The Mobile Information Access Experience – A User Perspective

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by

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ABSTRACT

Mobile technologies, such as mobile phones, smartphones and Palmtop computers, are in an upwards trend and earliest models of such devices are already available to end-users to communicate and access multimedia content on-the-move. As a logical outcome of this development in mobile technologies and devices, content provider companies have already started investing and piloting mobile multimedia content distribution and broadcasting technologies. Nevertheless, no matter how cutting-edge technology is and no matter how stylish the mobile devices are, the ultimate success of wireless communication technologies and devices are directly associated with the user adoption and embrace of these new equipment and technologies.

In this perspective, since multimedia content, for mobile or not, is ultimately produced for the education and/or enjoyment of viewers, the user's perspective concerning the presentation quality is surely of equal importance as objective Quality of Service (QoS) technical parameters, to defining distributed multimedia quality. In order to comprehensively understand user experiences whilst accessing information using mobile devices and technologies, we investigate user-mobile device interaction and look into the surrounding issues in a uniform manner by combining multiple aspects: user initial device experience (Out-of-Box Experience), mobile information access in a real-world context, device impact on user information access and perceptually tailored multimedia content impact on user information assimilation and satisfaction. Accordingly, an extensive experimental investigation has been undertaken to see how user experiences varied based on device familiarity, device type, real-world context and variable locations. The findings has shown that the overall perception, and effectively the user information access experience, is affected and improved when multimedia content is tailored according to user device type and context. Thus highlights that the future of mobile computing necessitates two-faceted research, which should combine both a user as well as a technical perspective.

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LIST OF PUBLICATIONS

The following papers have been published (or have been submitted for publication) as a result of the research discussed in this thesis:

JOURNALS

1. Gulliver, S. R., Serif, T., and Ghinea, G., (2004). "Pervasive and Standalone Computing: the Perceptual Effects of Variable Multimedia Quality". *International Journal of Human Computer Studies*, Vol. 60, pp. 640-665.

2. Serif, T., Ghinea, G., (2005). "HMD vs PDA: A comparative study of the User out-of-box experience", *Journal of Personal and Ubiquitous Computing*, Springer-ACM. Vol. 9, No. 4, pp. 238-248, July 2005.

3. Serif, T., Ghinea, G., (2005). "Device and Context Influence on Wireless Infotainment Access: A Real World Story", *The European Journal for the Informatics Professional (CEPIS UPGRADE).*

4. Serif, T., Ghinea, G., (2005). "Influencia del dispositivo y del contexto en el acceso sin hilos de la información y de la hospitalidad: Una Historia Verdadera Del Mundo", Novática (in Spanish), *Asociación de Técnicos de Informática (ATI).* Accepted for publication.

REVIEWED CONFERENCES

1. Serif, T., Gulliver, S. R., and Ghinea, G., (2004). "Perceptual Impact of Multimedia QoS: a Comprehensive Study of Pervasive and Traditional Computing Devices", *ACM Symposium on Applied Computing*, Nicosia, Cyprus, pp. 1580-1585.

2. Serif, T., Ghinea, G., (2006). "Device Impact on Wireless Infotainment Access", *4th International Conference on Pervasive Computing*, Dublin, Ireland, 07-10 May 2006. (Accepted)

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CHAPTER 1

Introduction

Today, mobile communications are part of the everyday fabric of life, continuing to encounter a strong upward growth trend. Accordingly, the total number of mobile phone subscribers worldwide at the end of 2005 grew to 2,129 billion, an increase of 384 million subscribers from the start of the year. Indeed, the number of mobile subscribers is expected to reach 3,964 billion by the end of 2011 [POR06]. Of course mobile communications would be an impossibility without the presence of a wide and diverse spectrum of mobile devices: every mobile subscriber has at least one device through which s/he accesses the desired services. Indeed, the upward trend also includes wireless devices that facilitate other communication means than voice, such as smartphones and handheld computers. Hence more than 280 million smartphones [VER06] and 181 million handheld computers [ETF05] are expected to be sold in 2010.

As a logical consequence of the development in mobile technologies and devices, content provider companies have already started investing and piloting mobile content distribution and broadcasting technologies. The most recent work in this area is led by Arqiva and O2, where the two companies are collaborating to broadcast 16 TV channels to mobile phone subscribers using Digital Video Broadcast – Handheld (DVB-H) technology. Their evaluation findings show a strong consumer demand for multi-channel broadcast TV on mobile devices [SLO05; DTG06].

However, no matter how cutting-edge technology is and no matter how trendy the information access gadgets are, the ultimate success of mobile and wireless communication devices is directly associated with the user adoption and embrace of these new devices. Consequently, the central theme of this dissertation will be the user mobile information access, which will be explored through four key manifestations, ranging from the initial experiences that the user has with such devices to the experience of perceptual and location-based tailoring of multimedia content.

Accordingly, this chapter is structured as follows: Section 1 describes the birth of digital mobile telephony in early 90s, which constitutes the foundation of today's mobile information access, and details the improvements that the technology subsequently encountered. As mobile information access is inextricably linked to the access of content, which in a contemporary setting more often than not entails the access of multimedia, Section 2 briefly summarises research focused on the user multimedia experience, while Section 3 explores work pertaining to the area of mobile information access, highlighting the opportunities for novel research that can be undertaken in this area. Finally, conclusions are drawn in Section 4.

1.1. Wireless Communication

The original analog mobile phones are considered the first-generation of cellular telephony (1G). In the early 1980s, first-generation systems were deployed. At the same time, the cellular industry began developing the second-generation of mobile telephony (2G). The difference between first-generation and second-generation is in the signalling techniques used: first-generation used analog signalling, second-generation used digital signalling.

After the 1G analog mobile systems, 2G mobile systems were introduced around 1991 [SCH03]. 2G systems had higher capacity and lower cost for the service providers, while for the user the benefits were short messaging and low-rate data services on top of the standard voice service. Primary thinking and concept development on third-generation (3G) mobile phones began just as 2G networks started to roll out, in the late 90s. As the general model of ten-years [KUK05] to develop a new mobile system has up till now been broadly followed, the timeline would suggest that fourth-generation (4G) should be expected to be operational sometime around 2011. The new generation of mobile technology will build on the second phase of 3G, which essentially means that all networks are expected to embrace Internet Protocol (IP) technology with anticipated 4G speeds being as high as 100 Mbps [RAY06].

From a different perspective, the fact that the Internet is now universally popular hints that someday wireless networks may be made to behave in a fashion similar to today's packet-based networks and computing devices, just as early mobile phones were made to emulate the functionality of wired phones. Ad hoc networking is a growing technology today and is in its early stages. Ad hoc networks of tomorrow, however, will collect immediate knowledge of physical networking layers with their adaptive nature, so that future networks can be rapidly optimised for performance specific instances of time [OHY05].

With current conventional wireless networks, where network access points are fixed and connected to broadband backbones, in the race for higher speeds, as experiences with wireless IEEE 802.11 b/g data rates show, more is better, especially in and around homes and buildings. There are, of course, other new and exciting technologies in this area, which promise a large impact on wireless technologies. Ultra Wide Band (UWB) is one such fascinating communication technology that relies on the fabrication of ultra-short baseband pulses that can provide huge bandwidths. Unlike conventional wireless systems, UWB has been demonstrated to provide reliable data rates exceeding 100 Mbps within buildings, with extremely low power densities.

The next generation of wireless technologies will enhance the effectiveness of the existing methods and change in a positive way our lifestyles. Deployment of such wireless technologies in our everyday lives could possibly realise services that will enhance our quality of life:

> *Virtual navigation:* A remote database contains the graphical representation of streets, buildings, and physical characteristics of a large metropolis. Blocks of this database are transmitted in rapid sequence to a vehicle, where a rendering program permits the occupants to visualize the environment ahead. They may also virtually see the internal layout of buildings to plan an emergency rescue, or to plan to engage hostile elements hidden in the building.

> *Tele-medicine:* A paramedic assisting a victim of a traffic accident in a remote location could access medical records (e.g., x-rays) and establish a video conference so that a remotely based surgeon could provide “on-scene” assistance. In such a circumstance, the paramedic could relay the victim's vital

information (recorded locally) back to the hospital in real time, for review by the surgeon.

Crisis-management applications: These arise as a result of natural disasters where the entire communications infrastructure is in disarray. In such circumstances, restoring communications quickly is essential. With wideband wireless mobile communications, both limited and complete communications capabilities, including Internet and video services, could be set up in a matter of hours. In comparison, it may take days or even weeks to re-establish communications capabilities when wired networks are rendered inoperable.

Following the initial introduction to wireless communication systems, which constitute the core of mobile information access concept, we now focus on research targeting the user multimedia access experiences and their findings in a standalone computing context.

1.2. The User Multimedia Experience

In computing, the user experience has always been attractive to researchers. Thus, arguably Human-Computer Interaction (HCI) is the most significant proponent of the user experience in computing. However, the focus of HCI has mainly targeted the application layer of the ISO/OSI stack and comparatively little work has been done to explore how user considerations at the application layer translate to requirements in layers further down the ISO/OSI stack, such as the network and transport layers.

Accordingly, a relatively limited number of researchers have concentrated on user perspective assessment for the purpose of extending QoS considerations to higher echelons of the ISO/OSI stack. Examples of such work are now summarised.

In early work, Apteker et al. [APT95] examined the influence that varying video frame rates have on user satisfaction with multimedia quality and showed that the dependency between human receptivity and the required bandwidth of multimedia video clips is non-linear. Consequently, for certain ranges of human receptivity, a small perceptual variation leads to a much larger relative variation of the required bandwidth – highlighting the potential for significant bandwidth savings if perceptual considerations are included in the transmission of multimedia.

Wilson and Sasse [WIL00a; WIL00b] using a 3-dimensional approach measured Blood Volume Pulse (BVP), Heart Rate (HR) and Galvanic Skin Resistance (GSR) to gauge stress caused when inadequate media quality is presented to a participant. Their findings showed that the GSR, HR and BVP data represented significant increases in stress when a video is shown at the lower quality of 5 frames per second (fps) in comparison to 25fps. However, only 16% of participants confessed to noticing a change in frame rate. Moreover, no correlation was found between stress level and user feedback of perceived quality.

Ghinea and Thomas [GHI98] presented users with a series of 12 MPEG-1 video clips to measure the impact of video (QoS) variation on user perception and understanding of multimedia video. The clips were chosen to cover a broad spectrum of subject matter, whilst also considering the dynamic, audio, video and textual content of the video clip. The QoS parameters varied were the multimedia video frame rate and colour depth, whilst maintaining a constant window size and audio stream quality. The findings of this work showed that a significant loss of frames (achieved by reducing the frame rate) or colour depth reduction does not proportionally reduce the user's understanding and perception of the presentation. Ghinea and Thomas's method of measuring user perception of multimedia quality, later termed Quality of Perception (QoP), incorporated both a user's capability to understand the informational content of a multimedia video presentation, as well as his/her satisfaction with the quality of the visualised multimedia.

Gulliver and Ghinea [GULL03] used an adapted version of QoP to investigate the impact that hearing level has on user perception of multimedia, with and without captions. They showed users a series of 10 windowed MPEG-1 video clips with a consistent sound quality and video frame rate. The findings of the study showed that deafness significantly impacts a user's ability to assimilate information. Interestingly, use of captions did not increase deaf information assimilation, yet increased the quality of context-dependent information assimilated from the caption / audio.

Having familiarised ourselves with research concerning the standalone user multimedia experience, in the next section we introduce research conducted in respect of mobile information access, with a specific focus on work undertaken to enhance the technology and easy of use for mobile devices. Consequently, we then highlight some research gaps in the mobile information access area.

1.3. Mobile Information Access

Mobile information access concept is a very active and evolving field of research, with a wide and diverse spectrum of unexplored areas, ranging from networking, HCI, QoS, to interoperability. So far, work on mobile networking has concentrated on issues such as Mobile IP [BHA96], ad hoc protocols [ROY99], selective control of data consistency [TAI92; TER95], bandwidth-adaptive file access [MUM95], and techniques for improving TCP performance in wireless networks [BAK95, BRE98]. However, even so, mobile devices cannot match the networking capacity of a wired device due to constraints such as unpredictable variation in network quality, lower trust and robustness of mobile elements, limitation on location resources imposed by weight and size, and battery power consumption.

Such constraints mean that another facet of mobile device research is related to adaptation, which involves the scalability and transformation of desktop content into a mobile-suitable format for better mobile information access experiences and a higher delivered QoS. Work in this area has explored issues such as:

- Network and client based adaptation via on-demand dynamic distillation [FOX96; FOX98], which implements a dynamic distiller server that will convert (image, audio, video and postscript) files according the hardware and network capabilities of the mobile device that has requested the content.
- Content adaptation for mobile information access devices based on real-time resource information (network bandwidth, network latency, disk space, CPU load, and battery power), rather than static profiles [NOB97].
- To enhance the mobile web browsing experience on small-screen handheld devices, Fulk [FUL01] has proposed a different method in his work. This

study, rather than adapting web content, suggests and evaluates an alternative display and interaction paradigm using fisheye views.

Ultimately, though, it is the end user which will determine the success of future mobile technology and applications. Thus, we argue, the user experience of mobile device interaction is the main factor that has to be looked at in this context. From this perspective, a number of studies have explored user and device experiences and interactions. Some of these are highlighted below:

- Research and development groups [IBMA04] and cross-company consortia [EOU00] have been established to explore and standardise a method of evaluation for user initial experiences with electronic devices.
- From a different perspective of mobile HCI, Jones et al. [JON99] evaluate usability issues raised while retrieving information from the World Wide Web using small screen devices. Their study takes into account and compares the scrolling and tapping/click time required to accomplish a set of tasks.
- Similarly, Buranatrived and Vickers [BUR04] implemented two multi-platform applications and evaluates them on two mobile devices (WAP phone and Palm PDA) which have different interaction paradigms.

Nonetheless, to the best of our knowledge, no work has explored in a uniform manner issues pertaining to mobile information access, ranging from the user's initial contact with the device, to perception- and location-based multimedia content tailoring for mobile devices.

1.4. Conclusions

In concluding we remark that the user experience, especially in the area of mobile computing, has only been investigated in a fragmented manner. Work has traditionally neglected the initial interaction between mobile devices and the user. Although research has explored the user experience of accessing information on a mobile device, these studies were undertaken in a laboratory context. The comparative user experience across multiple, interconnected, devices has remained unexplored, as has its investigation in a real-world context – the setting for the overwhelming majority of information access in practice. These isolated episodes we propose in our thesis to tackle in an integrated manner.

The structure of this document is as follows: in Chapter 2 we discuss methods relating to human multimedia quality assessment and how perception of content can be used to evaluate the user mobile information access experience, with the intent of defining research aims and objectives. In Chapter 3, we describe and justify the research methodology that shall be used in the studies described in Chapters 4, 5, 6 and 7.

In Chapter 4, we evaluate the user initial contact experience with two mobile devices, namely a Personal Digital Assistant and a Head Mounted Device, by following an industry standard out-of-box experience evaluation methodology. Moreover, we examine the impact interconnectivity issues that may arise while connecting these two devices using third-party components and adaptors.

In Chapter 5, we explore the real-world impact on the user mobile information access experience. The experiment is structured in such way that recognising the infotainment of accessed content the participants have to accomplish two set of tasks, which, are information and entertainment intensive, respectively.

In Chapter 6, we consider multimedia quality adaptation to measure the impact of display type on the user information access experience. In Chapter 7 we combine the findings of the real-world information access experience experiment (Chapter 5) and the results obtained from the device impact evaluation experiment (Chapter 6) to build pre-defined QoS transmission profiles to enhance the user experience. As part of this experiment we implement a Global Positioning System (GPS)-based campus guide application to evaluate the impact of tailored multimedia content on the user information access experience.

Finally, we conclude in Chapter 8 by highlighting our research findings and contributions.

CHAPTER 2

User Experiences and Mobility

2.1 Introduction

As indicated in Chapter 1, the central theme of the research work described in this dissertation focuses on the user experience when interacting with information accessed on mobile devices. Accordingly, in this chapter we review related research work, with the ultimate aim of defining the research aim and objectives of our study.

Since user experiences are closely linked to the five human senses, in Section 2.2 we briefly introduce the human sensory systems: the Visual system, the Auditory system, the Tactile system (touch), the Olfactory system (smell), and the Gustatory system (taste). As the quality of user experiences must be measured in some way and bearing in mind that information is conveyed by content, and that this content is represented, in most cases today, by multimedia, in Section 2.3 we describe methods of multimedia quality evaluation. Section 2.4 subsequently details issues relating to human perception of multimedia and how perception of multimedia quality has been defined across different studies. After then reviewing, in Section 2.5, research focusing on the user mobile computing experience, we are in position to identify and justify our research aim and objectives, which we do in Section 2.6. Lastly, concluding remarks are made in Section 2.7.

2.2 The Human Sensory System

The human sensory system obtains information about the surrounding and the context using the receptors in the eyes, nose, ears and other sense organs. The gathered information is then relayed to the brain using neural pathways. The received signals are then interpreted in terms of experiences, knowledge and expectations at the cerebral cortex, which is formed by neurons and nerve fibers. In this section, we aim to describe the five main human sensory systems that affect the human perceptual experience.

2.2.1 The Human Visual System

The eye is a complex biological formation, which takes visible light and converts it into a stream of information that can be transmitted via nerves. Light reflected from objects enters the eye thought the pupil and passes thought the lens, which beams the inverted image of the object on the retina (Figure 2.1). The retina consists of rods and cones that serve the task of detecting the intensity and the frequency of the incoming light. An eye is typically equipped with 120 million rods to detect the intensity of light and 7 million less light sensitive cones to capture colour within the human visual system. The rods and cones transmit nerve impulses to the brain via the optic nerve, which is bundled with the nerve cells on the very back of the eyeball.

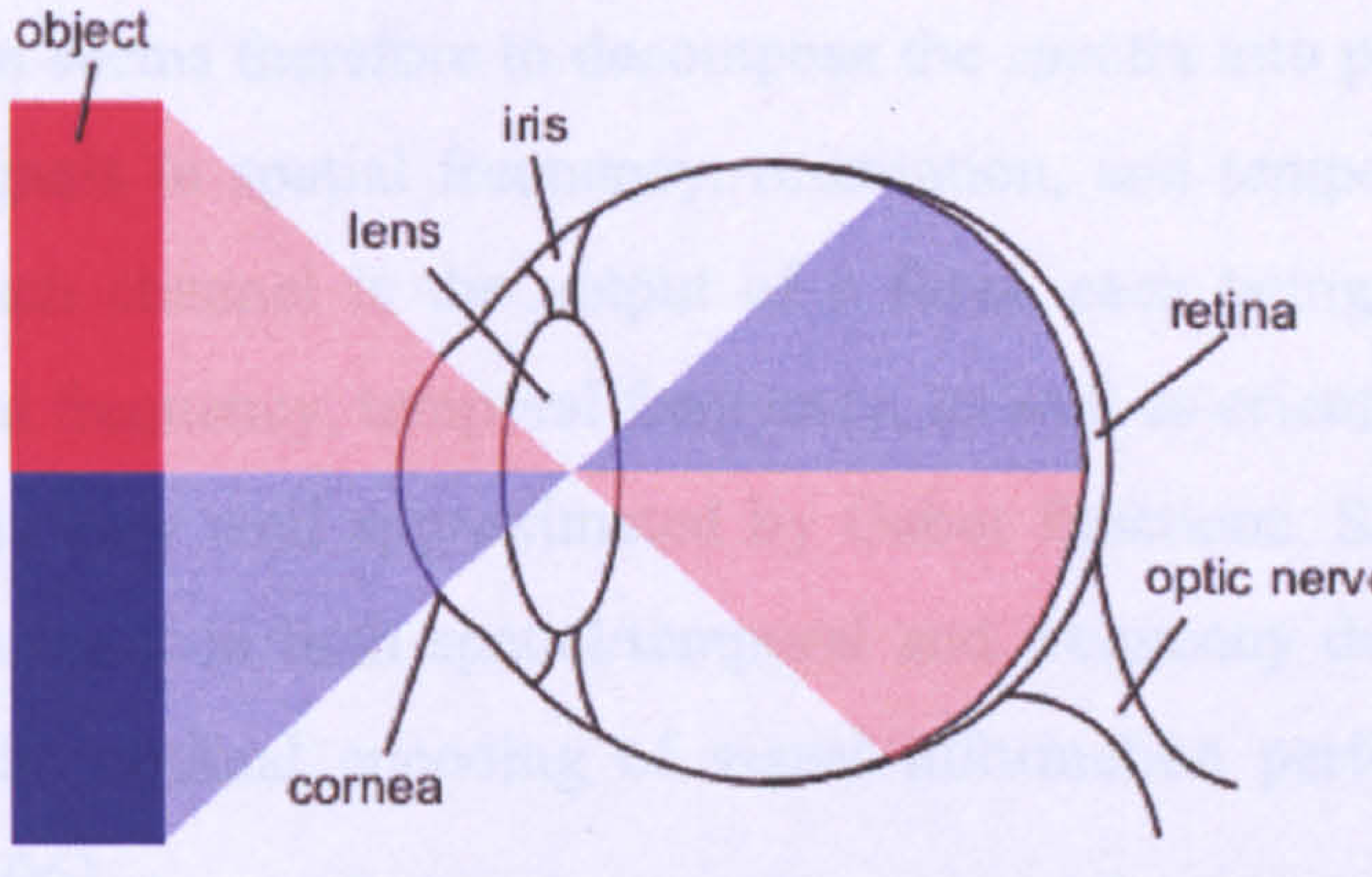


Figure 2.1: Diagram of the Human Eye [WIKa06]

The human visual system can be explained at several different levels. As far as we are concerned, our level of interest is at the cortex level. The formalism used is that of cognitive psychology or psychophysics, where the human visual system is modelled as a transfer function relating output to input stimuli [BRA96]. Models are then validated by psychophysical experiments in which human subjects are asked to determine stimuli visibility. Such modelling of human visual perception has to take into account three major characteristics of human vision [OLZ86]: its multi-channel structure, contrast sensitivity, and masking. These will now be explored in more detail.

2.2.1.1 Multi-Channel Structure

Visual neuro-physiological data has shown that the neural signals pass from the eyes to the primary visual cortex (also called area V1) and, from there, to the other cortical areas of the brain. However, experiments have shown that V1 is the main bottleneck in the visual path of primates and consequently everything that humans see will be mediated by neurons in that region of the brain. Thus, two images will appear to an observer to be the same if they trigger identical responses in V1 neurons; analogously, two images will appear to be almost identical if they trigger very similar responses in those neurons [TEO94].

Both physiological and psychophysical experiments performed on neurons of the primary visual cortex have shown the bandpass nature of the cells. Thus, the response of such neurons is tuned to a determined band limited portion of the spectral domain, with their associated peak sensitivity positions having a well-defined structure [BRAb96].

The human brain seems therefore to decompose the spectra into perceptual channels - band-limited signals in spatial frequency, orientation, and temporal frequency. This suggests that each channel is the output of a filter, each being tuned to particular regions of spatial frequency, temporal frequency, as well as orientation. The profile of these channels is very well approximated by Gabor functions. Since these functions are the most compact in both spatial/temporal and frequency domains, they can be thought of as the optimal encoding of visual information performed by the brain [BRA96; BRAb96].

Psychophysics has studied the specific number of perceptual channels involved in human vision. Temporal vision seems to be covered by two to three channels. The existence of the third such channel is controversial, as it seems to exist only at very low spatial frequency. The existence of the other two channels, though, is widely accepted. These are governed by two different mechanisms, respectively: the transient mechanism, which is band pass, and the sustained mechanism, sensitive to low temporal frequencies. The transient mechanism is sensitive to moving patterns, while the sustained mechanism is responsible for perception of still or slowly moving images. The spatial frequency is divided logarithmically (i.e. in octave bands) in four to eight bands. The number of orientation bands is roughly the same, although the division is linear here [WAT86].

2.2.1.2 Contrast Sensitivity

The fact that the sensitivity of the human eye varies with spatial frequency is well known and has been used in the design of video equipment [BRA96]. This property of the human visual system is commonly referred to as contrast sensitivity. It has been shown that the human eye has a spatial frequency that is bandpass with a peak frequency of around 4 cycles per degree (cpd). More precisely, the eye detects a signal only if its contrast is greater than a certain detection threshold, which varies as a function of spatial frequency. The inverse of this threshold is therefore also a function of frequency and is called the contrast sensitivity function (CSF).

2.2.1.3 Masking

While the CSF deals with the visibility of a single stimulus, another characteristic of the human visual system, called masking, accounts for interferences between stimuli. Given a noisy image, it has been shown that part of the noise will be masked by the background and will therefore not be perceived by the human visual system. Masking is thus the modification of the detection threshold of one stimulus in the presence of another.

In order to save on computational complexity, in most models of human vision it is considered that interference between two stimuli can only take place if they occur in the same channel. This approach follows the results obtained by Legge and Foley [LEG80] which sums excitation linearly over a receptive field. However, experiments subsequently done by Foley and Boynton [FOL94] have shown that inter-channel masking exists and that the phenomenon can be significant.

Another issue that arises is the one of separability of the contrast sensitivity function and the filter bank. The spatio-temporal CSF is non-separable and there exists experimental data to support this claim [FAL86]: the temporal properties of moving objects are dependent on their spatial characteristics, since the temporal dependency is band-pass at low spatial frequencies and low pass at high spatial frequencies. Burbek and Kelly [BUR80] have elaborated an interesting model of the non-separable CSF using an excitatory-inhibitory formulation: they express the CSF as the difference between two separable mechanisms, excitation and inhibition, which permits that the whole CSF be parameterised with a limited number of parameters.

Since the mechanisms of spatial vision are tuned in frequency and orientation, they have a polar structure, which makes the filter bank non-separable in Cartesian spatial co-ordinates. As far as the interaction itself between spatial and temporal perception is concerned, there are two conjectures which try and explain it. The first, the sensitivity scaling hypothesis, argues that there is a dependence between the peak sensitivity of the temporal filters and spatial frequencies. The second, called the covariation hypothesis, claims that there is a spatio-temporal covariation in the temporal properties across the population of filters and yields a more complex filter bank. Recent studies have shown the validity of the sensitivity scaling hypothesis, and it is this theory which has been integrated in most visual models [BRA96; BAD99].

Having reviewed research to do with vision and its modelling in computer environment we now explore the other four sensory systems that affect human stimuli.

2.2.2 The Human Auditory System

Hearing, or audition, is one of the five traditional senses, which refers to the ability to detect sound waves. An object creates a sequence of wave compressions in the air surrounding when it vibrates. These variations in air pressure spread away from the source of the vibration, reducing its magnitude while the energy is dispersed.

As a rule of thumb, the human ear is sensitive to vibration frequencies between 20 Hz and 20,000 Hz. Frequencies capable of being heard by humans are called audio or referred to as sonic. Frequencies higher than audio are referred to as ultrasonic, while frequencies below audio are referred to as infrasonic.

The ear is grouped into three parts: the *outer ear*, the *middle ear* and the *inner ear* (Figure 2.2). Sound waves travelling through the air is captured and focused through the *external auditory canal*. Sound waves that reach at the end of the external auditory hit to the eardrum and vibrate it. These vibrations cause rolling backwards and forwards in the three ear bones (*ossicles*), and relay the vibration to the *cochlea* via *stapes*. The cochlea is a fluid filled structure that houses the end of our *auditory nerve*. Vibrations from the *ossicles* set the cochlear fluid in motion, which stimulates the sensitive *auditory nerve* endings. The auditory nerve then carries the signal to the brain for processing [DAL86].

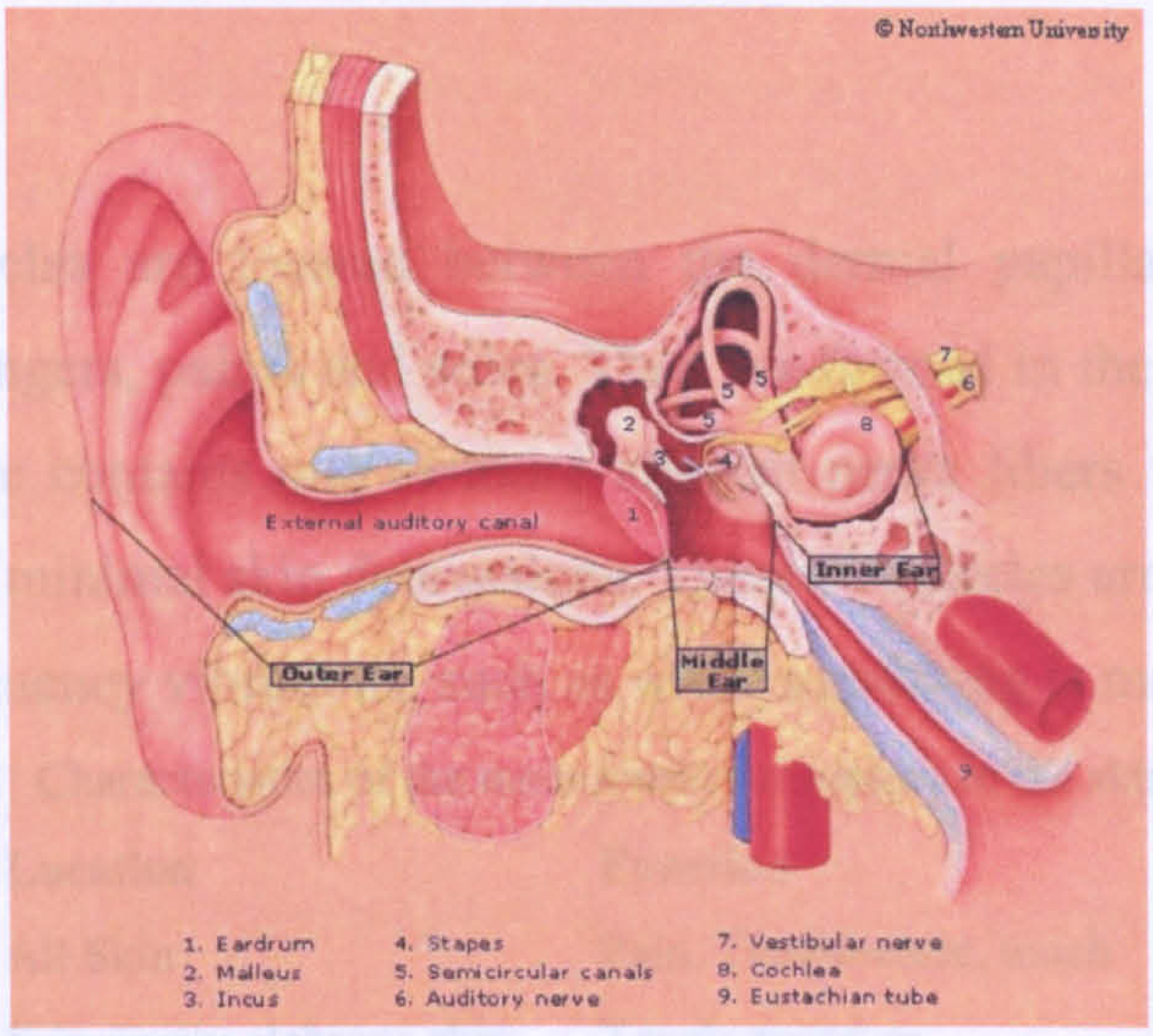


Figure 2.2: Human Ear Diagram [DAL86]

The temporal lobe is mainly responsible for organisation of sensory inputs, thus this is where the hearing signals are processed [REA81]. The temporal lobe's functions are not limited with hearing signal processing, since it is also responsible for perception, comprehension, naming, verbal memory and other language functions [KOL90].

2.2.3 The Human Tactile System

There are four main types of receptors responsible to provide information to the central nervous system about touch, pressure, vibration and tension (Table 1.1): Meissner's corpuscles, Pacinian corpuscles, Merkel's disks and Ruffini's corpuscles (Figure 2.3).

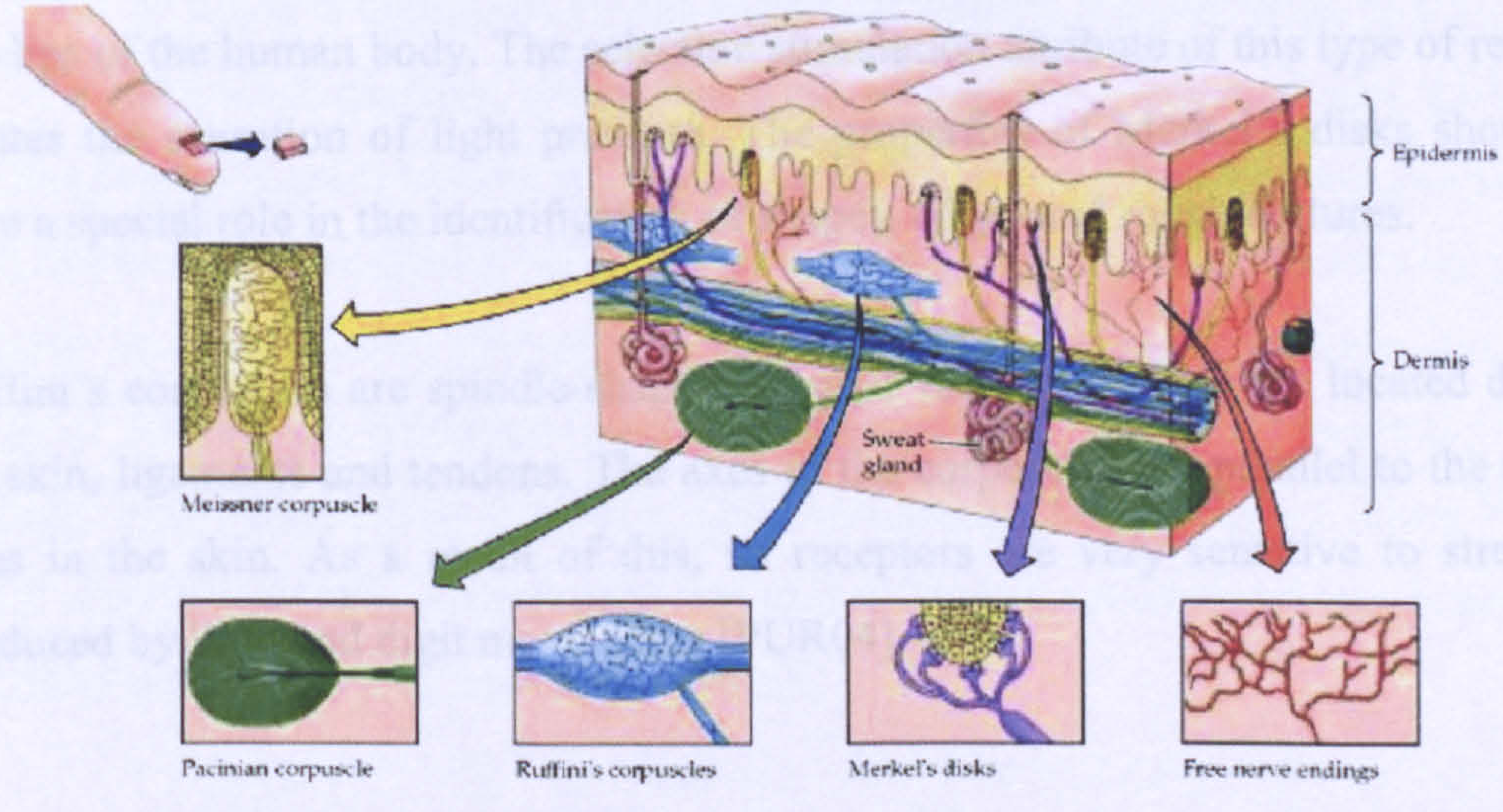


Figure 2.3: Human Skin Structure [PUR04]

Even a weak mechanical stimulation of the skin makes them produce action potentials and that is why they are known as low-threshold (or high-sensitivity) mechanoreceptors.

Meissner's corpuscles are located between the dermal papillae just beneath the epidermis of the fingers, palms and soles. They are formed in the shape of a capsule, which in the centre contains one or more afferent nerve fibers that generate action potentials even for minimal skin depressions. These corpuscles are especially efficient in sensing low frequency vibrations, such as when something is moved over the skin.

Table 2.1: Characteristics of the main sensory receptors in the skin [PUR04]

Receptor	Location	Function	Adaptation	Threshold
Free Nerve Endings	All Skin	Pain, Temperature, touch	Slow	High
Meissner's corpuscle	Principally glabrous skin	Touch, pressure	Rapid	Low
Pacinian corpuscles	Subcutaneous tissue	Pressure, vibration	Rapid	Low
Merkel's disks	All skin, hair follicles	Touch, pressure	Slow	Low
Ruffini's corpuscles	All skin	Stretching of skin	Slow	Low

Pacinian corpuscles are large onion-like encapsulated endings, which are located at the deeper dermis. Its capsule, which acts as a filter for disturbances at high frequencies, contains one or more rapidly adapting axons. Pacinian corpuscles make up 10-15% of the receptors in hand and induce a sensation of vibration and tickle in humans [PUR04].

Merkel's disks are in the epidermis and precisely aligned with the papillae under the dermal ridges. These types of receptors are particularly dense in the hands, fingertips and lips of the human body. The selective stimulation attribute of this type of receptor creates the sensation of light pressure. The properties of Merkel's disks show that have a special role in the identification of shapes, edges and rough textures.

Ruffini's corpuscles are spindle-shaped capsular receptors which are located deep in the skin, ligaments and tendons. The axes of the corpuscles are parallel to the stretch lines in the skin. As a result of this, its receptors are very sensitive to stretching produced by limb and digit movements [PUR04].

2.2.4 The Human Olfactory System

Using the sense of smell, we sample our environment for information. We are continuously testing the quality of the air we breathe (smoke or chemical gases), as well as using this sense to inform us of other relevant information, such as the presence of food or another individual. The humans use these means to identify potential danger (from spoiled food, chemical gases and fires), mates and predators, and sensual pleasure (the odour of flower or perfume) [LEF02]. Odours, smells, fragrances, perfumes, also play an important part in modern life. Some common everyday olfactory experiences are: one's favourite toiletries, the distaste of the motorway or underground, the attraction of the bakery on the high street [TRO01]. Accordingly, Sell [PYB99] commented that smell is a perception and cannot be measured objectively.

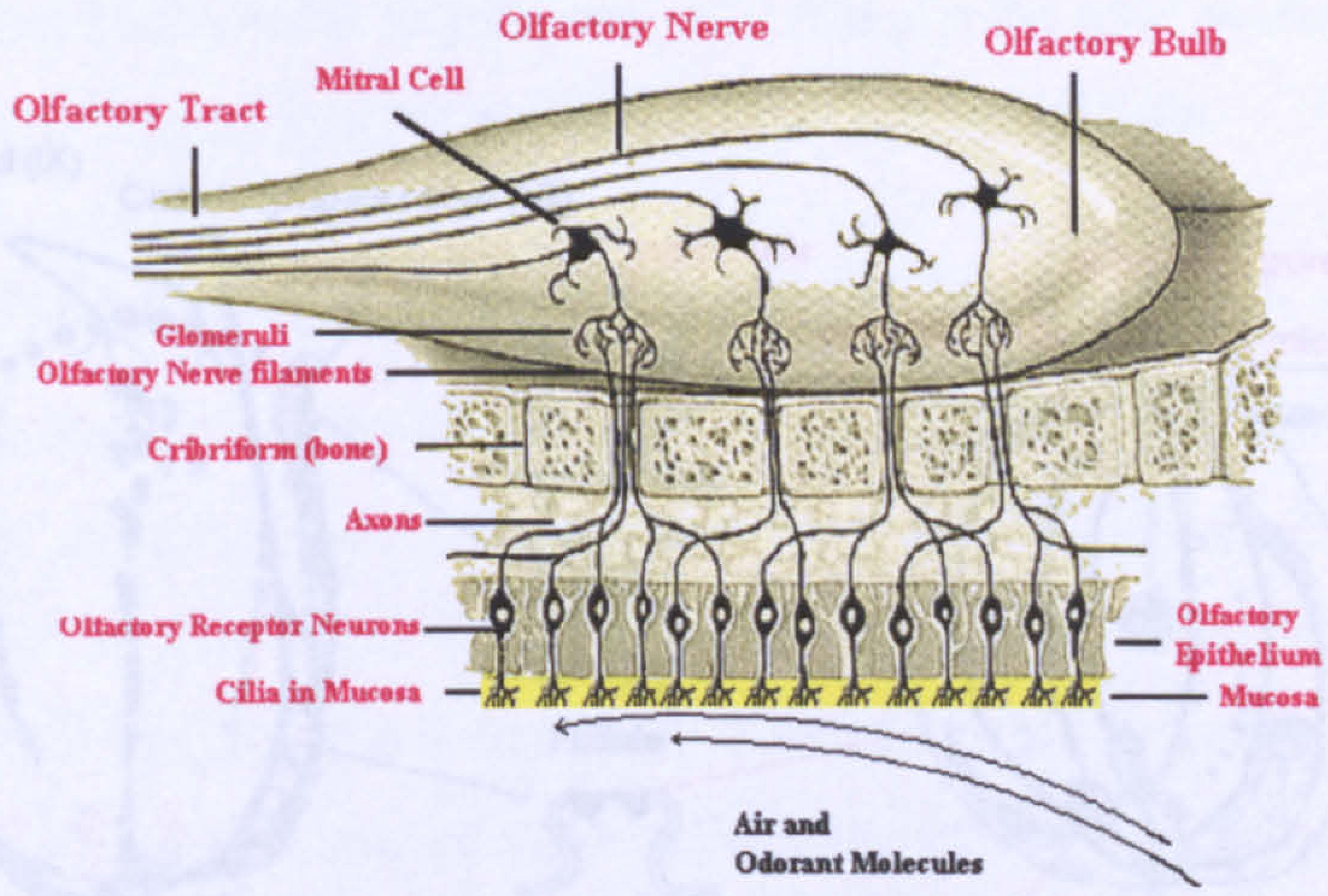


Figure 2.4: Human Olfactory System [LEF02]

The sense of smell is facilitated by the aid of 50 million receptor cells in a 2,5 cm^2 area of human nasal passage, which is called the olfactory region (Figure 2.4). The olfactory region is made of cilia projecting down out of the olfactory epithelium into a 60μm thick layer of mucous, which helps the transfer of odorant molecules to the receptive neurons. Above the olfactory epithelium, neuronal cells form axons in groups of 10-100 and penetrate cribriform plate of bone, eventually reaching to the olfactory bulb. Transferred messages are sent directly to the higher levels of the central nervous system in the corticomedial amygdala portion of the brain, via olfactory track, where it is processed [LEF02].

2.2.5 The Human Taste System

Taste is one of the most fundamental and common sense in humans. It can be summarised as the ability to respond to dissolved molecules and ions using taste receptor cells, which are clustered in *taste buds* (Figure 2.5). An average human tongue contains about 10,000 taste buds on the upper surface of the tongue. Taste buds are made of 50-100 taste cells grouped in an onion-like shape. Each of the tastes buds has a finger-like projection called *microvilli* that poke through an opening at the top of the taste bud called *taste pore*. The chemicals from food dissolve in saliva and contact the taste cells though the taste pore. There they interact either with proteins on the surfaces of the cells known as taste receptors or with pore-like proteins called ion channels. These interactions cause electrical changes in the taste cells that trigger them to send chemical signals that ultimately result in impulses to the brain [JAC03] [SMI01].

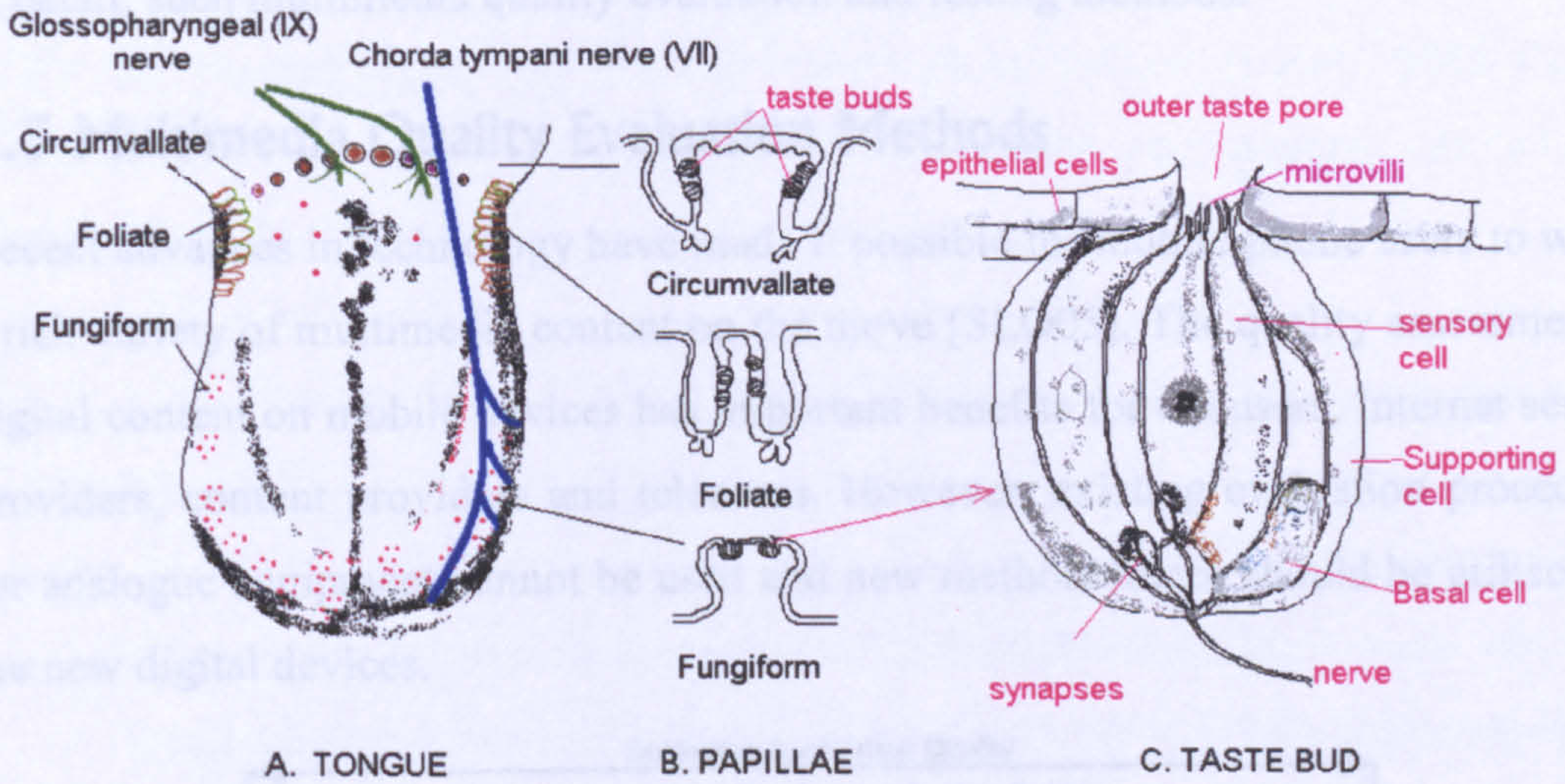


Figure 2.5: The structure of human tongue [JAC03]

The majority of taste buds on the tongue sit on raised protrusions of the tongue surface called papillae. Taste papillae can be seen on the tongue as little red dots, or raised bumps, particularly at the front of the tongue. On the human tongue, there are mainly four types of papillae [JAC03]:

Fungiform papillae - these types are slightly mushroom-shaped and mostly appear at the apex (tip) of the tongue. On average a human tongue contains 200 fungiform papillae.

Filiform papillae - these papillae are mechanical and not involved in gestation and do not contain taste buds.

Foliate papillae - these are predominantly sensitive to sour tastes and their numbers on average are around 5.4 foliate papillae on each side of the posterior part of the tongue.

Circumvallate papillae - these papillae are situated in the most posterior part of the tongue as two rows of structures forming an upside down "V", with pointing toward the throat and confer sour/bitter sensitivity.

So far, we have described the five human senses, all of them directly linked with human perception building. These are of particular importance to the central theme of our study, the user experience of mobile computing, since they are inextricably linked to the user experience of information access. As this information is accessed in practice through multimedia content, the next issue that naturally arises is how to measure this user multimedia experience; accordingly the next section will describe, in detail, such multimedia quality evaluation and testing methods.

2.3 Multimedia Quality Evaluation Methods

Recent advances in technology have made it possible for mobile phone users to watch a rich variety of multimedia content on the move [SLO05]. The quality assessment of digital content on mobile devices has important benefits for the users, Internet service providers, content providers and telecoms. However, existing evaluation procedures for analogue equipment cannot be used and new methodologies should be utilised for the new digital devices.

