Creating Experiences with Wearable Computing

Richard Hull , Josephine Reid & Erik Geelhoed
Hewlett-Packard Laboratories, Bristol, UK
E-mail: {richard.hull | josephine.reid | erik.geelhoed}@hp.com

Abstract

Wearable computing has the potential to deliver a rich variety of engaging user experiences that enhance everyday activities and situations through context-sensitive media and interaction. The Walk in the Wired Woods installation illustrates how such experiences might be designed and delivered in collaboration with artists and musicians. In this paper, we outline the beliefs underlying the experiential approach to wearable computing, describe the Walk in the Wired Woods experience, and reflect on the lessons that might be learnt from this work.

To appear in IEEE Pervasive Computing

As wearable computing moves from research laboratories into the real world, we can begin to explore what primary values of the technology might emerge for its users. Early research applications tended to focus on new types of utility enabled by a device that is always with you, such as context-sensitive information retrieval, alerts, and reminders [1-3]. However, we believe that the experiences evoked by a wearable device may turn out to be at least as valuable to users as its usefulness.

The experience provided by an object derives partly from the object's immediate characteristics – its appearance, ergonomics and user model. What an object is like to acquire, accommodate, learn, use and dispose of all influence the way it is perceived, with ease-of-use long being a guiding design principle. But there are also the *indirect* experiences generated as a result of using the object – for example, the thrill of racing downhill on a mountain bike, the fun of playing an instrument with friends, or the pleasure of losing oneself in a good book. In fact, these indirect experiences are often the reason why an object is acquired in the first place. We know from the success of the entertainment industry, and from the popularity of computer games and theme parks that such experiences are highly valued by consumers [4]. It seems possible that applications of wearable computing that deliberately set out to deliver engaging experiences to their users may eventually emerge as a dominant use of the new technology.

In the 4D Experience project at Hewlett-Packard Laboratories, we are investigating this possibility through a series of application probes that allow us to explore both what makes a wearable computing experience engaging, and how such experiences might be systematically delivered through the emerging technology. In this article, we will describe one of these probes, an art installation in which a traditional, physical exhibition space has been augmented with a location-sensitive digital soundscape, and attempt to draw out lessons from its deployment and use.

Exploring Experience

Our research is founded on three beliefs about experience. The first is that experience matters. We have already argued that experiential applications of wearable computing may turn out to have significant value for users. However, the experiential aspects of other applications of wearable computing may also need careful consideration. This follows from the observation that many wearable applications will inevitably be encountered while the user is already engaged in some ongoing experience or activity, for example while talking to friends in a restaurant or choosing new clothes in a favourite mall. The aim must naturally be to augment rather than detract from or diminish these ongoing activities, though this is not necessarily straightforward to achieve [5].

The second belief is that it is possible to unpack experiences to understand what makes them engaging (or otherwise), and to use that knowledge to systematically develop applications with the right attributes. We are encouraged in this belief partly by the emergence of Experience Design as a distinct field which draws on traditional disciplines such as architecture and graphics design, but which is increasingly engaging with digital technologies [6, 7]. In addition, we can draw on our own previous work exploring the experiences of visitors to a hands-on science museum. This study led to a provisional model predicting that compelling experiences will tend

to involve stimulation of the senses and imagination, challenge and self expression, and/or social interaction [8].

Thirdly, we believe that experiential applications are more likely to be engaging if they involve the participation of creative practitioners such as artists, musicians and games designers. Such people often depend for their livelihoods on their expertise in developing engaging experiences, though they may not use this terminology. However, like much expert knowledge, creative know-how tends to be tacit rather than explicit. Creative goals, skills and approaches can be elicited [9], but a direct engagement with creative practitioners is a more immediate way of complementing computer science skills and practices. This can be seen in the way that the computer games industry has tended to specialize roles recently, and the growing prevalence of blockbuster movies combining storytelling, animation and computer graphics expertise.

