for our research into ubiquitous experiences.

3 Situated Digital Experiences

Recently, a new discipline of *Experience Design* has emerged with a clear emphasis on the design of products and services that provide compelling experiences for their users. This new field draws on a number of traditional disciplines such as architecture and graphics design, but is increasingly beginning to engage with digital technologies [10, 11]. Little of this work has yet focussed on the emergence of ubiquitous computing, though the design group at Philips has generated some interesting and relevant ideas [12]. This is the area in which we hope to make a contribution.

We are undertaking this research in the context of a broader collaboration between Hewlett-Packard Laboratories and the Wearable Computing Group at the University of Bristol [13]. The collaborative project, known as Mobile Bristol, aims to equip the centre of Bristol as a

living testbed for wearable and ubiquitous computing. This involves the deployment of 802.11b base stations around the city, the development of prototype client devices capable of sensing the user's context, the development of prototype context-aware services, and subsequent studies of what users make of it all.

Our approach to experience design employs a research methodology that incorporates a fine-grained weave of technology development, deployment of prototype systems as experimental probes, and user studies that drive our understanding of experience. The role of prototype systems as experimental probes is particularly important if we are to discover meaningful responses from users of the new technology. Previous experience has shown that most people find it very difficult to imagine the benefits and drawbacks of potential new uses of technology until it is available for their experimentation, preferably in their own context. While fairly expensive in terms of time and other resources, real-world deployments are essential if we are to move from user speculation to user reflection.

As mentioned in the introduction, our application focus in this research is on *Situated Digital Experiences*, i.e. experiences that are:

- Context sensitive, particularly with respect to location
- Digitally mediated
- Compelling to their users

Context awareness is essential if we wish to move beyond the anything, anywhere, anytime mantra motivating much pervasive computing to the provision of the *right* thing at the *right* place and at the *right* time [14]. Many experiences are context sensitive – what seems fun on a sunny Saturday morning might not seem such fun late on a cold and blustery Thursday night. In particular, we are concentrating initially on location sensitivity, where the experience is modulated by the user's current position and path history, and by the presence of others.

One way of thinking about ubiquitous computing is to imagine the emergence of a new, digital dimension overlaying the physical world. This new dimension will be mediated in part by a user's personal devices and in part by the intelligent signposts, bus stops, shop fronts etc now populating the urban landscape. Our intention is to enhance a user's experience of that landscape through this new dimension, for example through the delivery of appropriate sounds and images, or by providing a virtual game space mapped onto the real world, or by enabling friends in different parts of the city to interact as if they were co-present.

Of course, the notion of augmenting reality is not particularly original. The Situated Documentaries work at Columbia University [3] is a good example of this approach, and the resource pages at [15] list many others working in the field. One interesting aspect of our research is the decision to concentrate initially on the use of audio as the primary (or only) method of communicating to the user. Audio is preferred for two main reasons; First, because it is much easier to maintain an illusion of a seamless continuum between the physical and digital worlds than is possible with either handheld or eyeglass displays, and second, because we feel it is a less intrusive (and less dangerous) form of interaction for people moving around a city and crossing busy roads.

In this focus on audio, we have much in common with previous work on augmenting workspaces with event alarms and ambient indications of state [16, 17], enabling

asynchronous interaction between visitors to public spaces [18], and providing a rich game space in an featureless hall [19]. One lesson from this previous work is that the nature of the audio content is very important. Good sound design is an established skill developed in other domains, such as radio broadcasting, that we need to apply to this new context [20].

In fact, the provision of good content is a general concern for experience design. If the content of the intended experience is weak, then the power and subtlety of the underlying technology will be irrelevant. To this end, we are developing our prototype situated experiences in collaboration with artists, musicians, games designers and other creative practitioners who are experts in the provision of compelling experiential content (though they may not describe themselves like that). This has been a liberating and very enjoyable aspect of the research work, and has resulted in much more appealing content than could have been generated by the authors alone. In the next section, we will look at the first fruits of such a collaboration.