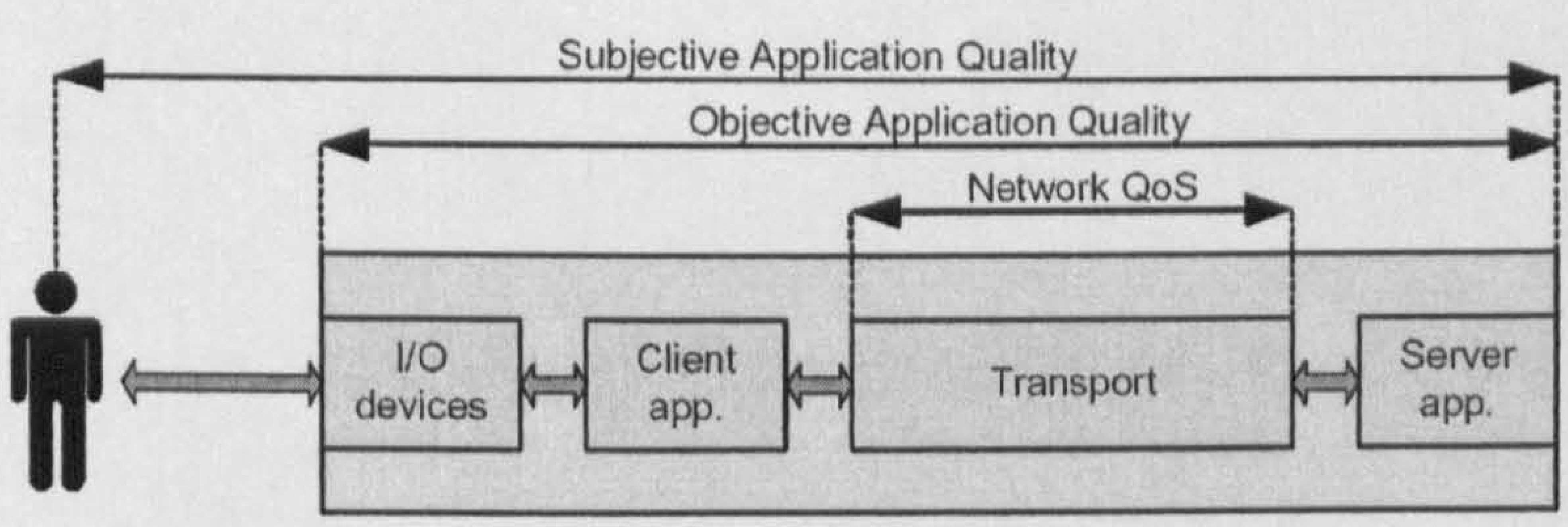


Figure.2.6: Scopes of Quality [SUT05]

There are two different quality assessment methods: *subjective* (which includes humans viewers), and *objective* (via appropriately defined quality metrics of the relevant component – see Figure 2.6). Unstructured subjective methods have the advantage of providing an abundance of information, but they have to be analysed extensively. Structured methods such as questionnaires and checklists can provide very concise and useful information very effectively. On the other hand, objective methods produce highly reliable information with a limited room for interpretation. In the following section we describe these two methods in further detail [MUL01].

2.3.1 Subjective Testing

Multimedia applications, mobile or not, are produced for the enjoyment and/or education of human viewers, so it is their opinion of the presentation quality is important. Although, for instance, there are a variety of objective evaluation methods available today for multimedia quality, there are impairments that are not easily measured but yet visible to the human eye. This is why subjective quality assessment forms the point of reference for quality definition.

2.3.1.1 Single Stimulus Methods

Single Stimulus (SS) Methods are ones in which multiple separate scenes are shown. There are two approaches: SS with no repetition of test scenes and SSMR (Single Stimulus with Multiple Repetition), where the test scenes are repeated multiple times. Commonly used scales are:

1. *Quality Scale* - This is a five point category scale where subjects assess the quality of the material giving scores from 5 to 1 corresponding to excellent, good, fair, poor, and bad, respectively. It is recommended by the International Telecommunications Union for appraisal of both audio (the ITU-T recommendations [ITUT8]) and video quality (the ITU-R recommendations [ITUR5]).
2. *Adjectival* (or *impairment*) *Scale* - Here, scoring is on an overall impression scale of impairment: imperceptible, perceptible but not annoying, slightly annoying, annoying, and very annoying. Half-grades may be allowed, however. Where tests involve only audio, rating can also be done on a listening effort scale where the graded might range from 'complete relaxation: no effort required' to 'no meaning understood without any feasible effort'
3. *Binary Scale* - in some cases, a binary scale might be used, where the subject answers 'yes' or 'no'. For instance, after grading an application using the quality scale, users might be asked whether or not they had any difficulty using it.

4. *Numerical Scale* - This is a 7- or 11-grade numerical scale, useful if a reference is not available.

5. *Non-categorical scale* - a continuous scale with no numbers or a large range, e.g. 0 - 100.

2.3.1.2 Double Stimulus Methods

Here, viewers are shown both test material as well as material depicting reference conditions. The main types of scales used are:

1. *Double Stimulus Impairment Scale* (DSIS) - Observers are shown multiple (reference-scene, degraded scene) pairs. The reference scene is always first. Scoring itself is made using the impairment scale.

2. *Double Stimulus Continuous Quality Scale* (DSCQS) - Here observers are shown multiple scene pairs, with the reference and degraded scenes randomly first. The user is not told which of the two is the original. S/he is then asked to rate the quality of the two by drawing a mark on a continuous quality scale that ranges from excellent to bad. Each scene of the pair is separately rated but in reference to the other scene in the pair. Analysis is based on the difference in rating for each pair rather than the absolute values.

3. *Stimulus Comparison Method* - is usually accomplished with two well-matched monitors but may be done with one. The differences between scene pairs are scored in one of two ways:

- Adjectival - a 7-grade, +3 to -3 scale labelled: much better, better, slightly better, the same, slightly worse, worse, and much worse.
- Non-categorical - a continuous scale with no numbers or a relation-number either in absolute terms or related to a standard pair.

2.3.2 Objective Testing

Information, which is registered without any bias in its process, is considered to be objective in nature [MUL01]. Using objective testing methods, certain system-based measures can be recorded automatically by the system in question, thus they are repeatable and can be estimated independently of the underlying transmission system and encoding process. Therefore objective testing offers standardised and relatively easily comparable results.

2.3.2.1 Signal to Noise Ratio

The signal to noise ratio is an engineering term for the power ratio between a signal (meaningful information) and the background noise. Even though it is not directly related to human perception, it is the most commonly used measure for quality assessment in engineering circles.

$$\mathrm{SNR(dB)} = 10\log_{10}\left(\frac{P_{\mathrm{signal}}}{P_{\mathrm{noise}}}\right) = 20\log_{10}\left(\frac{A_{\mathrm{signal}}}{A_{\mathrm{noise}}}\right) \quad (1)$$

The SNR is expressed as 20 times the logarithm of the amplitude ratio or 10 times the logarithm of the power ratio. A low noise signal has a high SNR, while a high noise signal has a low SNR. The metric is usually expressed in dB and in terms of peak values for impulse noise and root-mean-square values for random noise. If peak values are used for the magnitude of the amplitude of the signal then the metric becomes the *Peak Signal-to-Noise-Ratio (PSNR).*

2.4. User Perception of Multimedia Quality

Having introduced multimedia quality evaluation methods, we now review the existing work on the perceptual impact of varying multimedia quality of service. Multimedia perception is of direct relevance to our work since given the proliferation of multimedia content access from mobile devices it is an integral component of the user experience of mobile computing. Moreover, given the noisy and bandwidth limited nature of mobile communications, QoS factors are very likely to affect the transmission of multimedia content. Thus, it is essential that we review previous work which has examined the perceptual impact of multimedia quality, when multimedia has been affected by degradation and fluctuation in the delivered QoS.

2.4.1. Media Synchronisation Perception

Media synchronisation refers to the temporal relationship between two or more kinds of media or separate data streams. In a multimedia context this definition can be extended such that synchronisation in multimedia systems comprises content, spatial and temporal relations between media objects.

The most comprehensive results on the perceptual impact of synchronisation skews between media were reported in [BLA96; STE96]. Firstly, we shall take a look at the synchronisation between the audio and video streams when a human speaks, also known as *lip synchronisation.*

In the lip synchronisation experiment [STE96], test subjects viewed 30-second clips of a speaker in a TV news environment featured in head, shoulder and body shots. Such shots enabled the viewers not to be disturbed by background information and to concentrate their attention on the gesture, eyes and lip movement of the speaker. Moreover, the fact that the test scenes had high temporal redundancy made them ideal for transmission at low frame rates, with consequently relatively low bandwidth requirements, characteristic of wireless transmission.

Skews were artificially introduced between the video and audio streams of the clip and were shown to the viewers, together with the original recording. Users who did notice something wrong with the synchronisation were asked to quantify their level of annoyance on a 3-point scale ('acceptable', 'annoying', 'not sure if acceptable or annoying'). The main result obtained was that the dependency between perceived quality and lip synchronisation skew displayed a U-shaped characteristic, whereby between –80ms and +80ms lip synchronisation was deemed acceptable by most of the test subjects, with very few saying that if there was an error it affected the quality of presentation. Indeed, sometimes, some 'out of sync' clips were classified as being 'in sync'. Out of these bounds, however, synchronisation skew was increasingly detected and perceived as annoying, with the 'out of sync' portion comprising skews beyond –160ms and 160ms. At such skews, the annoyance that users felt with presentations often had adverse effects, such as users becoming distracted by the 'out of sync' effect and not focusing on the content of the clip. In the 'transient' region of the characteristic, an interesting result that surfaced was that audio behind video could be tolerated much better than the opposite case. Moreover, the closer the speaker and the better the resolution were, the easier it was for users to detect the synchronisation errors and the more likely for them to be described as disturbing.

A comparison using languages other than English (the language of the news-cast) revealed no difference in the results. Similarly, there were no variations between people with different habits regarding the amount of TV and films watched. Lastly, no difference was detected between the same person speaking in a fast, normal, or slow manner.

Synchronisation between *audio and animation* is also of potential importance to mobile multimedia applications, as can be exemplified by audio commentary of an animated representation of a product of interest to the user. Here, the perceptual tolerance limits identified were not as stringent as those in lip synchronisation, with a skew of ±80ms being tolerable.

A slide show is the most obvious combination of *audio and images*. In this case, a skew of around 1s, equivalent to the time required to advance the projector, is tolerable. Synchronisation of audio with text, also known as audio annotation, was found to have a permissible skew closely related to the pronunciation duration of short words, which is about 500ms, leading to an experimentally verified skew of 240ms.

As far as synchronisation between video and text or video and images is concerned, two cases can be distinguished. In the overlay mode, the image or text offers additional information to the displayed video sequence, as is the practice of having subtitles placed close to the topic of discussion in a multimedia video. Irrespective of video content, a skew of around 240ms has been shown to be sufficient in this case. When *no overlay* occurs, skew is less serious. In this case, one could imagine a drawing detailing assembly instructions of a product being displayed on a PDA together with a low frame rate video detailing the product's appearance when assembled. Here, a synchronisation of around 500ms between the video and image or the video and text is deemed sufficient, which is half the value of the roughly 1s required for human perception of simple images.

2.4.2. Frame Rate Perception

The first recorded work on human perception of different frame rates was done by Apeteker et al. [APT95]. They coined the term 'human receptivity' to mean not only just how the human user perceives multimedia video shown at diverse frame rates, but also more distinct aspects of a user's acceptance of a video message. These include clarity and acceptability of audio signals, continuity of visual messages, lip synchronisation during speech, and the general relationship between visual and auditory message components.

Human receptivity is expressed as a percentage measure, with 100% indicating complete user satisfaction with the multimedia data. The authors derived a set of categories of data resulting from a common Video Classification Scheme (VCS). These VCS curves were obtained on the basis of the temporal nature of the data (i.e. its dynamic nature) as well as the importance of the auditory and visual components of the video message. Various video clips were thus classified into eight main categories. A video from each of the eight categories was shown to users in a windowed multitasking environment. Each multimedia video clip in turn was presented at three different frame rates (15, 10, and 5 fps), in a randomised order. The end-users in these experiments had, however, no knowledge of the particular frame rate at which they were watching the video. The users rated the quality of the multimedia videos on a 7-point scale. A total of 60 people were tested for the 24 types of clips.

The most relevant result to come out of their work was that the dependency between human receptivity and the required bandwidth of multimedia clips is non-linear. Consequently, for certain ranges of human receptivity, a small variation of it leads to a much larger relative variation of the required bandwidth – a feature referred to as the asymptotic property of the VCS curves.

Related work has been done by Fukuda et al. [FUK97]. They take 4 video sequences and encode them using the MPEG-2 algorithm. They focus on three main QoS parameters:

1. The spatial resolution – 640*480, 320*240 and 160*120 pixels
2. The Signal to Noise Ratio – this is affected by the value of the quantiser used in the MPEG-2 algorithm. The quantiser is applied in the encoding algorithm to each block 16*16 pixels large; if a large quantiser is

applied the quality of the decoded block becomes poorer, which in turn leads to a lower SNR value.

3. The number of frames per second – 10 and 30 fps.

The authors then go on to show that, in the case of the 4 MPEG-2 clips considered, there is a common mapping between these parameters and the required bandwidth, independent of video content. Through tests involving only 5 participants, the authors then gauge the human perception of the 4 clips in order to map users' preference onto bandwidth.

Each user gave a score ranging from 1 (Poor) to 5 (Excellent) to the video sequences; based on these ratings the overall video quality of each video is given by a *Mean Opinion Score* (MOS). Finally, based on the MOS vs. bandwidth curves thus obtained and their deduced mapping, the authors propose a QoS management mechanism which delivers a high perceptual score in spite of bandwidth constraints.

2.4.3. Media Loss Perception

In contrast to earlier work done by Apteker and Steinmetz which assumed that the underlying network communication system provided lossless multimedia streams, Wijesekera et al. have carried out a series of experiments which evaluate user perception in the presence of media losses[WIJ96; WIJ99]. Their work is of particular importance bearing in mind the noisy, bandwidth-constrained environment characteristic of mobile communications, and the QoS handoff issues which arise in this context.

One of their initial results was that missing a few media units will not be negatively perceived by a user, as long as too many such units are not missed consecutively and that this occurrence is infrequent. They also found out that media streams could drift in and out of synchronisation without considerable human annoyance.

Their study also explored human tolerance of transient continuity and synchronisation losses with respect to audio and video. Media loss was of two types in their study:

Consecutive - this refers to the maximal number of consecutive media data units (e.g. frames or audio packets) the loss of which could be tolerated

Aggregate - here, the number of consecutive media units loss was kept fixed, but was replicated at random intervals during the multimedia presentation

Rate variation was a parameter which was also explored in their experiments. This refers to the ideal rate of a media flow and the maximum permissible deviation from it and was examined both from an intra-stream as well as from an inter-stream point of view.

Only two video clips of 30s duration were used in their experiments. Both of them featured bust views of a speaker (different in each of the clips) explaining didactic and academic related matters. Users were asked to give their opinions on a 10-point Likert scale (where 1 was poor, while 10 was excellent). Similar to [STE96], participants were also asked to categorise each clip as 'Do not mind the effect if there is one', 'I dislike it and it's annoying', and 'I'm not sure'. Their main results can be summarised by the following points [WIJ99]:

- The pattern of user sensitivity varies depending on the type of media defect.
- Viewer discontent for aggregate video losses increases gradually with the amount of losses, while for other types of losses and synchronisation defects there is an initial sharp rise in viewer annoyance which afterwards plateaus out.
- Video rate variations are tolerated much better than rate variations in audio.
- Because of the bursty nature of human speech (i.e. talk periods interspersed with intervals of silence), audio loss in this case is tolerated quite well by humans as it results merely in silence elimination (21% audio loss did not provoke user discontent).

2.4.4. Quality of Perception

A different approach to evaluating the perceptual impact of varying QoS was adopted in [GHP00]. Recognising multimedia's infotainment duality, the authors proposed to enhance the traditional view of QoS with a user-level defined Quality of Perception

(QoP). This is a measure which encompasses not only a user's satisfaction with multimedia content, but also his/her ability to perceive, synthesise and analyse the informational content of such presentations. The author subsequently investigated the interaction between QoP and QoS and its implications from both a user perspective as well as from a networking angle.

The approach to evaluating QoP was mainly empirical, as is dictated by the fact that its primary focus is on the human-side of multimedia computing. Users from diverse backgrounds and ages (12-58 years old) were presented with a set of 12 short (30 - 45 seconds' duration) multimedia clips. As detailed in Table 2.2, these were chosen to be as varied as possible, ranging from a relatively static news clip to a highly dynamic rugby football sequence. All of them depicted excerpts from real world programmes and thus represent informational sources which an average user might encounter in everyday life. Each clip, selected snapshots of which are given in Figure 2.7, was shown with the same set of QoS parameters, unknown to the user. After each clip, the user was asked a series of questions (ranging from 10 to 12) based on what had just been seen and the experimenter duly noted the answers. Lastly, the user was asked to rate the quality of the clip that had just been seen on a scale of 1 - 6 (with scores of 1 and 6 representing the worst and, respectively, best perceived qualities possible).

Table 2.2: Video categories used in QoP experiments

VIDEO CATEGORY
1 - Action Movie
2 - Animated Movie
3 - Band
4 - Chorus
5 - Commercial
6 - Cooking
7 - Documentary
8 - News
9 - Pop Music
10 – Rugby
11 – Snooker
12 - Weather Forecast

Because of the relative importance of the audio stream in a multimedia presentation [BLA96] as well as the fact that it takes up an extremely low amount of bandwidth compared to the video it was decided to transmit audio at full quality during the experiments. Parameters were, however, varied in the case of the video stream. These include both spatial parameters (such as colour depth) and temporal parameters (frame rate). Accordingly, two different colour depths were considered (8 and 24-bit), together with 3 different frame rates (5, 15 and 25 frames per second - fps). A total of 12 users were tested for each (frame_rate, colour_depth) pair.

Figure 2.7: Snapshots of video clips used in QoP experiments [GHP00]

In summary, the results obtained in the QoP experiments showed that [GHP00]:

- A significant loss of frames (that is, reducing the frame rate) does not proportionally reduce the user's understanding and perception of the presentation. In fact, in some instances s/he seemed to assimilate more information, thereby resulting in more correct answers to questions. This is because the user has more time to view a frame before the frame changes (at 25 fps, a frame is visible for only 0.04 sec, whereas at 5 fps a frame is visible for 0.2 sec), hence absorbing more information. This observation has implications on resource allocation.
- User assimilation of the informational content of clips is characterised by the wys<>wyg (what you see is not what you get) relation. What this means is that often users, whilst still absorbing information correctly, do not notice obvious cues in the clip. Instead the reasoning process by which they arrive at their conclusions is based a lot on intuition and past experience.
- Users have difficulty in absorbing audio, visual and textual information concurrently. Users tend to focus on one of these media at any one moment, although they may switch between the different media. This implies that

critical and important messages in a multimedia presentation should be delivered in only one type of medium, or, if delivered concurrently, should be done so with maximal possible quality.

- The link between perception and understanding is a complex one; when the cause of the annoyance is visible (such as lip synchronisation), users will disregard it and focus on the audio message if that is considered to be contextually important.
- Highly dynamic scenes, although expensive in resources, have a negative impact on user understanding and information assimilation. Questions in this category obtained the least number of correct answers. However the entertainment value of such presentations seems to be consistent, irrespective of the frame rate at which they are shown. The link between entertainment and content understanding is therefore not direct and this was further confirmed by the second observation above.

All these results indicate that Quality of Service, typically specified in technical terms such as end-to-end delay, must also be specified in terms of perception, understanding and absorption of content - Quality of Perception in short - if multimedia presentations are to be truly effective.

The notion of quality in computing is intimately related to that of the user experience. Having so far reviewed quality evaluation methods and work pertaining to quality of user multimedia perception, we are now in a position to describe research revolving around the user mobile computing experience – the central theme of this dissertation.

2.5. The User Mobile Computing Experience

2.5.1. Initial Experiences

An integral part of the human-computer interaction is represented by the initial user contact and experiences with the computers – the Out-Of-Box Experience (OOBE) – which is of a great strategic and marketing importance. The initial experience affects one of the potentially most difficult and stressful interactions a user will have with the product, when the user knows the least about the product's capabilities and interaction style. Hence the OOBE is defined as:

> *"The interactions and first impressions a user has with technology when first opening the box it comes in and installing it, as opposed to the point-of-sale experience or the interaction experience of an expert user."* [USA05]

Accordingly, the importance of the OOBE has been acknowledged as such by most major players in the industry, through studying it within the context of in-house research groups [IBMa04] or cross-company consortia [EOU00], and by endeavouring to ensure that products are shipped with the capability and know-how that will enhance the user's/buyer's OOBE [THU00].

The challenges faced by designers of the OOBE are numerous: these range from ensuring a consistent initial user experience across a range of possibly interconnected/interdependent devices [FOU00], to establishing the essential components of the OOBE [MCM01], and indeed, towards formulating a generic approach for the OOBE design itself [BRO02; IBMa04; IBMb04].

Table 2.3: Main causes of ease of use dissatisfaction [EoU00].

Area of Dissatisfaction	Main Cause of Dissatisfaction
Boot /Reboot	Users perceive they have to reboot too frequently and booting takes too long.
Communications	Users have trouble accessing and using the internet.
Environment	Users perceive PC performance and reliability can degrade over time.
Failure Detection	Users perceive hardware and software fail too often, and failures are difficult to diagnose.
Install/Uninstall	Users often feel it is difficult to install and uninstall hardware and software.
Interoperability/Compatibility	As users add applications and hardware, applications and hardware sometimes do not work very well.
OOBE (Out of Box Experience)	Many users are dissatisfied with how long it takes, and how difficult it is, to set up and use the PC for the first time.
User Task Assistance	Users cannot always determine how to do what they want to do on the computer.

The importance of the OOBE has also been highlighted in a study [EoU00], which examined core areas of user dissatisfaction, based on data gathered from usability tests, technical support centre calls, and user research from 26 companies, including major industry players such as Intel, Microsoft, IBM, Dell, Siemens and Hitachi.

According to the findings of the report, there were eight main causes behind user dissatisfaction (Table 2.3), with OOBE being the only non-technical one.

Further examination of user experiences [EOU00] showed that the most frequent causes for discontent with the OOBE were:

- PC initial setup time;
- Too many physical cables (connectors, adaptors);
- An overwhelming amount of documentation, and
- Confusing content of user manuals

As a result of the dissatisfactions due to the initial experiences with electronic devices, the researchers in this field have looked into various ways of measuring and evaluating the user OOBE.

In late 1998, usability researchers and leading technology companies collaborated to develop a means to help identify the initial usability problems and predict the OOBE of the user. Accordingly, they designed the Initial Experience Prediction checklist, which was designed as a tool to help and improve end user's initial experience with consumer desktop PCs [INT99]. The contents of this questionnaire-style tool was created by combining the newly designed questions, of the researchers, with the already existing literature from National Institute of Standards and Technology, Intel guidelines and QUIS (Questionnaire for User Interaction Satisfaction).

After a few pilot studies and refinements, the evaluation of the newly developed tool showed that it had achieved its goals. The validation of the project aim was made based on three criteria [INT99]:

- *Reliable* – result scores for a given system remain constant even among different evaluators.
- *Predictive* – valid in predicting the end-user experience, meaning that scores for a given system correlate highly with performance measure in usability testing for the same system with novice users.

- *Economical* – using the tool adds no more than 30 minutes to the process of setting up a new PC system.

In related work, IBM Research has also concentrated on user initial experiences and proposed methods for the design, evaluation and testing of the OOBE. According to their work, differences in design approaches and characteristics may be dictated for different categories of users and various usage environments. User categories, based on skill and experience, should be considered important influences in the design of an OOBE. Based on their studies, proposed user categories are: novice, occasional and experienced. Accordingly, the user's initial interaction environment is an important factor and should be divided into three subcategories, namely individual/family, small business and enterprise. The work suggests that based on the demographic information mentioned above, the OOBE evaluation should consider 8 key elements [IBMa04]:

- *Packaging*: Assessment of the user's quality perception on the first encounter with the product.
- *Unpacking*: Efficiency of unpacking experience evaluation
- *Setup*: Ease of hardware setup and arrangement evaluation
- *Power on*: Evaluation of the immediate feedback provided by the product
- *Configuration*: Ease of product personalisation evaluation
- *Initial use*: Assessment of product feature and capability
- *Doing work*: Easy of doing meaningful tasks evaluation
- *Assistance*: Ease of using digital troubleshooting and FAQ evaluation

Lastly, OOBE research is ongoing and currently examining the experience impact of mobile and wireless devices. Findings with wireless devices show that the setup of such equipment requires that the user is familiar with networking and computer hardware, and, because of this, it is frequently an intimidating and frustrating process for most users [EOU02]. Moreover, research has also highlighted that the notion of a singular, device-specific, OOBE is potentially flawed – the initial user experience increasingly concerns the configuration of more than one device, and the consequent interaction between the different device- and company-specific OOBEs can lead to less than desirable outcomes [FOU00].

2.5.2. Multimedia Access Devices

The user experience of mobile computing is inextricably linked to the devices that are being used to access content. In this section we aim to provide a review of the literature relating to the specific output display devices being considered in our experiments, which allow us to consider the user's mobile information access implications on devices with variable levels of mobility. These devices range from a traditional fixed computer monitor, to a traditional laptop monitor with limited mobility, to a head-mounted display (allowing greater autonomy of movement), through to a personal digital assistant, allowing full personal mobility.

2.5.2.1. Head Mounted Display

Head mounted displays (HMDs) are a sub-set of wearable computer technology, which aim to allow hands free access to computer functionality. The reasons for hands free access to computing devices are often varied, and range from individuals with a restrictive physical disability [GIP96] to individuals working in dangerous or hazardous conditions [XYB03]. Integration of wearable mobile devices with network technology, touch pen, speech recognition inputs, interactive glove or face mounted devices (as in the case of Xybernaut's Mobile Assistant) allow extremely adaptable mobile solutions. Devices such as HMDs have often been considered synonymous with virtual reality development, however, due to falling cost and improved technology, head-mounted displays devices are becoming increasingly available in the retail sector.

It is thus unsurprising that there is an increasing body of research focusing on the use of HMDs. Thus, the Smart Spaces [PAB02] project promises to implement anywhere / anytime automatic customisable, dynamically adaptable collaboration tools. In order to achieve these goals head-mounted displays, smart spaces, augmented reality and ubiquitous information access devices are being used. The main driving force of this research is information access anytime / anywhere, whilst doing something else. Hitachi is also involved in the implementation of wearable Internet appliances targeting both industrial users and consumer users. The aim of the WIA (Wearable

Internet Appliance) project [EBI02] is to provide mobile Internet and resource access using head mounted displays. Industrial users can employ this device to communicate between colleagues as well as access company databases and other centrally stored information (diagrams, equipment explanations) relating to their work. On the other hand, consumers use these devices to remotely access the Internet, even in the most crowded public locations.

2.5.2.2. Personal Digital Assistant

Improvements in technology, especially in wireless networking, have pushed the barriers of anywhere / anytime information access. Portable information access raises the need for portable information access devices, such as communicator devices and personal digital assistants, which promise to supplant the desktop computer as ubiquitous technology on campuses and in business [WEI98].

Personal digital assistants represent a new technology that is still evolving and, as mobile devices, inherit many of their problems related to distributed systems and mobile computing [SAT01]. Distributed system problems include:

- Remote tolerance, such as protocol layering, the use of timeouts, remote procedure calls [BIR84].
- Fault tolerance, such as atomic transactions, distributed nested transactions [GRA93].
- Remote Information access, such as caching, distributed file systems and databases [SAT89].
- Security, related encryption-such as mutual authentication and privacy [NEE78].

In addition to the problems of distributed systems, personal digital assistants also suffer from issues relating to mobile computing devices [SAT01]. These include:

- Mobile networking, such as mobile IP [BHA96], ad hoc protocols [ROY99].
- Mobile information access, such as disconnected operation [KIS92].
- Support for adaptive applications, such as transcoding by proxies [FOX96].

- Location sensitivity, such as location sensing and location-aware system behaviour [WAR97]
- Navigation difficulty, since research has shown that users with small screens tend to follow hyper-links less frequently than users with a larger display unit [JON99].

Personal digital assistants represent, in our experiments, a truly mobile device, allowing the user full mobility of movement whilst viewing multimedia information. Having elaborated on the mobile multimedia information access concept and their issues, we next review the research on mobile information access methods and the tools that have been implemented to enable this on resource-restricted devices.

2.5.3. Mobile Information Access

Improvements in respect of mobile technologies and the affordability of mobile units have made it possible for a large range of clientele to experience mobile information access. Today, according to the figures of National Statistics, 75 percent of adults in the UK own a mobile phone [STA06]. This therefore makes for a huge market for mobile service and content providers, where the estimated multimedia content download value was about £600 million pound sterling in 2005 [ETF05]. Also, if one adds wireless enabled PDAs and smartphones to the scene, with 58.5 million unit sales projected by 2008 [ETF05], the conclusion can only be that the trend for accessing information 'on the go' is here to stay and will experience a dynamic growth in future years.

2.5.3.1. Device Impact

Mobile devices generally are compact with small screens and have relatively limited battery, memory and processing capacity, which is why early research in mobile computing concentrated on enhancing the user's mobile information access experience using various techniques and technologies. However, recent advances in hardware technology have made it possible for researchers to explore new application areas of mobile computing (e.g. patient monitoring system, real-time stock brokering). In the following part, existing research and implementations are detailed.

The Event Horizon User Interface model [TAI99] was proposed to overcome some of the limitations of small screen mobile devices, such as personal digital assistants, by compressing and expanding objects radially farther away or closer to an event horizon in the middle of the screen.

In related work, Kim and Albers [KIM01] explored how the amount of text presented on a PDA affects a person's ability to retrieve information and identified factors which may affect the user's ability access and use the information on a PDA screen. To evaluate the information search burden caused by the PDA size and identify the difference between the normal computer monitor and a small PDA screen, they implemented a questionnaire in conjunction with a set of tasks that require the user to make search on 650-word web page. Contrary to their initial hypothesis that the participants would exhibit more errors when searching for information on the small screen, repeated MANOVA (Multivariate Analysis of the Variance) measures showed that differences between two conditions were not significant. The main experimental hypotheses on participants taking more time when searching, locating information in the middle and end of the web pages rather than in the beginning and locating textual information rather than numerical information on a small screen, were also proven to be wrong.

In a similar study, Jones et al. [JON99] compared the web browsing experience difference between small and traditional computer monitors. The main aim of this study was to quantify the effect of small display space on web-based task completion and to gain qualitative impressions on how reduced displays might affect the ways users approach web-based information retrieval. Participants in this experiment were 20 computing science staff and students, made up of both males and females ages ranging between 18-45. As part of the experiment, participants were divided into two groups, normal screen and small screen users, and asked to complete two sets of tasks on a website. The normal screen experiments were conducted on a browser with its display resolution set to 1074x768 pixels. On the other hand, the small screen device users were asked to complete the tasks on a 640x480 pixels screen resolution to simulate the size of a small display device.

Results showed that the large screen group answered twice as many questions correctly than the small screen group. Also, questionnaire results highlighted that the smaller screen size impedes task performance – 80% of small screen users indicated that they felt screen size impacted on their ability to complete the tasks; this compares with 40% of large screen users.

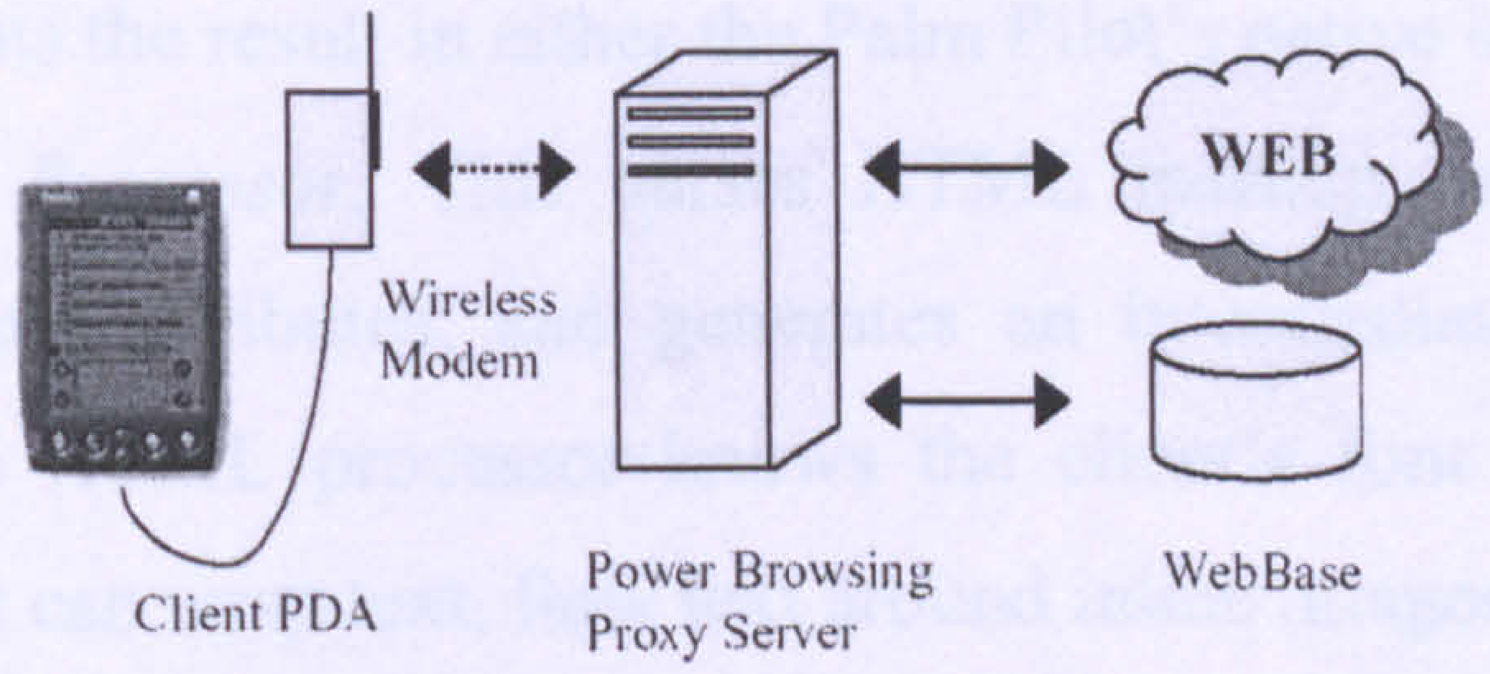


Figure 2.8: The Power Browser Architecture [BUY00]

To enhance the user's web browsing experience on a low bandwidth, small display and slow CPU, Buyukkokten et al. [BUY00] propose the use of *Power Browser*. In this system, there are five main elements, namely the client PDA, Wireless Modem, Power Browsing Proxy Server, WebBase and the web content (Figure 2.8).

The connection between the PDA and the Proxy Server is established through a wireless modem. The server has a wired link to the web, and therefore downloads the pages faster. It processes the data and sends only a small fraction of it to the client at a time. The proxy server uses local tools, such as an HTML parser, and an incremental crawler, which can recursively fetch the linked web pages to the user's current page. The main functionality of the WebBase in this structure is its knowledge base in ranking the web page content and summarising them according to the user's mobile device. To evaluate the system, 10 participants were asked to perform a total of 6 tasks with and without using the Power Browser prototype system. The results showed that the Power Browser system average helped user on average to save 45% of browsing time and 42% of pen action.

For the same purpose, Fox et al. [FOX98] implemented an adaptive middleware proxy which re-formats traditional web pages and their content to improve the user's web browsing experience on a Palm Pilot PDA. The proposed system is structured in a way that all browsing requests sent by the PDAs are relayed to a proxy server, which acts as a gateway to the internet via a fast wired connection. The proxy server itself has the capability of transformation, aggregation, caching and customisation to tailor personalised content based on the user's profile. These functionalities are facilitated using three main units that reside within the proxy server:

- *Image and HTML Processor:* The image processor reads GIF and JPEG images (the two most common Web formats), converts them to an intermediate bitmap form, optionally scales, colour-quantizes and dithers, and finally outputs the result in either the Palm Pilot's native image format.
- *The HTML Processor:* This parses HTML markup, maps HTML tags to supported font attributes, and generates an intermediate-form page layout. Because the HTML processor knows the client's font metrics and display properties, it can wrap text, flow text around inline images.
- *Aggregators:* An aggregator queries one or more Web sites for specific content and collates and formats the results for presentation to the client.
- *Zip, PalmOS, and Doc Support:* If the client fetches a Zip file (a popular format for PalmPilot software archives), the zip processor formats a listing of the archive contents in HTML, such that following the link for a particular archive member will cause the zip processor to return the selected member.

Performance comparison showed that despite the fact the comparative examples were text-only proxies, the proposed system was still faster overall.

In related work, Freire et al. [FRE01] facilitate the user's access of web information, entertainment and e-commerce on the go. The proposed system, called WebViews, is a solution for creating customized views of Web content and services. The main idea is to let end-users easily create and maintain simplified views of Web content and services, from news headlines to bank balances by allowing users to create their own Web views, customised for specific devices. In addition, since these Web views provide a simpler view of sites and services, they are considerably simpler to transcode into other languages (or formats).

There are two main steps involved in creating Web views: retrieving a Web page that contains the desired information, and extracting relevant content from the retrieved page. On a desktop computer, using a browser and the WebViews Recorder applet (Figure 2.9), a user can create a Web view by simply browsing the desired page and selecting on that page the components of interest. After a Web view is created, its content can then be accessed through a WebViews server, using any one of the access devices such as a WAP-enabled phone, Palm PDA or conventional phone.

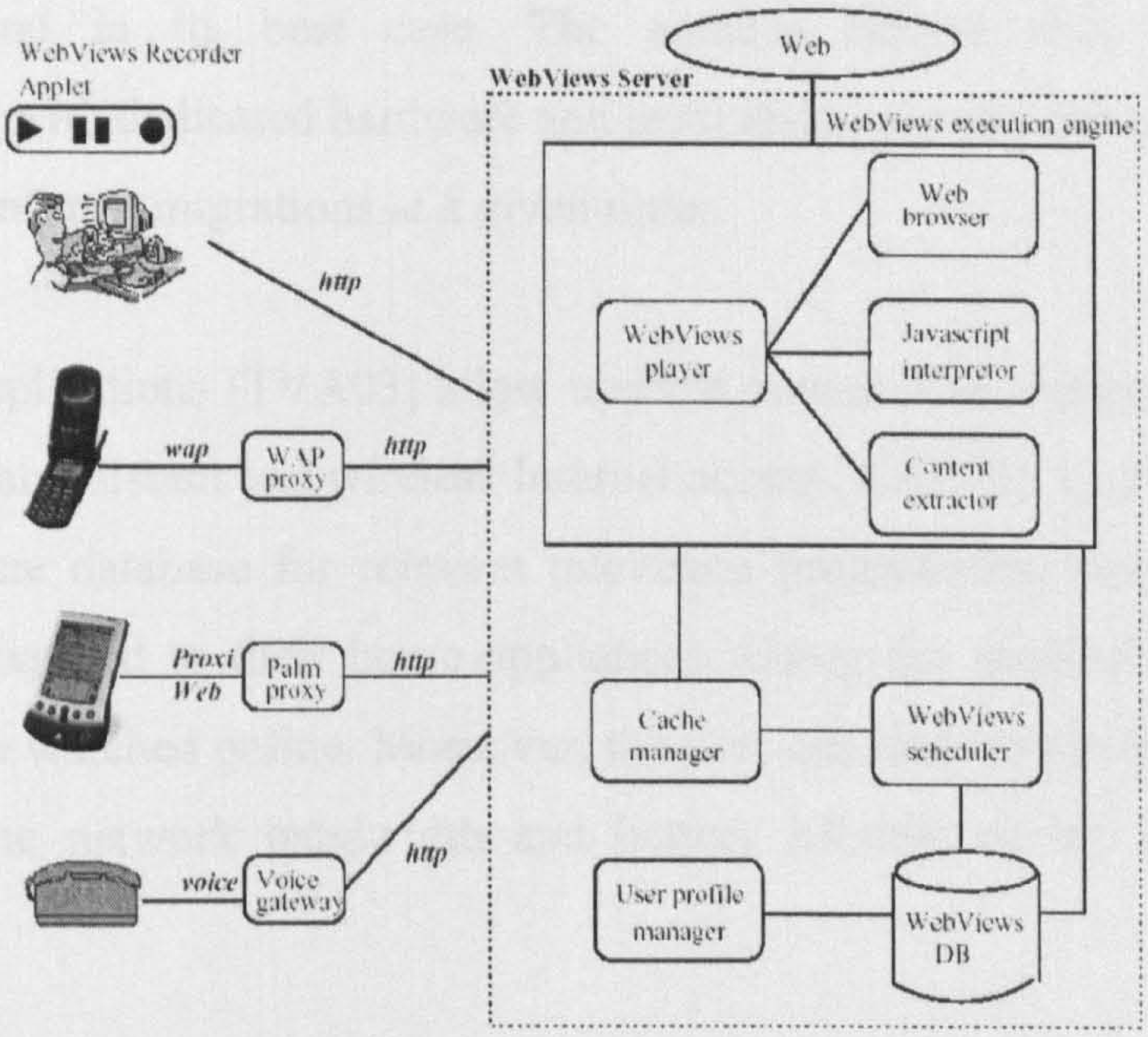


Figure 2.9: WebViews Architecture [FRE01]

Chandrasekaran and Joship [CHA02] in their work address issues related to mobility, personalisation and asynchronous operation to support efficient access to the World Wide Web. As a solution they propose a prototype, called MobileIQ, which performs mobility management at the application layer. In this system the authors aim to exploit the web caching by dynamically migrating the user to the nearest replica web content. Thus, users no longer need to maintain a constant connection to the original source.

MobileIQ is a proxy-based system that aggregates web content on the wired side based on user profiles and provides it to the user when they connect to the proxy. The system has also been designed to offer personalisation and asynchronous operations to support wireless access to the web. MobileIQ builds on proxy analogy to add mobility management features, content pre-fetching and location-based information. Using MobileIQ, a given user, while away from his/her home site, does not have to connect to the home proxy server for personalized services, but can use the closest proxy to him/her without having to create a new profile. Wherever the user might be, his/her profile is replicated and sent to the new foreign proxy server. The system also performs local server discovery, user authentication, profile synchronization, content caching, and geographic location based information retrieval.

The scalability evaluation results of the proposed system showed that the general purpose PCs running the MobileIQ proxy server could handle about 8 user migrations/second in its best case. The authors believe that by tuning the implementation with dedicated hardware and local disks, a proxy can potentially serve a large number of user migrations at a given time.

TV-Anytime applications [TVA03] allow users to access their profiles remotely with a personal digital assistant and wireless Internet access [KAZ03]. Logged in users can search the online database for relevant television programmes, documentaries and movies and download to their home appliances. Using the application, programme previews can be watched online. Moreover, the user can also set the length of the clip according to the network bandwidth and battery lifetime of the personal digital assistant.

Hung and Zhang [HUN03] have utilized the Wireless Application Protocol (WAP) mobile communication protocol to implement a patient monitoring system. This system consists of three main devices: the WAP-enabled mobile phone, WAP gateway and the content server. The WAP phone initially connects to the gateway and sends requests, which then these are converted and sent to the content server. Upon receiving the requests, the content server sends the related data to the gateway, which is then relayed to the end user.

Using this approach, the prototype system provides patient information on the following: ECG Browsing heart rate-estimation; blood pressure browsing; patient record browsing; clinic and hospital information inquiry; and doctors appointment browsing. The implemented system was then emulated for usability and functionality evaluation. The results showed that the response time was too long and the security was loose between the device and the content server. The researchers believed, nonetheless, that all these problems could be resolved using the newer version of WAP specifications on third-generation mobile phones.

2.5.4. Context-Aware Computing

Advances in computing hardware and software technologies are key factors behind the proliferation of mobile computing. However, the initial ideas on mobile technologies and devices came from Mark Weiser, according to whose vision the most profound technologies are the ones that weave themselves into the fabric of everyday life until they are undistinguishable from it [WEI91]. Weiser in his articles identifies two crucially important issues, namely location and communication, which are necessary to initiate the "disappearance" of wired computing and create the conditions necessary for the birth and growth of location and context-aware computing [WAN95, WEI91, WEI93, WEI98].

Context-aware computing, since it was introduced to the information systems and computing field, has had diverse definitions depending on the perspective and circumstances that it was used in. It was first discussed by Schilit et al. [SCH94] and described as software that "*adapts according to the location of use, the collection of nearby people, hosts, and accessible devices, as well as to changes to such things over time*". Similarly, Chen and Kotz [CHE00] see it as a paradigm of mobile computing where applications can discover and take advantage of contextual information (such as user location, time of day, nearby people and devices, and user activity). From a very different perspective, Pascoe [PAS98] defines context as a subset of physical and conceptual states of interest to a particular entity. However, Dey [DEY01] argues that the definitions introduced previously are too specific for the concept of context-aware computing, and proposes new definitions for terms context and the context-aware. Accordingly, context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves. Based on this definition, a system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the tasks in hand.

Following the introduction to the concept of context-aware computing and its definition, some example studies will now be reviewed. One of the earliest was ParcTab [WAN95], which was implemented at the Xerox PARC Research Labs based on the vision of Mark Weiser. The main objectives of this project were:

- to design a mobile hardware device, the PARCTAB, that enables personal communication;

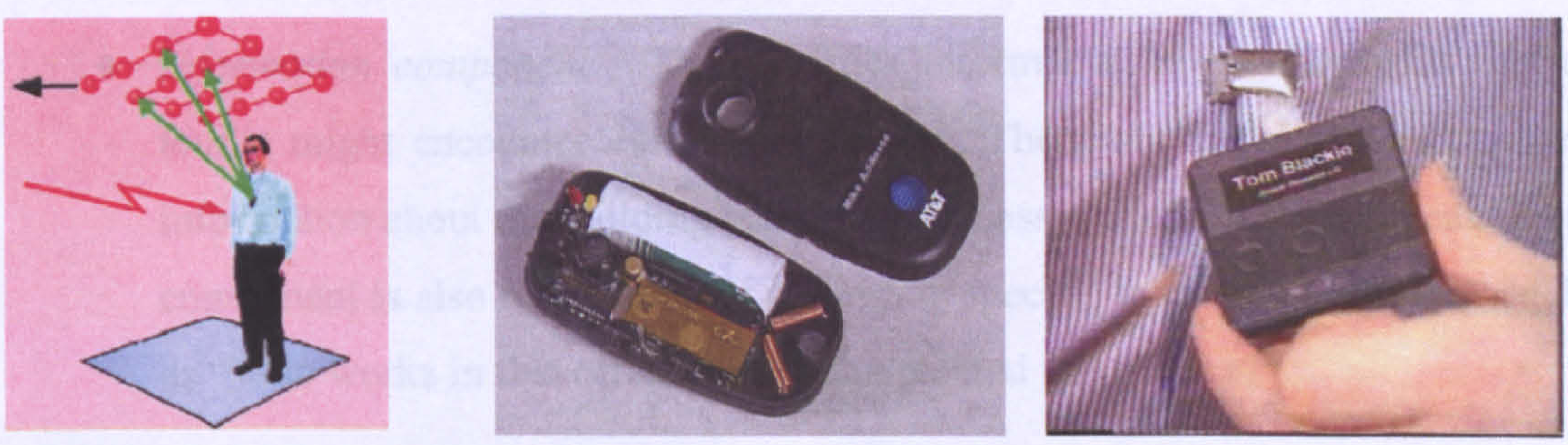
- to design an architecture that supports mobile computing; to construct context-sensitive applications that exploit this architecture, and
- to test the entire system in an office community.

As part of this prototype application, devices such as a palmtop computer, an electronic notepad and an electronic whiteboard (Figure 2.10) were used.

Figure 2.10: ParcTab Handheld Device [WAN95]

The result product of this was a digital office facilitated with some intelligent electronic gadgets. All the devices in use as part of this project were connected to the local area network using infrared (IR) connections, which also enabled the location management of the users. Knowing the location of the user, the relevant communications (e.g. emails and phone calls) were then routed accordingly to the user's physical location or computer terminal.

The active badge project conducted at Olivetti Research Laboratories in Cambridge, UK, in the late 90s significantly affected context-aware computing through the implementation of the first indoor positioning system [WAN92]. The system was initially implemented as a substitute for the pager system that was used to locate members of staff and assist receptionists with their switchboard operations.



a) b) c)

Figure 2.11:a) Indoor positioning b) Active Badge uncovered c) Active Badge in use [WAN92]

The system is facilitated with wearable badges, sized 55x55x7mm and weighing 40g (Figure 2.11), to produce a unique code for approximately a tenth of a second every 15 seconds. These transmissions are then picked by receivers, which are scattered around the host building. The received signal is then relayed to a location server processing the location of the user.

During the 10 day evaluation of this system, the incidence of telephone calls not reaching the correct person dropped substantially. Receptionists had a much easier time, since they were able to avoid many wasted trips, up and down corridors, trying to find members of staff. On the other hand, the perception of clients telephoning the laboratory was one of good organization, since the receptionist was able to say with great certainty where somebody was or when they were last seen, or indeed the likelihood that they had just taken a lunch break, all without the need to be explicitly informed by the staff.

One of the earliest examples of combining indoor and outdoor positioning technologies is the Cyberguide [ABO96]. This system was initially implemented as a building guide for the department open days at the Georgia Institute of Technology and then improved to guide its users throughout the whole city of Atlanta. The core functionality of the system is divided into four components:

- *Map component* - This contains cartographical data about the physical surroundings of the user, such as the location of the buildings, interesting sights within a building, or pathways that the user can access.

- *Information component* - This provides information about the sights that a tourist might encounter during his/her visit. The users of the system can get information about the building and the people associated with these areas. This component is also responsible of answering specific questions of the user such as "Who works in this office?" or "Who painted this picture?"

- *Navigator component* -This identifies the location of the user within a given area. This service is facilitated using a positioning module that delivers accurate information on the user's location and orientation.

- *Messenger component* - The user of the guide can interact or leave a message to the tour leader. Additionally, this module can broadcast messages to other tourists in the surrounding area.

Evaluation of the system with users highlighted issues with respect to the positioning at indoor locations and on-screen map representations.