We are exploring these beliefs experimentally by constructing proof-of-concept wearable experiences that are sufficiently complete to allow user evaluations. Our aim at this stage of the program is to discover whether the claims above really provide a sensible foundation by first acting as if they do and then reflecting on our experience (no pun intended). Such learning-by-doing naturally needs to – and will - be supplemented by a more formal, analytical approach, but the first imperative is to see whether the overall approach is sound.

Initially, we are focussing on what we have termed *Situated Digital Experiences* – wearable computing applications in which context-sensitive digital content is delivered to the user so as to enhance the user's experience of that context. As argued earlier, context is a crucially important aspect of experience - what seems fun on a sunny Saturday morning might not seem such fun late on a cold and blustery Thursday night. In particular, we believe that a sense of place is a key dimension of context in this regard. Consequently, we are concentrating on location sensitivity, where the user's experience is modulated by their current position and path history, and by the presence of others.

Examples of situated digital experiences might include art interventions that reflect and modulate their locations, physically distributed digital games in which a player's position and their proximity to other players condition what they 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.

Applications that augment reality in this way are not, of course, novel, and our interest in them overlaps with that of other groups, for example [10-12]. However, one difference in emphasis lies in our initial concentration on the use of audio as the primary (or only) method of communicating to the user. Audio is preferred for two main reasons; First, we believe that 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 [2, 13], enabling asynchronous interaction between visitors to public spaces [14], and providing a rich game space

in an featureless hall [15]. Incidentally, one lesson from this previous work is the need for expert sound design [16], reinforcing our belief in the value of creative collaborators.

A Walk in the Wired Woods

For our first experimental situated digital experience, we worked with artist Liz Milner and musician Armin Elsaesser to develop an art installation known as *A Walk in the Wired Woods*. The Woods is an example of a situated soundscape in which the user is automatically presented with audio content appropriate to their location in the exhibition space. The soundscape overlays a pre-existing photographic exhibition featuring striking images of a nearby wood and consists of some thirty pieces of music, woodland sounds and spoken narrative. As visitors equipped with our wearable device wander around the exhibition, they simultaneously view the photographs and listen to the associated sounds (see figure 1).

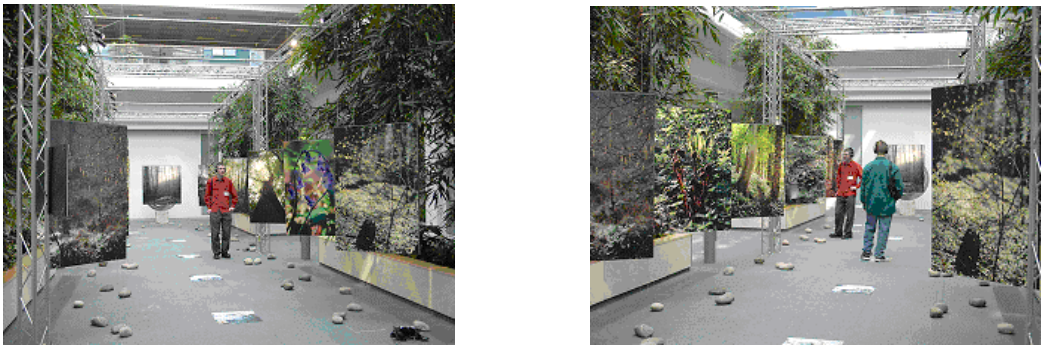

Fig. 1. Two views of the Walk in the Wired Woods installation

The Woods was installed in the atrium of the Hewlett-Packard laboratories building in Bristol between January and May 2002 and visited by several hundred people from a range of backgrounds. A typical visit to the exhibition lasted around twenty minutes and generated a very positive response. We will say more about this later. The reader may get a sense for the installation from a short video on a web site documenting the opening of the Woods at http://www.hpl.hp.com/hosted/mbristol/.