4 A Walk in the Wired Woods

The walk in the wired woods[1] is an art installation in the Hewlett-Packard Laboratories building in Bristol, UK. It is based on a photographic exhibition entitled *A Year and a Day* made by the artist Liz Milner and featuring striking images of a nearby woodland. An impression of the style and appearance of the photographs can be seen in figure 3.

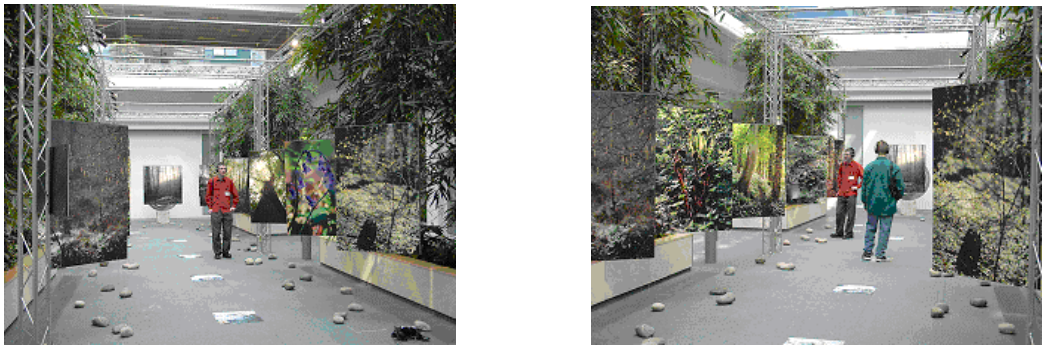

Fig. 3. Two views of the Year and a Day exhibition

This real-world exhibition, housed in an actual, physical space, has been overlaid by a location-sensitive digital soundscape created in collaboration with local musician, Armin Elsaesser. As visitors equipped with our wearable device wander around the exhibition, they are able to hear various pieces of music, woodland sounds and spoken narrative created and positioned by Armin and Liz to enhance nearby images. A typical visit to the exhibition lasts around twenty minutes and the informal feedback from visitors has been overwhelmingly positive. We will return to their reactions shortly.

In terms of the experience model in figure 2, the installation lies almost completely along the Drama/Sensation dimension. We did not attempt to incorporate any element of challenge, though many visitors enjoy trying to work out how particular sounds are triggered. Nor was there an attempt to provide a social dimension to the experience. Indeed, the particular

[1] This name was given to the installation early in its life and has stuck, though a far better title would have been A Walk in the *Wireless* Woods. Perhaps that name simply does not have the appropriate poetry ;-)

headphones that we chose to use let little sound through from the real environment and would have tended to discourage social interaction. So, the installation helps to address one of the issues arising from the model; whether a compelling experience can be successfully developed along a single dimension.

The installation was launched at an open day at the end of January 2002 during which it was visited by around a hundred people, with several hundred more visiting subsequently. A web site documenting the open day and providing a little more background information about the project can be found at [21].

4.1 Behind the Scenes

In this section, we briefly describe the technology underlying the installation. Location sensing in the exhibition space is based on a system developed by Cliff Randell at the University of Bristol [22]. An RF transmitter is used to broadcast a framing pulse and to trigger subsequent bursts from a series of ultrasonic transmitters strung above the space. A receiver on the client device hears both the radio pulse and as many of the ultrasonic transmitters as are in range. By comparing the expected and actual times of arrival of the ultrasonic bursts relative to the framing pulse, the client is able to calculate the times of flight from each of the ultrasonic transmitters, and hence compute its position by triangulation. This system has proved to be both reliable and accurate, with a spatial resolution of around 15cm.

The second key infrastructural component in the system is the 802.11b wireless network installed throughout the building. This is used by the client to access the directory server to discover what digital stuff is nearby, and to stream audio content from media servers.