In related work, Simcock et al. [SIM03] implement a location-based tourist guide application, using a PDA and a GPS connection, and examine the associated design and usability issues. The main aim of this project was to use off-the-shelf hardware and software components, create a simple and easy to use interface, as well as a simple and easy to update map, and an energy efficient tool that can operate for one fully working day. The main tasks undertaken by the system were to display attraction information in the form of HTML pages relevant to the user's position and to display the user position graphically on a tour map based on co-ordinates received from a GPS device. The user interface had three main modes of interactions: *Map view*, where the user can see his/her location and the surrounding buildings on a map; *Guide view*, where the user is provided with a path of interesting attractions, and finally the *Attractions view*, where the user is streamed audio-visual tourist information. All the colour schemes and map annotations are designed in a manner so that they are visible to the user on the move.

Figure 2.12: Screen capture of VRML aided mobile guide [BUR05]

In recent work, Burigat and Chittaro [BUR05] have implemented a tour guide system that combines the location information with an on-screen 3D VRML representation of the user's current location (Figure 2.12) on a PDA. To maximize the flexibility in the use of the system, three navigation modes in the VRML world are available to the user:

- *GPS-based navigation,* where the location of the user is acquired from the GPS receiver and calculated accordingly, thus facilitating the update of the guide screen so that it corresponds to the viewpoint of the use in the physical world.

- *Manual navigation* is the mode where the user moves in a 3D world by tapping on specific arrow buttons provided on screen to traverse within the digital map. This off-line mode is especially useful when the user wants to browse the sights of the city before actually visiting the area.

- *Replayed navigation* mode is when the system uses a pathway that is previously recorded by a human guide or by users themselves to animate a virtual tour of the city. To enable this, the data provided by the GPS device is logged and then fed into the guide application.

This prototype is composed of four main modules: the GPS module, 3D world module, information module and the user interface module. The GPS module processes the standard National Marine Electronics Association (NMEA) sentences which it receives from the GPS unit and passes the coordinates to the 3D world module, which then creates the 3D images of the user location. The information module obtains the information about the current location and delivers it to the user interface module, which combines the 3D image and the information to present to the user.

In earlier related work, Laakso et al. [LAA03] evaluated the use of 3D maps in combination with tourism information and GPS for mobile devices. In this study, an application called *TellMarisGuide* was implemented with the aim of supporting tourist when they are visiting destinations. The usability evaluation of the prototype system was done thoroughly, with 665 respondents for the quantitative survey and 30 interviews. Findings show that the digital 3D maps compared with 2D maps were not found to be particularly useful by participants. Indeed, the majority of respondents noted that they are so used to 2D maps that they do not really need 3D maps. However, some of them believed that they were likely to change their opinion with the next generation of improved 3D images.

From a different perspective, Munoz et al. [MUN03] implemented a context-aware instant messenger system in a hospital environment to share information among the members of staff and provide information about the patients. The context sensitive structure of this system enables the doctors to download the medical records about the patient near by them and register time sensitive information regarding the patient to his/her colleague in the next shift. The prototype system evaluation by 13 physicians, 8 nurses and 7 support staff showed that functionalities such as context-based messaging, user positioning, and access to the patient records on the move was useful and that 91 percent of the participants would use the system.

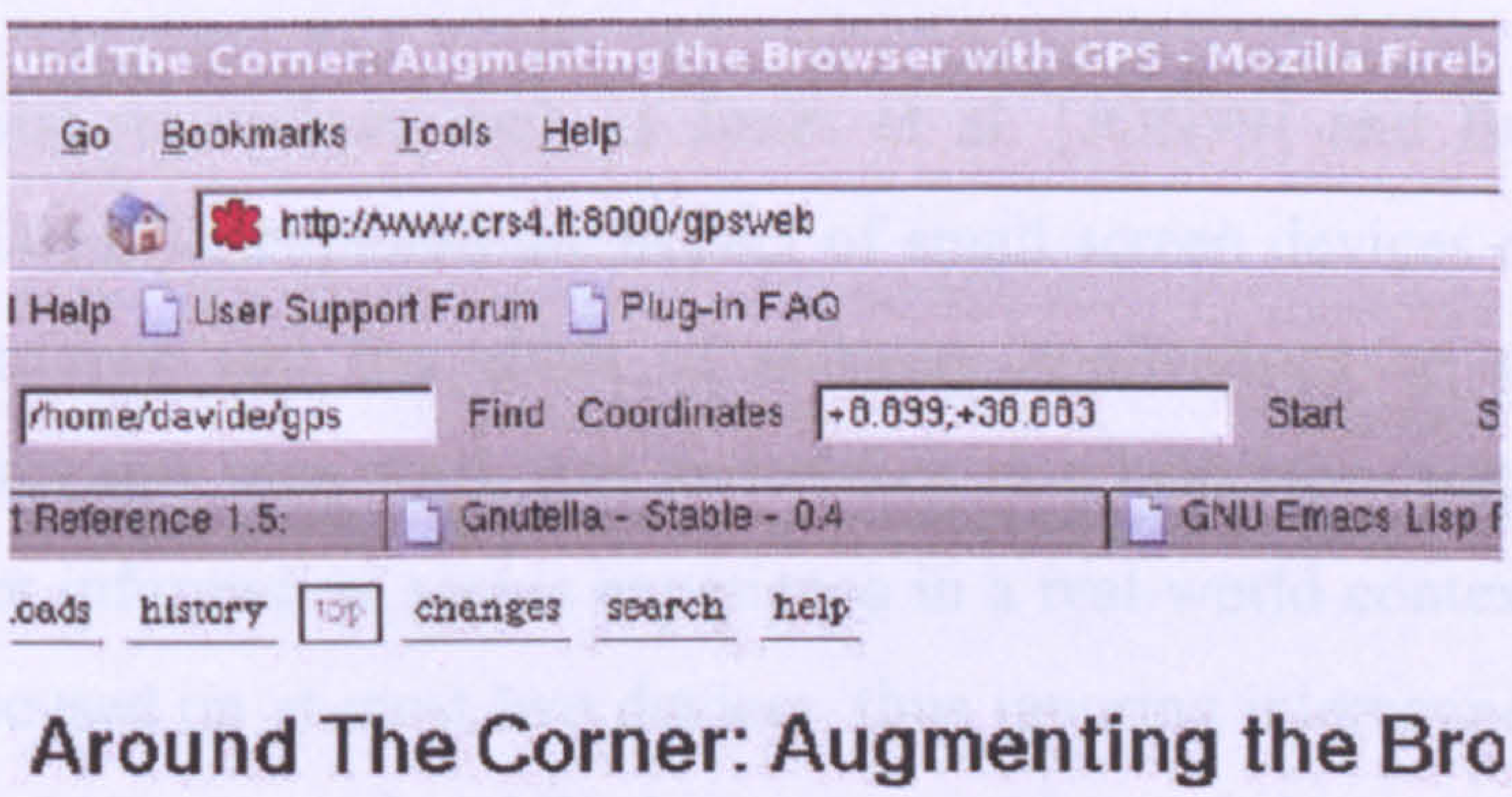


Figure 2.13: Screen capture of GPSWeb enabled web browser [CAR04]

Lastly, mention must be given to the work of Carboni et al. [CAR04], who developed and proposed the encapsulation of location data into HTTP requests so that the response sent to the user can be tailored accordingly. As part of their work, they have implemented a Java daemon that receives the location information from a GPS feed and saves the data on the user's computer in set interval. The plug-in running on the client's web browser then reads the coordinates and adds it to the HTTP request-response header as extended metadata (Figure 2.13). As a result of this, the server receiving the request can acknowledge the location of the client and provide the user with the most relevant information to his/her location (e.g. nearest airport, police station)

2.6. Understanding the User Mobile Experience – Research Aims and Objectives

The user's mobile information access experience is of great importance to the continued take-up and proliferation of mobile computing – users will not use mobile devices if the device and/or information access experience is frustrating. This chapter has so far reviewed the diverse range of studies that have been conducted to explore and improve the user mobile information access experience. To this end, whilst there have been OOBE evaluations and initial experience prediction methods examined by cross-company consortia [EOU00] and individual companies [INT99] respectively, nevertheless, work has not looked into the interconnectivity issues encountered when two or more mobile devices are associated.

In addition, even though user perception of multimedia-based information access has been previously explored [GHP00; GUL03], such work has mainly focused on single, non-mobile devices.

Moreover, whilst researchers such as Jones et al. [JON99] and Buranatrived and Vickers [BUR04] have explored the impact of small screen devices on the user web browsing experience and the effect of software applications on mobile devices, respectively, previous such work was undertaken in a laboratory setting and did not explore the user information access experience in a real-world context. Furthermore, such studies focused on at most two devices, thus ignoring interconnectivity matters, as well as the wider range of mobile devices currently available, and thus issues that might arise when a comparative analysis of the user experience is undertaken.

We also mention that whilst multimedia content has been previously tailored with respect to device [BUY00; FOX98; FRE01] and location [ABO96; BUR05], it has not been done so through the prism of perceptual requirements. Lastly, it also has to be emphasised that that these issues have not been explored in an integrated manner, and all the related work in this area has been undertaken in an isolated fashion, as our review has shown.

Accordingly, we have defined the following research aim for our study:

> *"to comprehensively assess the user experience of mobile computing, as manifested through four key facets: the initial (out-of-box) experience, the device and mobility impact on the user multimedia access experience, the mobile information access experience in a real-world context, and the user experience of accessing multimedia content tailored according to perceptual requirements, device and location."*

In order to achieve this aim, the following objectives will be met:

Objective 1: Evaluation of the OOBE associated with mobile devices. In particular, we aim to examine the initial and interconnectivity issues of the mobile devices. The OOBE has been identified as a significant factor contributing to user perception and acceptance of products and technologies. To ensure a fully comprehensive out of box experience evaluation we shall follow industrially designed experimental methodologies, and our work in respect this will be detailed in Chapter 4.

Objective 2: Exploration of the device impact on the user mobile multimedia experience. The perceptual impact of mobile devices on multimedia quality has particular importance in the areas of mobile Internet and mobile TV. In our research, we examine the impact of varying multimedia QoS on the user mobile experience, when multimedia is accessed through a range of devices of varying mobility. Our work in this respect will be described in Chapter 5.

Objective 3: Exploration of the real-life experience of using mobile information access devices. To assess the impact of a real-world context on the mobile information access experience, we intend to investigate experiences users have with mobile devices of different levels of mobility, when they are used in daily informal environments. The casual use of mobile information access devices is important since these devices are foreseen to be tomorrow's mobile phones. Our work in this respect will be detailed in Chapter 6.

Objective 4: Examination of the impact of tailored multimedia, in respect of perceptual requirements, location and mobile access device, on the user experience. This objective builds on the work of objectives 2 and 3, where the findings of objective 2 are used to tailor the multimedia content based on device type and the observations of objective 3 are used to refine the content type according to the location. The last component of our study is described in detail in Chapter 7.

2.7. Conclusion

In this chapter we have introduced the reader to issues concerning user mobile information access. We have reviewed the work that has been done so far to enhance the user mobile information access experiences and have accordingly identified a need for a comprehensive study measuring the user mobile experience at all phases – the user out-of-box experience, the information access experience when mediated by different devices in a controlled settings environment as well as in a real-world context, and, lastly, the user experience of tailored content. The methodology employed in our four investigations will now be detailed and justified in the following chapter.

CHAPTER 3

Research Methodology

3.1. Introduction

In the previous chapter, we have identified the four main objectives of our study. In the current chapter, we will describe and justify the methodology of research that is used throughout our studies to achieve the objectives defined in Chapter 2.

This chapter begins by defining positivism in research and describes its major assumptions and perspectives. In Section 3.3, the use of positivist research approach for our studies is justified based on the definition provided. In Section 3.4, the research design that is used in the course of our study is identified and justified. In Section 3.5 explains the validity issues and theory testing for positivist research, and finally, Section 3.6 enlists and describes the tools and the content that is used in our studies.

3.2. Research Perspective: Positivism

Positivism - the paradigm adopted in this study - has very specific assumptions that influence and affect its stance. A summary of the underlying themes of positivism and its major assumptions is the following [HUG98; TAS98; MER98]:

- Ontology (nature of reality): Positivists believe that there is a single reality and it is possible to know this reality within probability.
- Epistemology (nature of knowledge): Positivists believe that the knower and the would-be known are independent. Objective knowledge is an aim of science as the researcher manipulates and observes in a detached manner. Knowledge can be gained solely from experience – invisible or theoretical constructs are to be backed up by 'evidence' – that is observable.
- Methodology (approach to systematic inquiry): the experimental method de-contextualises behaviour to investigate specific pre-selected variables in a standardised manner.

- Aim - Universal Laws: Positivists believe that time- and context –free generalisations are possible, as long as the experimental conditions are met.
- Deductive logic: deduction is based on hypothesis and theory testing, going from the general to the particular.

However, according to critics of the positivistic paradigm [HUG97], during its heyday positivism was an:

1. 'arrogantly assertive doctrine which was summarily dismissive of all conceivable alternatives
2. generally dogmatic in its responses to criticism and argument as well as
3. boastful of its own aims and achievements.'

The main themes of positivism will be looked at in more detail throughout the sections of this chapter, and they will be described in terms of the methodology of this study. The relation between the positivistic paradigm and this study will follow, but below are provided the reasons why the positivistic framework was best able to address the research objectives of this study.

3.3. Positivistic paradigm and this study

The main aim of the present study was to investigate the mobile information access experience of the user. However, valuable as they might be, only views gathered informally would not be able to illustrate fully, and provide evidence for variables such as mobility, device type and location affecting user's experiences. The positivistic paradigm was the best possible approach to tackle this problem. As [BRE89] would put it: empirical measurement is essential to determine the nature and frequency of social phenomena. Guesses and impressions obviously will not do.

Looking at the patterns of relations of the variables under investigation in this study, there were patterns emerging from the data. However, interpretation of the results is based on evidence that has been systematically collected and analyzed. Interpretation is not the same with intuition or hunch [MUN95].

Additionally, research can either be descriptive or explanatory [VAU01]. As it has been argued before, this research addresses questions that have not been answered by the HCI community. Thus, the aim was to empirically explore the phenomena under investigation, bearing in mind that one cannot be a priori sure of the application of theories before they are confirmed. de Vaus [VAU01] maintains that explanatory research can only follow descriptive research, as one must know the dimensions of the phenomenon before one can set out to explore why it is the case. Thus, if the hypotheses under investigation are not confirmed, when advocating future research, the exploratory type of research would be considered to indicate why the hypotheses were not confirmed and the findings occurred in that particular manner.

Finally, induction starts from a sufficiently large number of observation statements as a prerequisite for developing a more general theory [HAL96; WIL96]. These statements can form a basis for generalisation, that, if repeated consistently under a number of conditions, can result in a universal law. Thus, the lack of experience of the investigator with the specific research area before this study commenced ensured that no such observational basis existed. The observations and intuition of others expressed in the form of theory formation [HAL96], were therefore the only available option.

3.3.1. Measurement, and systematic empiricism

Positivism comprises the following underlying themes, characterised by the belief that [MER98; KAN01]:

- only observable, objective, provable facts are science;
- causes in both natural and social words can be studied with experimental procedures;
- there is a value-free method for studying the world.

Thus, one would expect that the positivistic paradigm is in congruence with methodology and methods that have the same underlying assumptions and aims. Such a methodology has been termed 'systematic empiricism' [KAN01]. Empiricism refers to knowledge by experience, based on the senses [GRA93].

A definition of systematic empiricism could be 'the practice of relying on observation to draw conclusions. The phenomena studied in science must be objective and observable' [LEA95]. Empirical investigation involves a focused investigation and thus the researcher needs to prepare the few variables and a theoretical framework. It is a precise tool aiming to map the variables under investigation and only a very restricted range of behaviours are researched. [ROS91] defines it as 'descriptive research' while [ROB02] defines it as 'fixed research design'. Experimental research as well as relational research are part of what has been described as 'fixed research design' [ROB02], on which we shall now elaborate further.

3.4. Fixed Research Design

In alliance with the positivistic paradigm, fixed research design aims in 'objectivity' and can be used with specific variables to test hypothesis. Experimental design is definitely a fixed research design. The basic requirements that every experiment must meet are the following [JON95]:

1. Manipulation: In the experimental design there is at least a variable that is determined and manipulated by the researcher. This is the independent variable.
2. Measurement: An experiment must also have at least one dependent variable that is measured.
3. Control: As we know, the independent variable may not be the only variable affecting the subject's behaviour. Such other variables are called extraneous variables and can add variability to the data by interfering randomly with subjects' behaviour [JON95]. Moreover, a confounding variable is a special type of extraneous variable that varies systematically rather than randomly with the independent variable.

Several types of study where the researcher is not able to actively manipulate the experimental situation are classified as experiments. This is because they use dependent (referred to as outcome) variables [COO79] and independent (referred to as explanatory) variables [ROB02].

The experiments that cannot manipulate the independent variable can be referred to as 'passive experiments' [ROB02]. This study is a passive experiment because the allocation of the participants into age groups, or gender-based groups is beyond the capability of the investigator due to the limited sample size availability.

The present study is a small-scale, not 'classical experimental design' [VAU01] and correlational study involved only with novice, intermediate and advance users. This is because:

- The study occurs in a realistic and real-world environment.
- The independent variable is not the only variable to affect the data and thus the two groups of subjects differ in more that one aspect/variable.

The other type of fixed research design is the correlational design. The correlational design occurs where measurements or observations are made on a number of variables and correlation is the main analytical technique [ROB02]. This study is also correlational because it aims to correlate the set of user groups of varying computer literacy with the subject's perception of mobile information (multimedia content quality) and his/her experiences in accessing the content using various access devices.

Correlational research differs from experimental research in that there is no manipulation of variables. Rather, the relationships between two or more variables are studied without any attempts to influence them. Correlational research is also referred in the literature as descriptive research – because it simply describes the degree to which two or more quantitative variables are related [FRA96; MER98].

Finally, this study is comparative, as it does compare the groups of various levels of expertise, devices and locations as can be seen from the objectives of this study in Chapter 2. For our information access studies, the results of Ghinea and Thomas [GHI98] will be regarded as the reference group. However, these data will not be used throughout our studies due to the structure of our experiments and their research niche.

3.5. Internal – External Validity and Generalisability

Positivism comprises the following underlying themes:

- Results have high internal validity (valid in the predetermined setting), but not necessarily high external validity (valid in external settings) as the experimental setting is artificial within the positivistic paradigm [MER98; KAN01).
- Since the laws of cause and effect are identified, they can be used to make predictions, as long as the same conditions apply [GRA93; KAN01].

Leary [LEA95] maintains that strong experimental control increases the internal validity of the experiment in question. The experiment with tighter experimental control will have more internal validity, and therefore the stronger and more definitive are the conclusions that can be drawn about the causal affects of the independent variable. The down side is that the experiment might result in a highly specific and artificial situation. As a result, the increased control of a study leads to difficulty generalizing the findings or to decreased external validity. External validity refers to the extent to which findings can be generalised to other samples, research settings and procedures. Nonetheless, in our study we also undertake an experiment in a real-world context, in which the ability to have strict control of experimental variables is reduced.

HCI research usually aims for internal validity, as the main aim is to draw conclusions about the effects of the independent variable. The aim is very rarely to get generalisable results in experimental research. Thus, experimental research aims in testing and generalizing the theory rather than striving to make generalizations. [LEA95] states: the findings of any single experiment should never be generalised, no matter how well the study is designed [LEA95].

Leary [LEA95] maintains that although probability samples are the best way of increasing external validity for the target population, relatively little research is conducted on probability samples. In the case of this study it was impossible to obtain a probability sample meeting the inclusion criteria for this study simultaneously. Leary [LEA95] goes on to clarify that with a non-probability sample it is impossible to estimate how representative of the population the sample is, as well as the calculation of the estimate error.

Small-scale studies use non-probability samples and such studies are acceptable if there is need to make a generalization to the population beyond the sample surveyed [ROB02]. Moreover, non-probability samples are perfectly acceptable for behavioural research aiming to examine specific hypotheses. In fact, in experimental research the external validity can be only assessed by replication [LEA95].

The findings of this study will need replication if they are to be generalised. Thus, even if the data will lead to strongly correlated and clear results, there will always be a need for further research, to possibly replicate the findings from this study.

3.5.1. Deduction, hypothesis, theory, and theory testing

The experimental method is the best method that can actually test hypotheses, [MER98] and it possesses the same underling beliefs as positivism- deduction and theory testing.

Hughes and Sharrock [HUG97] question whether there is a way of observing the external world that is independent of theory. They question whether one can determine the world in the way one chooses in order to examine it. For example, reading tests are products of the reading models that are prevailing in the literature at the time of construction. The content of the tests 'provides evidence of the test maker's model of reading' [GOO90].

Deduction is one of the foundations of the positivistic perspective [KAN01]. It refers to determining in advance what is important to study and select only those elements for examination. Those specific elements are then tested by studies and experiments examining specific theories.

Brewer and Hunter [BRU89] maintain that studies can be differentiated on the criterion of generating or verifying theories. They claim that studies aiming for the generation of theory tend to rely on qualitative methods, fieldwork and non-reactive sources of data as opposed to experiments and surveys used by studies that verify theories.

However, explanation is strongly connected with prediction. If an explanation is good, then it will lead to successful prediction. Additionally, it is a bilateral relation and where a prediction is found to be correct it implies within it an explanation (Williams and May 1996).

A confirmed hypothesis provides an explanation for why some behaviour occurs [SHA00]. In the case the results differ from what is hypothesised, then the proposed explanation might need modification and a new hypothesis once developed has to be examined in a new experiment.

Researchers such as those in the area of HCI perform experiments and studies that aim to provide answers to specific hypothesis about the phenomena under investigation [SHA00]. The purpose of conducting such experiments is to test empirically hypotheses that result from HCI theories.

'A hypothesis contains a statement of relationship between constructs and a practical translation between the realm of ideas in to the word of the observable. It is based on a proposition or statement about the relationship between two or more variables' [KAN01]. However, a theory in itself cannot be tested but its function is to explain and predict a phenomenon.

Shaughnessy et al. [SHA00] conclude that the process of setting and testing hypotheses can be a long and painstaking process. However, the 'self correcting interplay between experiments and proposed explanations can become a challenging and satisfying approach to understanding the causes of the way we think, feel and behave' [SHA00].

Positivism claimed that the scientific method (if properly done) will result in scientific knowledge. Scientific method refers to a number of 'sure' procedures, for example, experiments, hypothesis testing theories, public scrutiny of method and results, measurement [HUG97]. However, the belief in scientific method, as described by positivism, being superior is no longer the case, and it is questionable whether there is a 'scientific' method as such [HUG97].

3.6. Instrumentation

Instrumentation is very significant within the positivistic paradigm [KAN01].

1. The tasks / questions are drawn so that they address the variables that interest the researcher.
2. The questions / tasks are pre-tested on people to ensure that they produce the required information.
3. Measurement is standardised, carried out in the same way using the same instruments for all participants and the administrators are trained to follow the standardised procedure [MER98; KAN01].

The research techniques used by researchers in the positivistic paradigm are usually quantitative, as the variables are clearly defined, measured and the results are associated with numbers [KAN01]. The methodology of this study reflects the themes and tools described below.

3.6.1. Structured and Non-Structured Experiments

Structured experiments are those that follow a predefined order or direction, with the ultimate aim of consistently measuring changes in pre-ordained experimental factors. Structured experiments require the design and use of questionnaires and/or checklists to extract relevant information to identify specific results or outcomes.

Non-structured experiments do not necessarily require a clear-cut or pre-defined order or direction. Accordingly, non-structured experiments are neither consistent in content, nor measure pre-designed experimental factors. Use of open interviewing or participant observation provides a rich source of information, partly as participant response is not placed within a rigid experimental structure, however as limited experimental organisation exists, results can only be analysed using interpretative methods. The choice between structured or non-structured experiments thus allows the choice between either rich (unstructured) or limited (structured) data.

As repeatability is central to ensuring a consistent user focus, and subsequently user perception, it is paramount to the successful implementation of our study that we rely primarily on structured experiments. We have identified a clear set of structured aims and objectives, which facilitates the effective measurement of critical experimental factors. Consequently, structured experimentation, incorporating predefined questionnaires, will be used throughout our studies to determine the user's experiences with mobile devices.

3.6.2. Laboratory and Field Studies

The use of the structured experimental method in our studies facilitates the intentional manipulation of one or more independent variable(s). Consequently, the statistical effects of the independent variable(s) are measured in terms of change that occurs on one or more dependent variable(s). This section determines the difference between laboratory (true) and field experiments and considers the relevant benefits of both methods when used in the context of our aims and objectives.

Laboratory studies, also known as true experiments [COO94], control all variables that may confound or influence the current aims and objectives. To achieve this control over experimental variables, tasks and measures, a controlled environment is required. Although laboratory studies facilitate highly focused, consistent and accurate studies, literature [COO94] highlights four main weaknesses of the laboratory experiment:

1) the artificial environment.
2) the reduced ability to generalise experimental results.
3) the restricted list of variables.
4) the reduced level of situational realism.

If, as part of a structured laboratory experiment, an unrealistic experimental design or an unnatural process is forced upon participants, then unreliable results are likely, e.g. if the user is asked to look out for particular items or perform a specific task then the focus of the user will be unnaturally affected [YAR67], which in turn affects the user's interaction with the device. Moreover, if experimental emphasis is placed only on particular variables, then use of structured laboratory experiments risks limiting the richness of feedback information. Accordingly, Robson [ROB94] suggests minimal interaction between the participant and the experimenter to prevent any possible bias.

In contrast, field experiments allow investigation within a real world environment. As with true experiments, field studies manipulate one or more independent variable(s) and measure the statistical effect of dependent variable(s). Although field studies can represent 'real-world' situations, they do not give the experimenter full control of the environment. Thus confounding variables are almost impossible to control in a non-laboratory environment, field studies provide the possibility for a greater richness of data. In our experiments we will use both of the above explained methods to conduct our study. The main purpose of this is to have the best of both worlds i.e., on the one hand, to investigate user initial experiences with mobile devices under laboratory conditions and on the other to evaluate the user mobile information access experience in a real-life context, and thus obtain a multi-faceted picture of the user mobile computing experience.

3.6.3. Quality of Perception

3.6.3.1. Defining Quality of Perception

Distributed multimedia applications are produced for the enjoyment and/or education of human viewers, so the user-perspective is important to any quality definition. Thus, when defining user perception in this context it is important to consider the symbiotic infotainment duality of multimedia: the ability to transfer information to the user, yet also provide a level of satisfaction (both concerning the video QoS as well as the content of the video). One of the objectives of our work is to investigate the impact of the access device on the user mobile multimedia experience. In line with our infotainment view of multimedia content, the user perspective must consider both how the multimedia presentation was assimilated / understood by the user, yet also examine the user's satisfaction.

In order to explore the human side of the multimedia experience, we have used the QoP concept. Ghinea and Thomas [GHI98] initially used QoP to measure level of information assimilation and satisfaction, when multimedia video clips were shown at varied frame rates. QoP is a concept that captures multimedia's infotainment duality and more closely reflects multimedia's infotainment characteristics (i.e. that multimedia applications are located on the informational/entertainment spectrum). QoP is based on the idea that the technical-perspective alone is incapable of defining the perceived quality of multimedia video, especially at the content-level [BOU01; GHI98; WAS97]. Quality of Perception uses level of 'information transfer' (QoP-IA) and user 'satisfaction' (QoP-S) to determine the perceived level of multimedia quality. To this end, QoP is a term used in our work that encompasses not only a user's satisfaction with the quality of multimedia presentations ('Satisfaction' - S), but also his/her understanding, that is an ability to analyse, synthesise and assimilate the informational content of multimedia ('Information Assimilation' – IA).

3.6.3.2. Measuring Quality of Perception

There are four basic methods to measure subjective perceptual quality [CLA99; GHI98; WIL98]: Forced Choice, in which test subjects are presented the same clip under two different quality levels; Content Query, in which test subjects are asked questions about the content of video clips after watching them; Effectiveness Study in which different quality videos are used for real life tasks and task effectiveness, then, becomes the measure of quality; and Quality Opinion Score, in which test subjects are asked for an opinion score during or after watching a video clip. In our study we use content query and quality opinion scores to measure user QoP-IA (information assimilation and user QoP-S (satisfaction) respectively. To understand QoP in the context of our work, it is important that the reader understands how QoP factors were defined and measured. These issues shall now be addressed.

Measuring Information Assimilation (QoP-IA)

In our approach, 'Information Assimilation' (level of objective information assimilated) was expressed as a percentage measure, which reflected a user's ability to assimilate specific information from visualised multimedia content. Thus, after watching a particular multimedia clip, the user was asked a standard number of questions which examined information being conveyed in the specific clip that had just been presented to the participant. The level of information assimilation was then calculated as being the proportion of correct answers that users gave to these specific questions.

To allow objective measurement, all information assimilation questions must, of course, have a definite answer, for example: (from the Rugby video clip used in our experiment) "What was the score of the match at the beginning of the video clip? As this question has an unambiguous answer (England 0 / New Zealand 7), which is clearly presented in the video content of the multimedia clip, it was possible to determine whether the participant had assimilated this information by marking whether they were able to correctly answer the question. As this question is presented in the video content of the clip the participant is awarded a video mark for that specific question if, and only if, the question is answered correctly.

Since, in our experiments, questions can only be answered if certain information is assimilated from specific information sources (for example, the words of a song can only be gained from the audio stream), it is possible to determine the percentage of correctly answered questions that relate to the different information sources within specific multimedia video clips. For each feedback question, the source of the answer was determined as having been assimilated from one of the following information sources:

V : Information relating specifically to the video window, for example, pertaining to the activity of lions in a documentary clip.

A : Information which is presented in the audio stream.

T : Textual information contained in the video window, for example: information contained in a caption (for example: the newscaster's name).

Thus, by calculating the percentage of correctly absorbed information from different information sources, it is possible to determine and compare, over a range of different multimedia content, potential differences that might exist in information assimilation when participants are presented multimedia video clips using different output display devices, each with a varying level of mobility.

Measuring Level of Satisfaction (QoP-S)

The subjective Level of Satisfaction experienced by a user when watching a multimedia presentation was polled by asking users to express, on a six-point Likert scale of 0 - 5, how much they enjoyed the presentation (with scores of 0 and 5 representing 'complete dislike' and, respectively, 'absolute enjoyment' with the multimedia video presentation). A six-point Likert scale was used to exclude a mid-point decision, preventing a completely neutral subjective opinion. This information was used to determine whether a user's ability to assimilate information has any relation to his/her level of perceived enjoyment.

3.6.4. Experimental Content

3.6.4.1. Device Impact on the User Mobile Multimedia Experience

The multimedia content used to assess the quality of the user mobile multimedia experience when mediated by different access devices was previously used by [GHI98; GHI00, GUL03], who similarly examined issues of user perceptual multimedia quality in their work and, in particular, have employed the QoP metric, of particular interest to this study. The experimental multimedia content is made up of a series of 12 windowed MPEG video clips (Figure 3.1), the duration of which was between 26 and 45 seconds long. This is ideal for use with QoP, due to the limitations of human working memory [ALD95], for if duration is substantially longer than 30 seconds, it can cause users to forget information shown at the beginning of the clip. In addition, the clips were chosen to present the majority of individuals with no peak in personal interest, whilst limiting the number of individuals watching the clip with previous knowledge and experience.

These multimedia video clips were specifically chosen to cover a broad spectrum of infotainment and varied from those that are informational in nature (such as a news / weather broadcast) to ones those that are usually viewed purely for entertainment purposes (such as an action sequence, a cartoon, a music clip or a sports event). Specific clips were chosen as a mixture of the two viewing goals, such as the cooking clip. These videos were:

- **Band clip** - this shows a high school band playing a jazz tune against a background of multicoloured and changing lights.

- **Commercial clip** - an advertisement for a bathroom cleaner is being presented. The qualities of the product are praised in four ways - by the narrator, both audio and visually by the couple being shown in the commercial, and textually, through a slogan display.

- **Chorus clip** - this clip presents a chorus comprising 11 members performing mediaeval Latin music. A digital watermark bearing the name of the TV channel is subtly embedded in the image throughout the recording.

Figure 3.1: The 12 video clips used in our device experience study

- **Cooking clip** - although largely static, there is a wealth of culinary information being passed on to the viewer. This is done both through the dialogue being pursued and visually, through the presentation of ingredients being used in cooking of the meal.

- **Animation clip** - this clip features a disagreement between two main characters. Although dynamically limited, there are several subtle nuances in the clip, for example: the correspondence between the stormy weather and the argument taking place.

- **Weather clip** - this is a clip about forthcoming weather in Europe and the U.K. This information is presented through the three main channels possible: visually (through the use of weather maps), textually (information regarding envisaged temperatures, visibility in foggy areas) and by the oral presentation of the forecaster.

- **Documentary clip** - a feature on lions in India. Both audio and video streams are important, although there is no textual information present.

- **Pop clip** - is characterised by the unusual importance of the textual component, which details facts about the singer's life. From a visual viewpoint it is characterised by the fact that the clip was shot from a single camera position.

- **News clip** - contains two main stories. One of them is presented purely by verbal means, while the other has some supporting video footage. Rudimentary textual information (channel name, newscaster's name) is also displayed at various stages.

- **Rugby clip** - presents a test match between England and New Zealand. Essential textual information (the score) is displayed in the upper left corner of the screen. The main event captured is the score of a try. As is expected, the clip is characterised by great dynamism.

- **Snooker clip** - the lack of dynamism is in stark contrast to the Rugby clip. Textual information (the score and the names of the two players involved) is clearly displayed on the screen.

- **Space clip** - this was an action scene from a popular science fiction series. As is common in such sequences, it involves rapid scene changes, with accompanying visual effects (explosions).

3.6.4.2. Location Impact on the User Mobile Multimedia Experience

Since one of the objectives of this study was to examine the perceptual impact of multimedia tailored according to location, the original set of clips used in previous QoP experiments could not be used, as they were not adapted to specific locations. Instead, we had to create new such multimedia content, which we now proceed to describe (Figure 3.2).

St John's Building

Bannerman Centre

Figure 3.2: Video clips used in our location-based experiments

Since in this study we were going to use real locations in order to examine the user experience of location-based computing, the multimedia clips and the locations themselves were chosen so that they are representative of infotainment content and infotainment access locations. Eventually, we selected three sites from Brunel University's Uxbridge Campus in West London. These were the School of Information Systems, Computing and Mathematics (St John's Building), the library (Bannerman Centre) and the university lawn, which respectively represented an information intensive location, an entertainment intensive location, and a site in which a mixture of both entertainment and informational content would be accessed. With the exception of the entertainment location, for which we proposed to use an existing video clip (Animation), the two other locations required new related content. For this purpose, we produced two new, 32 second long video clips for these locations. These were as follows:

- **St John's Building** - contains a walk-through presentation of the Department of Information Systems and Computing, has extensive information regarding the number of professors, number of research students, location of lecturers and administration staff, and student facilities.

- **Bannerman Centre** - is a walk-thought presentation of the Brunel University, Uxbridge Campus Library. This clip is entertaining as much as it is informative, providing basic information about library services, and mixing it with more dynamic content such as student union facilities (bar/café shop/refectory) located in the same building.

3.6.5. Experimental Questionnaires

In our study, we employed questionnaires to evaluate the user mobile information access experience at each of the four stages identified in Chapter 2. These questionnaires were semi-structured, containing a mix of closed and open-ended questions, the content of which shall now be described.

3.6.5.1. User Initial Experience Questionnaire

Our experiments followed the User-Centred Design (UCD) process [IBMa04] in order to appraise the OOBE. Accordingly, user OOBE was broken down into eight categories, with the user having to accomplish a set of five tasks for each of the categories identified:

- *Packaging*, this category measures the users' first impressions regarding the packaging of the equipment.
- *Unpacking*, this category concerns itself with the efficiency and the easiness of the users' unpacking experience.
- *Setup*, the easiness of physical arrangement and assembly of components, as well as intuitiveness of the related instructions provided are examined here.
- *Power on*, the design of the power-on experience is looked at here: this includes issues such as feedback that setup was successful, rewards, together with elements such as thank-you and welcome messages.
- *Configuration*, this set of tasks tests the post-setup configuration experience.

- *Initial Use*, this category examines easy accessibility of product features and capabilities.
- *Doing work*, this group of tasks examines how easy it is for the user to do meaningful things that they want to do.
- *Assistance*, the availability of multiple assistance sources for every step of the initial experience, such as written instructions, troubleshooters, online support, and user help groups is typically evaluated here.

The user experience in each of the above categories was expressed with respect to a group of five statements (per category), on which the participants had to express their opinions on a 5-point Likert scale (*strongly agree, agree, neutral, disagree, strongly disagree*). In keeping with good questionnaire design, the questionnaire contained a roughly equal split of positive and negative statements. Lastly, an open ended question asked participants for any other comments they might have had as regards their OOBE. For full details of the experimental questionnaire, see Appendix A.

When examining the user OOBE, we were also interested to investigate whether user computer proficiency had any bearing on their experiences. In our study, following the taxonomy of McMurtrey [MCM01], computer proficiency was assessed via a questionnaire which grouped participants according to their computer proficiency in 3 main groups – novice, intermediate, and advanced. This categorisation was based on participants completing a short questionnaire (prior to beginning the experiment proper) that assessed their computer abilities and experience (Table 3.1).

Table 3.1: User computer proficiency questionnaire

Do you regularly use electronic mail (e-mail)?	Yes ☐	No ☐
Do you regularly use search engines (Google, AltaVista)?	Yes ☐	No ☐
Do you regularly use word processing applications (Ms Word, WordPerfect)?	Yes ☐	No ☐
Do you regularly use spreadsheet applications (Ms Excel, Lotus)?	Yes ☐	No ☐
Have you ever successfully installed software on a computer?	Yes ☐	No ☐
Have you ever written and successfully run a computer program?	Yes ☐	No ☐

Accordingly, users who answered 'yes' to 0-2 of the questions were categorised as novice, those who answered 'yes' to 3-4 of the questions were deemed to be intermediate, whilst those who answered 'yes' to 5-6 questions were assigned to the advanced category.

3.6.5.2. Device Impact Questionnaire

As highlighted in Section 3.6.3.1, when examining the user experience of multimedia quality when it is being mediated by different access devices, we have used the same multimedia content that was previously employed in similar studies [GHI98; GHI00; GUL03]. Since all of these studies employed the QoP metric, it comes therefore as no surprise that we have used the QoP metric and its questionnaires (the full details of which are presented in Appendix B) to assess the device impact on user perceptions of multimedia quality.

Table 3.2: Multimedia Information Distribution – Video, Audio and Textual

Video Title	Information		
	Video	Audio	Text
Bath	7	2	0
Band	10	1	0
Chorus	11	0	0
Animation	8	4	0
Forecast	8	3	5
Documentary	10	1	0
Pop	6	2	4
News	1	11	3
Cooking	9	6	0
Rugby	9	3	3
Snooker	8	1	4
Space	9	1	0

Accordingly, QoP-S was expressed by participants on a Likert scale, whilst QoP-IA was assessed by a series of clip-specific questions targeting information assimilation. As the emphasis of information assimilation varies between the different video clips the importance of gaining feedback from specific information sources also varies considerably across the clips. Accordingly, the number of QoP-IA questions, relating to different information sources, also varies (see Table 3.2).

3.6.5.3. Mobile Information Access Questionnaire

This part of our study examines the user experience of mobile information access, where these took place in two real world settings: in a café and on a busy urban street. The questionnaire designed for this experiment, the full details of which are given in Appendix C, reflects this fact and comprises statements related to participants' experiences when accessing information in such context. Accordingly, opinions are expressed on a 5-point Likert scale, with the statements comprising a roughly equal mix of positive and negative sentiments related to participant experiences.

There were two sections in this questionnaire, one for the café scenario and the second one for the on-the-street scenario. In each of the sections, participants were asked to indicate their opinions on a 5-point Likert scale to a series of seven statements concerning the tasks at hand. Lastly, participants also had the opportunity to express any other comments they might have had in respect of their experiences. For the detailed scenarios, task and the questionnaire see Appendix C.

3.6.5.4. Location-based Perceived Multimedia Quality Questionnaire

In order to assess the perceived quality of multimedia content tailored according to user location, we have again employed the QoP metric, the only quality metric that takes multimedia's infotainment duality into account. Moreover, as was detailed in section 3.6.3.2. we have also created specific, location-based, tailored multimedia content to be used in our study. Whilst users would still express their QoP-S on the standard Likert scale employed in QoP studies [GHI98, GHI00, GUL03], in order to assess QoP-IA, fresh questionnaires had to be devised for the two newly created multimedia video clips. For each of these, 10 questions were used, each examining content from a range of multiple information sources (Table 3.3).

Table 3.3: Location Impact Evaluation Content – Video, Audio and Textual

Video Title	Information		
	Video	Audio	Text
St John's Building	4	4	5
Bannerman Building	5	4	4
Animation (Lawn)	8	4	0

In keeping with QoP methodology [GHI98], we originally had a series of 12 questions per clip. As we were interested in median participant performance, after a pilot study comprising 8 participants, we eliminated, for each clip, the two questions for which participants fared worst, respectively best. For a full listing of the questionnaire, see Appendix D.

3.6.4.5. Analysis of Results

To analyse the results of the four questionnaires statistically, we used SPSS (Statistical Package for the Social Sciences - Version 11.5), which is a data management and analysis software developed by SPSS, Inc. in Chicago, Illinois. Among its features are modules for statistical data analysis, including descriptive statistics such as plots, frequencies, charts, and lists, as well as sophisticated inferential and multivariate statistical procedures like analysis of variance, factor analysis, cluster analysis, and categorical data analysis. SPSS is particularly well suited to survey-based (questionnaire-based) research, which is the main reason for using it in our analysis. We have carried out a variety of statistical tests to analyse our experimental results. These include: ANOVA (ANalysis Of Variance) and MANOVA (Multiple ANalysis Of Variance) tests (both supported by Post-Hoc Tukey tests), as well as Willis K-independent Non-parametric tests (depending on the ANOVA homogeneity of variables), which were used to determine the impact of parameter variance on user mobile device experiences. In our statistical analysis, the results were considered to be significant if $p<0.05$. This indicates that the mean of a specific data set is greater / less than two standard deviations from the overall mean, as a result of a specific variable adaptation - approximately 5 percent of all samples.

3.6.6. Experimental Devices

In this section we aim to provide detailed information about the technical specification and the selection criteria of each one of the devices, with ranging level of mobility and intrusiveness (see Table 3.4), used in our experiments. These devices range from a traditional fixed computer monitor, to a traditional laptop monitor with limited mobility, to a head-mounted display (allowing greater autonomy of movement), through to a personal digital assistant, allowing full personal mobility.

Table 3.4: Mobility and Intrusiveness of the devices used in our experiments

Device	Generic Monitor Eye Tracker	Laptop	Eye Trek (Head-Mounted Display)	Personal Digital Assistant
Mobility	No mobility due to the nature of desktop monitor	Limited, due to its large and heavy casing	Provides mobility, yet gives restricted vision and requires supporting equipment.	Causes no mobility restriction. Can be used on the go
Intrusiveness	Limited intrusiveness, users have to stand still for the best performance	Limited intrusiveness due to its screen, users have to position themselves to get the best angle	Slightly restricts the body movements due to the size of the equipment (Battery, control pack, glasses and processor)	No intrusiveness, due to the ergonomic design, size and weight of the latest personal digital assistants

Accordingly, generic desktop computer monitors are fixed to one location and do not support mobility; laptops offer some level of mobility, yet do not fully facilitate information access while the user is mobile. Head-mounted displays are known to have usability issues related to display size, weight and adjustability of physical and visual settings [BOW02], however they can be used whilst the user is mobile/in motion. The last device considered in our study was a PDA, which enables full mobility with its reduced dimensions and easy portability [FOX98; BUY00; FUL01].

There were two important practical influential issues that affected the selection of the devices used in our experiments. These issues were cost and availability.

- Cost: The laptop computer was provided by the School of Information Systems, Computing and Mathematics; however, we had £2000 allocated for the purchase of the PDA and the head-mounted display.
- Availability: Since our objective is to evaluate the user's experience with mobile devices, it was highly important to select devices that are currently available to the end-user.

We have thus employed a Toshiba Satellite P35-S611 Notebook PC, HP iPAQ 5450, Olympus FMD-200, and LifeView FlyJacket i3800 for our experiments. The rest of the section provides detailed technical specifications of these devices and justifies their selection.

3.6.6.1. Laptop

The laptop PC used in our experiments was selected from the inventory of the School of Information Systems, Computing and Mathematics. The selection was made among a Toshiba Satellite P35-S611, a considerably heavy HP Compaq NX9020s and an IBM T20s with a low processing and memory specifications. Accordingly, we picked a Toshiba Satellite P35-S611 Notebook PC, which ran Microsoft Windows XP Professional, and had a 3.33GHz Pentium IV processor, 512MB memory, 100GB hard drive, 17-inch XGA TFT Active Matrix Display and 64MB graphics adapter memory (Figure 3.3).

Figure 3.3. Notebook PC

3.6.5.2. Personal Digital Assistant

Improvements in technology, especially wireless networking, have pushed the barriers of anywhere / anytime information access. Portable information access raises the need for portable information access devices, such as communicator devices and personal digital assistants, which promise to supplant the desktop computer as ubiquitous technology on campuses and in business [WEI98].

As Chapter 2 has highlighted, personal digital assistants inherit many of their problems related to the distributed systems and mobile computing Nonetheless, the popularity of such devices has seen a strong upward surge in recent years, with Gartner Research [SIN05] predicting a record number of 15 million unit sales for 2005 worldwide, which was actually exceeded that year, and eTForecasts [ETF05] projecting 58.5 million unit sales in 2008. Personal digital assistants are mainly grouped based on their operating system. There are a few operating systems that cater for PDA computers. These are Microsoft Pocket PC (Windows CE), Palm, Linux and Symbian. Of these, the major players in the market are Microsoft based Pocket PC and Palm OS [ETF03]. Palm OS is a proprietary operating system for handhelds and smartphones. However, Microsoft Pocket PC (Windows CE) is a version of Microsoft Windows operating system for personal digital assistants and smart phones. Thus, it is highly compatible with Microsoft's desktop-based operating systems and applications. As an obvious consequence, the number of users choosing to opt to Microsoft PocketPC based devices is increasing [ETF03]. Due to its popularity and availability among end-users, we chose the HP iPAQ 5450 personal digital assistant with a Microsoft PocketPC operating system to be used in our experiments.

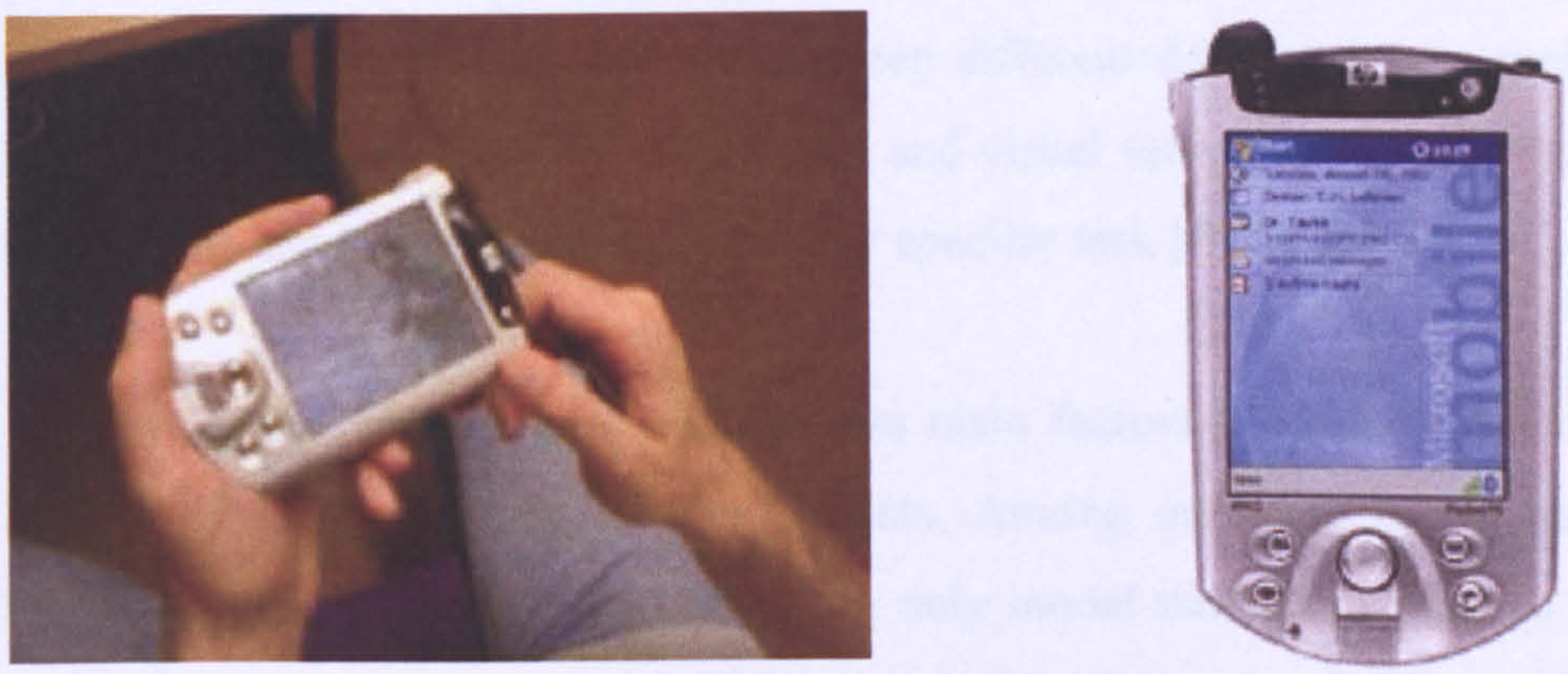


Figure 3.4. PDA Device.