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 [17]. 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 [18]. 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 2.

```
<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. 2. 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 3 shows a plan view of the audio auras mapped onto the floor plan of the exhibition space in which the different colours of the auras 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.

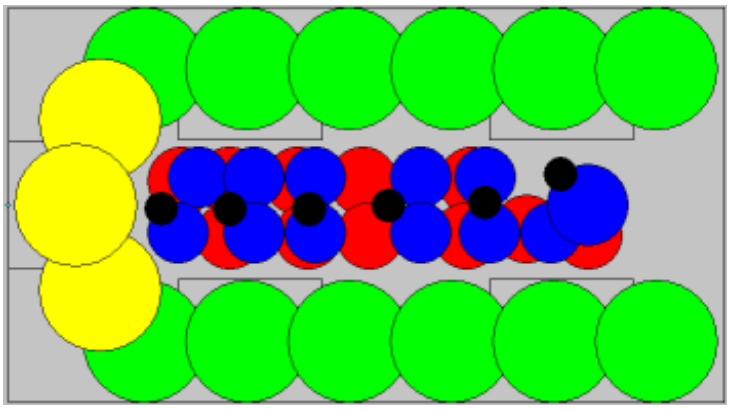

Fig. 3. A plan view of the audio auras mapped onto the physical space

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[1]. Where auras overlap, the one whose centre is closest to the location of the client device is designated as active[2]. However, two of the channels have been set up to have slightly different behaviours. The black auras shown in figure 3 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 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.

The client device itself is based on a HP 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 PocketPC 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 3. However, for normal

[1] 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.

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

use, the screen is turned off and the PocketPC is hidden in the sealed bag. The complete client configuration is shown in figure 4

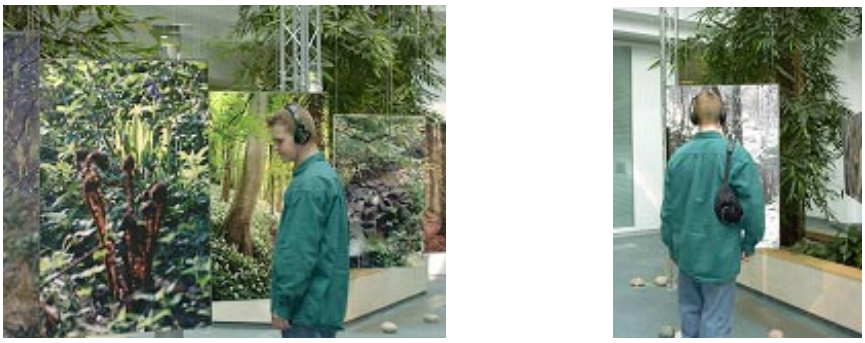

Fig. 4. Two views of the user's equipment

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.

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 5. 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.

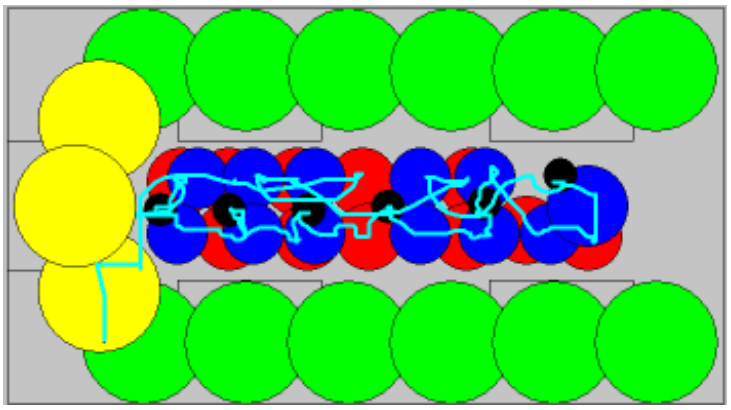

Fig. 5. One visitor's trail through the exhibition space

The 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, we carried out a formal evaluation in which we asked people to rank order two lists of seven items, using an incomplete block design, the Youden Squares Design [19]. The first list asked visitors what they felt most like from the list: *Lonely, Amazed, Strange, Immersed, Frustrated, Inspired* and *Normal*. The second list asked what this experience was most like, from: *Museum tour, Concert, Radio program, (real) Walk in the woods, TV program, Circus* and *Dive underwater*. The design involves presenting three items to rank at a time. In total, there are seven such blocks of three items to rank and each item appears three times. Each item is compared with the other six items once. A great strength of the Youden Squares design is that, on the one hand, it uses a forced choice method, when a subject ranks one (incomplete) block, and on the other hand it allows tied items (ranked the same) in an individual's ranked list. Thirty six subjects completed the "I felt most" exercise of which thirty-four completed the "This felt most like" rank ordering. Most people completed the task within five minutes.

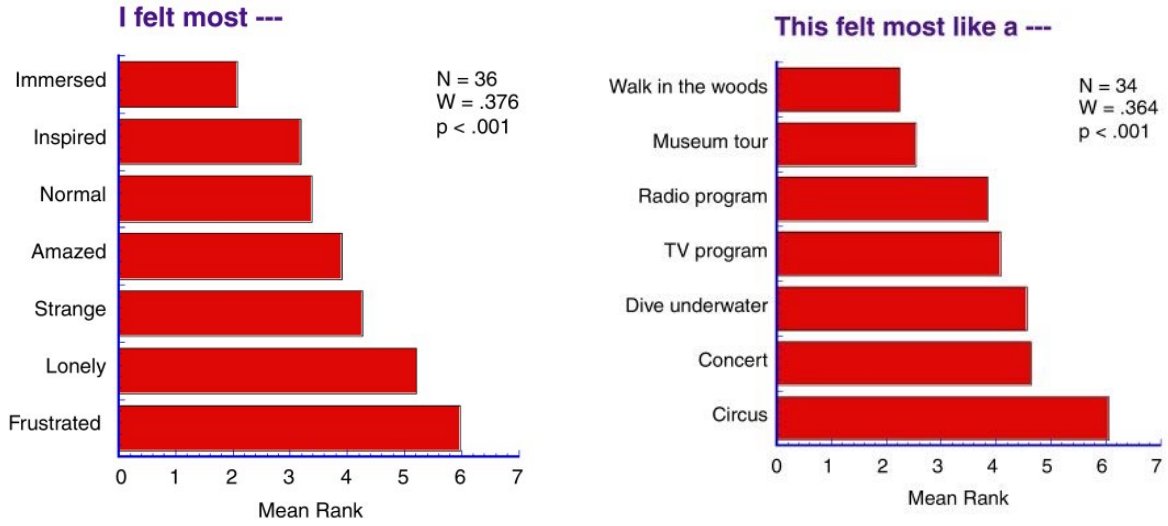

Fig. 6. Results from the ranking exercises

The results are shown in figure 6, where in this presentation, smaller numbers indicate a higher rank. Describing the experience of the exhibition, people felt most "immersed". This item, with a mean rank of 2.1, was clearly separate from the second and third items, "inspired" (mean rank 3.1) and "normal" (mean 3.3). The three items with a more negative connotation "strange", "lonely" and "frustrated" were low down on the list. Least of all, people felt frustrated with a mean rank of 6.1. For this list, the W of group concordance [20], a measure of how united people are in rank ordering the seven items, was highly significant $W = .376$, $p < .001$. For each individual a measure of consistency (in the way they ranked the items) was calculated (circular