Location-based service discovery is an active research area, with opinion seemingly divided between directory and broadcast approaches [23]. In this installation we have adopted a directory model in which a well-known server is queried to discover what the digital dimension contains at this location. The server responds to the query with an XML description of both the physical space and the digital overlay. A fragment of the XML representing a single digital audio aura is shown in figure 4.

```
<Aura>
    <Id>26</Id>
    <Channel>1</Channel>
    <Name>novr11</Name>
    <X>110</X>
    <Y>500</Y>
    <Range>100</Range>
    <URL>http://bristol11-prj-1/music/nov.mp3</URL>
    <Loop>n</Loop>
</Aura>
```

Fig. 4. A fragment of the XML code describing an audio aura

The aura is defined by a number of properties:

- A unique identifier, a channel assignment, and a name
- A location and the radius of a circle of applicability around that location
- The URL of the audio object associated with that aura
- Whether the audio should be looped on completion

The choice of these attributes was somewhat pragmatic and driven by the particular application. Moreover, we subsequently embedded channel behaviours in the client device that would have been more properly incorporated into the XML. The design of an appropriate specification language for such soundscapes is now an interesting line of investigation in its own right.

Figure 5 shows a plan view of the audio auras mapped onto the floor plan of the exhibition space.

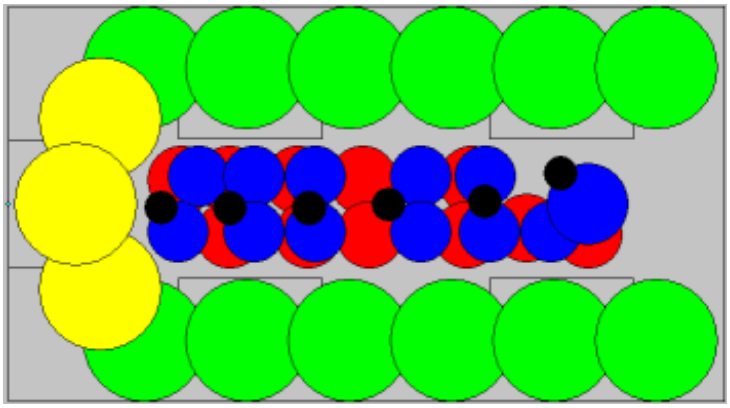

Fig. 5. A plan view of the audio auras mapped onto the physical space

The different colours of the auras in figure 5 represent different channel assignments. Originally, channels were to be used to provide alternative paths through the soundscape, selected by the user. For example, the red channel might contain music, the blue channel natural woodland sounds and so on. As the artistic design of the soundscape evolved, however, it was decided to make all of the audio in the soundscape available to the user at all times. The channel idea then mutated to include the notion of (potentially) different client behaviours.

In practice, the default behaviour for each aura is to act as if it were a switch. When the user enters the region of applicability of an aura, their client device immediately (fetches and) plays the audio specified by that aura's URL[2]. Where auras overlap, the one whose centre is closest to the location of the client device is designated as active[3]. However, two of the channels have been set up to have slightly different behaviours. The black auras shown in figure 5 correspond to "stepping stone" images laid into the flooring of the exhibition space. The idea was that standing on one of these stones triggered one of a number of spoken

[2] An alternative approach would have been to treat the locations of the auras as point sound sources and to make the intensity of the associated audio presented by a client device relative to its distance from that location. Both approaches have attractions and drawbacks for the artists.

[3] Though the client device could also be set to mix and play all of the audios associated with overlapping auras.

narratives about woodland. The artists wanted the narratives to be heard in a particular sequence regardless of the order in which users encountered the stepping stones. This was achieved by specifying a set of audios for each of the black auras and selecting among them on the client device according to the user's path history. Similarly, the auras in the green channel surrounding the space are used to trigger wolf growls to encourage visitors back into the main exhibition space, but are disabled when the user has encountered enough of the mainstream auras. As mentioned earlier, these behaviours have been hard-coded into the client device. It remains an open question how to provide a specification language that allows such behaviours to be defined declaratively in the XML description of the soundscape.