The HP iPAQ 5450 PDA has 16-bit touch sensitive transflective thin film translator (TFT) liquid crystal display (LCD) that supports 65,536 colour. The display pixel pitch of the device is 0.24 mm and its viewable image size is 2.26 inch wide and 3.02 inch tall. It runs the Microsoft Windows for Pocket PC 2002 operating system on an Intel 400Mhz XSCALE processor and allows the user complete mobility. Furthermore, it comes with a full wireless connectivity suit, which is made of WiFi (802.11b/g, Bluetooth and Infrared). By default it contains 64MB standard memory and 48MB internal flash ROM. Additionally in the course of some of our experiments a 128 MB secure digital memory card was used for multimedia data storage purposes (Figure 3.4).

3.6.5.3. Head-Mounted Display

A head-mounted display is made of two canonical displays, and usually consists of two liquid crystal or cathode-ray tube display screens that are either mounted on a helmet or glasses-frame structure. Head-mounted displays can be either binocular, showing the same image to both eyes, or stereoscopic in nature, showing different images to each eye. The choice between binocular or stereoscopic depends on whether three-dimensional interaction or presentation is required. Head-mounted displays use a range of display resolutions. It is important to note, however, that a trade off exists between the resolution used and the field of view, which in turn impacts the perceived level of experienced immersion. A low field of view decreases the experienced level of user immersion, yet a higher field of view involves spreading the available pixels, which can cause distortion on the picture. Finally, ergonomic and usability factors vary considerably between different devices. Issues such as display size, weight and adjustability of physical and visual settings all affect the usability of a particular head-mounted display for any specific task [BOW02].

In the selection process, we used our two main factors to identify the most suitable head-mounted display for our experiments. Among our options, we had the range from Olympus, with FMD-200 being the only model that could work in battery-only mode [OLY00]. On the other hand, our other options were I-Glasses [I-G06] with lower resolution specifications and MicroOptical [MIC06] monocular display with a price beyond our initially allocated funds. As a result, we picked the Olympus FMD-200 for our experiments due to wide availability and a high performance/value ratio.

Figure 3.5. HMD Device

The Olympus Eye-Trek FMD 200 head-mounted display uses two 0.55-inch LCD displays and simulates a display view that is equivalent to a 52-inch screen at a distance of 2 meters. Each one of the displays contains 180.000 pixels and the viewing angle is 30.0° horizontal, 27.0° vertical. It supports Phase Alternating Line (PAL) format and has a display weight of 85g (Figure 3.5).

3.6.5.4. LifeView FlyJacket

A standard HP iPAQ 5450 cannot be connected to a head-mounted display or any other standalone display because of its compact design, which does not leave space for sockets. Thus, to facilitate such connectivity between the PDA and the HMD, we chose to use a LifeView FlyJacket i3800 multimedia expansion jacket for iPAQ handhelds. The expansion jacket contains a true VGA and Audio/Video connector that enables a direct link from the PDA to an external display, such as a TV, projector or a HMD (Figure 3.6).

Figure 3.6: LifeView Flyjacket

The device weighs 159.4g and is 12.8cm wide, 8.6cm tall, and 1.7cm deep. It contains a 3.6V (1400mAh) internal battery, which is easily rechargeable though the PDA's power adapter, to extend the iPAQ battery life. It supports 3 display resolutions: VGA (640x480 / 64k colour), SVGA (800x600 / 64k colour) and XVGA (1024x768 / 256 colours). The Audio/Video connector cable contains S-Video (4-pin mini-DIN) and composite video connections with both PAL and National Television System Committee (NTSC) format support.

3.7. Conclusion

In this chapter we introduced, elaborated upon and justified the research methodology that will be followed throughout our study. We also considered and explained the reasons for using structured field and laboratory experiments. Moreover, we described and justified the use of the QoP metric in our study, as well as the experimental material, the experimental questionnaires and analysis method that shall be used, in order to achieve the defined research aim and objectives. In chapters 4, 5, 6 and 7 we shall be exploring and evaluating, respectively, the user out-of-box experience, the information access experience when mediated by different devices in a controlled settings environment as well as in a real-world context, and, lastly, the user experience of tailored content.

CHAPTER 4

Information Access Device Impact on User Initial Experience

4.1. Introduction

In this chapter we address the first objective of our research and focus on the OOBE since, as Chapter 2 highlighted, it represents an important side of the initial user experience of mobile computing. Specifically, we explore the OOBE when asking users to configure, and then connect for inter-operability purposes, a Personal Digital Assistant and Head Mounted Device.

This chapter is structured as follows: Section 4.2 gives an overview of the main themes of OOBE research, whilst Sections 4.3 and 4.4 describe general usability issues pertaining to PDAs and HMDs, respectively. Section 4.5 details the methodology followed by our experiments, while results are presented and analysed in Section 4.6. Lastly, conclusions are drawn in Section 4.7.

4.2. Out-of-Box Experience Overview

Although a considerable amount of work has been undertaken from a usability perspective in the design of mobile and wearable devices [BUY00; FUL01; MAC03; WAY03], the established emphasis has been on issues such as ergonomics, multimodal interaction, haptics, personalisation, navigation, as well as novel interaction paradigms. Consequently, such work has frequently ignored the initial user experiences with the device – the OOBE – which in many cases can be crucial to user acceptance of the technology.

Whilst there has been an increasing recognition of the importance of the OOBE to the consumer experience, research in this area has prevalently examined issues such as ease of use, the establishing of appropriate factorisations of the OOBE, as well as the creation of appropriate evaluation methodologies [EoU01; EoU02; IBMa04; IBMb04]. Moreover, while there have been indications that the OOBE may suffer when the user contact extends across several companies [FOU00], an important question, namely, how is the OOBE affected when the experience itself spans several devices, is yet to be answered though.

In this chapter, we address this issue and explore the user OOBE for two mobile devices: a Personal Digital Assistant (PDA) and a wearable Head Mounted Device (HMD), both of which are ultimately interconnected to give the user a mobile, wearable, computing experience. We now proceed to describe the general usability issues pertaining to the devices deployed throughout this study.

4.3. Personal Digital Assistants

Improvements in technology, especially in wireless networking, have pushed the barriers of anywhere / anytime information access. Portable information access raises the need for portable information access devices, such as communicator devices and personal digital assistants, which promise to supplant the desktop computer as ubiquitous technology on campuses and in business [WEI98], with Gartner Research projection of 15 million unit sales in 2005, which was exceeded [SIN05].

PDAs inherit human-computer interaction and ergonomic related issues, such as small screen size, slow input facilities, low bandwidth, small storage capacity, limited battery lifetime and slow computer processor unit speed, which are all possible obstacles to the success of mobile and pervasive computing objectives [BUY00; FUL01].

It is not surprising then that PDA research is mainly involved in overcoming such barriers. Thus, for instance, Jones et al. [JON99] studied the effect that screen sizes have on web-browsing related tasks, and their results showed that users with small screens followed hyper-links less frequently than those with a larger display unit. In related work, MacKay [MAC03] looked into web content adaptation for small-screened devices using a gateway/transcoder. The proposed gateway displays the web page designed for a large screen on a smaller one by reducing the web page in scale to fit the screen. The users of the gateway can focus on any part of the screen to interact with it or just to navigate, helping the user to create a mental model of the site s/he is visiting and feel in control. From a different perspective, Waycott and Kukulska-Hulme [WAY03] evaluated student experiences using PDAs when employed as tools for reading and learning, and their findings showed that due to the aforementioned problems typical of PDAs, it was difficult to read and interact with documents using such devices. A fresh approach is the one proposed by Siemens Corporate Research, who put forward a framework that accommodates ubiquitous multimedia access using small-screened devices. This allows PDA users to access rich multimedia content and services without having to shrink or tailor the content to match the capabilities of the PDA device. This is achieved by the collaboration of the PDA with its surrounding electronic appliances (e.g. TV, mobile phone), under the coordination of a Smart Server [PHA00].

4.4. Head Mounted Displays

As Chapter 2 has highlighted, HMDs are increasingly popular mobile devices. This, however, does not mean that they are free of usability concerns. The current lack of available media that properly facilitates immersive technology is one such example: full-motion immersive video imaging emerged during the last ten years [BOH97] yet is still not commercially available. The current high cost of the head-mounted displays that display both high resolution and wide field of view is a major factor. The large and encumbering size is an important factor, especially for users of cathode-ray tube based displays [LAN97]. The visual limitation within the real world and reduced social interactions when wearing HMDs are potential barriers, which must be overcome in order for HMDs to proliferate further.

A number of research studies have also explored the symptoms related to head-mounted display usage, such as nausea [REG95], dizziness [COB95], headaches [KEN95] and eyestrain [KOL95]. From a different perspective, Geelhoed et al. [GEE00] investigated the comfort level of various tasks, such as text reading and video watching, on two different head-mounted displays, identifying that tasks requiring more long-term attention, such as watching video, cause a greater level of discomfort to the user.

Other factors, such as hygiene and weight, also have possible unknown long-term medical implications on the supporting muscles and even on the eyes. Nonetheless, despite the computational costs and usability drawbacks of head-mounted displays, they are used widely in active research from virtual environment to wearable Internet applications [VIR06] [HIV06].

4.5. Experimental Method

4.5.1. Participants

Our study involved 18 participants, nine male and nine female, who were aged between 23 and 37 and were taken from a range of different nationalities and backgrounds – students, clerical and academic staff, as well as white and blue collar workers. All participants spoke English well enough to be educated in this medium, whilst the average duration of participant computer usage was 7 years and 1 month. All participants had not previously used the type of devices employed in our OOBE experiment. The split of users according to gender and computer proficiency (determined as per the questionnaire described in Chapter 3), is given in Table 4.1, where, as can be seen, the participants in our experiments turned out to be evenly distributed in terms of their computer expertise.

Table 4.1: Participant breakdown according to gender and type of user

User Type / Gender	Male	Female
Novice	4	2
Intermediate	1	5
Advanced	4	2

4.5.2. Experimental Variables

Three experimental variables were examined in our study – these were type of user, type of device and gender. Type of user is an important factor which has been identified in the OOBE context [IBMb04], whereas the influence of device type was looked at in order to gauge the effect, if any, on the OOBE. The two types of devices used in our experiments were a PDA and an HMD (whose technical characteristics are given in Section 5.3), whilst the possible impact of gender on the OOBE was also examined, in order to see the extent to which possible customisation of the OOBE can reach.

Data were analysed with the Statistical Package for the Social Sciences (SPSS) for Windows version (release 11.5). An ANOVA, suitable to test the significant differences of three or more categories, and t-test, suitable to identify the differences between two categories [STE97], were applied to analyse the participants' responses. A significance level of $p < 0.05$ was adopted for the study

4.5.3. Experimental Material

In our experiments, participants interacted with two devices. The first was an Olympus Eye-Trek FMD 200 head-mounted display, which uses two liquid crystal displays and allows a greater autonomy of movement than a generic computer monitor. Each one of the displays contains 180.000 pixels and the viewing angle is 30.0° horizontal, 27.0° vertical. It supports PAL (Phase Alternating Line) format and display weight is 85g (Figure 4.1).

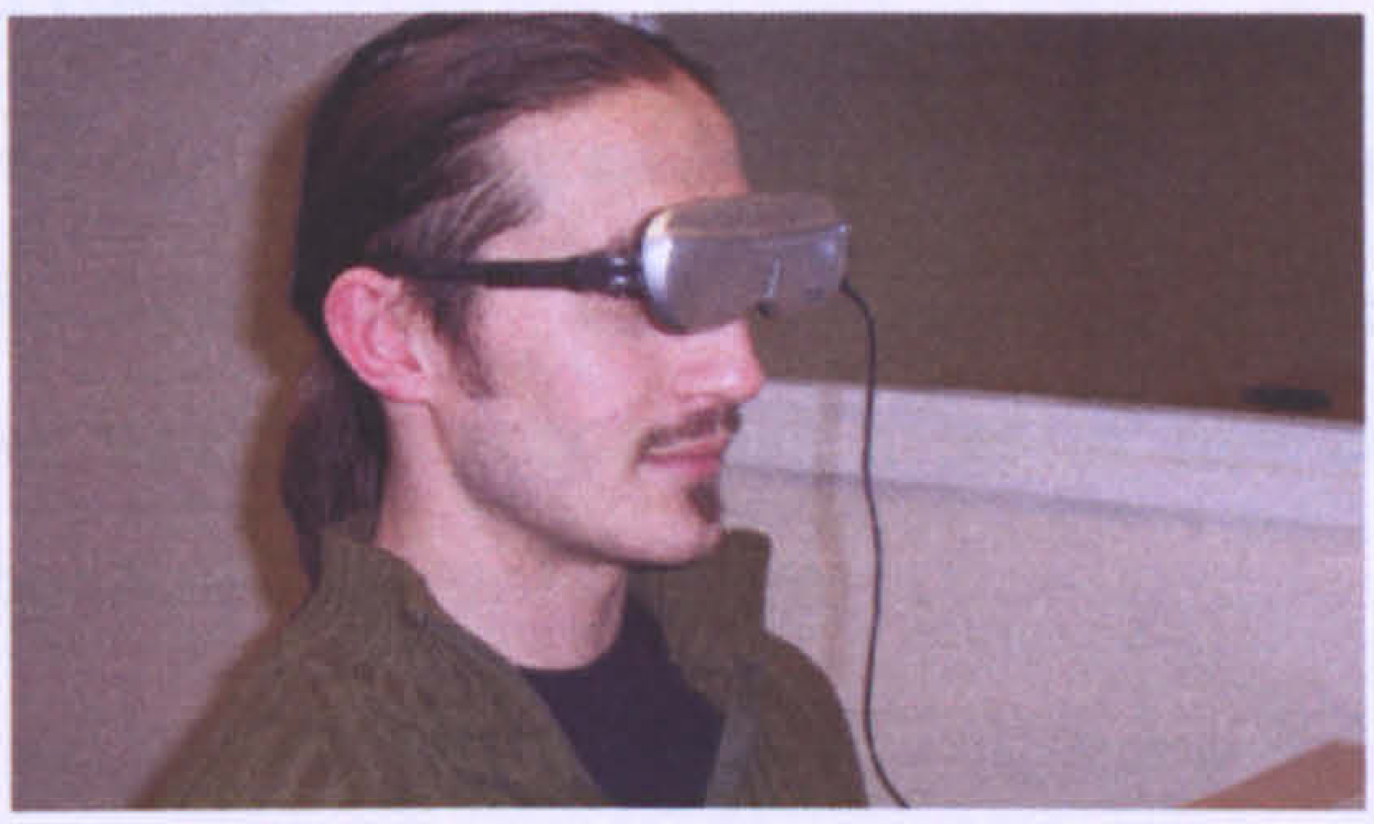


Figure 4.1: Head Mounted Display Device in use

The other device was a Hewlett-Packard iPAQ 5450 personal digital assistant with 16-bit touch sensitive transflective thin film translator liquid crystal display that supports 65,536 colour. The display pixel pitch of the device is 0.24 mm and its viewable image size is 2.26 inch wide and 3.02 inch tall. It runs the Microsoft Windows for Pocket PC 2002 operating system on Intel 400 Mhz XSCALE processor and allows the user complete mobility. By default it contains 64MB standard memory and 48MB internal flash read only memory. Additionally, in the course of this experiment, a 128 MB Secure Digital memory card was also used (Figure 4.2), while the interface between the HMD and the PDA was provided by a Lifeview FlyJacket i3800. The FlyJacket has its own internal rechargeable battery and provides VGA, S-Video and Composite output from the PDA device. It supports full motion video previewing up to 30 fps and 1024x768 VGA resolution.

Figure 4.2: Personal Digital Assistant with Lifeview Flyjacket i3800 attached

4.5.4. Experimental Process

Our experiments followed the User-Centred Design (UCD) process [IBMa04] in order to appraise the OOBE. Accordingly, user OOBE was broken down into eight categories, with the user having to accomplish a set of five tasks for each of the categories identified. The OOBE categories were:

- *C1: Packaging*

This category measures the users' first impressions regarding the packaging of the equipment. Ideally, a product should be packaged in a way that allows the user to transport it to a target location easily and safely, and clearly identify the contents of each box. Thus, in this category the participants were asked to check the weight of the packages, to identify the content of the package based on their labels and finally to check whether or not it would be easy to transport them.

- *C2: Unpacking*

This category concerns itself with the efficiency and the easiness of the users' unpacking experience. The aim is for the package to be ready for setup quickly and easily. In this category participants were asked to understand the interior organisation of the package, do an inventory check on the content using the manual and finally to identify the related components (i.e. cables, adaptors and connectors).

- *C3: Setup*

The easiness of physical arrangement and assembly of components, as well as intuitiveness of the related instructions provided are examined here. The aim is to prepare all components to use as quickly as possible and leave no opportunity for mistakes. In this category, the participants are asked to understand the physical arrangement of the components and assemble them.

- *C4: Power on*

The design of the power-on experience is looked at here: this includes issues such as feedback that setup was successful, rewards, together with elements such as thank-you and welcome messages. The aim is to immediately verify that setup or assembly was done properly and everything is working correctly. In this category, the participants were asked to read the appropriate section of the user manuals and turn on the devices to observe the responses according to their expectations.

- *C5: Configuration*

This class of questions measures the post-setup configuration experience. The aim of the configuration element is to be as automatic and transparent as possible, with minimal user interaction. Due to the substantial difference between device types and their respective configuration methods, two separate sets of tasks were prepared. For the PDA, the participants were asked to agree with licence terms and install ActiveSync in order to subsequently synchronise the Pocket PC with a desktop computer. For the HMD, the participants were asked to link the HMD with the PDA and unlock the HMD device using a default password.

- *C6: Initial Use*

This category measures easy accessibility of product features and capabilities. The main aim is to reaffirm that users' product decision was wise and give them confidence that they will be able to use the product to its fullest capabilities. A similar approach to the Configuration category is used due to the feature differences of the devices concerned. For the PDA, participants were asked to personalise and synchronise the device with a desktop computer, and set the security settings so no one else can access their data. For the HMD, participants were asked to personalise the device colour settings and reset the password according to their preference.

- *C7: Doing work*

This class of questions examines how easy it is for the user to do meaningful things that they want to do. The main aim is to make productive use of the device used. Accordingly, for both devices the participants were asked to transfer a video clip file from a desktop computer to the PDA, and play the specific movie on the PDA. Following this, they had to turn on the wireless networking and surf the local network.

- *C8: Assistance*

The availability of multiple assistance sources for every step of the initial experience, such as written instructions, troubleshooters, online support, and user help groups is typically examined here. The aim is to help the user resolve problems and get assistance as quickly as possible. In this category, the participants were asked whether the devices provide real-time help, whether a support website is clearly provided on the user manual, and if the respective manuals' structure is considered to be user friendly.

User OOBE was assessed via a questionnaire (given in Appendix A), which the participants had to complete as they went through the tasks. Accordingly, after the users had completed the profile questions, they were asked to indicate, on a five-point Likert scale of 1 - 5, for each task undertaken, their opinions (ranging from "1 - Strongly Disagree" to "5 - Strongly Agree") with respect to a statement regarding the respective task. In its final part, the questionnaire also solicited any open-ended comments that the participants might have wished to make.

Participants were accordingly instructed to work their way through the tasks, and complete the relevant sections of the questionnaire as they went along. To ensure that the participants did not feel under test conditions, it was made clear that their skills/ability to interact with the devices was not being tested (rather it was the case of evaluating initial contact with the devices), and that they consequently should not be concerned if they were unable to complete any of the tasks that the experiment contained. Furthermore, they were told to accomplish the tasks at their own pace, with no pressure being put on the part of the experimenter (the same experimenter was used throughout) for participants to abort/finish early any of the experimental tasks. However, as the duration of the OOBE is one of its key components [EoU00], the overall time in which the experiment was completed was recorded for each user, even though s/he was unaware that this was being done. Accordingly, the fastest completion time for the experiments was 95 minutes, whilst the longest was 211 minutes. The average duration of our experiment was calculated to be 136 minutes. Lastly, we mention that environmental variables were kept constant for all participants in the experiment, as this took place in the same room of the Brunel University usability laboratory.

A pilot test study of 2 participants was used to check and validate the questionnaire and the experimental process. Apart from requests for slight rephrasing of questions/statements in order to ease their understanding, this study revealed that one of the initial tasks in the "Doing work" category could not be successfully undertaken due to limitations of PDA memory size and battery power. Accordingly, in the final version of our experiments, this task was replaced by a feasible one (Task T3 of Category C7, as given in Appendix A).

4.6 Results

4.6.1. Device Impact on OOBE

The most important result to come out of our analysis was that there are significant differences in the Configuration and Doing Work categories of the user OOBE, depending on the particular device at hand – PDA or HMD. Accordingly a paired samples t-test highlighted that in the Configuration category, users found tasks T1-T4 (respectively ($t(20)=-1.369$), ($t(20)=-2.682$), ($t(20)=-1.826$), ($t(20)=-1.391$)) to be significantly easier in the case of the PDA (Figure 4.3), whilst in the Doing work category, users responses indicated that all tasks in this class were again significantly easier in the case of the PDA (Figure 4.4).

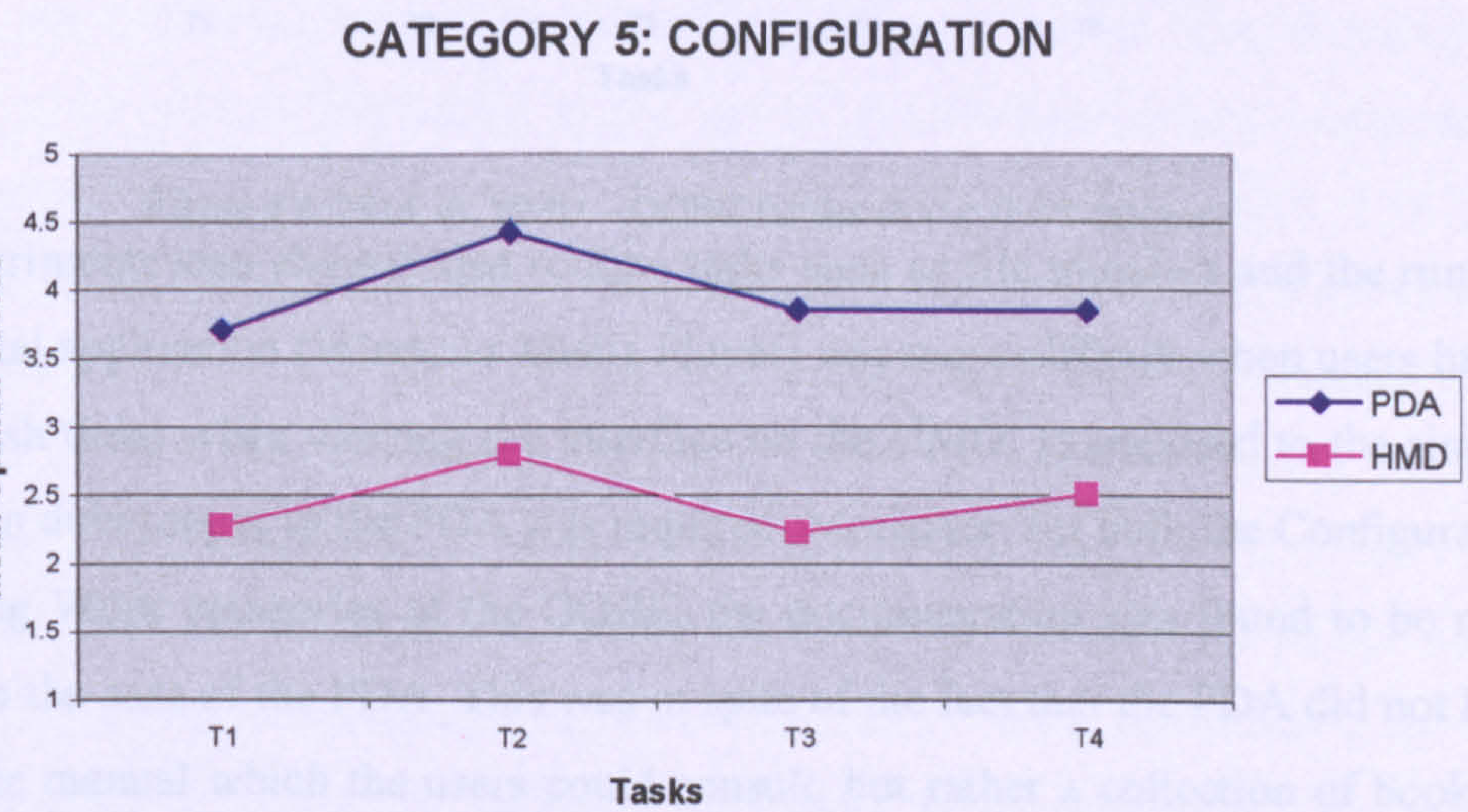


Figure 4.3: PDA vs. HMD – OOBE for the *Configuration* category

This result highlights the difficulties that users found in interconnecting devices, and particularly with wiring and audio/video cable identification, essential components of this goal, as is software installation. Thus, in order to link the HMD with the PDA, users had to attach the Lifeview FlyJacket to the PDA and install the associated device drivers. Whilst users did not encounter particular difficulty in installing the ActiveSync software associated with the PDA, they did so in the case of the FlyJacket device drivers. A similar observation can be made with respect to the interconnection between the PDA and the desktop machine, where users had comparatively little trouble achieving this, whilst the task of connecting the PDA to the HMD was found to be significantly more difficult. This result complements the observation of Fouts [FOU00], who argues that the OOBE, when extended across several companies, can be compromised – in our research we did indeed find that the initial inter-connection of different devices proved to be one of the hardest tasks experienced by users, with consequent negative implications on their OOBE.

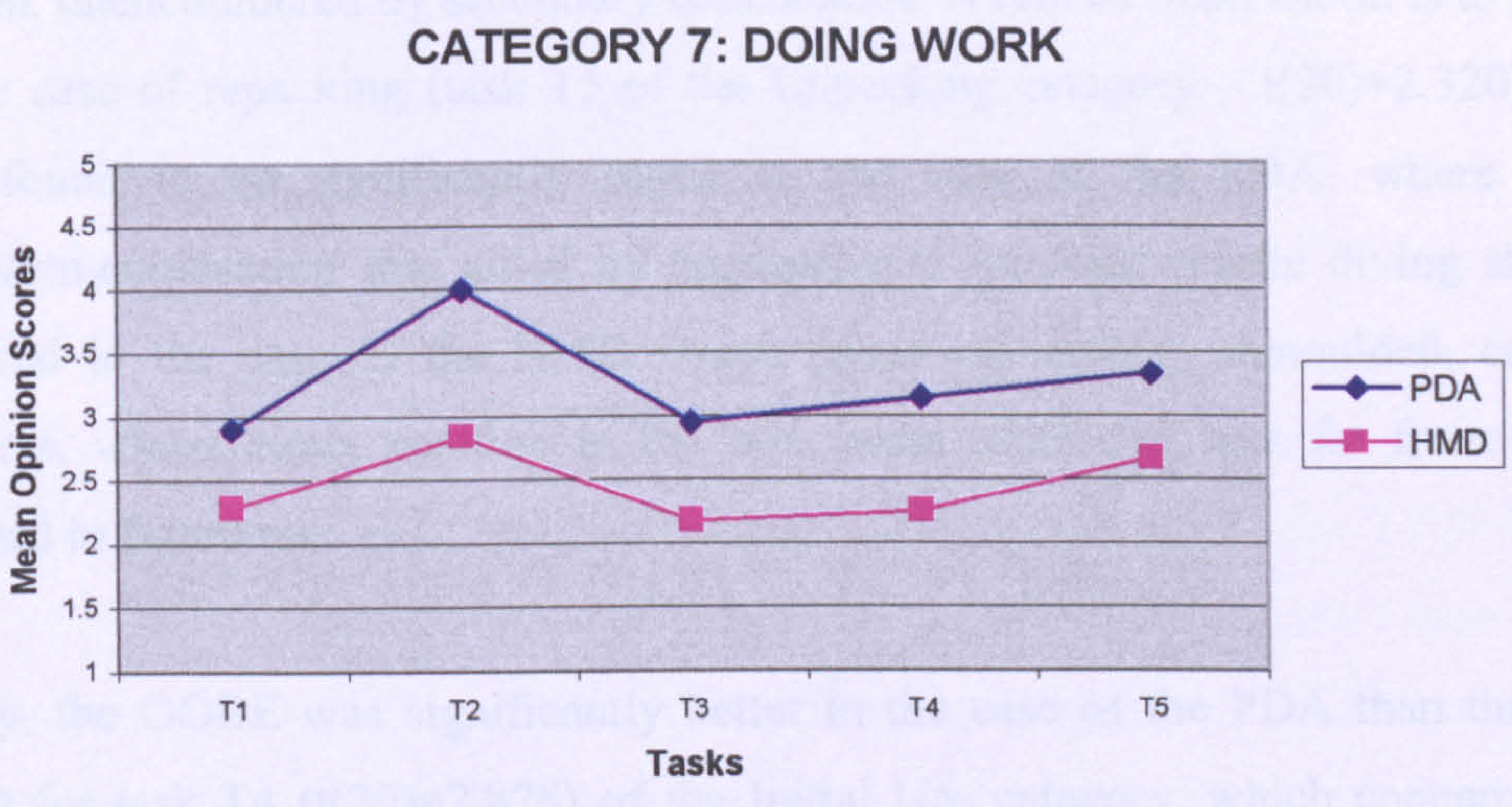


Figure 4.4: PDA vs. HMD – OOBE for the *Doing Work* category

Our experiments also showed that routine tasks such as file transfers and the running of a typical application (Windows Media Player) was more difficult when users had to accomplish these when viewing the interface on the HMD, as opposed to the simpler case when direct input to the PDA was required. Moreover, for both the Configuration and Doing Work categories of the OOBE, the documentation was found to be more helpful in the case of the PDA. This was in spite of the fact that the PDA did not have one single manual which the users could consult, but rather a collection of booklets, each addressing particular functionalities (e.g. Bluetooth, WiFi, Setup), which was found by some participants to be a source of insecurity and disorientation in finding help. However, in the case of troubleshooting for help in the setup of the two devices (the last task of the Setup category), the fact that the HMD had an explicit troubleshooting section in its manual explains why users found the HMD documentation in this case to be better than the one of the PDA.

Analysis of our results also revealed that the carrying the devices' boxes (task T1 of the Packaging category – $t(20)=2.961$) was found to be significantly easier in the case of the HMD, though, which might be a reflection of the fact that, whilst the overall weight of the two boxes was similar, the one containing the PDA was more voluminous. On the other hand, the easiness of identifying the boxes' respective contents based on the labelling used, was found to be significantly greater in the case of the PDA. This, in our opinion is due to a rather ambiguous exterior label on the HMD box (which depicted a person wearing an HMD whilst also playing a computer game on a console), whilst the PDA box had a clear picture of the device contained therein, unencumbered by secondary connections. A related observation is to be made in the case of repacking (task T5 of the Unpacking category – $t(20)=2.320$), which was found to be significantly easier in the case of the PDA, where internal compartmentalisation was aided by appropriately moulded plastic diving sheets, as opposed to the case of the HMD which relied on simple, unmoulded, cardboard dividers, whose exact position in the box, once taken out, was far from straight-forward to figure out.

Lastly, the OOBE was significantly better in the case of the PDA than that of the HMD for task T4 ($t(20)=2.878$) of the Initial Use category, which concerned itself with initialising security settings for the devices, and for task T1 ($t(20)=3.432$) of the Assistance category. The former result probably is a consequence of the fact that the PDA has a dedicated, streamlined interface for this task, in contrast to the HMD in which this task can only be accomplished with the user interacting via a non-dedicated, multi-functional set of buttons. On the other hand, the latter result comes about due to the PDA running a modified version (Windows CE) of the Windows Operating System, and users' general familiarity with obtaining help in this environment.

4.6.2. Impact of User Type on the OOBE

The OOBE for the two devices considered by our study is generally unaffected by the particular user type (novice, intermediate and advance) – this is the conclusion of a one way ANOVA applied to our results (Figures 4.5 and 4.6). This analysis highlighted that only sporadic tasks (three in all, out of a total of forty) were found to be user-dependent, an observation which probably reflects the care taken by designers to make sure that the OOBE is not perceived differently by different categories of users. Moreover, this conclusion is further reinforced by the fact that the same analysis also revealed that the length of time taken by users to complete our experiment is again unaffected by the particular user type.

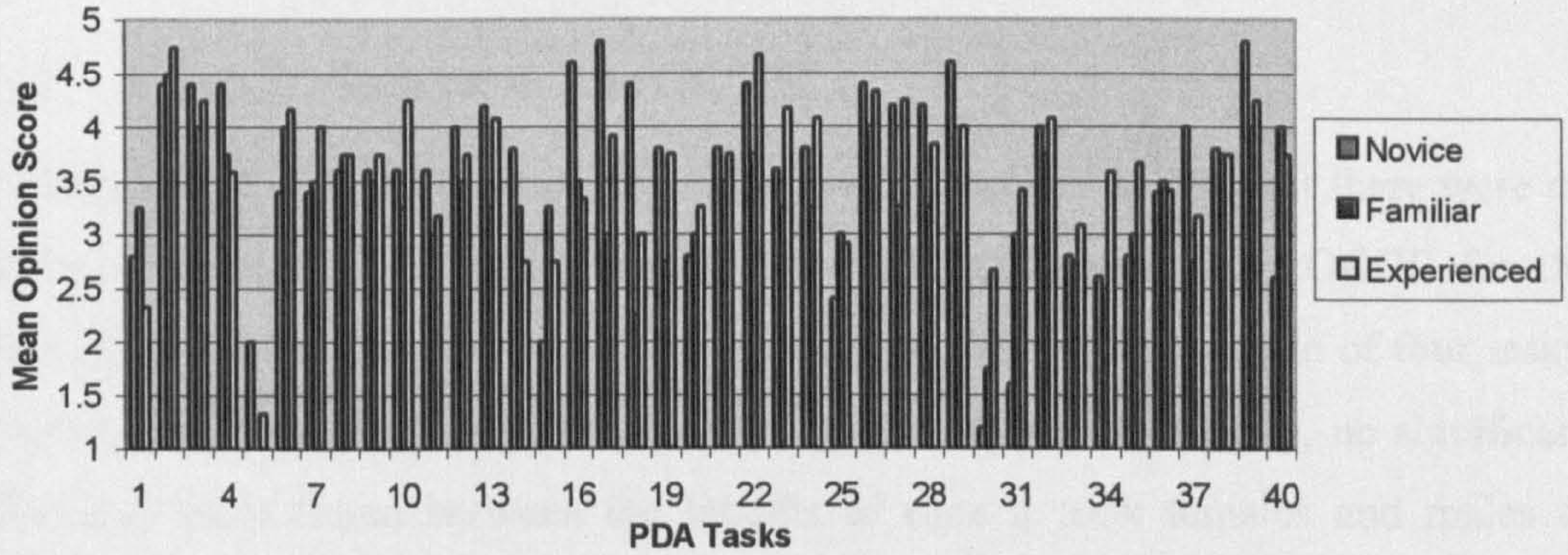


Figure 4.5: The OOBE for the PDA according to User Types

Tasks that were found to be dependent on user-type include (surprisingly) task T3 (F=6.557) of the Power On category for the PDA, together with tasks T1 (F=5.756) and T3 (F=3.819) for the Initial Use category for the HMD. The first of these has to do with noticing the blinking light of the PDA, indicating that the device is being powered. We believe that user-type being an influencing factor in this case is probably a reflection of the fact that Novice users in our experiments, whilst noticing the light itself, did not in fact make the connection to it being an indicator of available power supply.

The last two tasks found to be user-dependent is a possible indication of the rather limited, console-type interface (consisting of four multi-functional buttons) that the HMD provided for their realisation on its control panel. Accordingly, the two tasks focused on switching on the HMD and the setting of appropriate colour/brightness levels, and it is quite likely that Experienced users, given their familiarity with the concept and use of multi-functional interfaces, would have found these tasks significantly easier than the other user categories considered in our study.

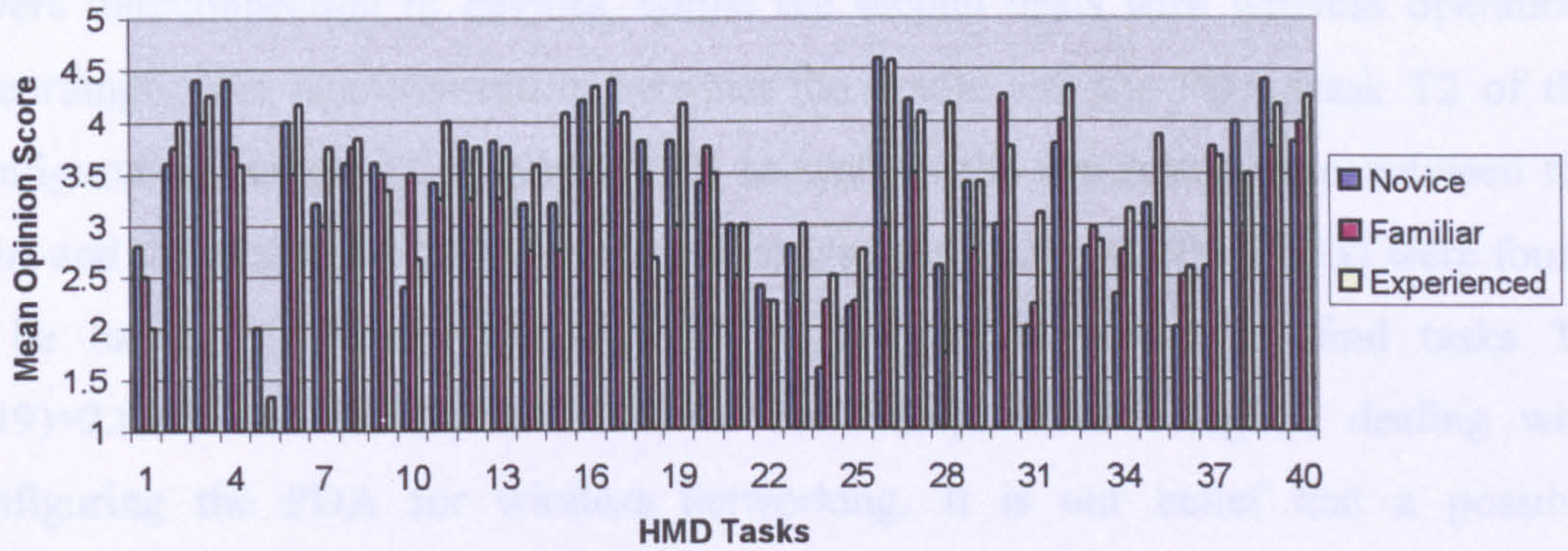


Figure 4.6: The OOBE for the HMD according to User Types

4.6.3. Gender Impact on the OOBE

An independent samples t-test on our experimental results showed that there were no significant differences between females and males as regards their OOBE for the HMD (Figure 4.7). The same analysis revealed that, with the exception of four tasks, the same observation held true for the PDA (Figure 4.8). Additionally, no significant differences were found between the lengths of time it took females and males to complete the tasks of our experiments.

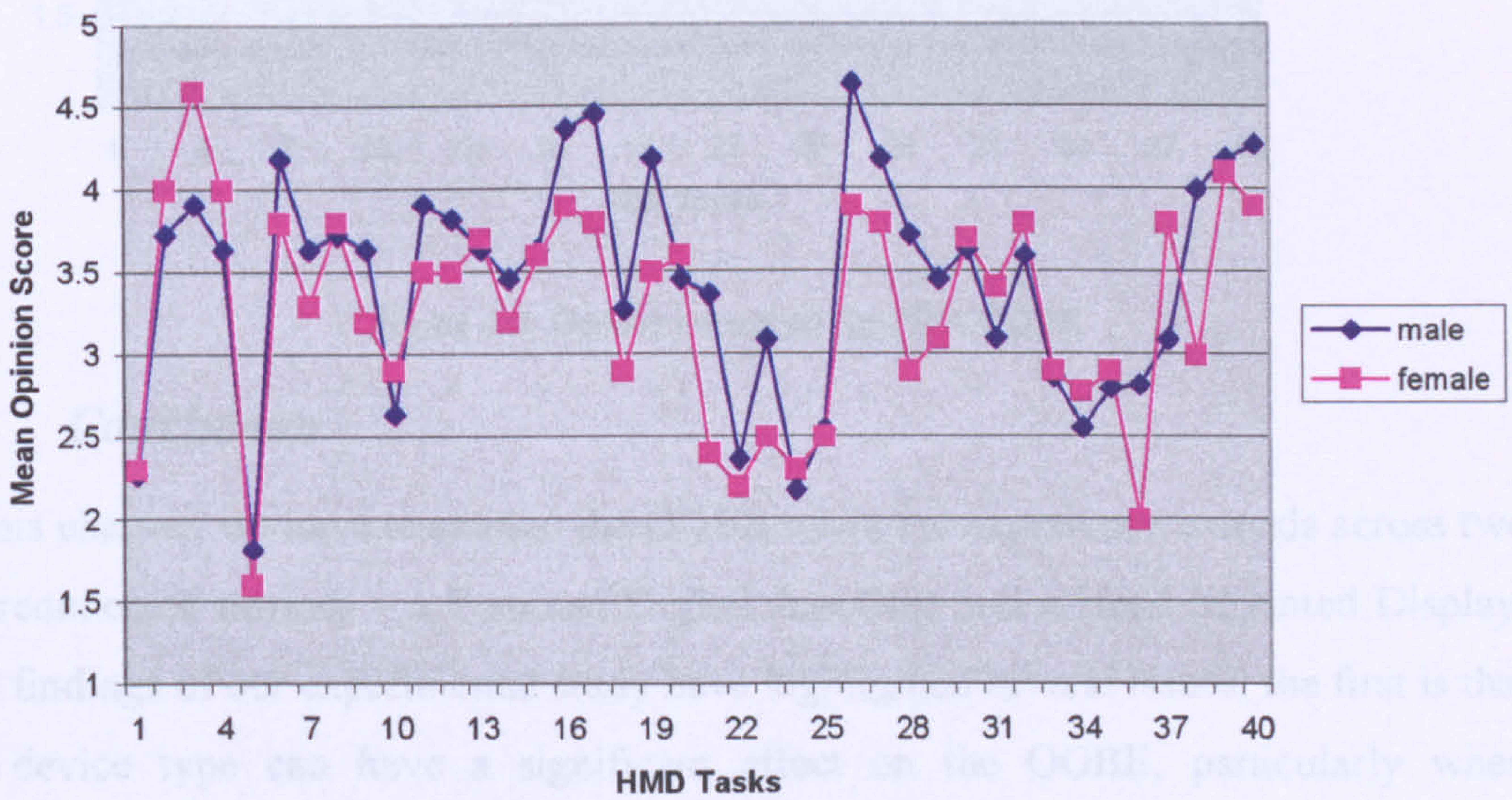


Figure 4.7: Gender impact on the HMD OOBE

Most of the tasks in which there were significant differences between the PDA OOBE for females and males can be broadly categorised into two main groups: the first covers interconnection of devices, whilst the second deals with wireless operation. Accordingly, the interconnection between the cradle and the PDA (task T2 of the Configuration category – t(19)= 2.077) as well as the synchronisation between the PDA and the desktop (task T2 of the Initial Use category – t(19)= 2.513) were found to be harder by female participants. In the second group we find tasks T3 (t(19)=2.864) and T4 (t(19)=2.538) of the Doing Work category, dealing with configuring the PDA for wireless networking. It is our belief that a possible explanation for this results rests with the diminished spatial ability of females [LAW94], although this is an interesting avenue for future work.

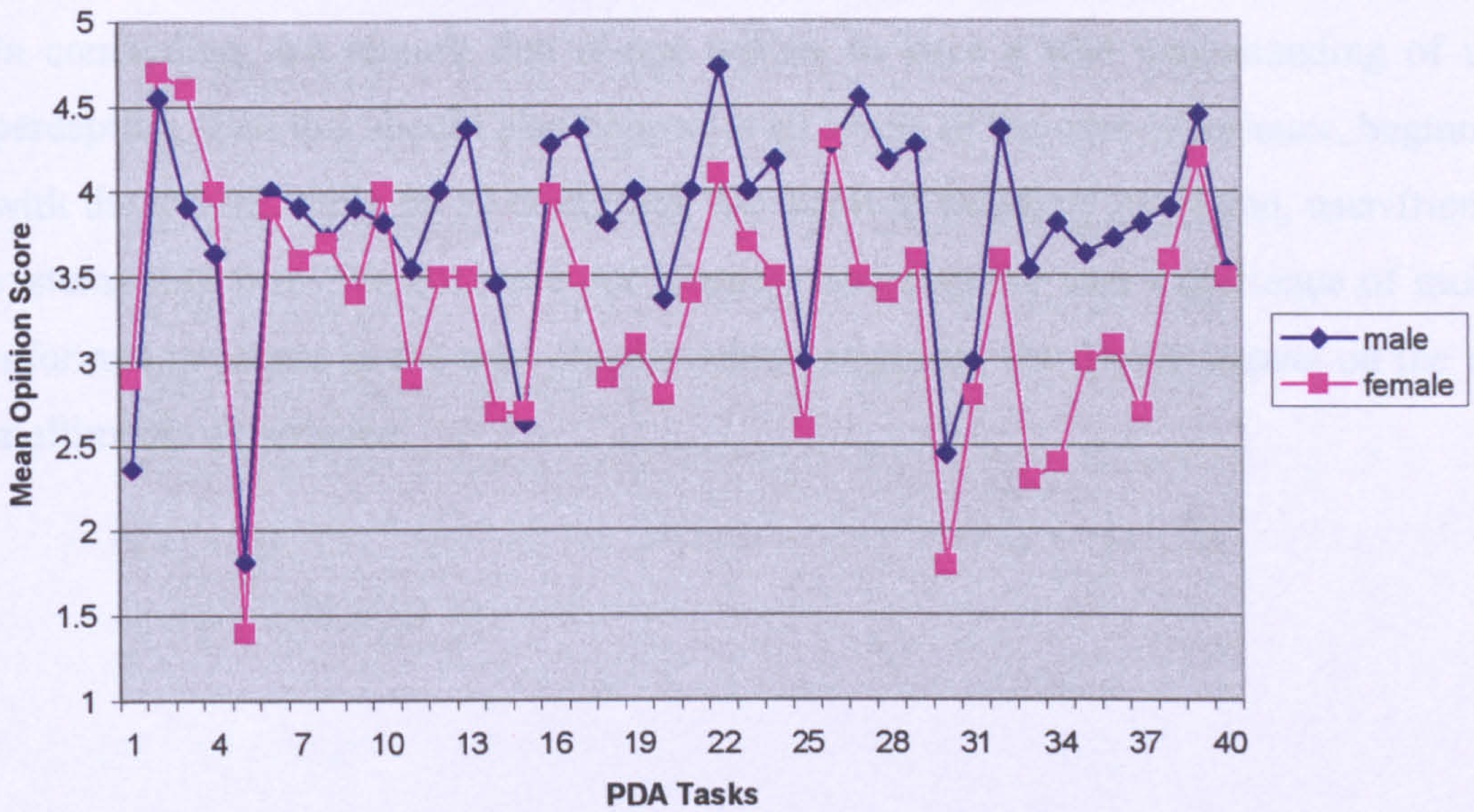


Figure 4.8: Gender impact on the PDA OOBE

4.7 Conclusion

In this chapter, we have examined the OOBE when the experience extends across two interconnected devices – a Personal Digital Assistant and a Head Mounted Display. The findings of our experimental study have highlighted several issues: the first is that the device type can have a significant effect on the OOBE, particularly when configuring the devices and trying to perform routine tasks. Moreover, most of the participants in our study found the experience of interconnecting the devices daunting and frustrating.

Indeed, our results question the assumption that smart gadgets by themselves have sufficient novelty appeal to ensure a positive user OOBE – this is especially more so when such devices need to be interconnected in order to provide, for instance, the premises for a user to experience wearable computing. This finding would seem to indicate that integration of multiple functionalities on a single device (with the corresponding reduced need for interconnection), coupled with enhanced multi-modal interaction (to possibly compensate for the one-wearable-device-fits-all-functionalities setting), might be the way forward. Additionally, our findings have also shown that the OOBE is mainly unaffected by user computer experience and gender, which highlights that the OOBE designers of the two devices have made efforts to consider these categories and provide a broadly uniform OOBE.

In concluding, we remark that if one wishes to have a true understanding of user perception, then this should also happen at all levels of the user experience, beginning with the OOBE. Only by so doing will the claim of building integrated, user-friendly systems ring true. We continue our journey assessing the user experience of mobile information access in the next chapter which examines the device impact on the user multimedia experience.

CHAPTER 5

Device Impact on User Multimedia Experience

In this chapter, we measure the device type impact on user QoP when s/he is presented with multimedia video clips at three different frame rates, using four different display devices, simulating variation in participant mobility. Devices used include a fixed head-position eye-tracker, a traditional desktop limited mobility monitor, a HMD, and a PDA. These devices represent considerable variation in screen-size, level of immersion, as well as level of mobility, which are all of particular importance in the fields of virtual reality and mobile communications. Device impact evaluation is achieved through use of diverse experimental video material and information access devices. As defined in our research aims, user perception evaluation method will consider both user understanding and user satisfaction (QoP-IA, QoP-S) to evaluate and measure the device impact on multimedia experience of the user.