triads, [20]). Across the group as a whole the mean number of circular triads was low (.67), 67% showed no inconsistencies at all.

The results for the second list indicated what this experience was most like. Perhaps unsurprisingly, a real "Walk in the woods" (mean rank = 2.3) and a "Museum tour" (mean rank = 2.5) were top of the list. Third and fourth with an almost equal rank were "Radio program" (mean 3.9) and "TV program (mean 4.1). The fifth and sixth place were also virtually tied: "Dive under water" (mean 4.6) and "Concert" (mean 4.7). Finally clearly at the bottom of the list with a mean rank of 6.1, was "Circus". Also for this list, there was a highly significant group concordance, $W = .364$, $p < .001$, and the mean number of circular triads was even lower at .44 on average, with 82% having no circular triads at all. Thus, for both lists, people were united in their response (high W of concordance) and very consistent in the way they ranked the items (low numbers of circular triads).

Broadly speaking, the evaluation shows that the Woods experience was deeply engaging and immersive. Video-tapes of the exhibition show people moving around slowly in a concentrated manner, not interacting with others but rather remaining in their own "bubble". This seems to be similar to the kind of immersiveness that is exhibited in virtual reality environments based on eyeglass displays [21].

Perhaps the most pleasing result from the evaluation for the developers is that about as many people likened the exhibition to a real 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 explain *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.

Reflections

So, what lessons can be drawn from the Woods installation and evaluation, and do they support the views on experience stated earlier in this article? First, we must acknowledge that our comments are influenced by observation of the design process and visitor responses as much as by the formal evaluation just described. Nonetheless, given that proviso, we believe that the Woods does provide some evidence that we may be on the right path.

First, the Woods did provide an engaging experience for visitors despite having no obvious utility and very simple functionality. Of course, that is what art is like, but that is also the point. Art, hobbies and other pastimes have tremendous value for people. The Woods was a successful attempt to plug into that type of value.

In terms of the model described in [8], the Woods experience lies almost completely along the Drama/Sensation dimension. We did not attempt to incorporate any element of challenge into the experience, though many visitors enjoyed trying to work out how particular sounds were triggered. Nor was there an attempt to provide a social dimension to the experience. Indeed, the particular headphones that we chose to use let little sound through from the real environment and

would have tended to discourage social interaction. So, although the Woods supports the prediction of the model that compelling experiences will exhibit one or more of the three elements identified - Drama/Sensation, Challenge/Achievement, Social – the most interesting observation from this perspective may be that it is possible to create an engaging experience with only one of those dimensions.