The client device itself is based on a HP Jornada PocketPC with a compact flash WLAN card and a small extension board to interface to the location sensing infrastructure. The client has the ability to:

- detect its location within the exhibition space using the ultrasonic positioning system
- interpret its location with respect to the map linking the physical and digital exhibition space
- fetch audio data (and other information) on demand from servers over the wireless network
- mix and play multiple stereo audio streams via headphones
- log the user's movements around the space and the auras encountered

Physically, the Jornada and its extension board are contained within a small shoulder bag from which wires run to a pair of headphones containing an integral ultrasonic receiver. The client software is written in Embedded Visual C++ and includes a debug screen showing the device's current location in the exhibition space using the map display in figure 5. However, for normal use, the screen is turned off and the Jornada is hidden in the sealed bag. The complete client configuration is shown in figure 6.

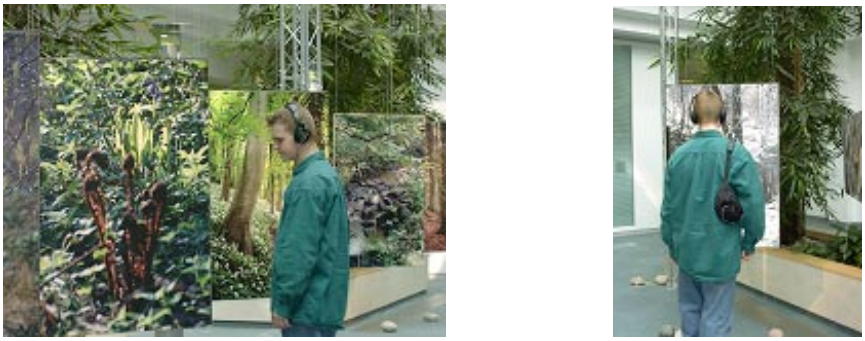

Fig. 6. Two views of the user's equipment

4.2 User Response

Naturally, visitors to the installation are not burdened with a description of the underlying technology. Rather, they are presented with a shoulder bag and headphones, told that the exhibition contains sounds appropriate to the photographs and invited to wander around and discover what is there. They are not given specific instructions, nor do they need to control the client device other than by moving from place to place. Our aim is that the technology should disappear into the background, leaving the user free to simply enjoy the experience.

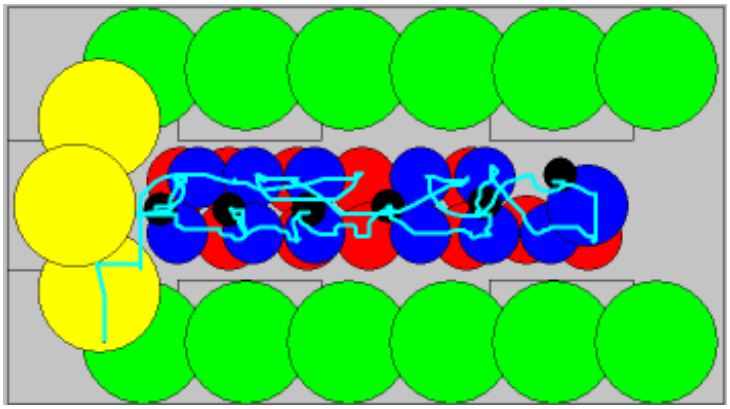

Fig. 7. One visitor's trail through the exhibition space

Our observations suggest that the installation is indeed successful at attracting and maintaining interest. Visitors typically spend around twenty minutes wandering around, looking at the pictures and pausing to listen to the corresponding music, woodland sounds and narrative. A representative path followed by one visitor is shown in figure 7. Informally, we would describe the visitors as generally absorbed in the experience on the basis of facial expressions and the lack of interaction with other visitors (though see the comments on the headphones above).

Anecdotal feedback from visitors is overwhelmingly positive. Of course, the high quality of the photographs and music contributes significantly to this outcome, However, most visitors report that the extra dimension added by the contextual juxtaposition of the two media does indeed add extra value. To dig a little deeper, a colleague, Erik Geelhoed, carried out a more formal evaluation of visitor responses during the open day. Visitors were asked to engage in two short ranking exercises designed to discover which of a set of adjectives they would most apply to their experience of the installation, and which of a set of other experiences this one is most like. The results are shown in figure 8.