5.1. Introduction

The inclusion of multimedia capabilities in pervasive and mobile communications devices is a feature that, whilst increasing their allure, raises new challenges. Of these, the provision of good quality multimedia, both from a technical and user perspective will be paramount for the take-up and spread of multimedia-enabled pervasive computing. Indeed, we are of the opinion that it is the person and not the machine or the underlying technology which is the ultimate determinant of quality: if an application is perceived to deliver low quality, users will rarely be convinced to pay for the privilege of using it, irrespective of its intrinsic appeal.

In this study, we explore user experiences on variable information access devices by measuring the quality of the information received by the user. Quality, in our perspective, has two main facets in a pervasive multimedia environment: of service and of perception. The former illustrates the technical side of computer networking and represents the performance properties that the underlying network is able to provide. The latter characterises the perceptual experience of the user when interacting with multimedia applications and forms the focus of this chapter, which examines the three-way interaction between the multimedia quality of service provided by the network and its user-centric QoP, when mediated across different access devices, with varying level of mobility.

Accordingly, this chapter is structured as follows: in Section 5.2, we provide a brief introduction to the output device types being considered in this study, allowing the reader an understanding of the research that has been done, especially relating to the area of multimedia perception. Section 5.3, describes the experimental methodology used in our work. Section 5.4 describes the empirical study undertaken as part of our research, while Section 5.5 presents the main results obtained. Finally, in Section 5.6 conclusions are drawn based on the findings of our study.

5.2. Experimental Information Access Devices

In this section we aim to provide the reader with a succinct introduction to literature relating to the specific output display devices being considered in this chapter, which allow us to consider the perceptual implication of varying mobility. These devices range from a fixed head-position eye-tracker, to a traditional desktop limited mobility monitor, to a HMD (allowing greater autonomy of movement), through to a PDA, allowing full personal mobility.

5.2.1. Eye Tracking

The eye naturally fixates on areas that are most likely to be informative [KAU69]. Therefore, monitoring eye movements offers insights into visual perception, as well as the associated attention mechanisms and cognitive processes, and is therefore a logical way of determining factors that affect user perceptual processes.

The process of visual attention itself can be broken into two sequential stages: the pre-attentive stage and the limited-capacity stage [HOF78; TRE86]. The pre-attentive stage of vision subconsciously defines objects from visual primitives, such as lines, curvature, orientation, colour and motion [SAL66] and allows definition of objects in the visual field. When items pass from the pre-attentive stage to the limited-capacity stage, these items are considered as selected [GLE95].

Interpretation of eye movement data is based on the empirically validated assumption that when a person is performing a cognitive task, while watching a display, the location of his/her gaze corresponds to the symbol currently being processed in working memory [JUS76] and, moreover, that the eye naturally focuses on areas that are most likely to be informative [MAC70].

There are several approaches to sensing eye movements [YOU75] including: the use of a camera [HUT89; RAZ98] or imaging systems to visually track some feature of the eye and then a computer or some neural network [POM93] to do the reverse geometry to determine where the user is looking; the use of contact lenses, either combined with a camera- or magnetic-based feedback system; or alternatively the use of electrodes next to the eyes that sense the electro-oculographic potential [GIP96]. As a result, eye-tracking equipment varies considerably depending on the technique being implemented.

Eye tracking is increasingly being used as a tool for obtaining information about human perceptive and cognitive processes [KOW90; PEL00], as it is based on the empirically-validated assumption that the eye naturally centres on areas that are most likely to be informative. Thus, Mackworth and Bruner [MAC70] studied the eye movement of participants whilst looking at blurred pictures. The visual area was divided into 64 squares, each with an informative weighting. The most informative areas attracted more fixations [MAC67; MAC70]. Mackworth and Morandi identified that informative areas are identified within the first two seconds of observation, a conclusion that has been reported in other studies of eye movement [DEG66; YAR67]. Moreover, eye tracking is being employed as an input device in the design of user interfaces, as an efficient interface ensures, for instance, that commonly-used controls are located in areas where the eyes' gaze is most likely to rest [PAR00], and that eye movement between these controls is minimal. Additionally, use of eye-based interfaces as an input device also help users (especially disabled) to execute interface input [MAJ02].

Eye-tracking systems can be combined with purely display devices or can provide the user with interactive functionality [ISO00; REI02]. Depending on the equipment, eye-tracking devices can be considered as either intrusive or non-intrusive in nature [GOL02] and can be developed as either pervasive [SOD02] or standalone systems. Level of immersion, whilst using eye-tracking equipment, may be high [HAY02] or low [PAS00], depending on the specific equipment type.

To allow the perceptual impact of devices of varying mobility to be compared, our study requires a non-mobile / intrusive display device. A camera based eye-tracker, with fixed head position, has been chosen to fulfil this task.

5.2.2. HMD

A HMD was chosen for our study, which although still limiting mobility (the user is restricted by limited vision and somewhat cumbersome equipment), facilitates a greater autonomy of movement than traditional display devices. The technical specification of the device used in our study is given in section 5.3.3.

Although the performance of HMDs in virtual environments has been previously investigated [BOW02], unlike our work, this research only covers the performance of three dimensional immersive displays. In our case, we look at the perception and satisfaction performances of a binocular HMD device.

5.2.2. PDA

As a result of the advances in the mobile and networking technologies, PDAs have taken over the mobile device market. Nowadays, most of the mobile phones available for the consumers are PDA based that run on desktop-based operating system like MS Windows Pocket PC 2003, Palm OS and/or Linux. This enriches the capabilities and the applications that can be offered by the service providers, thus enabling the user to access an abundance of information – such as electronic mail, World Wide Web, navigation information through global positioning equipment – on-the-move. However, all these hybrid mobile phones still inherit issues typical of mobile devices, such as small screen size, slow input facilities, low bandwidth, small storage capacity, limited battery lifetime and relatively slow CPU speed [BUY00; FOX98; FUL01].

Nonetheless, there is a clear trend for functionality integration and device convergence, with a rich body of research in the area, as Chapter 2 has highlighted.

5.3 Experiment Description

In our study, levels of informational transfer and user satisfaction are measured by incorporating the QoP concept, as defined in Chapter 3. In the following section we present specific information concerning the QoP-based experiments undertaken as part of our study and how the impact of device type on user experience was measured.

5.3.1. Participants

Our experiment involved 48 participants, who were aged between 18 and 56 and were taken from a range of different nationalities and backgrounds – students, clerical and academic staff, white collar workers, as well as a number of retired persons. All participants, however, spoke English as their first language, or to a degree-level qualification, and were computer literate.

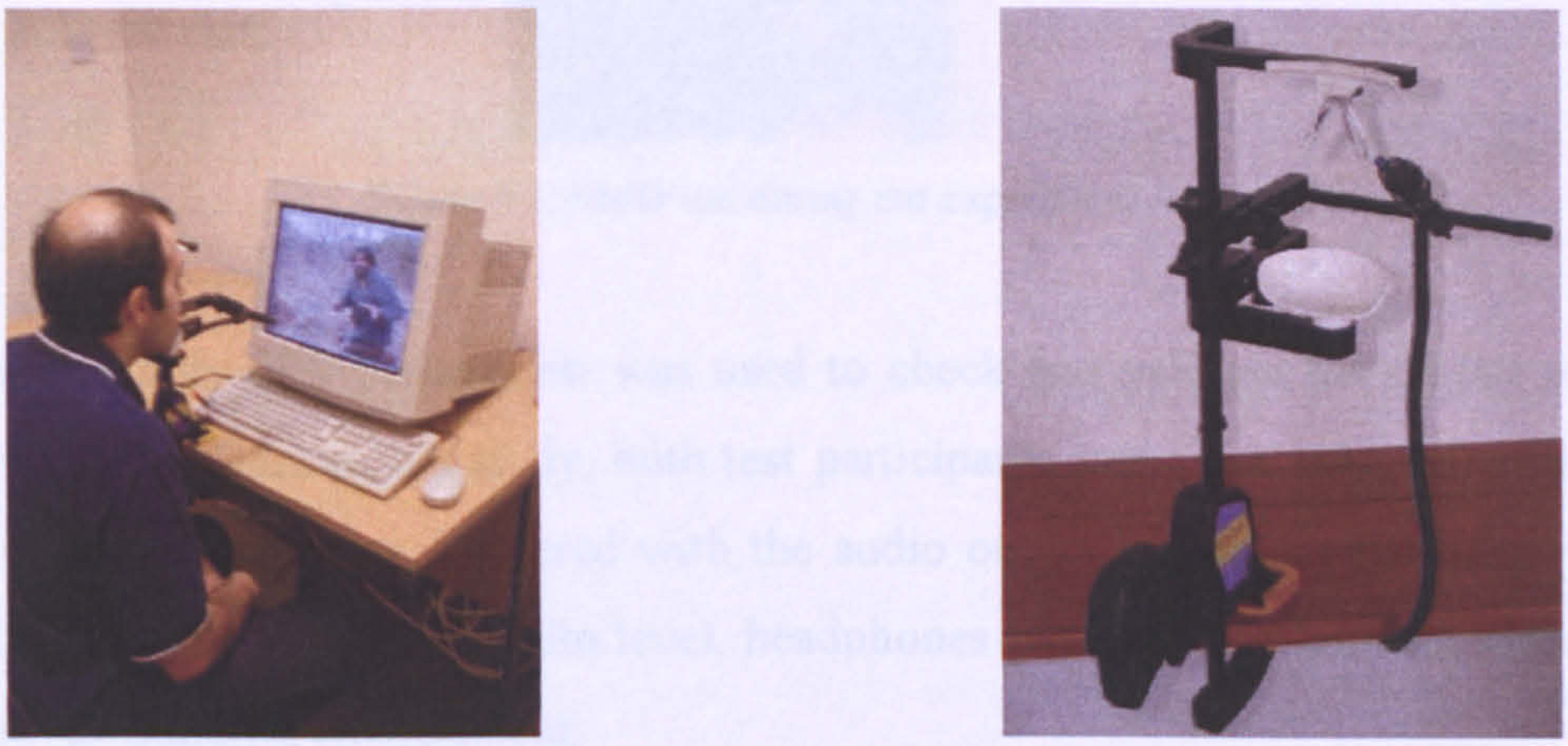
5.3.2. Experimental Variables

Three experimental variables were manipulated in our study – these were type of device, multimedia video frame rate and multimedia content. Accordingly, four types of display devices were considered in our experiments (representing varying levels of user mobility), and three multimedia video frame rates: 5, 15 and 25 fps. We chose frame rate as the QoS parameter of interest to this study, because it is the main factor affecting multimedia bandwidth requirements, of primordial importance, due to its scarcity, in distributed mobile multimedia environments. As far as multimedia content is concerned, 12 video clips, which were described in detail in Chapter 3, were utilized to maximise the possibility of covering all users' interests.

5.3.3. Experimental Set-up

To allow the perceptual comparison of different display equipment on a user's ability to assimilate information from multimedia video, the participants were evenly allocated to four different groups. Within each respective group, users were presented video clips using a specific display equipment. Thus, Group 1 acted as a control group (standard mobility) and was therefore shown the video clips full screen using a normal 15 inch SVGA generic computer monitor enabled with a Matrox Rainbow Runner Video Card.

Group 2 also viewed the video clips full screen using a computer monitor, however, the participant was simultaneously interacting with a Power Mac G3 (9.2) powered Arrington ViewPoint EyeTracker, used in combination with QuickClamp Hardware (Figure 5.1) providing limited mobility. The ViewPoint EyeTrackter allows an accuracy of approximately 0.5° - 1.0° visual arc and has a temporal resolution of 30htz.



a) b)

Figure 5.1: a) Power Mac G3 (9.2) ViewPoint EyeTracker, used in combination with QuickClamp Hardware b)

Group 3 viewed the multimedia video clips using an Olympus Eye-Trek FMD 200 HMD, which uses two LCD displays and allows a greater autonomy of movement than a generic computer monitor. Each one of the displays contains 180.000 pixels and the viewing angle is 30.0° horizontal, 27.0° vertical. It supports PAL format and display weight is 85g (Figure 5.2).

Group 4 viewed the video clips using a HP iPAQ 5450 PDA, allowing the user complete mobility. The PDA had a 16-bit touch sensitive transflective thin film translator (TFT) liquid crystal display (LCD) that supports 65,536 colour. The display pixel pitch of the device was 0.24 mm and its viewable image size 2.26 inches wide and 3.02 inches tall. It ran the Microsoft Windows for Pocket PC 2002 operating system on an Intel 400Mhz XSCALE processor. By default it contains 64MB standard memory and 48MB internal flash ROM. Additionally, in the course of this experiment a 128 MB secure digital memory card was used for multimedia data storage purposes.

Figure 5.2: HMD use during our experiment

A pilot test study of 2 participants was used to check and validate the output of all display devices. During this study, both test participants using the PDA commented that environmental noises interfered with the audio output. As we hoped to provide participants with a consistent audio level, headphones were used to limit interference from the surrounding environment.

In addition to participants viewing video material on different display devices, participants viewed video clips using one of three orders. Thus, each participant viewed four video clips at 5 fps, four video clips at 15 fps, and four video clips at 25 fps, with the order as defined in Table 5.1. Although a within-subject frame rate manipulation reduces the size of samples groups it also reduces the impact that participant effects have on results, therefore allowing a more accurate measurement concerning the impact of frame rate on user QoP.

Table 5.1: Frame rate and video order presented to experimental groups

Video	Order 1	Order 2	Order 3
Band (Jazz Band)	25	5	15
Commercial	5	15	25
Chorus – Choir	15	5	25
Cooking	15	25	5
Animation	25	15	5
Weather	5	25	15
Documentary	5	15	25
Pop	15	25	5
News	5	25	15
Rugby	25	5	15
Snooker	15	5	25
Space	25	15	5

5.3.4. Experimental Process

All participants, independent of the display device being used, were asked a number of short questions concerning their sight, which was followed by a basic eye-test to ensure that participants were able to view menu text on the screen. This was especially important for the eye-tracking device as participants were not able to wear corrective spectacles or lenses for the duration of the experiment. Participants were informed that after each video clip they would be required to stop and answer a number of questions that related to the video clip that had just been presented to them. To ensure that the participants did not feel under test conditions, it was made clear that their intelligence was not being tested and that they should not be concerned if they were unable to answer any of the information assimilation questions.

After introducing the participant to the experiment, the appropriate system software was loaded and the specific display device was setup for the user's requirements. In the case of the eye-tracker, time was taken to adjust the chin-rest, infrared red capture camera and software settings to ensure that pupil fix was maintained throughout the user's entire visual field.

When display calibration was complete, the participant was asked to get into a comfortable position and in the case of the eye-tracker place his/her chin on the chin-rest. The correct video order was loaded (see Table 5.1) and the first video was displayed.

After showing each video clip, the video window was closed and the participant was asked a number of QoP questions about the video that they had just seen. All questions were chosen in accordance with the QoP definition, described in Chapter 3, to encompass both objective QoP-IA and subjective QoP-S. Once a user answered all questions relating to a specific video clip, and all responses had been noted, experimental setup was repeated and the next video clip was displayed. This process repeated for all 12 videos, independent of the display device.

5.4. Results

5.4.1. Device Type Impact on QoP-IA

Variation of device type was used in this study to identify whether any significant changes occur to user QoP, as a result of the device, and therefore the level of mobility, used to display the multimedia presentation. To check the effect of device type on information assimilation, we used a one-way Analysis of Variance test, with information assimilation (Video), information assimilation (Audio) and information assimilation (Text) as dependent variables and device type as the independent variable. As the homogeneity of variance proved that only video information assimilation results to be valid, a K-independence non-parametric test was used to test the significance of information assimilation (Audio) and information assimilation (Text). Results demonstrated that only level of video information assimilation was significantly affected by variation in display device ($F = 3.048$) and therefore level of user mobility. Information assimilation (Audio) and information assimilation (Text) was found not to be significantly affected by device type. Post Hoc Tukey tests showed that a significant difference occurred between the mean video information assimilation ratings (mean number of video questions answered correctly per video) of participants using eye-tracker and HMD devices ($p = 0.018$). The HMD and eye-tracker, with respectively mean video information assimilation ratings of 5.78 and

4.75, were identified as respectively the best and worst devices for user video information assimilation.

We believe that the reason for the difference is due to the level of immersion available to the user whilst using the two devices. The Olympus Eye-Trek HMD is designed to simulate a 52-inch display monitor, thus proving a high level of user visual immersion. HMDs also allow full head movement without changing the relative position of the screen and the eye. In comparison, the Arrington ViewPoint EyeTracker is used in combination with QuickClamp Hardware, which intrusively restricts the movement of the user's head. Although restricted head movement is vital to this specific eye-tracker device to map and interpret eye-gaze location, it is intrusive and far from conducive to user immersion. Additional aspects, such as a smaller perceived display screen (15-inch generic monitor), as well as the users' conscious awareness of the eye-tracker device are all possible factors that reduce participant visual immersion.

5.4.2. Device Impact on QoP-S

To check the effect that device type has on satisfaction, as the QoP-S data did not satisfy the conditions for ANOVA analysis, we used a K-independence non-parametric test to check the effect of device type on QoP-S. This analysis showed that device type significantly affected a users' level of quality $\{\chi^2 (3, N = 576) = 11.578, p = .009\}$, with a significant difference between mean level of quality score for control (3.05) and HMD (2.63) participant groups. Despite facilitating the greatest video information assimilation, users' perceive the HMDs as displaying the worst level of quality video – see Figure 5.3.

We believe that a significantly lower QoP-S may be due to one of two specific issues. The first proposed reason why HMDs cause a reduction in the perceived level of quality is as a result of increased level of video immersion. As previously stated, a trade off exists between the resolution used and the field of view. A low field of view decreases the experienced level of user immersion, yet a higher field of view involves spreading the available pixels, which can cause distortion on the picture.

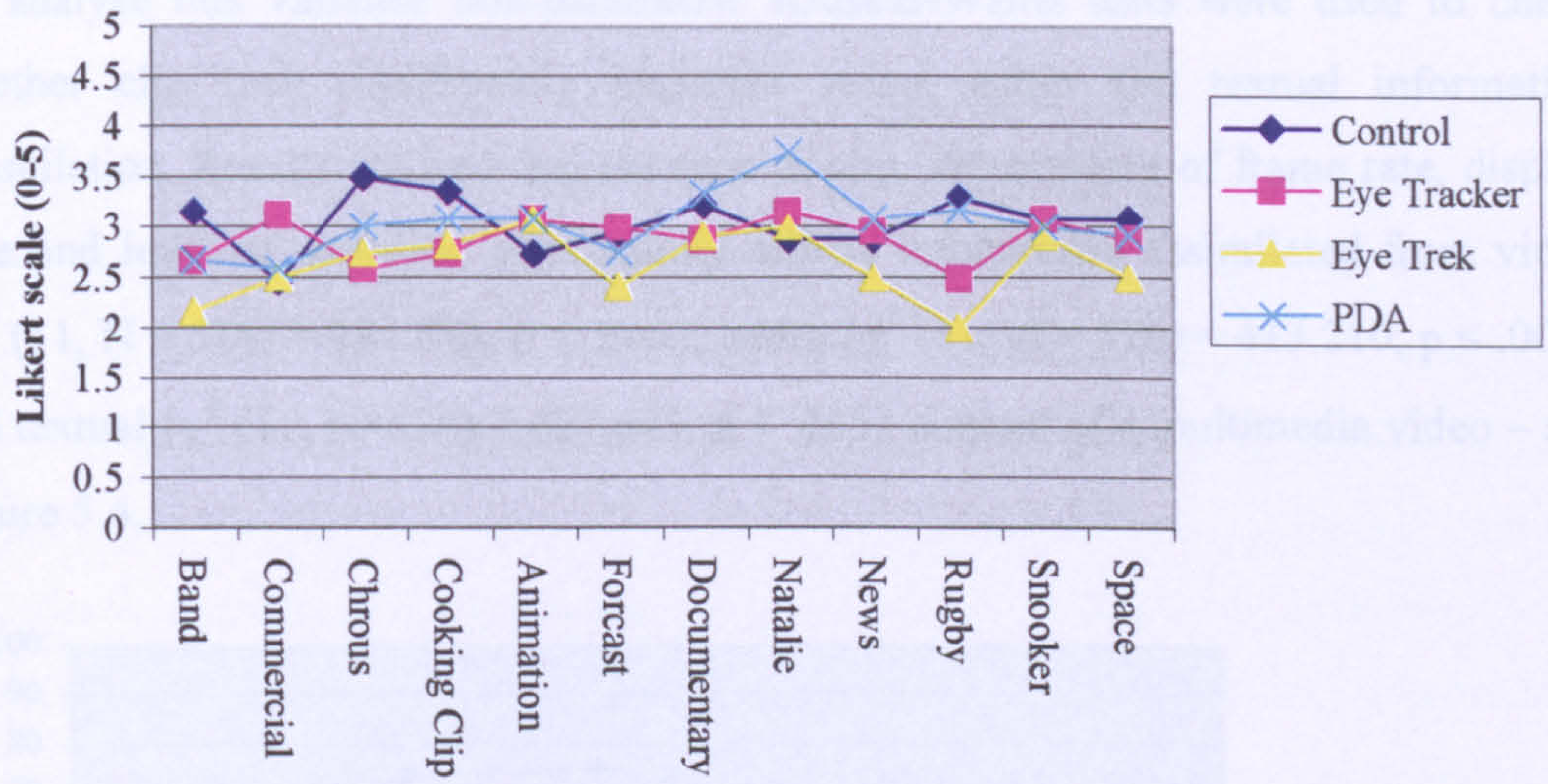


Figure 5.3: Average perceived quality, for all frame rates, across all video clips.

The Olympus Eye-Trek HMD is designed to simulate a 52-inch display monitor, providing the user with a high level of video immersion. As the same video clips were used for all devices, the authors suggest that pixel distortion as a result of a higher field of view was perceived as being of bad 'quality'. It is interesting to note that users viewing exactly the same videos on the 2.26 x 3.02 inch PDA screen, perceived them to be comparatively higher 'quality'.

The second proposed reason why HMDs cause a reduction in the perceived level of quality is due to physical discomfort. Geelhoed [GEE00] showed that, whilst using a HMD, tasks requiring more long-term attention, such as watching a video, causes a greater level of discomfort to the user.

Irrespective of the reason, the reduction of perceived quality has interesting implications on the future use of HMDs.

5.4.3. Video Clip Type Impact on QoP-IA

Clip type obviously affects the quantity of specific questions being used in our experiment, for example: the band clip has no textual content, therefore no textual feedback questions were used. However, when results were displayed as a percentage measure of the number of questions being asked, as defined in the QoP definition, considerable variation was still observed in the level of video, audio and textual information assimilation between the different clips used throughout this experiment.

To analyse this variance non-parametric Kruskal-Wallis tests were used to check whether clip type significantly impacted video, audio and textual information assimilation. Results showed that the type of clip, independent of frame rate, display type and level of mobility, significantly affects information assimilated from video $\{\chi^2\ (11, N = 576) = 287.833, p < .005\}$, audio $\{\chi^2\ (11, N = 576) = 413.210, p < .005\}$ and textual $\{\chi^2\ (11, N=576) = 427.643, p < .005\}$ content of a multimedia video – see Figure 5.4.

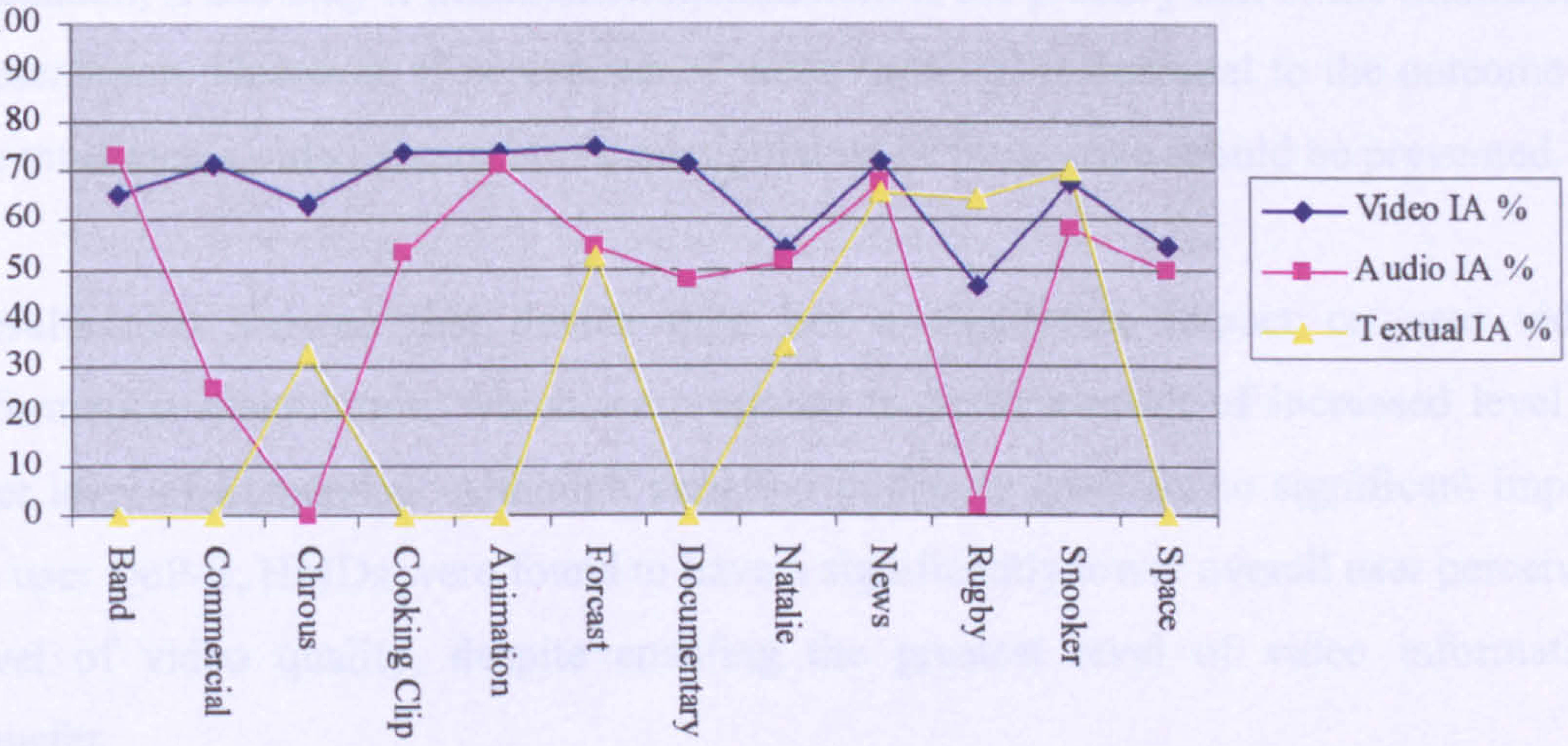


Figure 5.4: Average video, audio and textual information assimilation, independent of device type and frame-rate, for all video clips.

Our study shows that the video clip type, used as part of a multimedia presentation, has more of a significant affect on a users' level of information transfer than either the frame rate, display device type and therefore the level of mobility being used to present the multimedia presentation. The significant impact of the contents of the clip could be for a number of reasons: user preference leading to greater level of maintained attention, cultural level of pre-knowledge, clearer transfer of relevant information or even capable cognitive load. Although further work is required to determine the relationship between clip contents and level of information assimilation, the authors believe that this result justifies our view that when considering 'multimedia quality', especially in the pervasive multimedia environment, we must consider two main facets: of service and of perception. Quality of digital multimedia has traditionally been measured using quality of service technical parameters, however, our work has implications on using purely objective testing when defining multimedia quality.

5.5. Conclusion

In this chapter, we have evaluated the device type impact on user QoP when s/he is presented with multimedia video clips at three different frame rates, using four different display devices, simulating variation in participant mobility. Our results show that despite a considerable loss of frames (that is, a reduction in the frame rate), the level of QoP-IA, affecting the users' experience of the multimedia presentation, does not significantly fluctuate. This gives justification for a reduction in bandwidth allocation, if and only if information assimilation is the primary aim of the multimedia presentation. However, if perception of video 'quality' is essential to the outcome of the multimedia video presentation, manipulation of frame-rate should be prevented.

Results also showed that device type has a significant impact on user video information assimilation, which we proposed to be as a result of increased level of user level of immersion. Although variation in device type has no significant impact on user QoP-S, HMDs were found to have a significantly lower overall user perceived level of video quality, despite enabling the greatest level of video information transfer.

Our study also considered the impact that clip-content has on the perception of multimedia video quality. Results showed that clip type was found to have a more significant effect on a users' level of information transfer than either frame rate or display device type (and therefore level of mobility). Additionally, whilst a user's QoP-S is significantly affected by variations in frame rate and display device being used, it is not significantly affected by the content of the video, implying that users are able to distinguish between their subjective enjoyment of a video clip, and the level of 'quality' with which they perceive the video clip to possess.

This chapter has addressed the second objective of our study and examined user information access experiences, when mediated across different access devices, with varying level of mobility. The following chapter builds on the results of the present one and addresses the third objective, by focusing on the user mobile information access experience in a real-life context.

CHAPTER 6

Device Impact on User Real-life Information Access Experience

The importance of the user perspective to the wireless information access experience cannot be understated: simply put, users will not indulge in devices that are perceived to be difficult to use and in technologies that do not offer quality infotainment – combined information and entertainment – content. In this chapter, we address the third objective of our study and investigate the impact that mobile devices have on the user wireless information access experience. To this end, we have undertaken an empirical study placed in a 'real-world' setting, in which participants undertook typical infotainment access tasks on three different wireless-enabled mobile devices: a laptop, a PDA and a HMD device.

6.1. Introduction

Portability, convenience and affordability are all factors behind the increase in take-up of wireless devices. Improvements in technology, especially in respect of computational processing capabilities, together with the homologation of the IEEE 802.11 family of wireless networking standards have pushed the barriers of anywhere / anytime information access.

While the allure of ubiquitous information access still has novelty appeal, it is unlikely that appeal per se will still be enough in the future to sway customers to adopt such technologies if the expected infotainment (i.e. combined information and entertainment) return is not going to justify the initial outlay. However, whilst research in the area has focused on themes such as usability, multimodal interaction and haptics [BUY00; FUL01; MAC03; WAY03], the field of context aware computing has primarily concentrated on application-centred issues [NYL04], as well as personalisation [CHA02] and adaptation based on location and device [HOD99; SAT96; ZHA04]. Nonetheless, comparatively little work has been done examining the user mobile information access experience when this is mediated by different devices – which is the precise issue we address in this study. Moreover, we adopt a "real-world" approach in our work, in that the experiments on which it is based employ people in realistic contexts engaged in everyday information access tasks.

Accordingly, the structure of this chapter is as follows: Section 6.2 presents an overview of mobile information access devices, while Section 6.3 reviews work done with respect to user experiences of mobile computing. Such work provides the foundation for our project, whose experimental method is described in detail in Section 6.4. Whilst Section 6.5 presents the results and implications of our study, Section 6.6 draws conclusions of this experiment.

6.2. Mobile Information Access Devices

Although there are a plethora of available mobile devices, in this chapter we shall concentrate our attention on those that can access the World Wide Web wirelessly. As the Web is the largest repository of networked information, it is no surprise that we view "accessing information" and "accessing Web information" synonymously in this study. Accordingly, we give an overview of such devices, with an emphasis on the ones considered in our work.

6.2.1. Laptops and Tablet PCs

Laptop technology emerged in the late 1980s and hit mainstream computing in the 1990s. Initially, similar to the case of other mobile devices, laptops were beset by issues of bulk and weight, and had comparatively less resources – from memory and processing power viewpoints– than their standalone counterparts. It is only recently, however, with the advent of 3G and WiFi technology that laptops have been able to harness the full potential of the Web wirelessly.

Tablet PCs are devices designed for highly mobile users, which enable interaction via the users own handwriting by employing digital ink [MCC00; WOL02; ANDb04]. Tablet PCs are intermediate in size and weight, between laptops and Personal Digital Assistants (PDAs). Although such devices are usually pen-based, they also have a detachable keyboard accessory – nonetheless, tapping and handwriting recognition remain the primary input methods, much like PDAs, with users finding the ability to annotate documents and presentations in their own handwriting particularly useful [ANDa04; BER04; GOL04; SIM04]. Nonetheless, takeup of Tablet PC technology has lagged behind expectations, with reasons being cited for this state of affairs ranging from a scarcity of existing software for Tablet PCs to lack of publicity [THU00].

6.2.2. Personal Digital Assistants

PDAs probably exhibit one of the most popular and easily recognisable showcases of portable computing, manifesting a 28% market growth in Western Europe in the second quarter of 2004 [IDC04]. Nonetheless, they do inherit issues typical of mobile devices, such as small screen size, slow input facilities, low bandwidth, small storage capacity, limited battery lifetime and relatively slow CPU speed [BUY00; FOX98; FUL01].

The apparent contradiction between the increasing popularity of PDAs and the above enumeration of problems have made PDAs a popular area of research, upon which we have elaborated in Chapter 2.

6.2.3. Head Mounted Displays

HMDs are a sub-set of wearable computer technology, which aim to allow hands free access to computer functionality. Whilst HMDs, and the research topics that they have spawned, have been described in Chapter 3, we would like to note here that ergonomic and usability factors vary considerably between different devices, with issues such as display size, weight and adjustability of physical and visual settings all affecting the usability of a particular head-mounted display for any specific task [BOW02]. Additionally, the large and encumbering size of CRT-based HMDs is also an identified obstacle towards their adoption [LAN97], as is the current high cost of HMDs that display both high resolution and a wide field of view. Indeed, the fact that HMDs afford the user the experience a high degree of visual immersion, yet in everyday life a user's field of view is limited, has been shown to be an inhibitor in their popularity, rather than a contributing factor. Moreover, from a medical perspective, the weight of HMDs has possibly detrimental implications on the supporting muscles and even on the eyes, with issues of hygiene also being singled out as possible deterrents to the proliferation of HMDs.

Nonetheless, despite the computational costs and usability drawbacks of the head-mounted displays, they are widely used in current research, ranging from virtual environments to wearable Internet applications. Whilst such application-oriented research is attractive, the emphasis of our study, though, is on the user experience of mobile information access, when it is being mediated by different access devices. Accordingly, in the next section we provide an overview of work in the area.

6.3. Mobile Information Access and User Experience

Since the first GSM (Global System for Mobile Communications) system started operating in 1991, mobile information access and mobile services have represented one of the most vibrant research areas in telecommunications [COL94; PEE00]. Today, GSM-based information access services are already being used for medical [DEA03], business [FRI98] and entertainment [REG04] purposes. However, the latest advances in hardware and networking technologies have pushed researchers in the direction of seamless and pervasive information access, a direction ultimately affecting the way of life of the individual and resetting industry standards.

From this aspect of the individual, McClard and Sommers [MCC00] studied the integration of tablet PCs into the home environment. Their findings show that tablet PCs are primarily used at locations where mobility and multi-tasking of the user is important – the living room, the bedroom and, in their particular case, the porch. On the other hand, Anderson et al. [ANDa04] studied experiences with a tablet PC-based lecture system in computer science courses. The proposed wireless system enables collaboration between the projected slide and students' tablet PC, so that either lecturer or students can make notes using digital ink. Evaluation of the developed system in an educational context showed that the new approach increased student attention during lectures by 55 percent.

From a different perspective, Freire et al. [FRE01] developed WebViews, an application which performs transcoding of traditional web content so that it could be accessed via mobile devices. Here, the user creates views of any web content that would like to access on-the-move and saves them into his/her profile. The WebViews server then reformats the profile contents and sends the data to the requesting mobile device (PDA, WAP-enabled phone or mobile phone) accordingly. Similarly, in

MobileIQ, Chandrasekaran and Joshi [CHA02] also used profile-based transcoders to look into issues like mobility management, disconnection management, content personalization, bandwidth utilization, download latencies and user privacy. Their findings highlight that the use of transcoders for mobile information access purposes is generally expensive to implement for multiple users and inefficient in most cases due to malformed code which requires manual parsing of the HTML data.

Although in Chapter 5 we have detailed our work which investigated how user perceptions of variable multimedia quality are affected by access devices of different mobility, however, to the best of our knowledge no work has been done exploring how a user's experience of mobile information access is affected by the different access devices that s/he is utilising in a real world context. This forms the focus of our current investigation, whose methodological approach we now detail.

6.4. Experimental Method

6.4.1. Participants

Participants in our experimental study were aged between 18 – 32 years old and were drawn from various professional backgrounds (students, academics, psychologists, nutritionists, bankers, blue-collar workers). A total of 72 people participated in the study. None received any remuneration for participating; however they all were offered a cup of coffee of their choice, as part of the experiment.

Participants were grouped according to their computer proficiency in 3 main groups – novice, intermediate, and advanced. This categorisation was based on the participants completing a short questionnaire (the details of which have been given in Chapter 3) prior to beginning the experiment proper that assessed their computer abilities and experience.

6.4.2. Experimental Variables

Experimental variables in our study included: device type, computer expertise, user location, and task group type. Accordingly, our study incorporated three different types of mobile access devices – a laptop, a PDA, and a head mounted device – all of which boasted varying information display capabilities, as shall be described in section 6.4.3 and varying degrees of portability (these range from a relatively bulky laptop, to a handheld PDA, to a wearable HMD). As mentioned above, three levels of computer expertise were considered in our study. The experiment took place in two different settings – one was an 'on-the-street' setting, in which participants accessed information whilst physically being on a busy high street bench; the other was a 'coffee shop' setting in which participants accessed the Web from a café. Lastly, as part of the experiments, users were asked to perform two groups of tasks, each of which reflected one of the main reasons behind users' wishes to access Web material – accordingly, one group of tasks was mainly informational in nature, whilst the other was entertainment-related, both of which will be described in more detail in Section 6.4.4.

6.4.3. Experimental Material

Three different types of devices were used in our experiments. The first was a Toshiba Satellite P35-S611 laptop equipped with a 54Mbps Netgear PCMCIA wireless network card. The laptop ran the Microsoft Windows XP operating system, and was equipped with 3.33GHz Pentium IV processor, 512MB memory, 100GB hard drive, 17-inch XGA TFT Active Matrix Display (Figure 6.1a). In our experiments, the laptop represented mature technology.

The second device, a representative of 'contemporary' technology, was an HP iPAQ 5450 PDA with a 16-bit touch-sensitive TFT LCD that supports 65,536 colour. Although we also considered having Tablet PCs in our study, bearing in mind the more widespread take-up of PDA technology and our wish to employ only one point-and-tap device in the experiments, we decided in favour of the latter.

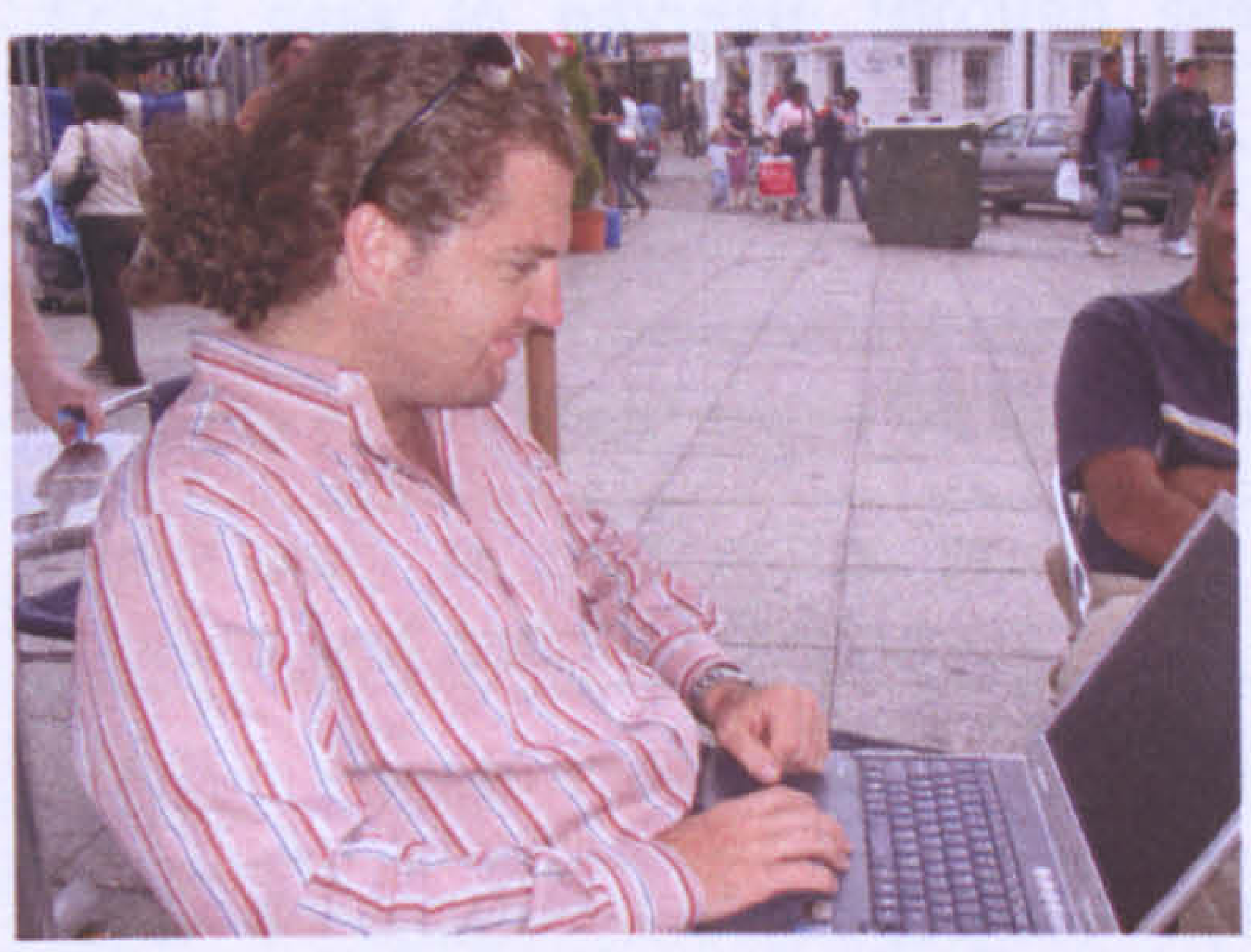
The third and last device employed in our study was an Olympus Eye-Trek FMD 200 head-mounted display, and was considered as a representative of technology of the future, due to its relative novelty and incipient take-up. Although the HMD by itself is not wireless enabled, it was interfaced via a Lifeview Fly Jacket with the PDA employed in our study, and thus connectivity was ensured (Figure 6.1b).

6.4.4. Experimental Set-up

Our study involved real participants engaged in real-life tasks in realistic scenarios. Accordingly, as previously mentioned, participants undertook two main tasks, the first of which was mainly informational in nature and involved a mixture of physical and digital searching. This involved users searching for their nearest shopping centre on the Web, and then locating sports stores in the centre, also via the Web. Once this was done, participants had to physically go to the identified sports stores (there were two) and had to obtain price information on a specific good (a sports shoe, in our case). Participants then had to find the corresponding price for the good over the Web and e-mail the cheapest price found to a friend via e-mail.

The second task was mainly entertainment-related. This comprised users listening to a mainstream online radio station, noting down the details of the track currently being played and then searching for the album cover of the respective track on the Web. Once this was done, users were asked to download the cover on their device for future reference in a music store.

These two tasks were undertaken in two different real world environments, reflecting situational contexts that users might find themselves in during their everyday activities. The first involved users accessing the required information needed to fulfil their tasks on a busy high street bench, whilst the second involved users undertaking the same set of tasks in a comparatively secluded café. Both locations were covered by WiFi blankets.


a)


b)

Figure 6.1 a) On-the-street scenario using a laptop; b) Coffee-shop scenario using an HMD

The 36 participants involved in our study were evenly assigned to one of the two environments ('on-the-street' and 'coffee-shop') in which our experimental study took place. Moreover, participants were also evenly distributed as far as the use of the three experimental devices is concerned, with 12 participants being allocated for the laptop, PDA and HMD, respectively. Lastly, care was taken that each device should be used by an equal number of novice, intermediate and advanced computer users.

6.4.5. Experimental Process

Inf1: ***Connect to the Internet using the device provided.***
Inf2: ***Go to the*** [redacted] ***website and search for shopping centres in the area.***
Inf3: ***Open a shopping centre's web page and find its interior map and identify the sports shops within.***
Inf4: ***Find the cheapest price for*** [redacted] ***from the local shops.***
Inf5: ***Search on the Internet and compare the online prices with the prices in hand.***
Inf6: ***Send the cheapest price available to a friend via email***

Figure 6.2: Group of information-related tasks

Ent1: ***Logon to*** [redacted] ***web site.***
Ent2: ***Tap on the appropriate button on the website and start listening to the stream.***
Ent3: ***Listen to online radio.***
Ent4: ***Note down the singer and the title of the song that is currently playing.***
Ent5: ***Use the details to search for the album cover on a music market web site of your choice***
Ent6: ***After finding the album cover, download the image file to the mobile device for future use in the music store.***

Figure 6.3: Group of entertainment-related tasks

Q1: It is easy to logon to the Internet.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
Q2: It easy to navigate through search results on the device.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
Q3: It is easy to find sports shops in the malls near to you.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
Q4: It is easy to read maps on my device.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
Q5: It easy to find online prices of the product and make a comparison.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
Q6: It is easy to send e-mails.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
Q7:I am comfortable using the device in a public place	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

Figure 6.4: Information-related tasks questionnaire

Before undertaking the experiment, all participants were verbally explained that the experiment consisted of two main groups of tasks (Figure 6.2 and Figure 6.3), which they should accomplish at their own pace. Once this was done, they were given the respective experimental devices they were to use towards the accomplishment of the tasks. Although users did not need to log on to any of the devices, they were given the user name and password needed to log on to the wireless internet service provider employed in the study.

Participants were then asked if they would like to order a coffee (all of whom accepted!) and the experimenter (the same person conducted all experiments of the study) duly went and ordered the specific type of coffee requested. For participants in the 'on-the-street' scenario a 'to-go' coffee was ordered in the nearest café and brought to them, whilst for those in the 'coffee-shop' setting the order was delivered at the participants' respective table.

For each of the tasks involved, participants were asked to indicate their opinions on a 5-point Likert scale (strongly agree, agree, neutral, disagree, strongly disagree) to a series of seven statements concerning the tasks at hand (Figures 6.4 and 6.5).

Q1: It is easy to navigate through the [redacted] website.	1 □	2 □	3 □	4 □	5 □
Q2: It is easy to listen to online radio.	1 □	2 □	3 □	4 □	5 □
Q3: It is easy to identify the track that is playing.	1 □	2 □	3 □	4 □	5 □
Q4: It is easy to interact with the device.	1 □	2 □	3 □	4 □	5 □
Q5: It is easy to do searches on the Web.	1 □	2 □	3 □	4 □	5 □
Q6: It is easy to access information and save it on my device.	1 □	2 □	3 □	4 □	5 □
Q7:I am comfortable using the device in a public place	1 □	2 □	3 □	4 □	5 □

Figure 6.5: Entertainment-related tasks questionnaire

Once this was accomplished, users could indicate in writing any further comments that they had about their experience. Lastly, participants were thanked for their time and effort.

6.5. Results

6.5.1. Device Impact

A one way Analysis of Variance (ANOVA), with type of device as independent variable revealed that, with the exception of four tasks, across the two scenarios of our study, the particular device type does not have a significant impact on the user information access experience. This observation holds true, even though, as Figures 6.6 and 6.7 show participant mean opinions scores for the HMD were (with only one exception) consistently lower than that of the other two devices considered in our investigation. The one exception to this trend is users' ability to identify the currently playing track on the visited online radio station – in the case of the PDA this was facilitated by three factors: the first is that the online radio site had a lite version tailored for PDA browsers (the HMD accessed the web through the PDA, as previously mentioned); moreover, in this version the details of the current track being played were placed on top of the page, in an instantly viewable location.