This result can be compared to the findings from the Pirates game in which participants were offered both puzzle-solving challenges and social interaction via battles, but concentrated on the former [22]. This suggests that the challenge/achievement dimension may also be sufficient to evoke a positive experience. However, the fact that players did engage in some battles suggests that social interaction added to the experience as the authors expected. This raises the possibility that the dimensions of the model might be additive in certain circumstances. In our recent work, we tested this possibility by experimentally comparing the responses of users (11-12 year old children) to two versions of a rich desert island soundscape, one of which involved a rescue game [23]. We discovered that these users found the game version (drama/sensation plus challenge/achievement) significantly more interesting to the version that only had stimulating situated audio (only drama/sensation).

Clearly, further work to test and refine the model is needed. However, there is also another issue to consider. So far, we have tended to equate “enjoyed” with “valued”. That is, we know that visitors to the Woods enjoyed their experience, and we infer that they valued it. To an extent, the inference is valid, but it begs the question: How much did they value it? In particular, to prove our case, we will eventually need to show that users valued an experience sufficiently that they were prepared to undergo some cost to get it, whether that is a financial cost, the cost of having the equipment with them in the first place, or the opportunity cost of giving up some other option to pursue the experience. Such real-world tests are beyond our scope at present but cannot remain so indefinitely.

Our second observation is that the Woods does encourage the notion that experiences can be deliberately and systematically developed. As we have just suggested, the model of experience described suggests fertile directions along which to orientate an intended experience, even if those directions at present remain broad. What is still lacking, however, are design guidelines - the middle ground between the descriptive model and a prescriptive process for developing experiences. This is still very much work in progress and we should not be overly optimistic about the prospect of turning experience design into a turn-key operation. After all, most of us can make marks on paper, but few of us can produce drawings, or poetry, or musical compositions that inspire and thrill millions.

In the immediate absence of fixed, guaranteed procedures, we are confirmed in our view that the participation of skilled creative practitioners in experience design is at least advisable, and perhaps essential. We found the creatives with whom we worked to be imaginative, meticulous, experimental, interested in research, and comfortable with speculative, what-if discussions in a development environment in which the content and underlying technology were deliberately fluid [24].

One of the characteristics of the Woods installation was that it had a deliberately simple functionality that might be characterized as *What You Hear Is Where You Are*. In other words, users heard audio that was chosen automatically for them on the basis of their location. The correspondingly simple user model had two advantages for the experience designers. First, it was fairly straightforward after a little practice to either imagine or simulate the effect of a particular design choice, such as where to locate a piece of audio. Second, it was possible to provide simple editing tools in both tabular and graphical forms that allowed those design decisions to be rapidly implemented.