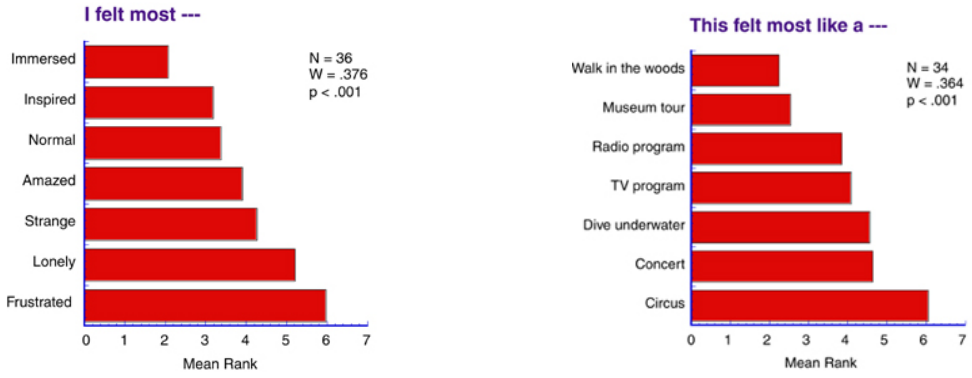

Fig. 8. Results from the ranking exercises

In this presentation of the results, smaller numbers indicate a higher rank. As may be seen, visitors tended to report feeling "immersed", "inspired" and "normal" rather than "strange", "lonely" or "frustrated". Moreover, about as many people likened the exhibition to a walk in the woods (which it attempts to evoke but really is not) as to a museum tour (which it really

is). The results do not themselves suggest *why* such responses were evoked by the installation, but they do reinforce our belief that it is possible to create a convincing and compelling experience with the kind of technology that we can expect to become ubiquitous over the next ten years.

The results also suggest that compelling experiences can be focussed on a single dimension of the experience model of figure 2. One interesting issue arising from the installation is to what extent the nature of the experience it evokes is tied to the form of the content it incorporates. In other words, would it be possible to develop experiences that emphasized the Challenge/Achievement or Social dimensions of the experience model using the same photographs and/or sounds? That would be a fascinating follow-on experiment.

5 Conclusions

In this paper, we have reported our research into the nature and delivery of compelling consumer experiences using ubiquitous technology. We have shown through the Zap Scan hands-on exhibit and the Year and a Day art installation that it is indeed possible to develop applications of technology that evoke such experiences.

Through a combination of experimental prototypes and analytical studies, we have developed a provisional model of consumer experience that has three main dimensions:

- Challenge/Achievement
- Social
- Drama/Sensation

The model suggests a different set of desired attributes for technology artefacts than those normally assumed from a historic focus on ease-of-use. Much of our ongoing research can be seen as intended to correct, refine and apply this model. Some progress has already been made, for example we show that a compelling experience can be evoked through an application that emphasizes just a single (Drama/Sensation) dimension of the model.

In the next stage of our research, we will begin to apply the model to the development of experiences to be deployed in the streets and public spaces of central Bristol, as part of the broader Mobile Bristol project. The larger canvas and more challenging environment of the streets will inevitably raise issues that have not yet become apparent in the in-building applications developed so far. In addition, we will begin to explore a wide range of related issues such as:

- Using a wider variety of sensors to establish a richer understanding of the user's context
- Providing a more flexible specification language for the designers of the content encountered in the experience
- Supporting dynamic discovery and management of (part of) the digital dimension overlaying Bristol
- Incorporating richer media such as 3D spatialized audio and streaming video
- Enabling users to add their own content to the evolving experience

Ultimately, we aim to develop an open environment that will allow anyone to create and deploy a context-sensitive experience, much as anyone can create a web site today.

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