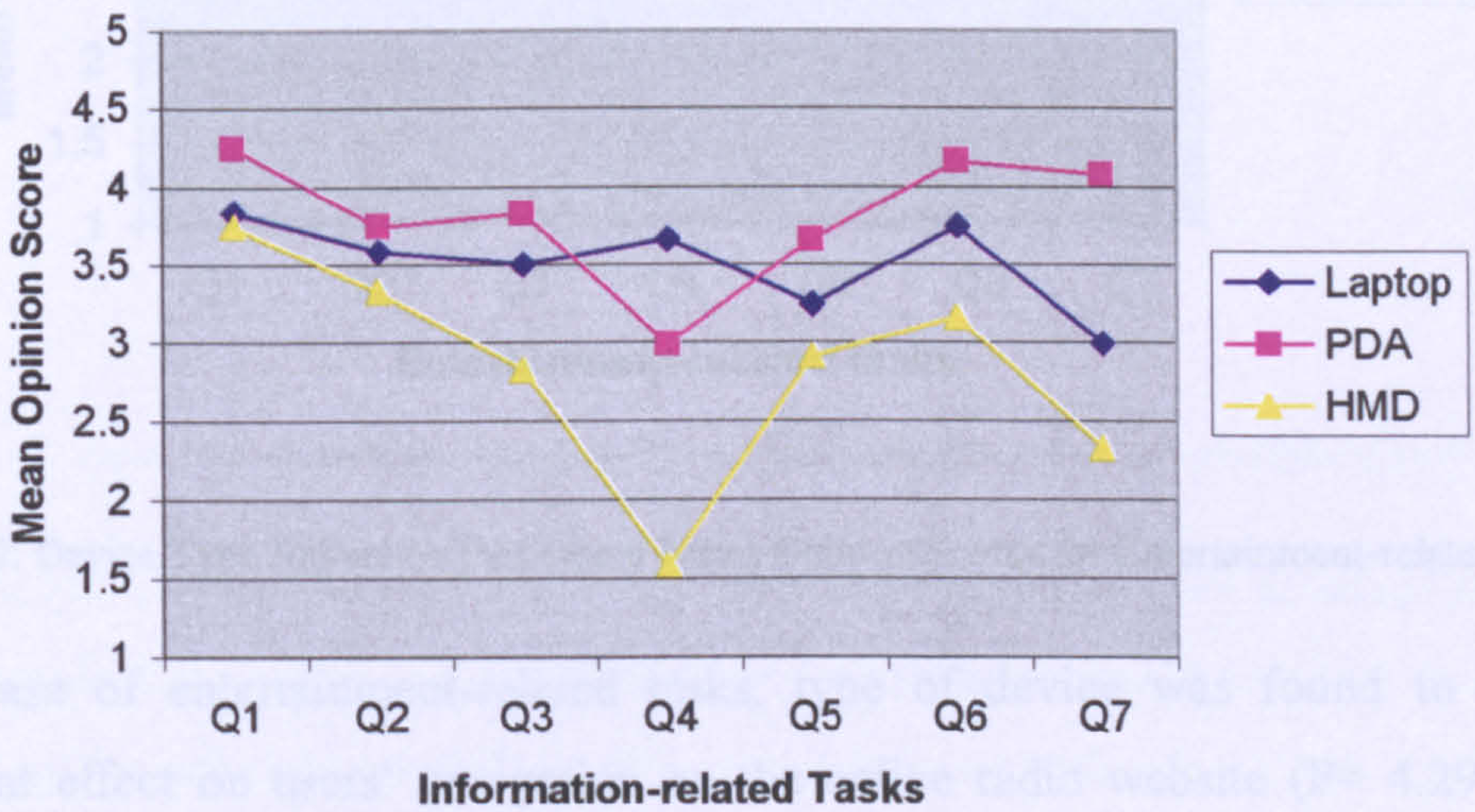


Figure 6.6: Device Type Impact on Participant Mean Opinion Scores for Information-related Tasks

Lastly, when the relatively small screen of the PDA was blown up to near full immersion size quality, the HMD users felt that they were actually being 'hit' (actual words of three participants) with this particular information.

The particular type of device employed was shown to have a significant impact on the user information access device in the case of reading maps from the screens of the device (F=9.420), and users' comfort factor with respect to using a mobile information access device in a public place (F=6.492). We believe that reasons for the first finding is that most maps that people found online had virtually unreadable labels – this problem was exacerbated in the case of the small screen PDA, whilst in the case of the HMD, which did provide full immersion, this was done so at the expense of resolution. As far as the second observation goes, it should come as no surprise that participants who wore HMDs should feel particularly self-conscious in public places, as would those accessing information via relatively bulky laptops – people were most comfortable with using the PDA as an information access device in a public context, which might be one of the main drivers behind their popularity.

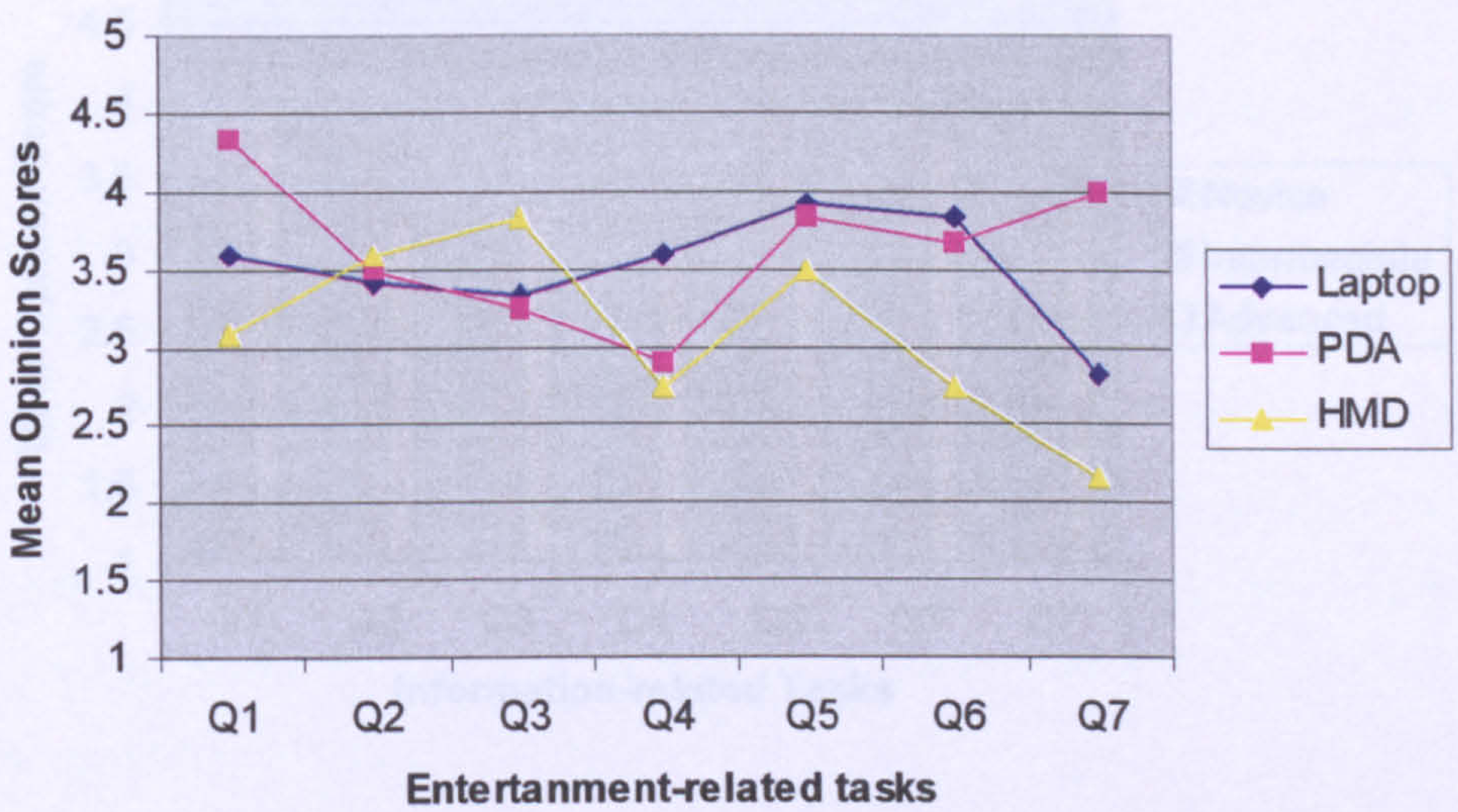


Figure 6.7: Device Type Impact on Participant Mean Opinion Scores for Entertainment-related Tasks

In the case of entertainment-related tasks, type of device was found to have a significant effect on users' navigation on the online radio website (F= 4.295) and, again, on their comfort factor associated with using a wireless access device in public (F=7.869). Whilst we have already elaborated upon what we believe are the reasons behind the latter (and we can additionally remark that the relative ordering of comfort levels associated with the respective devices is the same in the case of entertainment-related tasks as in for the information-related ones), we believe that the reason for the former observation lies in the fact that many users found it difficult to navigate through a website using the point-and-tap functionality of the stylus whilst wearing the HMD – this contrasts markedly to the case where the same (adapted, lite) website was accessed by the PDA alone, for which users gave the highest ratings of all devices employed in our study.

6.5.2. User Type Impact

User computing background has, with two notable exceptions, no significant impact on the mobile information access experience (Figures 6.8 and 6.9). The only exceptions to this observation were, in both the information-related group of tasks as well as the entertainment one, the users' perception of ease of conducting searches for pricing information (F= 8.007) and on the Web, generally (F=4.915).

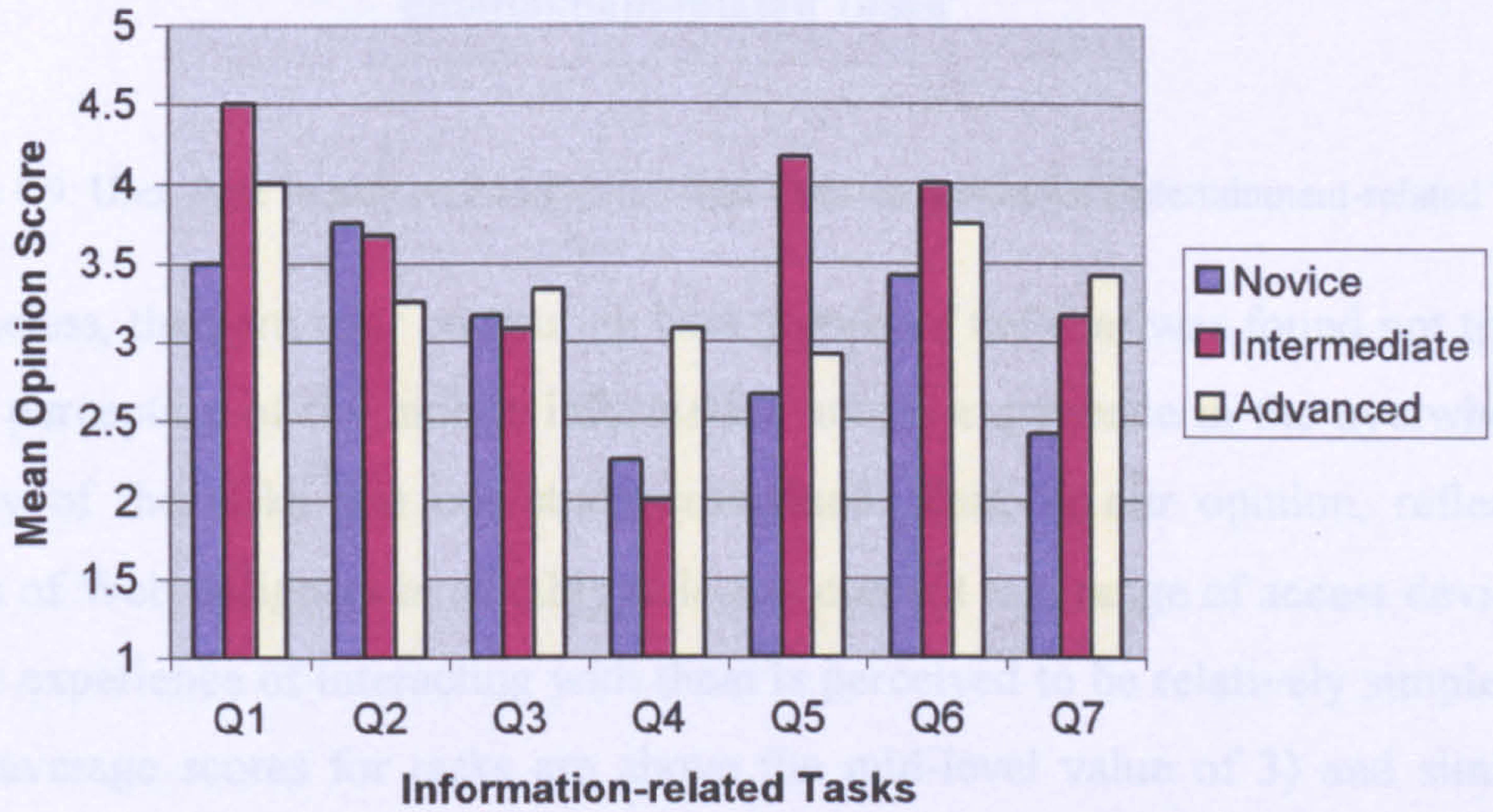


Figure 6.8: User Type Impact on Participant Mean Opinion Scores for Information-related Tasks

Interestingly, it is intermediate users who perceive that Web-based searches are quite easy to accomplish, whilst, as expected, novice users encountered the most difficulties in searching for information, and rated the experience accordingly. Whilst the fact that advanced users found Web searching to be comparatively more difficult that their intermediate counterparts might appear at first sight to be counter-intuitive, our observations of the experiments highlighted that intermediate users were more flexible and prepared to experiment with different types of devices; this is in contrast to advanced users, who seemed to be constrained by their everyday searching idiosyncrasies, and seemed to regard their adaptation to different devices as an imposition.

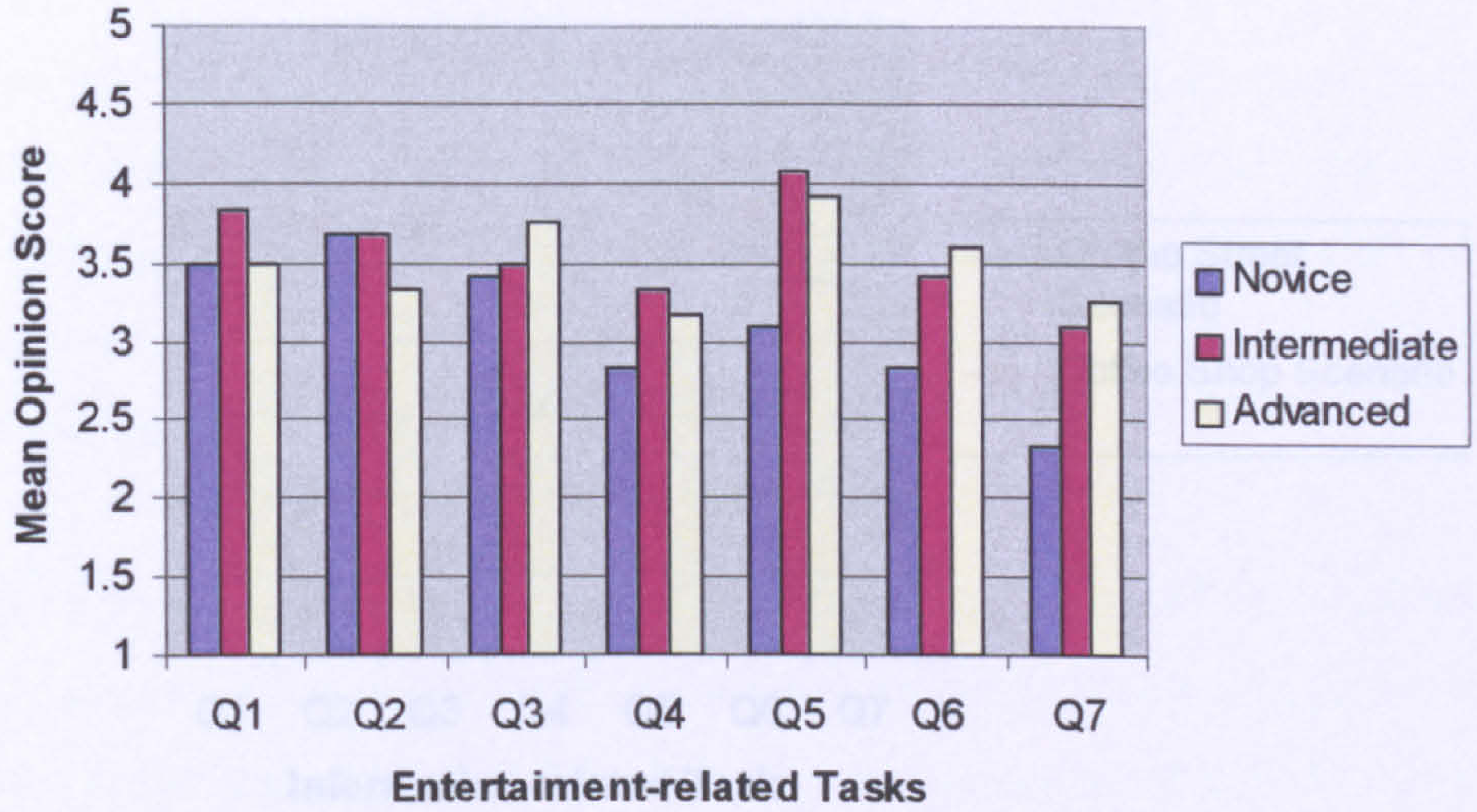


Figure 6.9: User Type Impact on Participant Mean Opinion Scores for Entertainment-related Tasks

Nonetheless, the particular computing background of the user was found not to affect his/her perception of the mobile information access experience in the overwhelming majority of the tasks that our study comprised. This, in our opinion, reflects the success of Web designers in suitably tailoring content to a range of access devices, so that the experience of interacting with them is perceived to be relatively simple (most of the average scores for tasks are above the mid-level value of 3) and similar by different categories of users.

6.5.3. Location Impact

An independent samples t-test revealed that information-related tasks were not affected by the particular location of the user (Figure 6.10). However, as far as the group of entertainment-related tasks is concerned, navigation (F=14.331) and ease of listening to online radio (F=11.824) was found to be significantly affected by user location (Figure 6.11).

These results highlight that when a user is engaged in accessing content for informational purposes, s/he is prepared to disregard possibly detrimental environmental factors such as noise and lighting levels, as well as the proximity, in inevitably crowded shopping centres and high streets, to fellow consumers.

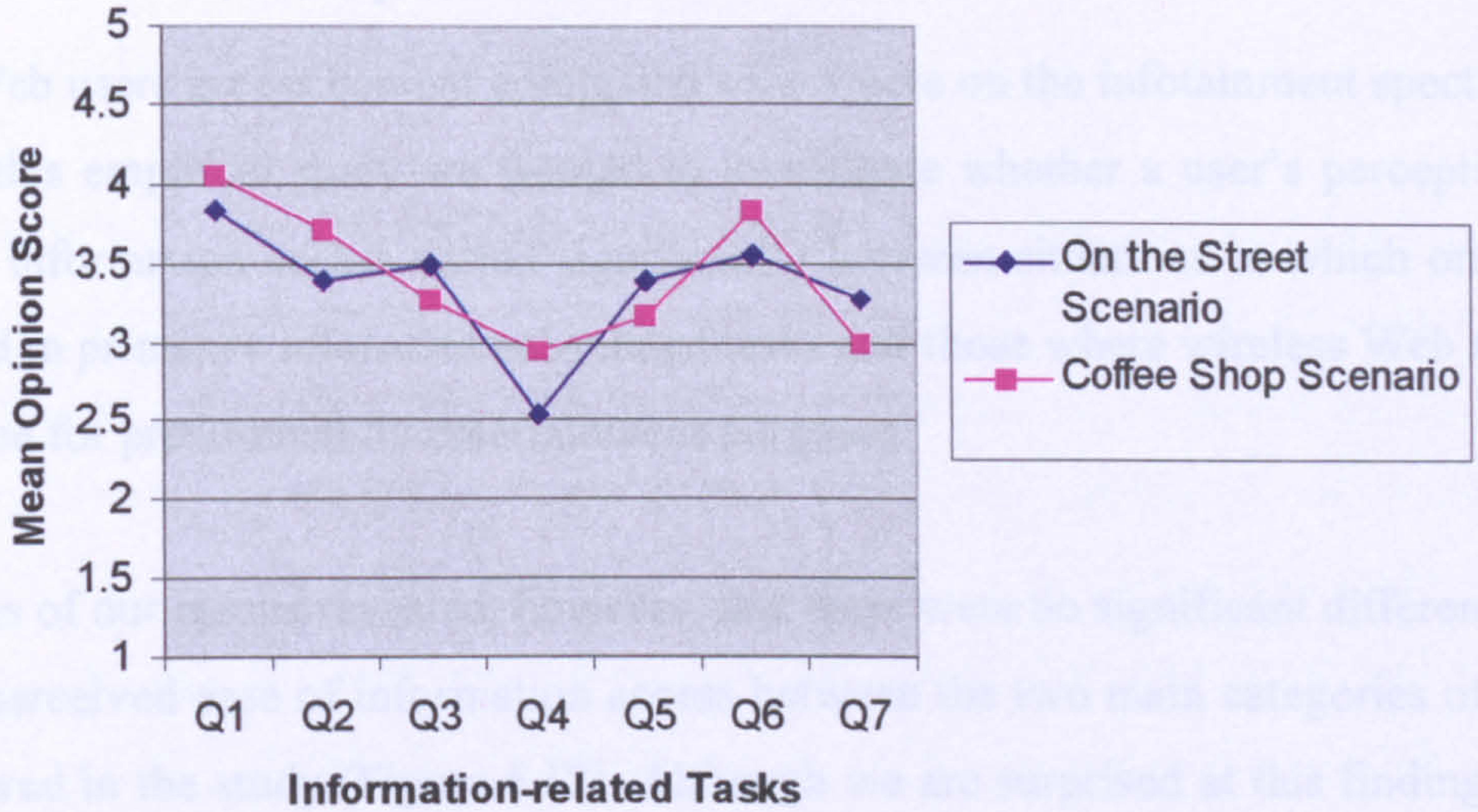


Figure 6.10: Impact of Location on Information-related tasks

However, when accessing entertainment related material, levels of lighting (brighter and sunnier in the 'on-the-street' scenario) affect the glare of the device being used, and, as such, negatively impact upon the user experience. Similar considerations apply to the case of listening to online radio – in the relative seclusion of a café the experience is perceived to be more enjoyable than when attempted in a busy and noisy outdoors environment.

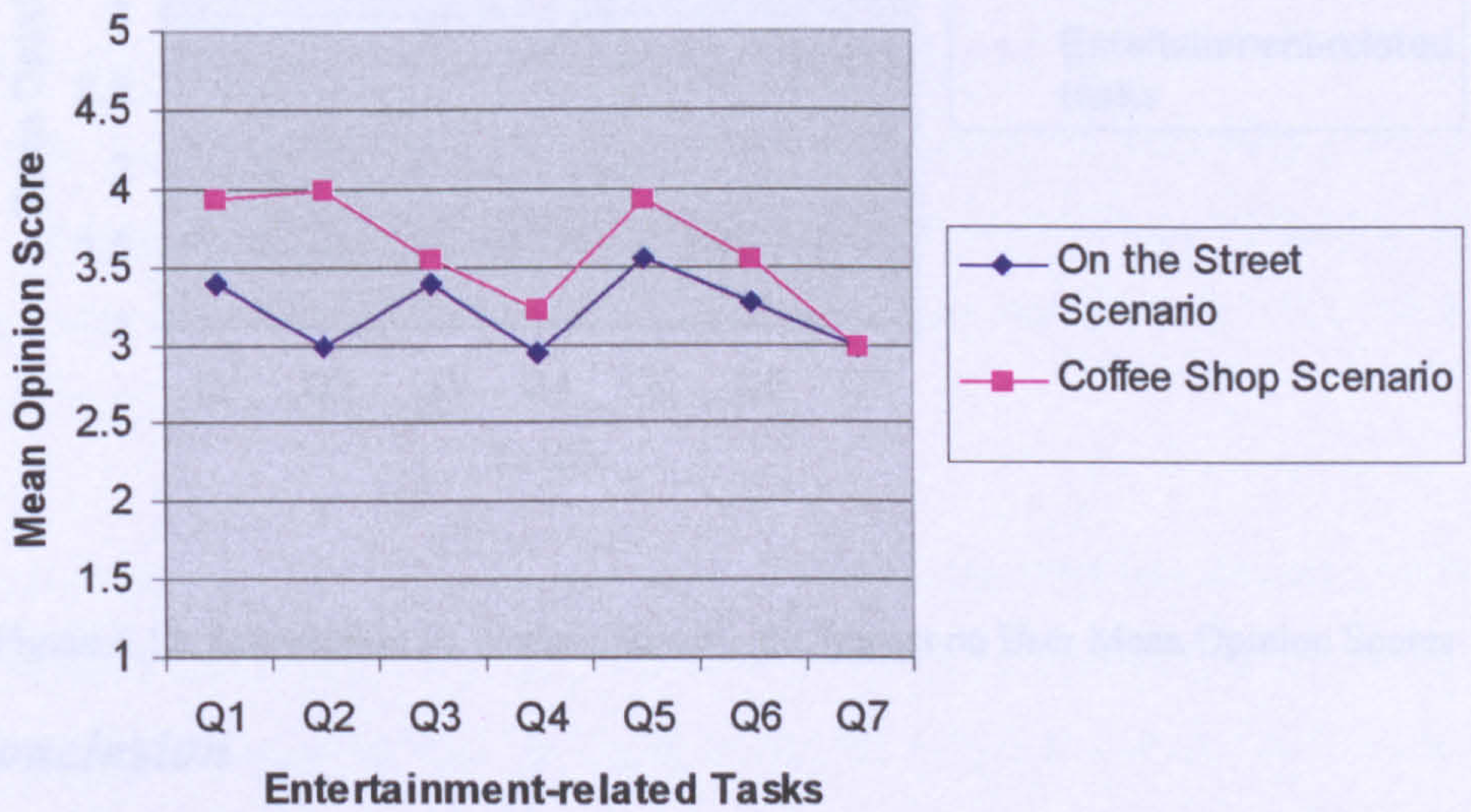


Figure 6.11: Impact of Location on Entertainment-related tasks

6.5.4. Infotainment Impact

Most Web users access content comprised somewhere on the infotainment spectrum – and in this empirical study we wanted to investigate whether a user's perception of ease of information access varied significantly between situations in which one was engaged in primarily informational-related tasks and those where wireless Web access was done for predominantly entertainment purposes.

Analysis of our results revealed, however, that there were no significant differences in users' perceived ease of information access between the two main categories of tasks considered in the study (Figure 6.12). Although we are surprised at this finding – for we were expecting user tolerance levels to be higher in the informational-related tasks – we believe it highlights the fact that users have equally stringent expectations for both information- and entertainment-related tasks. Whilst in the former case, emphasis might be put on the quality of information retrieved, in the latter the focus might be on the quality of the playback media – whilst the emphasis might be different in the two scenarios, expectations are certainly not.

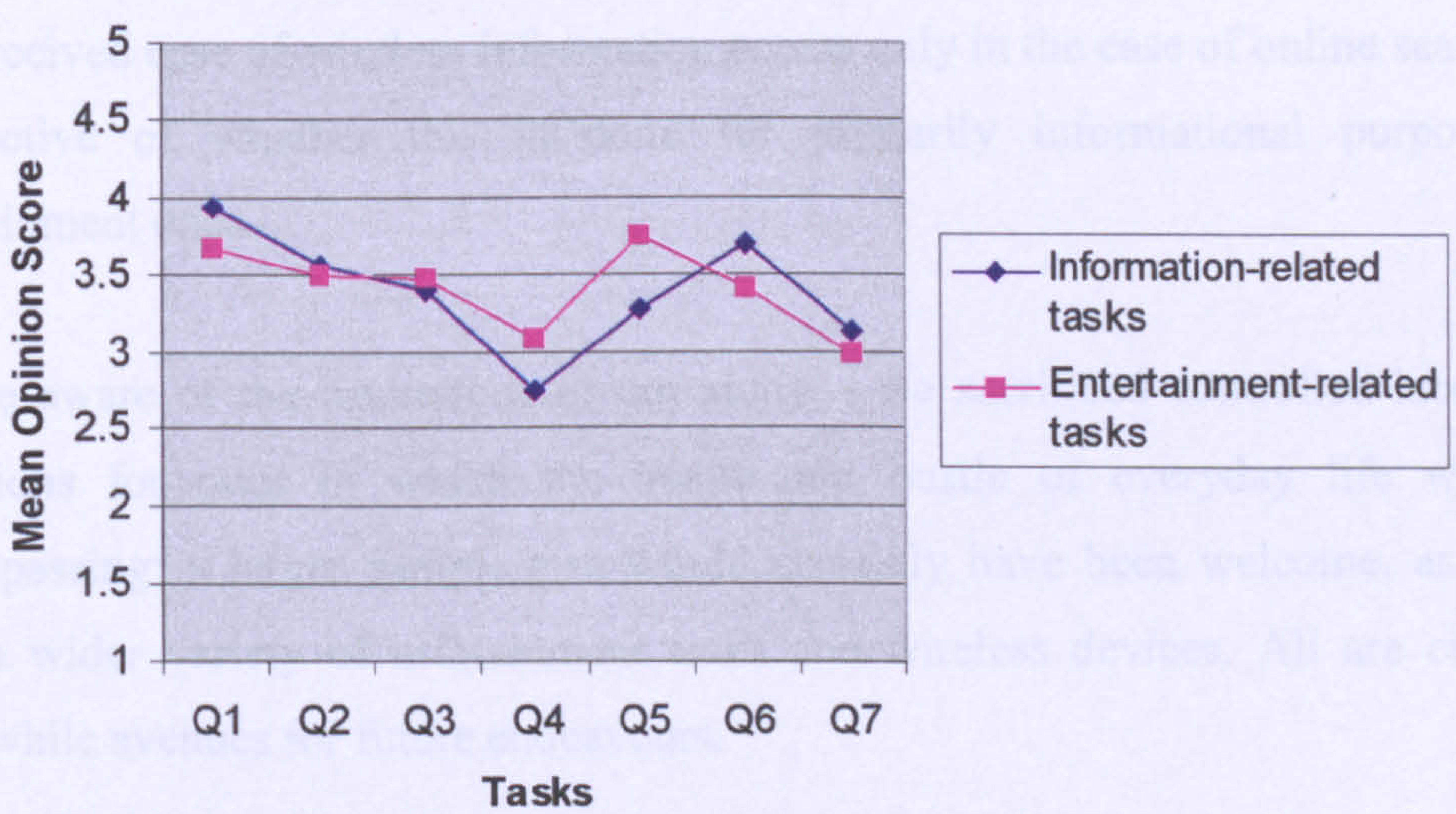


Figure 6.12: Information vs. Entertainment – the Impact on User Mean Opinion Scores

6.6. Conclusion

The user experience of interacting with technologies and devices is an important driver behind their ultimate social acceptance and commercial uptake. In this chapter, we have concentrated our attention on precisely this issue and explored the user wireless information access user experience, when this is mediated by three different access devices in a real world context.

Our results highlight that although mobile device types seem to heighten user levels of self-consciousness in public places – particularly if the device in question is a wearable one – generally the user information experience is unaffected by the type of wireless device responsible for it. Moreover, whilst user computing background was found to influence searching activities in both an informational and entertainment context, this was an exception, rather than the norm. Ambient noise and light do impact on users' efforts to wirelessly access entertainment content; such factors, however, are ignored when informational content is sought, though.

Results show that, with the exception of participants' level of self-consciousness when using such devices in public environments, the user wireless information access experience is generally unaffected by device type. Location was shown, though, to be a significant factor when users engage in tasks such as listening to online music or navigation. Lastly, a user's particular computing experience was shown to influence the perceived ease of wireless information access only in the case of online searching, irrespective of whether this is done for primarily informational purposes or entertainment ones.

We are aware of the limitations of our study – we sacrificed controlled laboratory conditions for ones in which the hustle and bustle of everyday life was all-encompassing; a larger sample size would certainly have been welcome, as would have a wider variety of infotainment tasks and wireless devices. All are certainly worthwhile avenues for future endeavours.

In concluding we note that, for the user, wireless information access holds both a promise and a challenge – a promise in that s/he will be liberated from the tyranny of the wires; a challenge in that, in order to achieve this, future research will have to recognise that the user is not easily fooled: novelty appeal per se will not convince him/her to overlook deficiencies in the design of devices themselves nor of the content presented therein. In the following chapter, we build on the previous work findings on multimedia content based on device type (as explored in Chapter 5) and location (the focus of Chapter 6) to implement an prototype service that tailors the multimedia content on-the-fly, and then evaluate its impact on the user experience.

CHAPTER 7

Device and Location Impact on Multimedia Content Transmission

7.1. Introduction

So far we have examined the user's initial interaction and his/her out-of-box experience with mobile devices, the user mobile information retrieval through a range of displays and Internet access devices, as well as the impact of display device on user perception and information assimilation. In this chapter, we build upon the findings of our two previous experiments by harnessing the results together to create pre-defined profiles based on QoP requirements, device type and location, for context-aware multimedia content streaming, and, in so doing, enhance the concept of context to include perceptual requirements.

Accordingly, this chapter is structured as follows: Section 7.2 provides a brief background on location-based systems and the use of GPS in ubiquitous computing. Section 7.3 describes the design and implementation of the Campus Guide experiment application using code snippets, figures and UML descriptors. Section 7.4 explains in detail the experimental setup and design, while Section 7.5 elaborates on the results of the experiment. Lastly, Section 7.6 draws conclusions about the experiment conducted and the impact of its findings.

7.2. Global Positioning Systems and Ubiquitous Computing

As computing environments are getting mobile and information access on the move is becoming a norm, computing research has extended to cover contextual information such as a user's location, situation and circumstances. Even though it is a relatively new research area, there is an abundance of projects and experiments conducted to-date.

One of the earliest examples of this kind is the Cyberguide [ABO96], which was initially implemented as a building guide at the Georgia Institute of Technology for the computer science department open days, and was later improved and extended to guide its users through the city of Atlanta. The core of this system is divided into four components, namely map component, information component, positioning component, and the commutation component. This system is implemented on Borland's Delphi and Microsoft Visual Basic. Evaluations of the system with real users highlighted issues with respect to positioning at indoor locations and on-screen map representations.

A similar piece of work was undertaken by Simcock et al [SIM03] who build a location based tourist guide application, using a PDA and a GPS connection, and look at the design and usability issues. The application is implemented with Microsoft Visual C++ for Windows CE operating system. The user interface has three main modes of interactions: *map view*, where the user can see his/her location and the surrounding buildings on a map; *guide view*, where the user is provided with a path of interesting attractions, and, finally, the *attractions view*, where the user is streamed audio-visual tourist information. All the colour schemes and map annotations are designed in a manner that is clearly visible to the user on the move.

From a very different perspective, Elting et al. [ELT02] implemented a static tourist information system and looked at the effect that different output modality-combinations have on the devices' effectiveness to transport information and on the user's acceptance of the system being used. Their developed system uses three devices: a PDA, a television and a desktop computer to investigate whether the best modality depends on the device. As test data, it uses a web based tourist guide that contains text and images. Their results show that the most appealing form of information transfer is combined picture, text and speech. However due to multi-modal cognitive load, especially when using a PDA, the most effective form of information transfer is shown to be just combined picture and speech.

Nonetheless, to the best of our knowledge, no research has explored user multimedia perception and experiences with a support of a GPS-based, location aware, mobile guide. Although multimedia has been previously tailored according to user location

[ABO96; BUR05] and device [FOX98; BUY00; FRE01], such tailoring up till now has ignored perceptual quality considerations, even though, as Chapters 5 and 6 have shown, bandwidth – a scarce resource in ubiquitous computing environment – could be more efficiently utilised this way.

7.3. Campus Guide: Design and Implementation

7.3.1. Methods and Objectives

In this experiment, in line with our fourth study objective (see Chapter 2), our main aim is to evaluate the user experience of accessing streamed multimedia content tailored according to perceptual requirements as well as location and device type. In order to achieve this, we had to harness together a number of technologies: GPS to identify the user's location, 54 Mbits wireless communication technology (IEEE 802.11g) to stream the relevant multimedia files to the user, and a content server to host the application logic of the system.

To make context-aware technology work for our university campus, we built a campus guide application. The first step involved digitally mapping the Brunel University Uxbridge campus using the geographic coordinate system (latitude and longitude). Thus, any region of interest in campus could conceptually be enclosed in a rectangular frame (Figure 7.1).

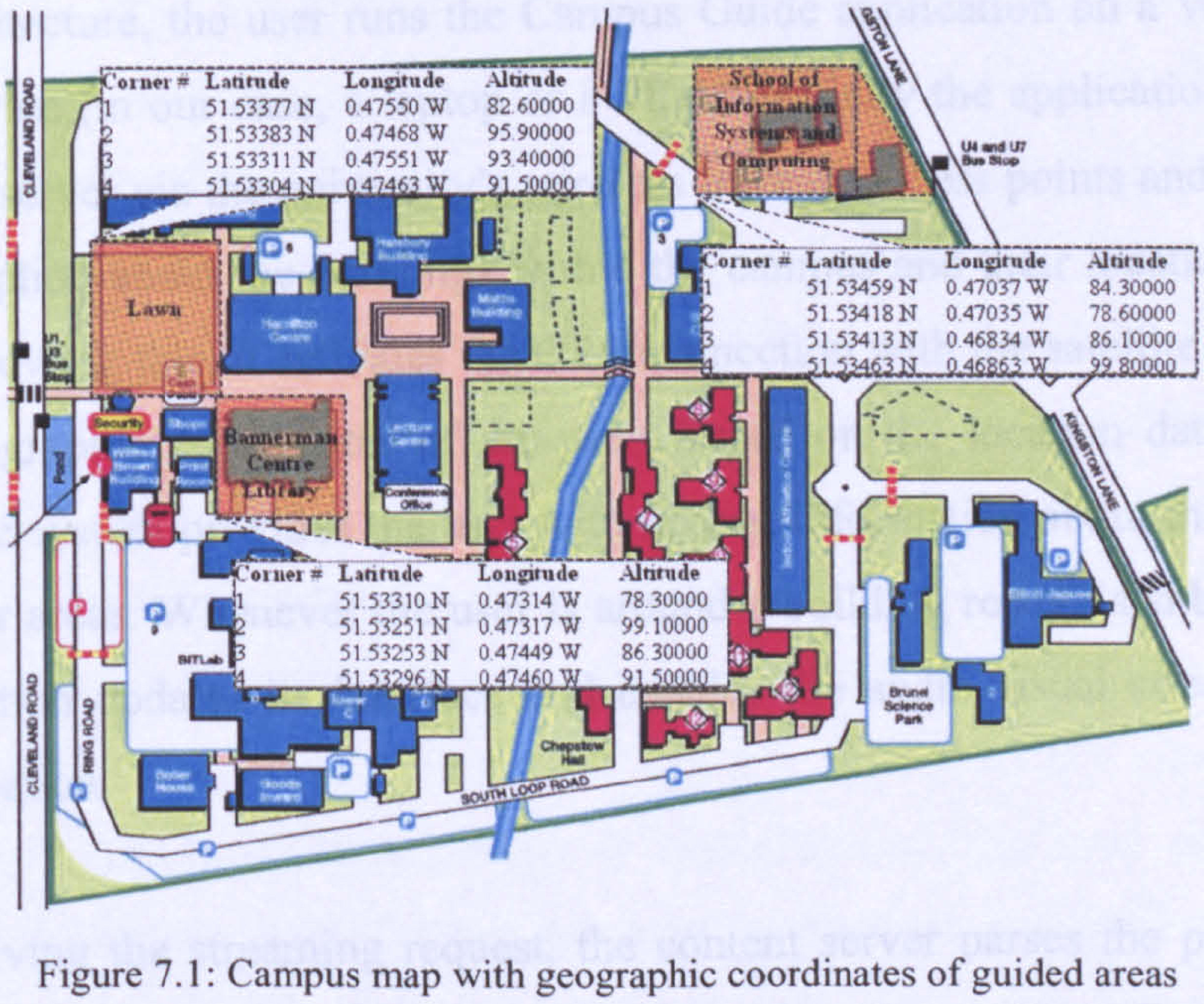


Figure 7.1: Campus map with geographic coordinates of guided areas

By knowing the latitude and longitude co-ordinates of this frame, we were able to detect if a user was inside one of the three regions. Moreover, knowing the coordinates of a user traversing the university campus, we were also able to calculate the user's whereabouts within the campus and his/her distance to a particular region and provide him/her with context aware tips to guide the user through the campus.

7.3.2. System Architecture

The underlying architecture of this system is based on an n-tier, is also known as multi-tier, architecture. In such client-server architectures, an application is executed by more than one distinct software agent [WIKb06]. The main components of our system are a GPS satellite, a WiFi/GPS-enabled device, and the content server with application logic and a backend database (Figure 7.2).

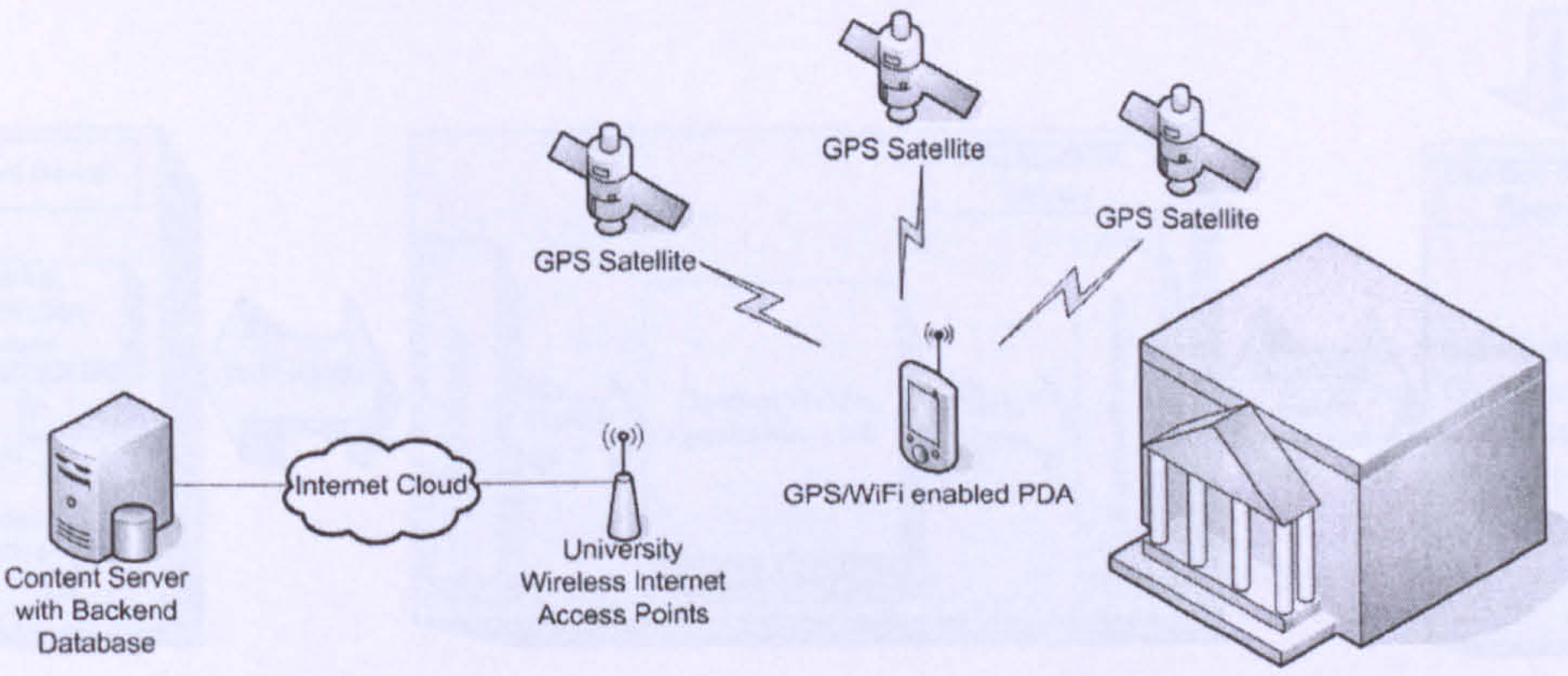


Figure 7.2: System architecture diagram

In this architecture, the user runs the Campus Guide application on a WiFi and GPS enabled device (in our case, a laptop or a PDA). Initially the application connects to the content server via the university's wireless Internet access points and downloads a brief description about the buildings within the campus and their locations, using the HTTP. Following this, it activates the GPS connection with the satellite and reads the current geographic coordinates of the user. Based on the location data sent by the satellite, the system provides the user with textual information about the surrounding buildings or areas. Whenever the user is around a building recognised by the system, the application updates its interface and enables the audio-visual streaming for the specific location.

Upon receiving the streaming request, the content server parses the parameters and identifies the type of device and the location of the user. Accordingly, the server selects a suitable clip using its knowledge base of pre-defined QoP transmission profiles, which resides in its backend database, and streams the multimedia content to the user.

7.3.3. Application Structure

The developed Digital Campus Guide application is designed and developed so that it can run both on Windows XP and Windows CE based devices. The main application and its components are implemented using Microsoft Visual Basic 6.0 and Microsoft Visual C++ 6.0, which is part of Microsoft's development suite Visual Studio 6.0. For the Windows CE version, the source code was re-compiled using Microsoft Embedded Visual Basic 3.0 and Embedded Visual C++ 3.0, which is part of the Microsoft Embedded Visual Tools package.

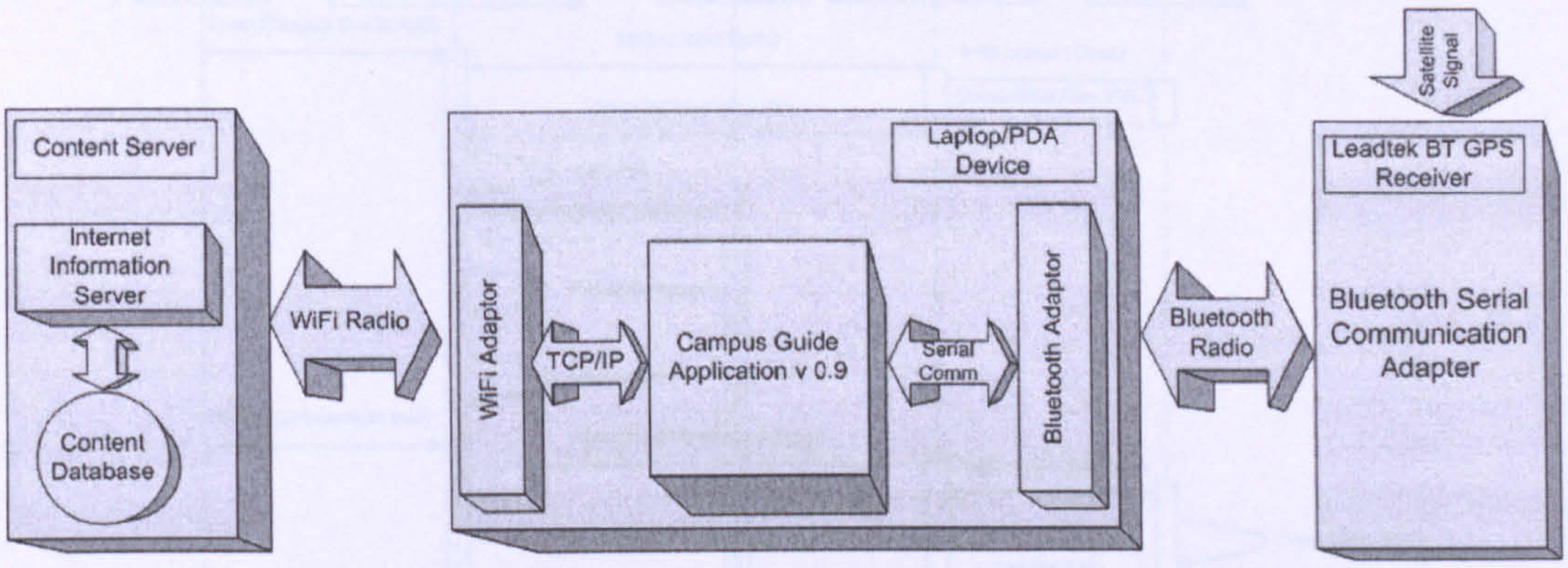


Figure 7.3: Application structure diagram

As can be seen from the structure diagram (Figure 7.3), the Digital Campus Guide application resides in the centre of the processes and coordinates the interaction between the user and the remote tiers. The application runs on the Microsoft XP/CE Platform and uses the Bluetooth serial communication stack to connect to the GPS receiver, in our case, a Leadtek 9537 High Sensitivity Xtrac 2. After the Bluetooth connection is established, the application queries the GPS receiver using the serial communication protocol and receives the location data in NMEA formatted sentences [WIKc06]. Using the location coordinates acquired from the parsed NMEA sentences, the user interface is then updated with the relevant location description.

Whenever a multimedia presentation is available and the user requests it, the application uses Microsoft Windows sockets stack to create a TCP/IP connection and send a request to the content server. The content server ran a Microsoft Internet Information Services web server with active server pages (ASP) scripting capabilities, which connects to a database through open database connectivity (ODBC). The server hosts the application logic, which is used to make the file selection according to QoP requirement, user device type and environment. As a result of this process, the most suitable video files are streamed to the user's mobile device.

7.3.4. Device Interaction Sequence

The developed system is conceptually made up of one user (a person travelling around the campus) and four devices, namely a GPS/WiFi enabled mobile computer, wireless Internet access point, content server, and a GPS satellite (Figure 7.4).