An aspect of our research not covered in this paper is the desire to provide end-user tools that will enable creatives to generate and deploy experiential applications of wearable technology without the participation of technologists, much as they (and almost anyone else) can independently produce web sites today. The Woods development experience encourages this endeavour, but again, there is a catch. As we have moved on from the simple soundscapes of the Woods to more interactive experiences such as the desert island game referred to earlier, we have had to add further features to the behavioural specification language illustrated by figure 2. For example, the island game depended on the players collecting magic tokens, for which we introduced state variables, their corresponding operations, and conditional actions. A later, multi-player game required the ability for devices to share state and notify each other of internal events. The problem is not that this extra complexity is intrinsically bad – after all, it means greater flexibility and perhaps richer experiences – but that it risks moving experience design for wearable computing back into the domain of programmers. Language features such as sequence, conditions and state are familiar to us, but alien to many creatives. How can we give them the power and flexibility they desire without expecting them to take a course in computer science?

The approach that we are beginning to explore is to provide two levels of complexity with corresponding toolsets, along the lines of an authoring environment such as Macromedia Director. The first level, aimed at creative practitioners, will provide point-and-click graphical tools that support experiences corresponding to a simple user model and limited client functionality. However, this level will have a “back door” that opens into a full programming environment capable of developing arbitrary behaviours. This may be a fairly conventional approach, but it is not without its difficulties. In particular, getting the border between the two levels right will be a significant challenge.

So, in conclusion, we consider that the experimental installation described in this article has provided some evidence for the experiential perspective on wearable computing and its underlying assumptions. As we go forward, we will attempt to address some of the issues raised in this last section. We are beginning to develop a more formal, experimental approach to evaluating prototype experiences and user responses, and we expect to see this strand of research grow in emphasis. We also intend to leave the protected physical environment enjoyed by the Woods installation, and venture out into the city streets as part of a broader Mobile Bristol project. The larger canvas and more challenging environment of the city will inevitably raise issues that have not yet become apparent in the in-building applications developed so far. This move will also raise the possibility of testing value directly, for example by charging users or simply requiring them to give up some of their free time while out shopping. Finally, we hope to

unleash a community of creative practitioners to independently develop experiences on our platform, by providing appropriate tools along the lines described.

Acknowledgements

We would like to acknowledge the contributions of our past and present colleagues at Hewlett-Packard Laboratories, including Alison Kidd (now at The Prospectory), Constance Fleuriot (now at the University of Bristol), Paul Marsh, John Honniball and Phil Stenton. We would also like to thank Cliff Randell and the other members of the University of Bristol Wearable Computing group, and the creators of A Walk in the Wired Woods, Liz Milner and Armin Elsaesser.