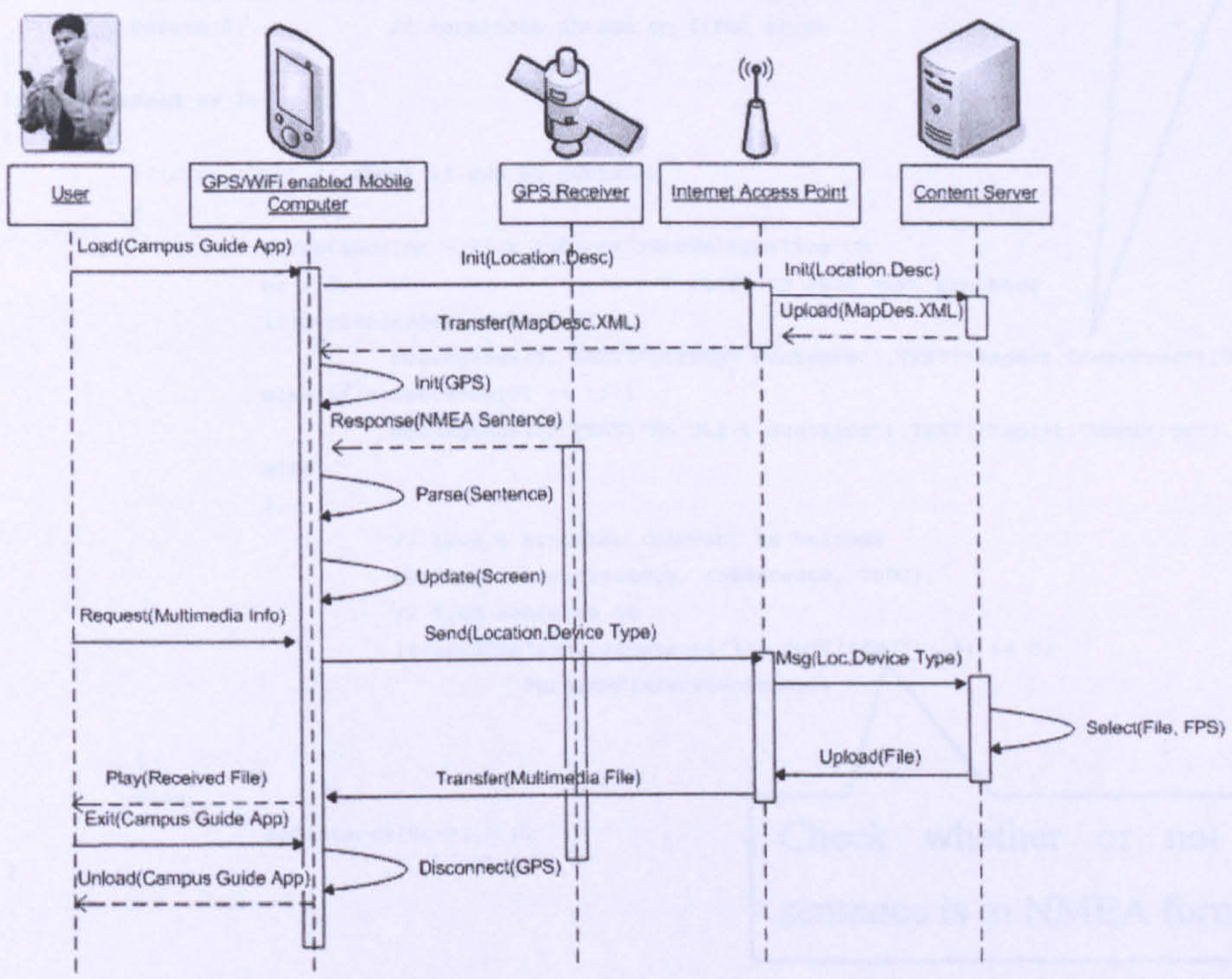


Figure 7.4: Device and user interaction diagram

The initial interaction takes place between the user and the mobile device, in which the user runs the Digital Campus Guide application. As soon as the application starts, it connects to the nearest Internet access point and sends the content server a request for the local map descriptions. The content server then responds with an XML (MapDesc.XML) file, which the mobile device uses as a local reference. Following this, the application initiates a Bluetooth connection with receiver. The GPS receiver responds to this connection created using NMEA formatted sentences, which are parsed and transformed into a geographical coordinate system (longitude/latitude) on the mobile computer. This interaction between the GPS receiver and transformation of the received data is repeated every 3 seconds in order to have real-time location of the user (Figure 7.5). Using the local reference file and the user's current coordinates, the mobile device is able to provide textual information about the surrounding buildings and regions.

```
// Thread function reads NMEA output from GPS device
DWORD WINAPI GPSReadThread(LPVOID)
{
DWORD dwBytesRead;
char szSentence[5000], c;
TCHAR szwcsSentence[5000];
int nc = 0;

SetThreadPriority(GetCurrentThread(), THREAD_PRIORITY_BELOW_NORMAL);
while(hGPSPort != INVALID_HANDLE_VALUE)
{
        if(!ReadFile(hGPSConn, &c, 1, &dwBytesRead, NULL))
        {
                MessageBox(0, TEXT("Reading comms port"),TEXT("Report:CommError"),0);
                return 0;           // terminate thread on first error
        }
        if(dwBytesRead == 1)
        {
                if(c == '\n') // check if end of sentence
                {
                        szSentence[nc - 1] = '\0';// remove trailing CR
                        nc = 0;                    // ready to read next sentence
                        if(strlen(szSentence) < 6)
                                MessageBox(0, TEXT("Corrupt Sentence"),TEXT("Report:CommError"),0);
                        else if(szSentence[0] != '$')
                                MessageBox(0, TEXT("No Start Sentence"),TEXT("Report:CommError"),0);
                        else
                        {
                                // have a sentence. convert to Unicode
                                mbstowcs(szwcsSentence, szSentence, 1000);
                                // find sentence ID
                                if(wcsncmp(&szwcsSentence[3], TEXT("RMC"), 3) == 0)
                                        ParseRMC(szwcsSentence);
                        }
                }
                else
                        szSentence[nc++] = c;
        }
}
return 0;
}
```

Check whether the NMEA sentence is corrupted or not

Check whether or not the sentence is in NMEA format

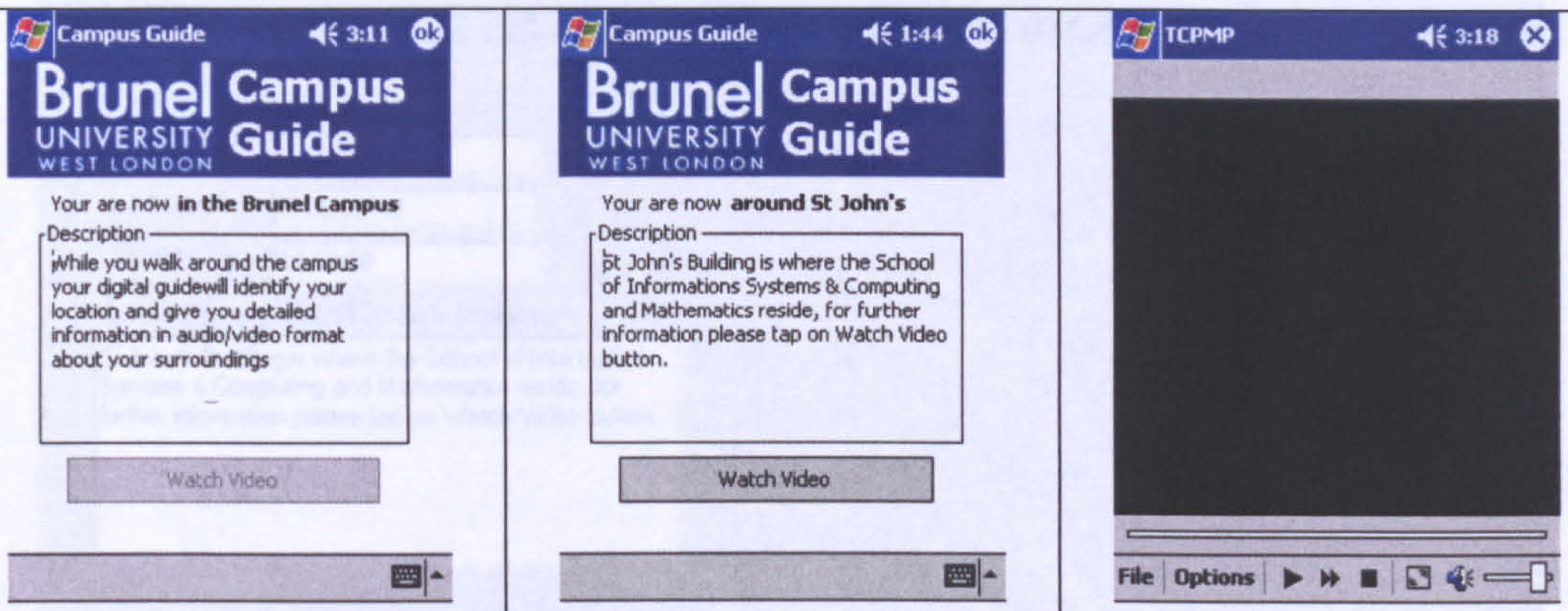
Figure 7.5: Visual C++ snippet of a function that creates GPS communication thread (Appendix E)

Whenever the user requests multimedia presentation of the site, the mobile device connects to the Internet access point and asks for the file by providing two parameters (namely, *device_type* and *location_coordinates*). The content server executes the two parameters with its application logic and uploads the most suitable quality clip to the device. On the other hand, whilst downloading, the mobile device runs its internal media player and starts playing the file being streamed in. The user watches the multimedia presentation and continues his/her tour.

7.3.5 Application Walkthrough

In the course of our experiments, we have used three different display devices and implemented a specialised user interface for each one of them. In the following section we explain each of the interfaces in detail.

7.3.5.1. PDA



a) b) c)

Figure 7.6: PDA Campus Guide application interface

The Campus Guide application for the handheld has two main user interface windows, which are the main application and the external video player. The main application window is relatively simple, and contains a university banner at the top of the screen, a textual reminder of the user's current location in bold characters, a textbox with description of the current location and a *Watch Video* button (Figure 7.6a). Unless the user is around a recognised building or area (such as *St John's Building*) (Figure 7.6b), the interface disables the *Watch Video* button and only reports to the user whether he/she is within the university campus or not.

As soon as the *Watch Video* button is tapped in a recognised location, the main application minimises itself and runs the local default media player (Figure 7.6c), which plays the streamed multimedia file in full screen to get as close as possible to the original size of the clip (320x240 pixels).

7.3.5.2. Laptop

The laptop user interface of the Campus Guide differs considerably from the PDA version of the same application. The screen resolutions of laptop PCs are considerably higher than the PDAs, thus full screen mode is not essential for original size playback of the multimedia clips. Accordingly, we have designed the window so that it contains all the data in an organised manner by splitting it into two panels. The information panel (left) contains mainly location related data, such as longitude, latitude, satellite time, location banner, description textbox and *Play Video* button. The video panel (right) has an embedded video player, which plays the presentation clip in its original size (Figure 7.7).

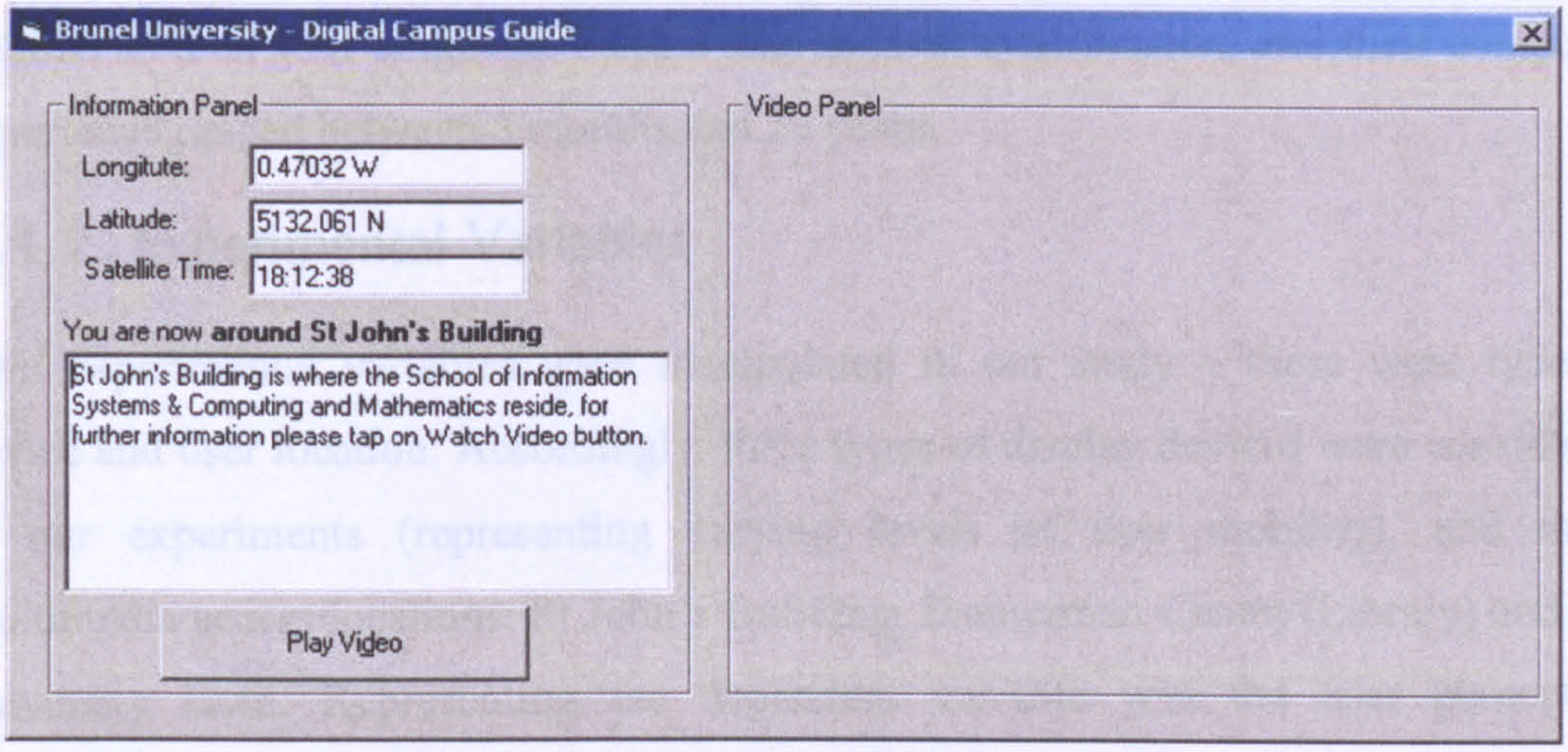


Figure 7.7: Laptop Campus Guide application interface

7.3.5.2. HMD

The head-mounted display version of the application is similar to the laptop version with the exception of the video player panel. The panels that do co-exist in the same window in the laptop design had to be spit into two full screen windows due to the resolution limitations imposed by the HMD device (Figure 7.8).

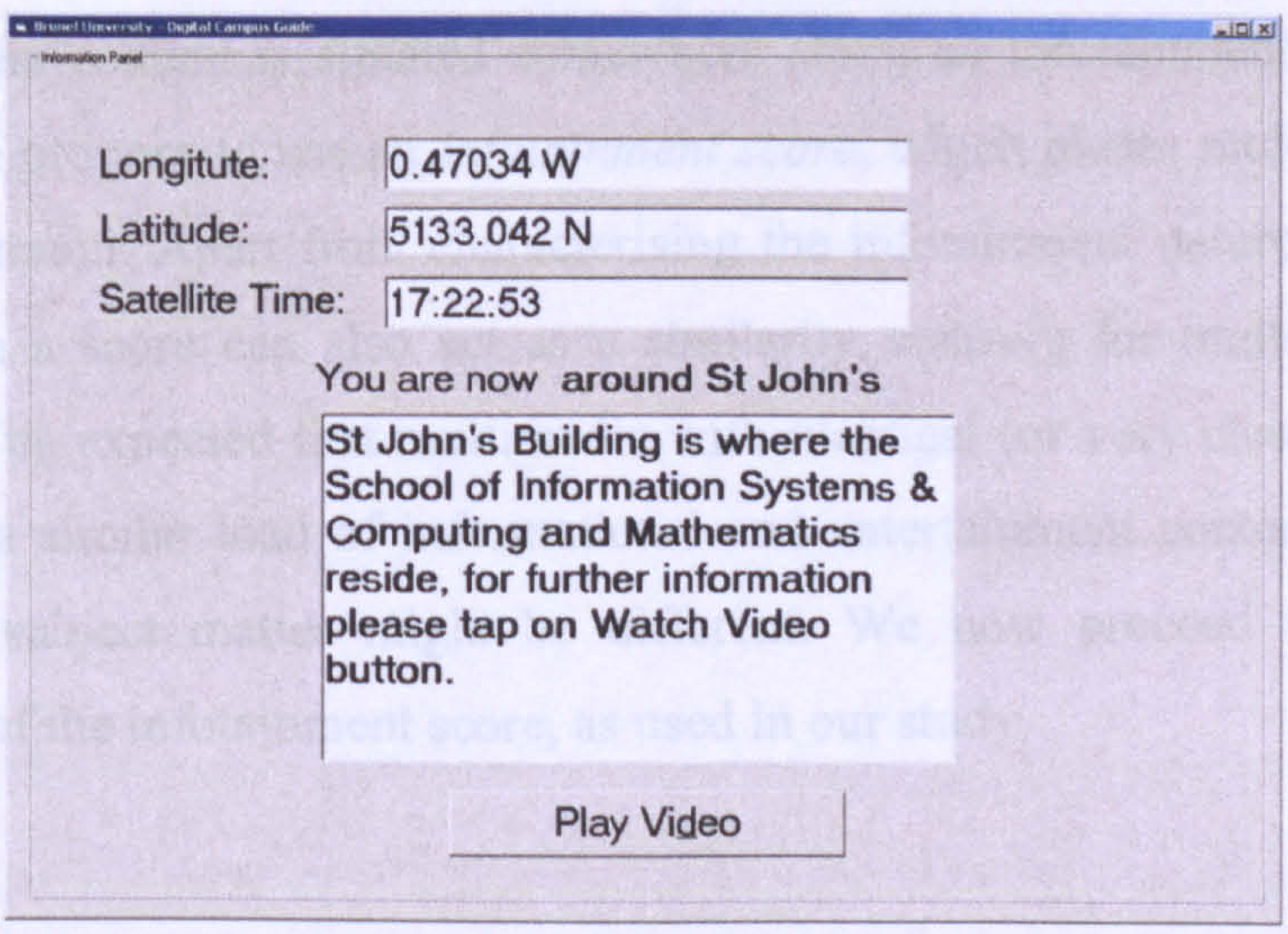


Figure 7.8: HMD Campus Guide application interface

7.4. Experimental Methodology

7.4.1. Participants

Our study involved 36 participants, aged between 20 and 45, who were taken from a range of different nationalities and backgrounds – students, clerical and academic staff, as well as a number of white collar workers. All participants, however, spoke English as their first language, or to a degree-level qualification, and their computer experience ranged between 3 months and 20 years.

7.4.2. Experimental Variables

Two experimental variables were manipulated in our study – these were type of device and user location. Accordingly, three types of display devices were considered in our experiments (representing varying levels of user mobility), and three multimedia access locations: St John's Building, Bannerman Centre (Library) and the university lawn. Representing the dependent variable was the user perceptual experience, as measured by the QoP metric. The choice of these variables is justified, for, as it has been shown in Chapter 2, there is a lack of research examining the tailoring of multimedia infotainment content to location, for the ultimate benefit of the user. The selection of the 3 experimental locations and their corresponding videos will be described in Section 7.4.5.

7.4.3. Calculating a Multimedia Infotainment Content Score

All multimedia content is situated somewhere along an infotainment continuum. In our work, we propose to use an *infotainment score*, which places multimedia content on this continuum. Apart from characterising the infotainment nature of multimedia content, such a score can also act as a similarity measure for multimedia content, since it is to be expected that multimedia with identical (or very close) infotainment scores have a similar load of informational and entertainment content, even though their actual subject matter might be different. We now proceed to describe the formulation of the infotainment score, as used in our study.

1) The infotainment of a clip *M* is a vector with two components, one describing the informational load of a clip, and the other the entertainment:

$$Infotainment_{Clip} = (Information_{Clip}, Entertainment_{Clip}) \quad (1)$$

where $Information_{Clip}$ and $Entertainment_{Clip}$ are, respectively, information and entertainment content weights, expressed in percentages.

Table 7.1: Characteristic weightings of S.R Gulliver [GUP04]

Clip	Dynamic (D)	Audio (A)	Video (V)	Textual (T)
Commercial	1	1.4	2	1
Band	1	2	1	0
Chorus	0.6	2	1	0
Animation	1	1.6	1.4	0
Forecast	1	2	1.3	2
Documentary	1	1.4	2	0
Pop Music	1	2	1.3	1
News	0.6	2	1.2	1
Cooking	1	2	1.4	.5
Rugby	2	1.5	2	1
Snooker	0.6	1	1	1
Space	2	1	1.2	0

As stated in previous work by Ghinea and Thomas [GHI98], the content of any multimedia video clip can be characterised by the relative importance of its video (V), audio (A) and textual (T) components, as well as by its dynamism (D) (Table 7.1). It is a natural progression to characterise the relative informational and entertainment content of a multimedia clip by considering the importance of these components for information and entertainment, respectively. Thus, in our approach we have differentially weighted these components, bearing in mind their importance to information and entertainment respectively. The informational component of the Infotainment score of a multimedia clip is thus given by:

$$Information_{Clip} = \overline{D} \times W_{I,D} + \overline{A} \times W_{I,A} + \overline{V} \times W_{I,V} + \overline{T} \times W_{I,T} \quad (2)$$

Analogously, the entertainment component of a multimedia clip is given by:

$$Entertainment_{Clip} = \overline{D} \times W_{E,D} + \overline{A} \times W_{E,A} + \overline{V} \times W_{E,V} + \overline{T} \times W_{E,T} \quad (3)$$

where $\overline{D}$, $\overline{A}$, $\overline{V}$ and $\overline{T}$ stand for the average dynamism, audio, video and textual content respectively of the clips in question. These are calculated by averaging the weights obtained in the studies of Ghinea and Thomas's [GHI98] and Gulliver et al. [GUL04] (Table 7.1).

Accordingly, in our work, we have taken the view that clips which are highly dynamic tend to imply that they contain predominantly entertainment material, as extracting informational content out of highly dynamic clips has proved to be problematic, whilst fast-paced, dynamic content usually has a high entertainment factor [GHI98]. At the other end of the spectrum, it is relatively unlikely that the appearance of textual content in content watched predominantly for entertainment purposes adds to the entertainment factor of the clip. Of course, textual information is usually important in content watched mainly for informational purposes. Thus, in our work we have chosen the weights $W_{E,D}=3$, $W_{E,T} = 1$ for entertainment purposes, with $W_{I,D}=1$, $W_{I,T} = 3$ for informational purposes. Previous research [KAW95; WAS97] has shown the importance of audio cues over video ones, in informational tasks, hence $W_{I,A} = 2$ and $W_{I,V} = 1$. On the other hand, true to the dictum *'that a picture is worth a thousand words'*, we have convened that the video stream has primacy over the audio, when content is viewed for entertainment purposes. Thus, we have $W_{E,V} = 2$, $W_{E,A} = 1$.

7.4.4. Calculating the Overall QoP Score from an Infotainment score

In previous work [GHI98], [GUL04], multimedia content has been shown to be an important factor affecting the user multimedia experience. It then becomes natural to reflect the impact of multimedia content on the user multimedia experience.

$$\textit{Overall } QoP_{Clip} = \text{Infotainment}_{Clip} \times QoP_{Clip}$$

$$= (\text{Information}_{Clip}, \text{Entertainment}_{Clip}) \times \begin{Bmatrix} \text{QoP-IA} \\ \\ \text{QoP-LoE} \end{Bmatrix}$$

$$= \text{Information}_{Clip} \times \text{QoP-IA} + \text{Entertainment}_{Clip} \times \text{QoP-LoE}$$

$$= QoP_{ClipInformation} + QoP_{ClipEntertainment} \qquad (4)$$

Bearing in mind multimedia's infotainment nature, we can, therefore, calculate the overall QoP score of the user multimedia experience associated with a particular multimedia clip through the following formula:

Here QoP-IA is the percentage of overall correct answers given and QoP-LoE is the subjective enjoyment grade of a clip (expressed as percentage), both representing the two components of the QoP metric. The calculation of the $Information_{clip}$ score and $Entertainment_{clip}$ score of the clip is done according to (2) and (3) respectively.

7.4.5. Experimental Material

As part of the Campus Guide experiment, we chose 3 key locations within our university campus for multimedia content streaming, namely the St. John's Building (School of Information Systems, Computing and Mathematics), the Bannerman Centre (Library) and the university lawn. These locations were chosen as we wanted to obtain a coarse mapping between location and multimedia content mediated by its infotainment score. Thus, recognising that in specific locations one is more information prone, or vice-versa, we selected the St John's Building, the university lawn and the Bannerman Centre to be representative of locations which are information intensive, entertainment intensive, and have an equal mix of information and entertainment, respectively. While the choice of the St. John's Building as an example of an information-intensive location is relatively straightforward (St. John's houses the Department of Information Systems and Computing and comprises lecture rooms, laboratories and offices of DISC academics), the choice of the Bannerman centre as a location of characteristic of roughly equal informational and education profiles, can be justified by observing that although the centre does house the University library (information), it also has a thriving café and is close to the Brunel student union bars (entertainment). Finally, the choice of the university lawn as an entertainment-intense site can be justified by its relaxing surrounding leisure areas, football pitches and shops, as well as the fact that it is the preferred place for students to take breaks during warm summer days.

Table 7.2: Clip infotainment scores

Clip	$Information_{clip}$	$Entertainment_{clip}$
Commercial	50%	50%
Band	43%	57%
Chorus	47.7%	52.3%
Animation	43%	60.9%
Forecast	56%	44%
Documentary	44.7%	55.3%
Pop Music	52%	48%
News	53.5%	46.5
Cooking	49.6%	50.4%
Rugby	46.3%	53.7%
Snooker	59%	41%
Space	39.1%	57%

In our experiment, we had to create context-sensitive content for each of the three identified locations. Whilst for St. John's and the Bannerman Centre new clips had to be produced (as previous QoP clips did not contain any information relevant to these locations), for the entertainment-intensive location (the university lawn) we had to identify, from previous QoP content, the clip with the highest entertainment component. We thus calculated the clip infotainment scores, according to (2) and (3), for all 12 QoP clips in light of our previous results (Table 7.2). From these, we chose the Animation clip, which had the highest entertainment score, as the entertainment intensive clip for the university lawn.

However, as remarked above, for the St John's Building and the Bannerman Centre, we created, for each of these locations, a number of 3 different presentation clips. In keeping with the length of previous clips used for QoP experiments, all the newly created clips were 32-second long and in 320x240-pixel MPEG-1 format. Each of these clips was then evaluated for their overall QoP scores with a pilot study of 8 participants. In line with QoP methodology [GHI00], we also asked each participant to categorise on a scale of {1, 2, 3} the importance, within each of the newly created clips, of its dynamism, as well as of the video, audio, and textual content and in calculating the QoP-IA scores eliminated the questions for which participants fared best and respectively, worst. Ultimately we chose the clip with highest resulting informational component for the St. John's location, and the one with the most balanced informational and entertainment components for the Bannerman Centre clip. The number of questions for each clip targeting the video, audio and textual components is given in Table 7.3 and the full listing of the questionnaires can be found in Appendix D.

Table 7.3: Quality of perception question distribution - Video, Audio and Textual.

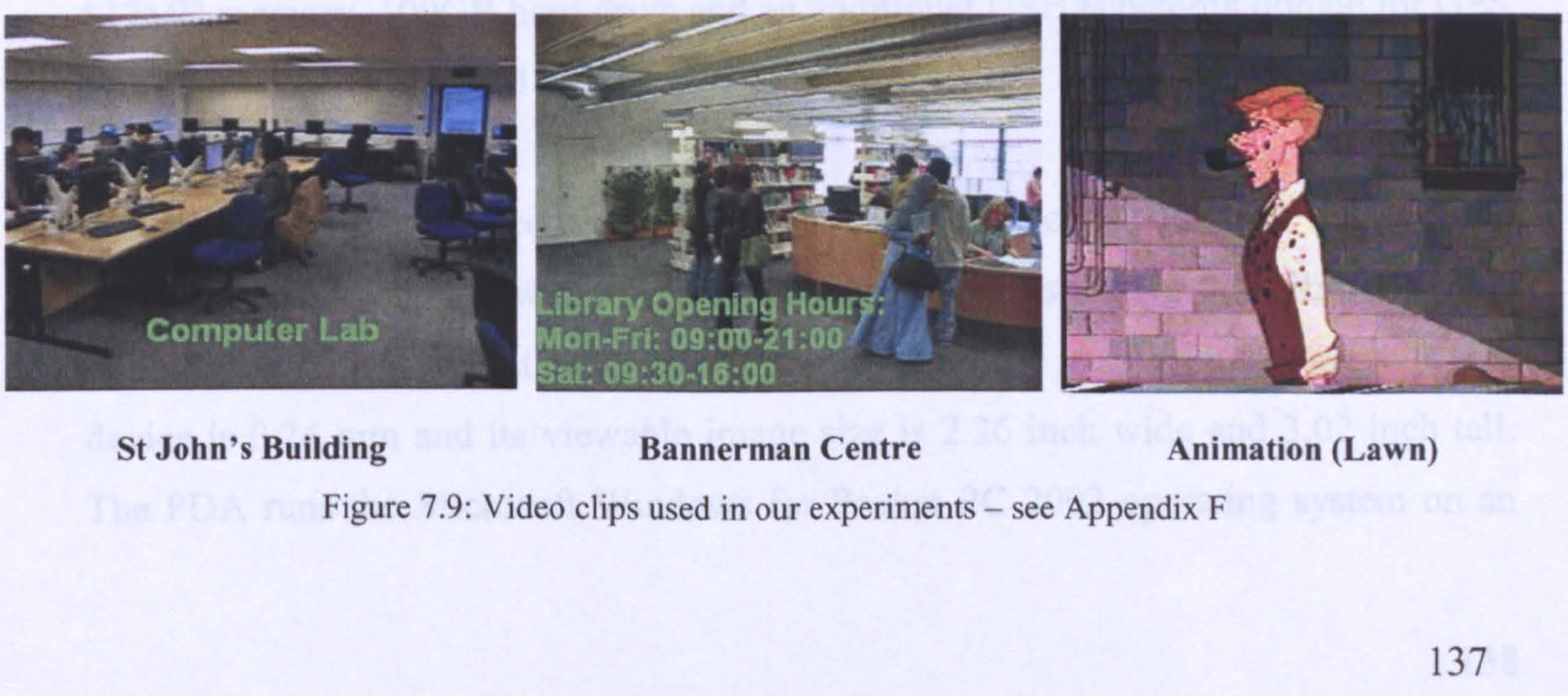
Location Video	Video (Number of Questions)	Audio (Number of Questions)	Text (Number of Questions)	Duration (Sec)
St John's (SISCM)	4	4	5	32
Bannerman Centre (Library)	5	4	4	32
Lawn	6	4	0	32

The clips themselves are (Figure 7.9):

St John's Building clip - contains a walk-through presentation of the Department of Information Systems and Computing; it has extensive information regarding the number of professors, number of research students, location of lecturers and administration staff, and student facilities.

Bannerman Centre clip - is a walk-through presentation of the Brunel University, Uxbridge Campus Library. This clip is entertaining as much as it is informative, providing basic information about the library services, and mixing it with more dynamic content such as student union facilities (bar/café shop/refectory) located in the same building.

Animation clip - features a disagreement between two main characters. Although dynamically limited, there are several subtle nuances in the clip, for example: the correspondence between the stormy weather and the argument.



St John's Building **Bannerman Centre** **Animation (Lawn)**

Figure 7.9: Video clips used in our experiments – see Appendix F

The frame rate quality for each of the devices was specifically tailored inline with the frame rate which resulted in highest QoP score for a particular device - described in detail in the previous chapter (see Chapter 5). Accordingly, the frame rate combinations used, based on device type and location, in the course of this experiment are as shown below (Table 7.4).

Table 7.4: Device, Location and Frame Rate matrix

	St John's Building	Bannerman Centre	University Lawn
PDA	25	15	15
HMD	5	25	15
Laptop	25	5	25

7.4.6. Experimental Devices and Set-up

One of the experimental variables manipulated in our study was access device type (Table 7.5). To allow the perceptual comparison of different display equipment on a user's ability to assimilate information from multimedia video, participants were evenly allocated to three groups. Within each respective group, users were presented the 3 video clips using a specific display equipment.

Table 7.5: Device resolution, mobility and screen size matrix

	Laptop	PDA	HMD
Screen Size	17 inch	2.26 x 3.02 inch	Simulates 52 inch display
Mobility	Limited mobility due its size and weight	Facilitates full mobility with its lightweight and ergonomic design	Has to be linked with a PDA/Laptop, thus its cabling may cause some restriction on the movements of the user
Resolution	1024 x 768	240 x 320	600 x 300

Thus, the first group was shown the video clips in their original size using a 17 inch XGA TFT Active Matrix Display of a Toshiba Satellite P35-S611 Notebook PC, which ran Microsoft Windows XP Professional with a 3.33GHz Pentium 4 processor, 512MB memory, 100GB hard drive and an additional USB Bluetooth dongle for GPS communication (Figure 7.10a).

The second group viewed the video clips using a Hewlett-Packard iPAQ 5450 personal digital assistant with 16-bit touch sensitive transflective thin film translator liquid crystal display that supports 65,536 colour. The display pixel pitch of the device is 0.24 mm and its viewable image size is 2.26 inch wide and 3.02 inch tall. The PDA runs the Microsoft Windows for Pocket PC 2002 operating system on an

Intel 400Mhz XSCALE processor and allows the user complete mobility. By default it contains 64MB standard memory and 48MB internal flash read only memory (Figure 7.10b).

The third group viewed the multimedia video clips using an Olympus Eye-Trek FMD 200 head-mounted display, which uses two liquid crystal displays and allows a greater autonomy of movement than a generic computer monitor. Each one of the displays contains 180,000 pixels and the viewing angle is 30.0° horizontal, 27.0° vertical. It supports PAL (Phase Alternating Line) format and display weight is 85g (Figure 7.11a). During this study, all of the above devices were connected to a Leadtek 9537 High Sensitivity Xtrac 2 Bluetooth GPS Receiver to access the geographical data (longitude and latitude) in order to get a fix of the user's location (figure 7.11b).

a) b)

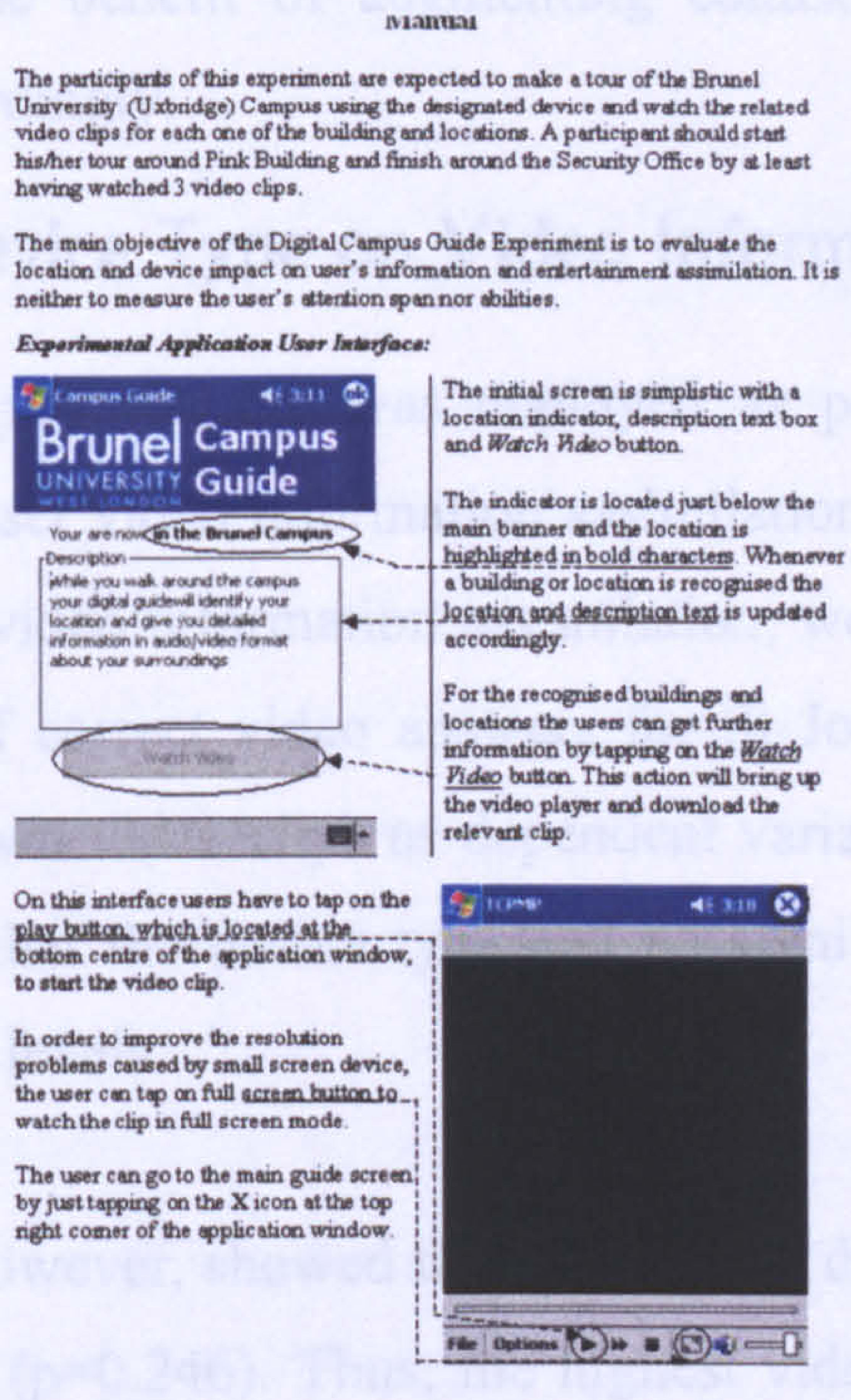
Figure 7.10: (a) Laptop and (b) PDA deployed in this experiment

a) b)

Figure 7.11: (a) HMD and (b) Bluetooth GPS Receiver used in this experiment

7.4.7. Experimental Process

The QoP experimental methodology was followed throughout in this study. Accordingly, all participants were briefed shortly about the aims and the content of this experiment. During this briefing, to ensure that the participants did not feel under test conditions, it was made clear that their intelligence was not being tested and that they should not be concerned if they were unable to answer any of the information assimilation questions.



Manual

The participants of this experiment are expected to make a tour of the Brunel University (Uxbridge) Campus using the designated device and watch the related video clips for each one of the building and locations. A participant should start his/her tour around Pink Building and finish around the Security Office by at least having watched 3 video clips.

The main objective of the Digital Campus Guide Experiment is to evaluate the location and device impact on user's information and entertainment assimilation. It is neither to measure the user's attention span nor abilities.

Experimental Application User Interface:

The initial screen is simplistic with a location indicator, description text box and *Watch Video* button.

The indicator is located just below the main banner and the location is highlighted in bold characters. Whenever a building or location is recognised the location and description text is updated accordingly.

For the recognised buildings and locations the users can get further information by tapping on the *Watch Video* button. This action will bring up the video player and download the relevant clip.

On this interface users have to tap on the play button, which is located at the bottom centre of the application window, to start the video clip.

In order to improve the resolution problems caused by small screen device, the user can tap on full screen button to watch the clip in full screen mode.

The user can go to the main guide screen by just tapping on the X icon at the top right corner of the application window.

Figure 7.12: Campus guide applications user manual

Following the introduction, the participants were provided with a one-page Campus Guide experiment how-to manual (Figure 7.12), a QoP questionnaire and the guide device (either laptop, PDA or HMD). After reading the manual, participants were asked to fill in their personal details (name, surname, age and, if any, eye sight problems) on the questionnaire paper and run the Campus Guide application. In the same manual the participants were also provided with an approximate route to follow to reach their targeted destination. As a result of this route, the participants went through all the key locations where streamed content was provided. At each such location, after requesting and watching the streamed video using their specific devices participants then answered the QoP questions (in terms of information assimilation and enjoyment) for each one of the location-specific clips. The whole process, including the briefing, took on average 49 minutes per participant.

7.5. Results

In this section, employing the same structure of analysis used in Chapter 5, we explore the device impact on video, audio and textual information assimilation (QoP-IA) and the device type impact on perceived satisfaction (QoP-S). Moreover, this section also explores the benefit of augmenting context with QoP and tailoring multimedia content accordingly.

7.5.1. Impact of Device Type on Video Information Assimilation

A diverse range of display devices was deployed as part of the Campus Guide experiment to evaluate user video information assimilation. To analyse the impact of device type on the user video information assimilation, we used a one-way ANOVA test, with the number of correct video answers for St John's Building, Bannerman Centre and university lawn video clips as dependent variable and device type as the factor. Results showed that the device type had no significant effect on user video information assimilation levels.

Post Hoc Tukey tests, however, showed that the biggest difference occurred between the PDA and the HMD ($p=0.246$). Thus, the highest video information assimilation was facilitated by the PDA and the worst was HMD (Figure 7.13). These results are in line with previous findings [GUL04] and highlight that head-mounted display technologies still have to enhance their resolution quality to become commercially attractive and part of our everyday life.

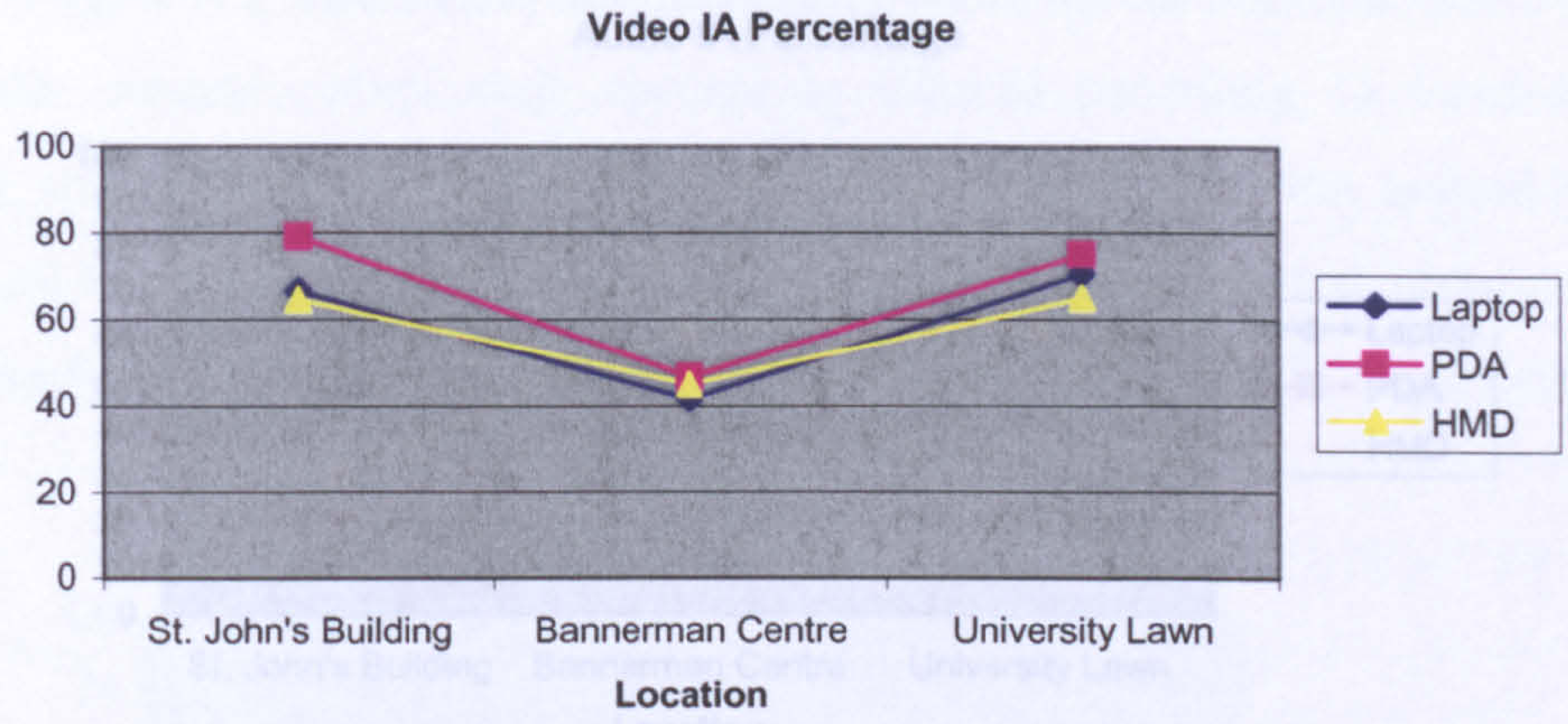


Figure 7.13: Average perceived video information assimilation based on device type

We believe that the reason for the difference in user video information assimilation levels between the two devices is due to screen resolution and user's physical discomfort. As can be seen from the technical specifications of the PDA device, its screen resolution matches exactly the display dimensions of the QoP clip (320x240 pixels). This means that if the clips are played in a full screen mode on the PDA, they have no pixel gain or loss. On the other hand, the HMD device has a much higher resolution than the clip itself and is designed to simulate a 52-inch LCD screen. As a result of this higher field of view, it causes pixel distortion which affects the user perception of the video quality and information assimilation. Secondly, we propose that the video information assimilation QoP-IA was lowest on the HMD due to the actual physical discomfort it causes users due to its mobility limitations and the distress it produces when is used for a protracted period of time. These findings are in line with the results of our previous experiment on device impact on user multimedia perception (see Section 5.5).

7.5.2. Impact of Device Type on Audio Information Assimilation

To check the device type effect on audio information assimilation, we used a one-way ANOVA test, with the number of correct audio answers for St John's Building, Bannerman Centre and university lawn video clips as dependent variable and device type as the factor. Again, analysis showed that there was no significant effect of device type on user audio information assimilation level.

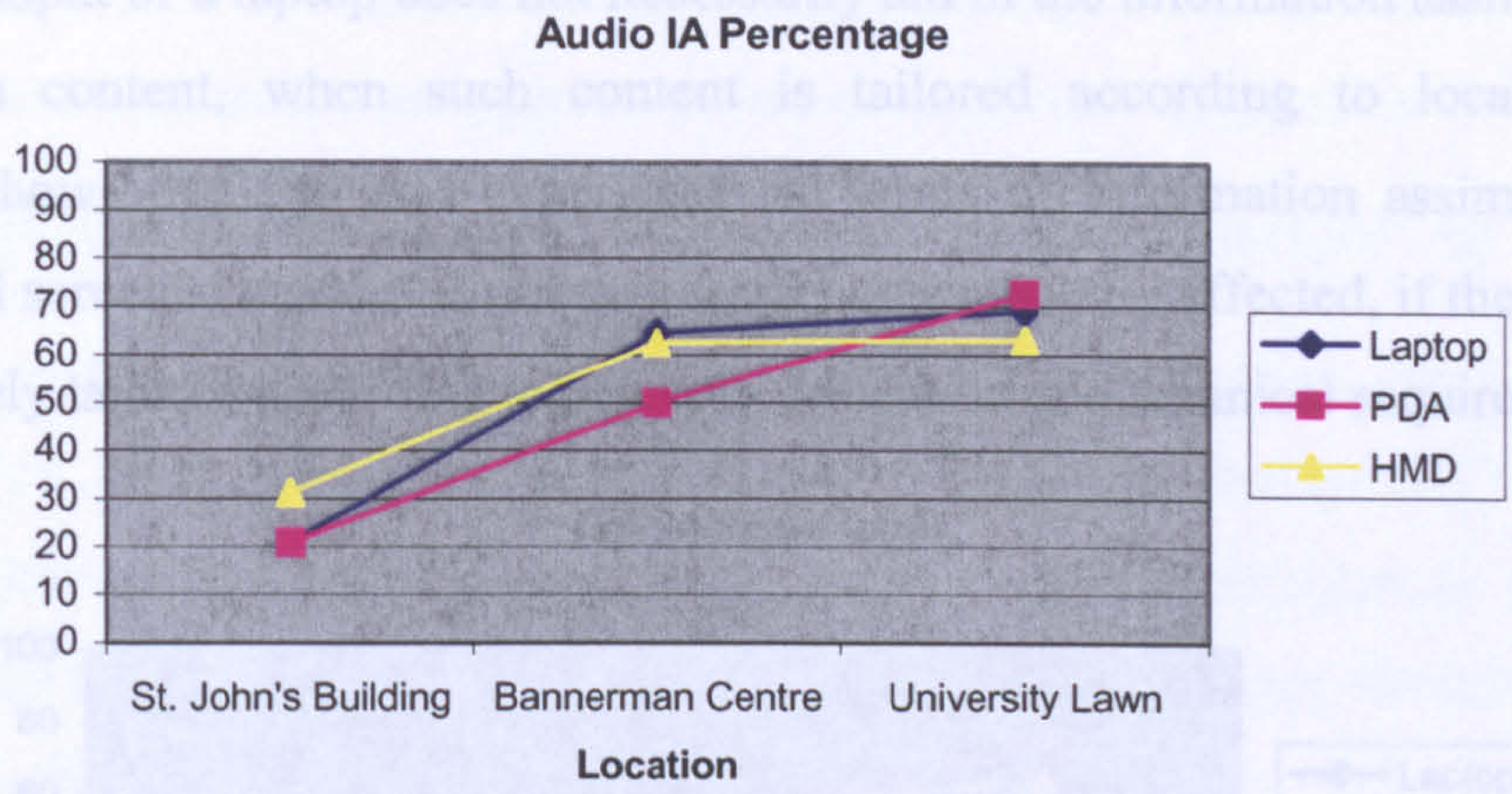


Figure 7.14: Average perceived audio information assimilation based on device type

The analysis revealed that the mean of correct answers for audio questions for the St. John's video clip was considerably lower than of the other two locations (Figure 7.14). The proposed reason for why audio information assimilation was lower than the other locations is due to the content of the video clip, which was shown at this location. The video clip in question is heavy with audio-visual and textual information, since it was specially designed to be the information intensive. Thus, we believe that exhaustive information content was hard for the users to follow the audio content of the video, especially in a noisy outdoors environment. These results show that even if multimedia content is entertainment rich, its audio component can be heavily deteriorated by the surroundings and cause dissatisfaction.