References

1. Bederson, B.B. *Audio Augmented Reality: A Prototype Automated Tour Guide*. in *CHI'95*. 1995. New York: ACM Press.
2. Mynatt, E.D., et al. *Audio Aura: light-weight audio augmented reality*. in *Tenth Annual Symposium on User Interface Software and Technology*. 1997.
3. Hull, R., P. Neaves, and J. Bedford-Roberts. *Towards Situated Computing*. in *First International Symposium on Wearable Computing '97*. 1997: IEEE.
4. Pine, J. and J. Gilmore, *The Experience Economy*. 1999: Harvard Business School Press.
5. Fleck, M., et al., *From Informing to Remembering: Deploying a Ubiquitous System in an Interactive Science Museum*. Pervasive Computing, 1(2), p13-21, April-June 2002
6. Shedroff, N., *Experience Design*. 2001: New Riders.
7. *Experience Design Group, American Institute of Graphic Arts*.
8. Kidd, A., *Technology Experiences: What Makes Them Compelling?* 2001, Hewlett-Packard Laboratories.
9. Stone, S., *How Do Experts Design Compelling Experiences: A Qualitative Identification Of Key Dimensions*, MSc Dissertation, Department of Computer Science. University of Bath, 2002.
10. Höllerer, T., S. Feiner, and J. Pavlik. *Situated Documentaries: Embedding Multimedia Presentations in the Real World*. in *3rd International Symposium on Wearable Computers*. 1999. San Francisco, California: IEEE.
11. Cheverst, K., et al. *Experiences of Developing and Deploying a Context-Aware Tourist Guide: The GUIDE Project*. in *MOBICOM'2000*. 2000. Boston: ACM Press.
12. Hallnäs, L. and J. Redström, *Slow Technology - Designing for Reflection.* Personal and Ubiquitous Computing, 2001. **5**(3): p. 201-212.
13. Mynatt, E.D., et al. *Designing Audio Aura*. in *CHI '98*. 1998: ACM Press.
14. Rozier, J., K. Karahalios, and J. Donath. *Hear&There: An Augmented Reality System of Linked Audio*. in *ICAD '00*. 2000. Atlanta, Georgia.
15. Lyons, K., M. Gandy, and T. Starner. *Guided by Voices: An Audio Augmented Reality System*. in *Proceedings of Intl. Conf. on Auditory Display (ICAD)*. 2000. Atlanta, GA.
16. Back, M. and D. Des. *Micro-narratives in sound design: context, character, and cariacture in waveform manipulation*. in *Third International Conference on Auditory Display*. 1996.
17. Randell, C. and H. Muller. *Low Cost Indoor Positioning System*. in *UbiComp 2001*. 2001. Atlanta: ACM.

18. McGrath, R., E., *Discovery and Its Discontents: Discovery Protocols for Ubiquitous Computing*. 2000, University of Illinois.
19. Maxwell, A.E., *Analysing Qualitative Data*. 1961, London & Colchester: Spottiswood, Ballantyne & Co. Ltd.
20. Kendall, M.G., *Rank Correlation Methods*. 1948, London: Griffith & Co.
21. Geelhoed, E.N., M. Falahee, and K. Latham. *Safety and Comfort of Eye Glass Displays*. in *2nd Int. Symp. on Handheld and Ubiquitous Computing*. 2000. Bristol, UK.
22. Björk, S., et al. *Pirates! - Using the Physical World as a Game Board*. in *Interact 2001, IFIP TC.13 Conference on Human-Computer Interaction*. 2001. Tokyo, Japan.
23. Nethercott, J., *An Experimental Comparison of Two Soundscapes Based on Two Theories of Motivation: Implications for the Design of Compelling Experiences*, MSc Dissertation, Department of Computer Science. University of Bath, 2002.
24. Hull, R. and J. Reid, *Designing Engaging Experiences with Children and Artists*, in *To appear in Funology: From Usability to Enjoyment*, A. Monk and M. Blythe, Editors. 2003, Kluwer.