7.5.3. Impact of Device Type on Overall Information Assimilation (QoP-IA)

To analyse the influence of device type on the overall information assimilation (QoP-IA), we applied a one-way ANOVA test, with the overall percentage of correct answers for St John's Building, Bannerman Centre and university lawn video clips as the dependent variable and device type as the factor. Results showed that the device had no significant impact on user QoP-IA.

Further analysis of the findings using Post Hoc Tukey tests confirmed these results and highlighted that the overall information assimilation between devices with varying mobility level and screen size, such as PDA, HMD and laptop, is unaffected (Figure 7.15). Accordingly, from this result, we can derive that the extra real-estate and easier input of a laptop does not necessarily aid in the information assimilation of and easier input of a laptop does not necessarily aid in the information assimilation of multimedia content, when such content is tailored according to location. This therefore shows that the user experience (in terms of information assimilation) of using small screened devices is not necessarily detrimentally affected, if the content is appropriately tailored according to perceptual-location and technical requirements.

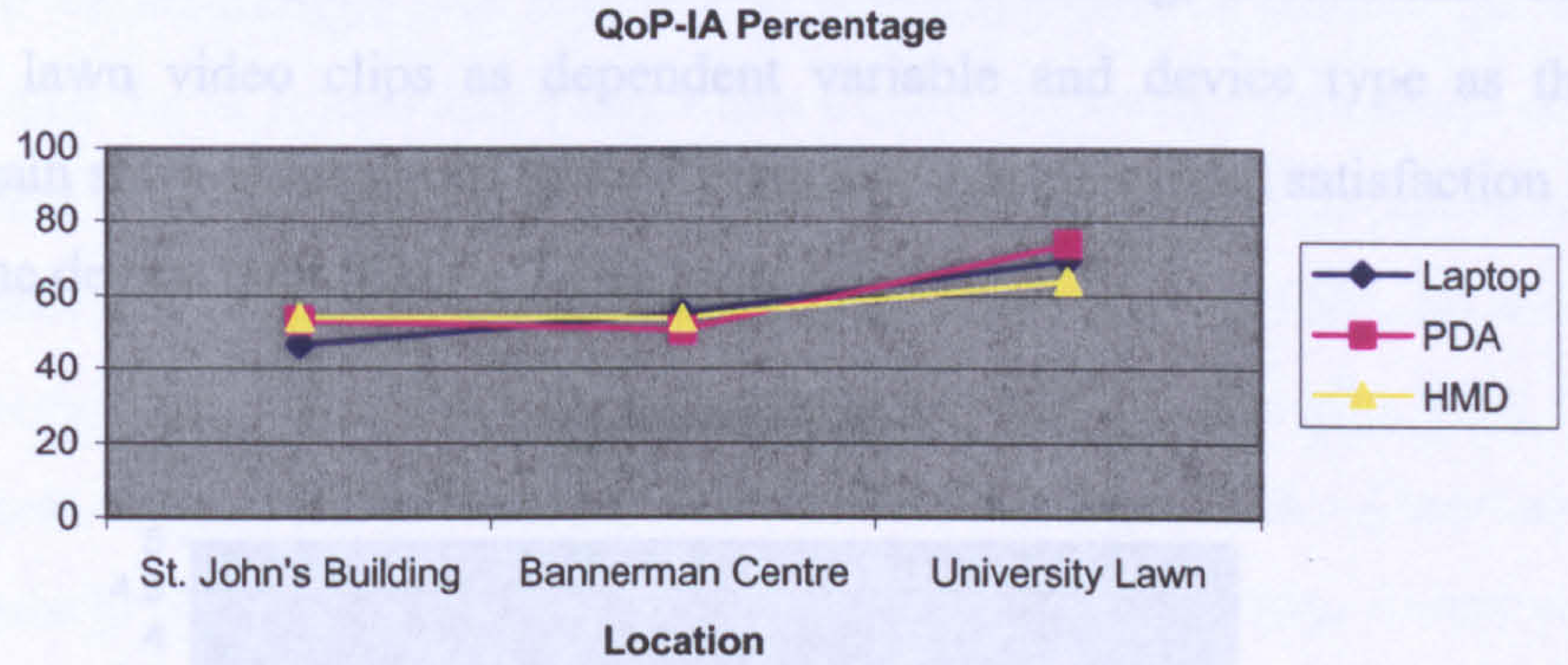


Figure 7.15: Overall quality of perception information assimilation (QoP-IA) based on device type

However, even though the difference is not significant, the device whose users had the worst overall information assimilation percentage in an information intense location is the laptop, whilst the best such percentage was obtained in the case of HMD users (p=0.577). We believe that the main reason for this is due to the laptop speaker output quality which prevented the user from absorption of audio information. Accordingly, the HMD device had the advantage of streaming audio content directly to the users without any loss by using a pair of headphones.

On the other hand, the other small difference (p=0.575) in overall information assimilation is between the PDA and HMD in an entertainment intense environment (University Lawn). Nevertheless, we believe that the reason for PDA users to score the highest and HMD users the lowest information assimilation percentage in a such location is on psychological grounds rather than technical ones, since apart from environmental factors such as surrounding noise (the university lawn tends to attract a considerable amount of students) which impacted participants' ability to concentrate, so did the fact that they were conspicuously wearing an HMD in a relatively crowded area. Consequently, we believe that the HMD causes self-consciousness on the user, thus preventing him/her from concentrating on the information, where as on the contrary the PDA is small and attracts no attention that can distract user's information assimilation process. This is also in line with our findings of our previous experiment on mobile information access experiences in real-world (see Chapter 6).

7.5.4. Impact of Device Type on Perceived Satisfaction (QoP-S)

To gauge the impact of device type on user satisfaction perception, we used a one-way ANOVA, with QoP-S values for St John's Building, Bannerman Centre and university lawn video clips as dependent variable and device type as the factor. Results again showed no significant difference in user perceived satisfaction level as a result of the device type (Figure 7.16).

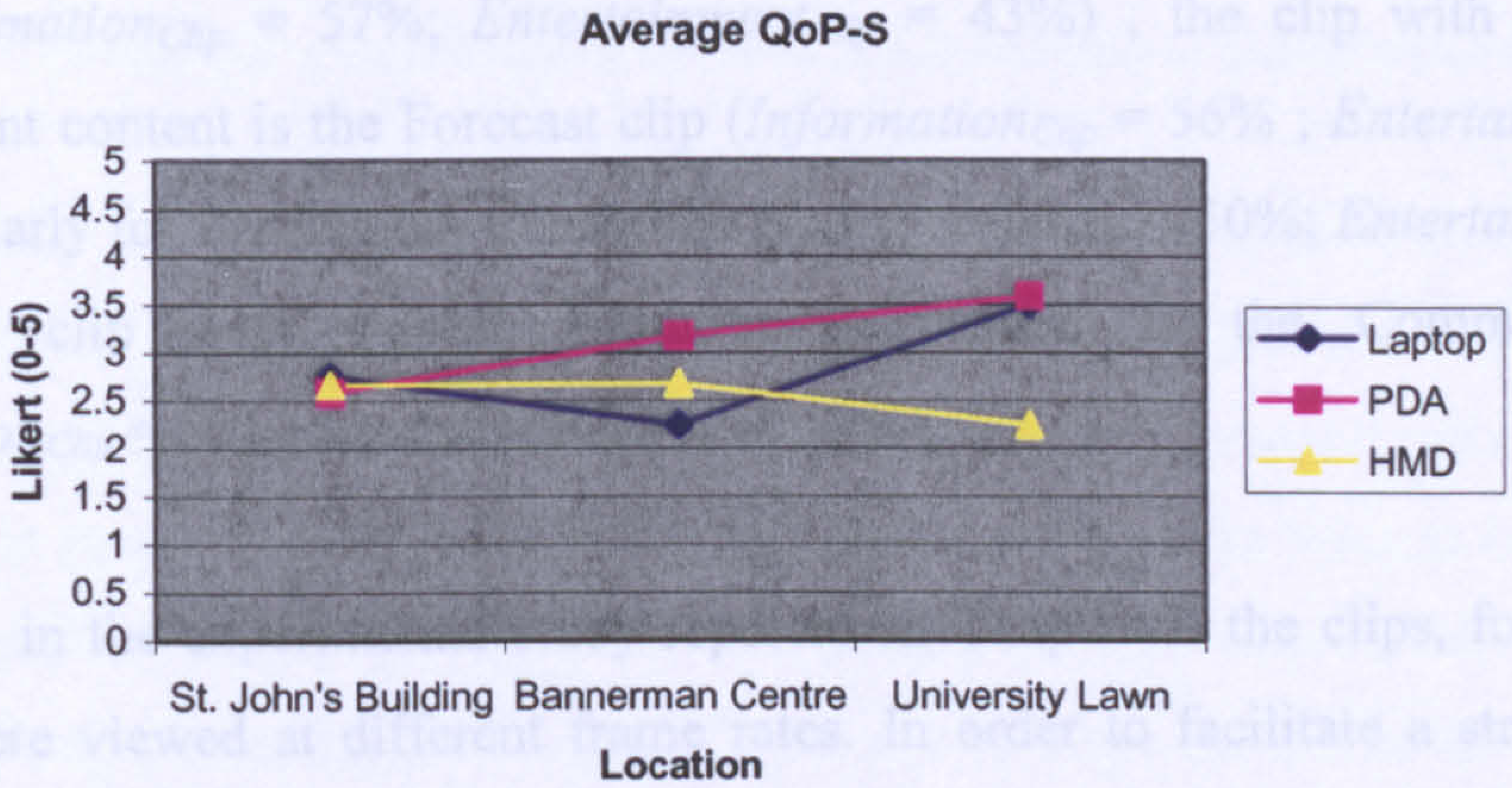


Figure 7.16: Average perceived satisfaction based on device type

Nevertheless, Post Hoc Tukey tests highlighted that the perceived enjoyment level was fairly affected by the use of HMD (p=0.079) at the university lawn. We believe that the reason for lower enjoyment level when using the HMD at the university lawn is due to user's conscious awareness while using the device. In a location such as the university lawn, where students gather to relax and rest, conventional information access devices such as laptops and the PDAs draw less attention. On the other hand, an HMD causes distress and sentiments of self-conscious for the user, which makes the whole process less enjoyable.

7.5.5. Comparison Between Tailored and Non-Tailored Content

In this section we explore, from a QoP perspective, the impact of tailoring multimedia content according to device and location. In order to do this, we have to compare the set of results obtained from the study described in this chapter, with that of a control group, in which no tailoring took place. In our case, the control group QoP results were those obtained as a result of running the experimental study reported in Chapter

5, which used the same set of devices as the current study. However, the visualised multimedia content is different, as the one used in Chapter 5 was not tailored according to location.

Matching multimedia content based on infotainment scores

Whilst the Animation clip was common to both experimental studies, the question of how to match the St John's and Bannerman Centre clips with multimedia content used in the study reported in Chapter 5 was solved by matching clips according to their infotainment content, calculated according to relations (1)-(3). Thus, for the St. John's clip ($Information_{Clip}$ = 57%; $Entertainment_{Clip}$ = 43%) , the clip with the closest infotainment content is the Forecast clip ($Information_{Clip}$ = 56% ; $Entertainment_{Clip}$ = 44%) similarly for Bannerman Centre clip ($Information_{Clip}$ = 50%; $Entertainment_{Clip}$ = 50%) the clip with closest infotainment content is the Commercial clip ($Information_{Clip}$ = 50%; $Entertainment_{Clip}$ = 50%).

Of course, in the experimental study reported in Chapter 5, the clips, for a specific device, were viewed at different frame rates. In order to facilitate a stringent QoP comparison between tailored and non-tailored multimedia content, we calculated the average overall QoP scores for each such frame rate and took the highest such value obtained (Table 7.6). It was this value that was then compared with the overall QoP scores obtained as a result of the tailoring described in this chapter.

Table 7.6: Highest QoP Scores for matching clips from Chapter 5 experimental study

		Forecast	**Commercial**
Laptop	Highest Overall QoP Score	46%	47%
PDA	Highest Overall QoP Score	80%	62%
HMD	Highest Overall QoP Score	69%	62%

To compare the overall QoP scores between the tailored and the control group, we used a two-way ANOVA test, with overall QoP as the dependent variable and the device type, experiment type and location as fixed factor. The results showed that experiment type ($F = 9.306$) and device type ($F = 7.106$) caused significant variation in user overall QoP.

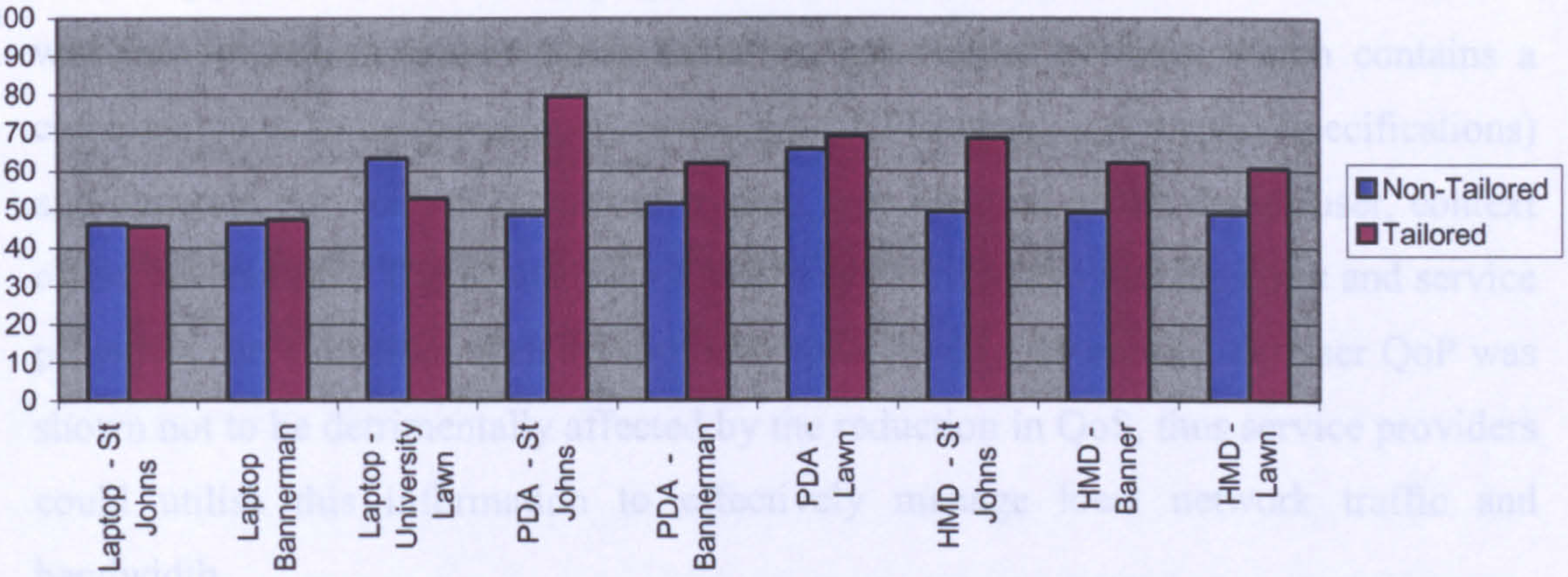


Figure 7.17: Overall QoP comparison between tailored and non-tailored content based on device

We believe that the significance in user overall QoP due to the type of the experiment is natural. The tailored experiment content was explicitly designed based on the user perspective quality evaluation of the non-tailored experiment so that it suits best to the device that is streamed at. Indeed, the overall QoP results of the tailored experiment, with the exception of Laptop-university lawn clip, are either equal or better than the non-tailored experiment (Figure 7.17). We believe that the reason for having a low overall QoP when the Animation clip was streamed to the university lawn is due to the cartoon characteristics and low clip audio volume which made it hard to follow in an environment surrounded by noisy distractions.

Similarly, the device type impact on user QoP is an expected outcome, since each one of the devices used in our experiment had different immersion levels and resolutions (See Table 7.4).

7.6. Conclusion

In this chapter we have described an investigation which explored the user experiences of accessing streamed multimedia content, when that content is tailored according to perceptual device and location characteristics. Thus, in the course of this study, we have built upon the findings of our previous two experiments to create pre-defined transmission profiles and stream perceptually tailored multimedia content to three different locations each characterised by different infotainment requirements.

In the light of our results, we propose that multimedia transmission to mobile and wireless devices should be made based on pre-defined profiles, which contains a combination of static (perceptual, device type, CPU speed, and display specifications) and dynamic information (streamed content type location of the device/user, context of the device/user). The evaluation of such a system showed that the users and service providers can gain from such an approach considerably. Moreover, the user QoP was shown not to be detrimentally affected by the reduction in QoS, thus service providers could utilise this information to effectively manage local network traffic and bandwidth.

This has been our last chapter describing experimental work undertaken as part of our research. In the next and final chapter of our study we summarise the research domain, state our research contributions and review our research findings.

CHAPTER 8

Conclusion

8.1. Research Domain

The user's mobile information access experience is one of the main drivers that support the continued take-up and proliferation of mobile computing – users will not use mobile devices if the device and/or information access experience is frustrating. Whilst there have been OOBE evaluations and initial experience prediction methods examined by cross-company consortia [EoU00] and individual companies [INT99] respectively, nevertheless, the OOBE associated with interconnectivity issues of two or more mobile devices has remained, up until now, an unexplored area. In addition, even thought researchers like Ghinea [GHP00] and Gulliver [GUP04] have previously explored user perception of multimedia-based information access, however, their work has mainly focused on single, non-mobile devices. Moreover, whilst Jones et al. [JON99] and Buranatrived and Vickers [BUR04] have investigated the impact of small screened devices on user web browsing habits and software application effect on mobile devices, respectively, no set of studies, however, have evaluated user experiences in a real-world context by combining device and the user perception of the audio and video content. Lastly, what also has to be emphasised is that these issues have not, up to the present work, been examined in an integrated manner, as all the related work in this area has been undertaken in an isolated fashion, as Chapter 2 has highlighted.

In the light of these finding, our research defined the following research aim: to comprehensively assess the user experience of mobile computing, as manifested through four key facets: the initial (out-of-box) experience, the device and mobility impact on the user multimedia access experience, the information access experience in a real-world context, and the user experience of accessing multimedia content tailored according to perceptual requirements, device and location.

To achieve this research aim, a series of four main investigations were implemented, each structured to explore one of the identified facets of the mobile information access experience and targeting a major research objective of our study.

- **Objective 1: Evaluation of the OOBE associated with mobile devices. In particular, we examined the initial and interconnectivity issues of the mobile devices.** The OOBE has been identified as a significant factor contributing to forming user perception and acceptance of products and technologies. Thus, in order to examine the initial user contact with mobile devices and associated interconnectivity issues, we followed industrially designed experimental methodologies. Although the impact of OOBE has been considered by commercial companies and consortia, previous studies fall short of considering mobile device interconnectivity, since they only target their research to one specific product at a time.

- **Objective 2: Exploration of the device impact on the user mobile multimedia experience.** Here, we examined the perceptual impact of mobile devices on multimedia quality, an aspect of particular importance to the areas of mobile Internet and mobile TV. In our research, we evaluated the impact of varying multimedia quality of service on the user mobile experience, when multimedia is accessed through a range of devices of varying mobility.

- **Objective 3: Exploration of the real-life experience of using mobile information access devices.** To assess the impact of a real-world context on the mobile information access experience, we investigated experiences users have with mobile devices of different levels of mobility, when they are used in daily informal environments. As a result of this study, we gained a first hand understanding of user real-world information access perceptions and how they impact on the user mobile information access experience. The casual use of a variety of mobile information access devices is important since the recognised trend is for their integration, proliferation and ubiquitous use.

- **Objective 4: Examination of the impact of tailored multimedia, in respect of location and mobile access device, on the user experience.** To combine and exploit the findings of our second and third objective, we developed a *Mobile Campus Guide* application with GPS support which tailored multimedia content based on perceptual QoP requirements, device type and location.

To ensure that perceptual measurement: (i) was consistent, (ii) considered the infotainment duality of distributed multimedia and (iii) ensured that satisfaction considered both the user's satisfaction with the objective QoS settings, as well as the enjoyment concerning the video content, our study employed the Quality of Perception (QoP) metric. QoP employs user 'information assimilation' (QoP-IA) and user 'satisfaction' (QOP-S) to determine the perceived level of multimedia quality. QoP-S is subjective in nature and in our study targets user subjective perception of the video content and transmission quality.

8.2. Research Contributions

The main contribution of our work stems from the defined research aims and objectives. Accordingly, in our work we have comprehensively considered the user's experience of mobile information access, by evaluating relevant layers that impact on user experience: device initial impact (OOBE), device type impact on content (evaluation of device experience), location impact on real-life mobile information access (real-world experiences), and evaluation of tailored multimedia content according to device and location (enhancing user information access using previous findings), thus ensuring that user experience evaluation of mobile information access considers both how much of the multimedia presentation was assimilated / understood by the user, yet also incorporates the user's satisfaction with the content.

In support of our main contribution, the following sub-contributions were made:

- We extended the multimedia QoP metric [GHI00] in order to better capture the user infotainment access experience in a mobile distributed environment. To the best of our knowledge, prior to our work, no multimedia quality models or metrics have been deployed to evaluate the user experiences. With a growing research focus on adapting distributed multimedia quality, especially with reference to the user's information access device, it is important that standard multimedia metrics are used to ensure consistency and comparison between research studies. Accordingly, we submit our extended metric as an effective means of comprehensive experience evaluation method.

- We extended the concept of the OOBE from that of the single device experience evaluation to one incorporating multi-mobile device interconnectivity. There is a growing body of research and evaluation methodology work in this area [EOU00; IBMa04; IBMb04]. However most of this work was sponsored by cross-company consortia, and so far, has only concentrated on single device evaluation. Nevertheless, with the growing number of mobile devices that are wirelessly interconnected to each other, single device experiences fall short of measuring the OOBE in a world of interconnected devices. Accordingly, we have followed the previously set design standards and extended the single device evaluation method to two and more devices, so we submit our extended initial experience evaluation approach as a more comprehensive assessment technique.

- We explored the user mobile information access experience in a real life context. Recent advances in mobile technologies have enabled user access to larger contents of information, such as music tracks, online radio, video games and electronic purchases. There has been an abundance of research in the area of mobile information access and content adaptation tools and applications [FOX98; JON99; BUY00; FRE01]. However, to the best of our knowledge, no-one has evaluated the current implications of a real world environment to the user's information access experience. Therefore, in this study we have evaluated real-life based scenarios using devices with various levels of mobility.

- We extended previous studies [GHI98; GUL03] which have looked at the interplay between QoS and QoP on single device and examined the issue across different frame rates, across different devices. Devices used in our work included a fixed head-position eye-tracker, a traditional desktop limited mobility monitor, a head-mounted display, and a personal digital assistant. As well as manipulating content and QoS parameters (frame rate), our study measured the impact of content type and QoS on user information access experience. To the best of our knowledge, no previous studies have comprehensively considered the impact of content type variation on the user's perception of multimedia quality.

- We extended the concept of context to include perceptual considerations, by incorporating QoP results. As highlighted in Chapter 2, context has various definitions depending on the scope at hand. Current research has looked into ways of improving and adapting QoS using contextual information. However, to the best of our knowledge no-one has extended the use of contextual information with perceptual considerations to enhance the user mobile information access experience. Therefore, in our work, we have sought to identify the impact of context on user information access and utilised the QoP metric to measure its effect.

- We developed a new metric – the Infotainment score – for matching and comparing multimedia content. Although the main components of QoP have been considered by other authors, none of these have required multimedia content matching and comparison as part of their work. However, in Chapter 7 of this study, we developed the infotainment score metric with the express purpose of weighing the combined information and entertainment values of the multimedia video content in hand. As a result, we put forward the infotainment score as an effective method of perceptual comparison of multimedia content.

- We developed a perceptual profiling method that enables content streaming based on location and device type. Previous research [BUY00; FRE01] has employed profiling methods to facilitate services based on device type, screen size, processor speed, battery amount and connection speed. However, to the best of our knowledge, no-one has incorporated perceptual preferences to build pre-defined QoS transmission profiles to enhance the user experience. In this study, we have developed profiles that contain perceptual information and act as a guideline in the selection of suitable QoS transmission parameters (in our case suitable frame rate).

8.3. Research Findings

Our research findings can be effectively divided into four sections. These sections correspond to the four main objectives of our work: the user initial experiences, device implications, real-world experiences and tailored content experiences

8.3.1. User Initial Mobile Device Experiences

The findings of our OOBE study (Chapter 4) have highlighted several issues: the first is that the device type can have a significant effect on the OOBE, particularly when configuring the devices and trying to perform routine tasks. Moreover, most of the participants in our study found the experience of interconnecting the devices daunting and frustrating.

This is especially more so when such devices need to be interconnected in order to provide, for instance, the premises for a user to experience wearable computing. This finding would seem to indicate that integration of multiple functionalities on a single device (with the corresponding reduced need for interconnection), coupled with enhanced multi-modal interaction (to possibly compensate for the one-wearable-device-fits-all-functionalities setting), and might be the way forward.

As a final remark, our findings have also shown that the OOBE is mainly unaffected by user computer experience and gender, which highlight that the OOBE designers of the two devices have made efforts to consider these categories and provide a broadly uniform OOBE. Whilst we attributed the (limited) gender impact to differences in spatial awareness, this in itself is also a worthy opportunity for future exploits.

8.3.2. Device Impact on User Experiences

We propose that due to granularity, the perceptual effect of different device types cannot be generalised by obvious division into defined groups, such as mobile and non-mobile computing. The impact of device should therefore be considered individually.

Our results from this study (Chapter 5) showed that the display device, used to watch a distributed multimedia video, significant impacts user QoP-IA. A significant difference was measured between the HMD device and the PDA, which were identified as respectively the best and worst devices for user information assimilation. We believe that the reason for the difference in user QoP-IA is due to the level of immersion, with high immersion devices (i.e. the HMD) facilitating a greater level of information assimilation. Although variation in device type does not significantly impact user level of enjoyment, HMDs were found to significantly lower overall user perceived level of video quality (QoP-S), despite enabling the greatest level of video information transfer. We suggest that this reduction in QoP-S is due to pixel distortion as a result of a higher field of view and highlights the information/satisfaction compromise of display systems, i.e. a higher field of view provides a higher QoP-IA, yet provides a lower QoP-S (and vice-versa).

This conclusion has possible implications on the future of fully immersive head-mounted display devices, as we believe that any device that is perceived to deliver low quality, despite its ability to improve the transfer video information, will rarely be commercially accepted by the user.

8.3.3. Real-World Experiences

The user experience of interacting with technologies and devices is the main momentum behind their social acceptance and commercial uptake. In our study (Chapter 6), we have concentrated our attention on precisely this issue and explored the user wireless information access user experience, when this is mediated by three different access devices.

Our results highlight that although mobile device types seem to heighten user levels of self-consciousness in public places – particularly if the device in question is a wearable one – generally the user information experience is unaffected by the type of wireless device responsible for it, a result in accordance with previous trends identified by Buranatrived and Vickers [BUR04] in their study of two mobile devices.

Moreover, whilst user computing background was found to influence searching activities in both an informational and entertainment context, this was an exception, rather than the norm. Ambient noise and light do impact on users' efforts to wirelessly access entertainment content; such factors, however, are ignored when informational content is sought, though.

8.3.4. Tailored Content Experiences

Our final study (Chapter 7) tailors multimedia content according to perceptual requirements device type and location and measures its impact on the user mobile information access experience. Throughout this study, we have built upon the findings of our previous two experiments to create pre-defined perceptually-based profiles and stream specially tailored video clips to three different display devices in three different locations based on their profile requirements.

The findings of this study showed that the overall QoP, and effectively the user information access experience, is affected and improved when multimedia content is tailored according to user device type and location. Additionally, it has to be highlighted that the device impact findings of this study were in line with the results of our previous study (Chapter 5), which effectively means that perceptual-oriented QoS delivery is beneficial to the user in a ubiquitous context characterised by wireless information access through a variety of different devices.

As a result, we propose that multimedia transmissions to mobile and wireless devices should be made based on pre-defined profiles, which contain a combination of both static (perceptual requirements, device type, CPU speed, and display specifications) and dynamic information (streamed content type location of the device/user, context of the device/user). The evaluation of such a system showed that the users and service providers can gain from such an approach considerably, from both a quality experience and bandwidth utilisation viewpoints, respectively.

8.4. Future Work

Our work has shown that consumer mobile information access acceptance and take-up cannot be achieved exclusively through technical considerations by means of purely technical, performance specification related (device type, screen size, processor speed, battery amount, connection speed and fps.) issues. Therefore, the future of mobile computing necessitates two-faceted research, which should combine both a user as well as a technical perspective.

We believe that a user will not continue paying for a mobile device or software that they perceive as causing dissatisfaction, regardless of the hardware or software capabilities of a new generation of mobile devices. As a result, if commercial mobile device development continues to ignore the user-perspective and experiences, giving exclusive preference to other factors, such as looks and technical specifications, then companies risk alienating and finally losing their customer-base and their good reputation. Indeed, a good example is represented by head-mounted displays, which, as our work has highlighted irrespective of their hype and futuristic design, will not be accepted by users if the associated mobile information access experience is not a positive one.

If commercial mobile device development, however, effectively integrated both user as well as technical considerations then, as our work has shown, multimedia provision would aspire to facilitate appropriate content, in context of the perceptual, hardware and network criteria of a specific user, thus optimising the quality of the user mobile information access experience, arguably the most important quality concept of all. In conclusion, by providing a comprehensive study of the mobile information access experience, our work has shown that the user perspective is as critically important to a distributed mobile content quality definition, as are technical parameters and considerations. Indeed, we would strongly argue that the development of user-perspective personalisation and adaptive content streaming can ultimately provide the customer with truly user-defined, accessibility that allows users to directly interact with mobile content on their own perceptual terms.

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APPENDICES

APPENDIX A
Out of Box Experience Questionnaires

Out Box Experience

Categories and Tasks for HP iPAQ 5450 & Eye-Trek

Please use the same tasks to answer the Head-Mounted Display (HMD) and Personal Digital Assistant (PDA) sections of each category on the questionnaire. The only exceptions for this are categories 5 and 6, which tasks and response for these sections are clearly marked, as 5a, 5b, 6a and 6b

C1: Packaging
T1: Try to carry around the one and/or two of the devices at the same time. **T2:** Try to identify the item based on the label on the boxes. **T3:** Try to group the boxes of the appliances in a car (or any means of transport). **T4:** Carry the boxes from the means of transport to your office/house. **T5:** Try using the handles on the boxes for easier transport.

C2: Unpacking
T1: Try opening the boxes finding the hard copies of the manuals (if exists). **T2:** Try identifying the devices that work together and have to be linked together from the organisation of the interior items. **T3:** Based on the content list, provided on the manual, check the inventory. **T4:** Empty all the contents of the box, put the related devices next to each other. **T5:** Try packing back the content of each box, using their original boxes and bags

C3: Setup
T1: Read the users' manual and understand the instructions for the initial setup **T2:** Read about how-to assemble the components that came with the device. **T3:** Assemble the components that came with the device. **T4:** Go back to the users' manual to check whether the components are linked correctly. **T5:** If not, check the user manuals Frequently Asked Questions (FAQ) section or troubleshooter

C4: Power On
T1: After all the setup has been done, turn on the device and verify that it works. **T2:** Try to identify whether the device has been setup properly. **T3:** Try to spot the welcome messages and/or thank-you notes. **T4:** Based on the message received compared with the expected message/image that is provided on the users' manual **T5:** In case of a problem, try to solve the problem using the FAQ section or troubleshooter.

C5a: Configuration (PDA)
T1: Make sure that the cradle is not attached to the USB port of your computer. **T2:** Install the required applications for the device, such as ActiveSync provided in setup compact disk (CD). **T3:** When the installation wizard requests position the PDA on the cradle and connect the cradle to the computer using the USB socket. **T4:** Follow the installation process and create a (***standard***) partnership between your computer and the personal digital assistant (PDA). **T5:** In case of a problem, try to solve the problem using the FAQ section or troubleshooter.
C5b: Configuration (HMD)
T1: Make sure that all required hardware to link the PDA with the Fly Jacket is there. **T2:** If they are on, turn off both of the devices **T3:** Using the manuals provided, try to link the Fly Jacket with the HMD device. **T4:** Position the PDA in the Fly Jacket and install the provided drivers to project the contents of the PDA screen to the HMD. **T5:** In case of a problem, try to solve the problem using FAQ section or troubleshooter.

C6a: Initial Use (PDA)
T1: Turn on the PDA device. **T2:** Position the PDA on the cradle and synchronise the applications running on the PDA with the ones on your desktop. **T3:** Personalise the synchronisation setting of the PDA by tapping on the ***Name*** section on the screen and type your name on the provided. To save hit OK. **T4:** Set the security settings for the device using fingerprint and password locking so that no one else can access your data. **T5:** Try accessing Secure Digital (SD) ***storage*** memory area and delete its content.

C6b: Initial Use (HMD)
T1: Turn on the HMD device. **T2:** Put on the Eye-Trek and insert the initial password – provided in the users manual – to enable the device. **T3:** Personalise the colour settings of the HMD based on your needs. **T4:** Set the security settings for the device using password locking so that no one else can use your HMD. **T5:** In case of a problem, try to solve the problem using FAQ section or troubleshooter.

C7: Doing Work
T1: Locate the PDA device on the cradle and using ActiveSync application transfer a file that is located on the C drive of the PC to the SD memory of the PDA device. **T2:** Run the Media Player application on the PDA open and watch the default video clip by pressing the *Play* button. **T3:** Go the Wireless Network (WLAN) settings and activate the wireless connection. Using the scanner, scan for available wireless networks in the area. **T4:** Using the identified wireless network, connect to ***http://192.168.0.2*** with the Internet Explorer application. **T5:** In case of a problem, try to solve the problem using the FAQ section or troubleshooter.

C8: Assistance
T1: Check for real time assistance that is provided on the devices (PDA, Eye-Trek).
T2: Search for FAQ or troubleshooter section on the manuals of the devices.
T3: Try to find out if there is any online (web) help/technical support available.
T4: Try to find out if there are any free-phone lines available for this purpose
T5: See if the assistance provided through manual and web site is multilingual.

Out of Box Experience

Evaluation Form

Evaluator Details	
Name:	Age:
Vision Problems (if known):	**Sex: M / F**

Please tick (☑) the appropriate box below considering that
5- Strongly Agree, 4- Agree, 3- Neutral, 2- Disagree, 1- Strongly Disagree

Packaging		
	PDA	**HMD**
The boxes are too heavy for their content to be carried around	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐
It easy to identify the contents of the boxes based on their labels	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐
It easy to group/organise the boxes in to a transportation vehicle?	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐
The boxes designed in such manner that eases the transportation?	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐
The boxes have handles to help transportation?	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐

Unpacking		
	PDA	**HMD**
It is easy to access the content of the box and access the user's manual.	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐
It is easy to understand the interior organisation of the box.	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐
It is easy to do an inventory check on the content of the box based on the manual.	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐
It is easy to understand the functionality and the relation between devices	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐
It is easy to repack the devices back to their original wrappings.	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐

Setup		
	PDA	**HMD**
The users' manual is easy to understand and leaves no opportunity for mistakes.	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐
It is easy to understand the physical	1 2 3 4 5	1 2 3 4 5

arrangement of the components	□ □ □ □ □	□ □ □ □ □
It is easy to assemble the components	1 2 3 4 5 □ □ □ □ □	1 2 3 4 5 □ □ □ □ □
It is easy to find a specific section on the manual.	1 2 3 4 5 □ □ □ □ □	1 2 3 4 5 □ □ □ □ □
It is easy to find a specific section on the Frequently asked questions or troubleshooter	1 2 3 4 5 □ □ □ □ □	1 2 3 4 5 □ □ □ □ □

Power on		
	PDA	**HMD**
It is easy to see that the device works (Light blinking/showing that it has battery)	1 2 3 4 5 □ □ □ □ □	1 2 3 4 5 □ □ □ □ □
The initial/welcome screen makes clear that the device works properly.	1 2 3 4 5 □ □ □ □ □	1 2 3 4 5 □ □ □ □ □
It is hard to understand if everything is ok or not.	1 2 3 4 5 □ □ □ □ □	1 2 3 4 5 □ □ □ □ □
After reading the manual, I know what I should expect as start-up screen	1 2 3 4 5 □ □ □ □ □	1 2 3 4 5 □ □ □ □ □
The manual provides guidelines about what to do if something goes wrong.	1 2 3 4 5 □ □ □ □ □	1 2 3 4 5 □ □ □ □ □

Configuration		
	PDA	**HMD**
It is easy to install the ActiveSync Application provided	1 2 3 4 5 □ □ □ □ □	1 2 3 4 5 □ □ □ □ □
It is easy to link the PDA device to the cradle.	1 2 3 4 5 □ □ □ □ □	1 2 3 4 5 □ □ □ □ □
It is easy to create partnership between the desktop and the PDA	1 2 3 4 5 □ □ □ □ □	1 2 3 4 5 □ □ □ □ □
It is easy to identify which applications I want to be synchronised with the PDA	1 2 3 4 5 □ □ □ □ □	1 2 3 4 5 □ □ □ □ □
The users' manual provides enough help for this phase	1 2 3 4 5 □ □ □ □ □	1 2 3 4 5 □ □ □ □ □

Initial Use		
	PDA	**HMD**
Setting up the precision of stylus is easy and copy paste presentation is easy to understand.	1 2 3 4 5 □ □ □ □ □	1 2 3 4 5 □ □ □ □ □
It is easy to synchronise the PDA with the desktop.	1 2 3 4 5 □ □ □ □ □	1 2 3 4 5 □ □ □ □ □

It is easy to personalise the PDA based on the requirements	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐
The external memories are easily accessible.	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐
Moving files to and from SD cards are easy.	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐

Doing Work		
	PDA	**HMD**
File transfer from the desktop to the PDA is easy.	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐
It is easy to run an application on the PDA	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐
It is easy to make changes on files and saving them.	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐
The wireless access settings are simple and easy to use.	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐
The users' manual provided enough information regarding this phase.	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐

Assistance		
	HMD	**PDA**
The application it self provides real time help when required.	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐
Extra help and guidance can be asked from the device itself.	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐
The user manuals' are easy to understand and provides wide information on how to solve problems.	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐
The online broad help provided by the companies website.	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐
The company website has its own user group links and forums on this device.	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐	1 2 3 4 5 ☐ ☐ ☐ ☐ ☐

Computer Literacy Assessment	
How long have you been using computers (PC, Laptop, PocketPC)?	_____ Months _____ Years
Do you regularly use electronic mail (e-mail)?	Yes ☐ No ☐
Do you regularly use search engines (Google, AltaVista)?	Yes ☐ No ☐
Do you regularly use word processing applications (Ms Word, WordPerfect)?	Yes ☐ No ☐

Do you regularly use spreadsheet applications (Ms Excel, Lotus)?	Yes ☐	No ☐
Have you ever successfully installed software on a computer?	Yes ☐	No ☐
Have you ever written and successfully run a computer program?	Yes ☐	No ☐

Overall					
Summary Evaluation	**Poor** ☐	**Fair** ☐	**Satisfactory** ☐	**Good** ☐	**Excellent** ☐

Comments/Notes/Requests:____

APPENDIX B

Device Impact Evaluation Questionnaires

Action Clip

1) Who fires first?
2) What is the intention of the main characters?
3) Are the space troopers eliminated?
4) Do the main characters escape? If yes, how?
5) How many guns does the blond actor have?
6) How many guns does his partner have?
7) What is the colour of the robots suit?
8) Is the scene of the action hot from a temperature viewpoint?
9) How was the control centre destroyed?
10) Are there any women in the clip?
11) How much time of actual video footage elapses between launch and explosion of grenade?

SATISFACTION: 1 2 3 4 5 6

Animated Movie Clip

1) What sort of character does the woman in the fur coat have?
2) What do the man and his dog have in common?
3) Is the woman in the fur coat fat or skinny?
4) What is the weather outside like?
5) How many insults does the woman in the fur coat use?
6) Why is she angry?
7) How many characters talk in the clip?
8) How many characters behave happily? Which ones?
9) Does the woman in the fur coat take her bag before she leaves?
10) Name an element of the clip similar to the temperament of the woman in the fur coat!
11) How many scared people are there in the clip? Who are they?

SATISFACTION: 1 2 3 4 5 6

Band Clip

1 - 3) Name three camera close-ups of instrument players!
4) Name a musical instrument that a girl is playing!
5) What is the rough age of the players?
6) Are they wearing uniforms?
7) What colour is the background?
8) What kind (category) of instruments are the majority of the players playing?
9) How would you describe the tune in one word?
10) Does the band have a piano?
11) How many people are roughly in the band?

SATISFACTION: 1 2 3 4 5 6

Chorus Clip

1) What is the predominant colour of the clip?
2) What is the shape in which singers are standing?
3) How many girls are roughly in the choir?
4) How many camera close-ups are there?
5) What is the direction of the lighting during the clip?
6) Are the studio walls decorated? If so, with what?
7) What channel was the show on?
8) Do you perceive the décor as being: a) warm b) cold or c) a mixture of the two?
9) How many candles are there in the clip?
10) Does the camera move during the clip?

SATISFACTION: 1 2 3 4 5 6

Commercial Clip

1) What is the relationship between the couple?
2) What is the colour of the product?
3) What is the man using the cream for?
4 - 5) Name two advertised qualities of the product?
6) What stereotype does the video attack?
7) Which of the qualities a) clever b) hardworking c) crafty would you associate with the male?
8) Name one feature of the man's behaviour suggesting that he would like to keep the product a secret from his wife!
9 - 10) In what form would the product be bought from the supermarket?

SATISFACTION: 1 2 3 4 5 6

Cooking Clip

1) Are there any forks/knives/spoons in the clip?
2) Do any of the characters wear aprons?
3) How many people are cooking? How many people are talking?
4) Do the characters wear cooking hats?
5) Is the cooking mixture boiling?
6) How many pans are on the stove?
7) Do you think that the mixture is chilli?
8) Does the chef appear in a hurry?
9) Name two seafood ingredients used!
10) Name three spices used!

SATISFACTION: 1 2 3 4 5 6

Documentary Clip

1) How many lions can you see in the initial sequence of the clip?
2) What are the cubs doing?
3) How many lions are there in the clip?
4) Use a single word to describe the vegetation!
5) What type of vegetation is it?
6) What is the speaker doing?
7) What is the approximate distance between the speaker and lions?
8) In what position is the guide in?
9) What is the colour of his shirt?
10) Are there any adult male lions in the clip?

SATISFACTION: 1 2 3 4 5 6

News Clip

1) How many pieces of news are there in the bulletin?
2 - 3) Name two of them!
4) What's the name of the presenter?
5) What channel was the news on?
6) What's the time of the day of the news broadcast?
7) Around what time did the shooting occur?
8) How were the drugs concealed?
9) According to the bulletin, what is the frequency of shootings in the area?
10) Where was the drug transported from?
11) What type of drug is it?
12) How much of it was being transported (expressed in monetary terms or as total weight)?

SATISFACTION: 1 2 3 4 5 6

Pop Music Clip

1) What time was it in the clip?
2) Tell us a textual fact about the singer?
3) What is the name of the singer?
4 - 5) Name two features of the clip related to the Orient!
6) How many different cameras shots are there?
7) What is the singer wearing?
8) What is the bald man's job?
9) How many kisses are there in the clip?
10) How many camera close-ups of the singer?
11) Is the main character on time according to the lyrics of the song?
12) According to the lyrics, how does the singer feel?

SATISFACTION: 1 2 3 4 5 6

Rugby Clip

1) What teams are playing?
2) Why was the try scored?
3) Roughly, how many passes are made before the first tackle?
4) Roughly, how many passes are made before the try is scored?
5) How many insults does the woman in the fur coat use?
6) Approximately, how many tackles are made before the try is scored?
7) How many stars does the flag waved immediately after the try have?
8) What is the score of the match when the try is scored?
9) From a New Zealand (team in black) perspective, on what side of the pitch is the try scored?
10) Name either the try scorer/ his shirt number/ the colour of his hair!
11) What team wins the ball from the line-out?

SATISFACTION: 1 2 3 4 5 6

Snooker Clip

1) How many players are there in the clip?
2) At what stage of the match a) beginning b) middle c) end are we?
3) What are the names of the players?
4) Who is leading?
5) What is the colour of the floor?
6) How many balls are pocketed during the clip?
7) What colour is the ball that is pocketed?
8) According to the commentary, is the position from which the shot is made easy or difficult?
9) How many balls are hit by the shot?
10) Is the player left or right handed?
11) Draw a diagram and indicate in what hole was the ball pocketed?

SATISFACTION: 1 2 3 4 5 6

Weather Forecast Clip

1) What day of the week is the forecast for?
2) What is the time of the weather forecast?
3) How will the weather in the central part of the Mediterranean be?
4) How many different weather maps have been used in the clip?
5) Where, according to the forecast, is there going to be sunshine?
6) Will driving be affected in the UK on that day?
7) What colour is the forecaster's hair?
8) What's the weather on the coast of the U.K. like?
9) What will the maximum visibility in foggy areas of the U.K. be?
10) What colour is the map of mainland Europe?

SATISFACTION: 1 2 3 4 5 6

APPENDIX C

Real-World Mobile Information Access Questionnaires

Interactive Mobile Information Access Scenarios

Scenario 1

In this scenario, the user is a shopper that compares the *Adidas Tuscany* prices on-the-move.

Our user initially, sits on the high street/coffee shop and sips his/her coffee while he/she is looking for shopping malls around the area with his/her wireless-enabled device. He/she visits *askjeeves.co.uk* to find this information. Following this he/she visits the website of the mall and looks for sports shops. After identifying their location, he/she visits these shops and gets their prices. After finding out the local prices for the product, the user gets online again and searches for the best price on the web. He/she retrieves the results and compares with the local shop prices. Then he/she sends the best price to his/her friend via email.

Actions:
- Look for local mall using the *askjeeves.co.uk* website
- Find the location of the sports shops
- Go online and get prices for the product online using kelkoo.co.uk
- Send the best price to your friend, using e-mail

Scenario 2

In this scenario, the user is having his/her lunch break.

Our user is having his/her lunch break and simultaneously is listening to *BBC Radio 1*. While he/she is listening to music, he/she finds one of the songs quite appealing and he/she checks out the name of the track from the mobile devices display. Following this, he/she goes to a search engine and types the keywords, the name of the singer and the song, which brings up a page with a picture of the album cover. He/she saves it on the device so can check the cover and buy that album on the way back to home.

Actions:
- Logon to the *BBC Radio 1* web page and start the radio stream.
- Listen to the music and note down the name of the song that you most like.
- Logon to *google.com* and search for the artist and the song name.
- Find the album cover, and save it to his/her mobile device's memory.

Interactive Mobile Information Access

Tasks

Scenario 1
T1: Connect to the Internet using the device provided.
T2: Go to www.a*skjeeves.co.uk* website and search for shopping centres in the area.
T3: Open a shopping centre's web page and find its interior map and identify the sports shops within.
T4: Find the cheapest price for *Adidas Tuscany* from the local shops.
T5: Search on the Internet and compare the online prices with the prices in hand.
T6: Send the cheapest price available to a friend via email

Scenario 2
T1: Logon to ***www.virginradio.co.uk*** web site.
T2: Tap on the appropriate button on the website and start listening to the stream.
T3: Listen to the online radio.
T4: Note down the singer and the title of the song that is currently playing.
T5: Use the details to search for the album cover on a music market web site (*www.cdnow.com, www.amazon.com, www.hmv.co.uk*).
T6: After finding the album cover, download the image file to the mobile device for future use in the music store.

Thank you for your time

&

Enjoy the coffee

Interactive Mobile Information Access Questionnaire

Details	
Name:	**Age:**
Device: PDA / HMD / Laptop	**Sex: M / F**
Start Time: **Finish Time:**	**Environment: Street / Cafe**

Computer Background		
How long have you been using desktop computer?	_____ Months	_____ Years
How long have you been using mobile computers (Laptop/PDA)?	_____ Months	_____ Years
Do you regularly use electronic mail (e-mail)?	Yes ☐	No ☐
Do you regularly use search engines (Google, AltaVista)?	Yes ☐	No ☐
Do you regularly use word processing applications (Ms Word, WordPerfect)?	Yes ☐	No ☐
Do you regularly use spreadsheet applications (Ms Excel, Lotus)?	Yes ☐	No ☐
Have you ever successfully installed software on a computer?	Yes ☐	No ☐
Have you ever written and successfully run a computer program?	Yes ☐	No ☐
Do you know how much RAM your computer has? (amount orally)	Yes ☐	No ☐
Do you know what a USB port is? (mention orally)	Yes ☐	No ☐

Please tick (☑) the appropriate box below considering that
5- Strongly Agree, 4- Agree, 3- Neutral, 2- Disagree, 1- Strongly Disagree

Scenario 1					
			Feedback		
It is easy to logon to the Internet.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
It easy to navigate through search results on the device.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
It is easy to find sports shops in the malls near to you.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
It is easy to read maps on my device.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
It easy to find online prices of the product and make a comparison.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
It is easy to send e-mails.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
I am comfortable using the device in a public place	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

Scenario 2					
	Feedback				
It is easy to navigate through the *Virgin Radio* website.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
It is easy to listen to an online radio.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
It is easy to identify the track that is playing.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
It is easy to interact with the device.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
It is easy to do searches on the net.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
It is easy to access information and save it on my device.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
I am comfortable using the device in a public place	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

Comments/Notes/Requests:__________________________________

APPENDIX D

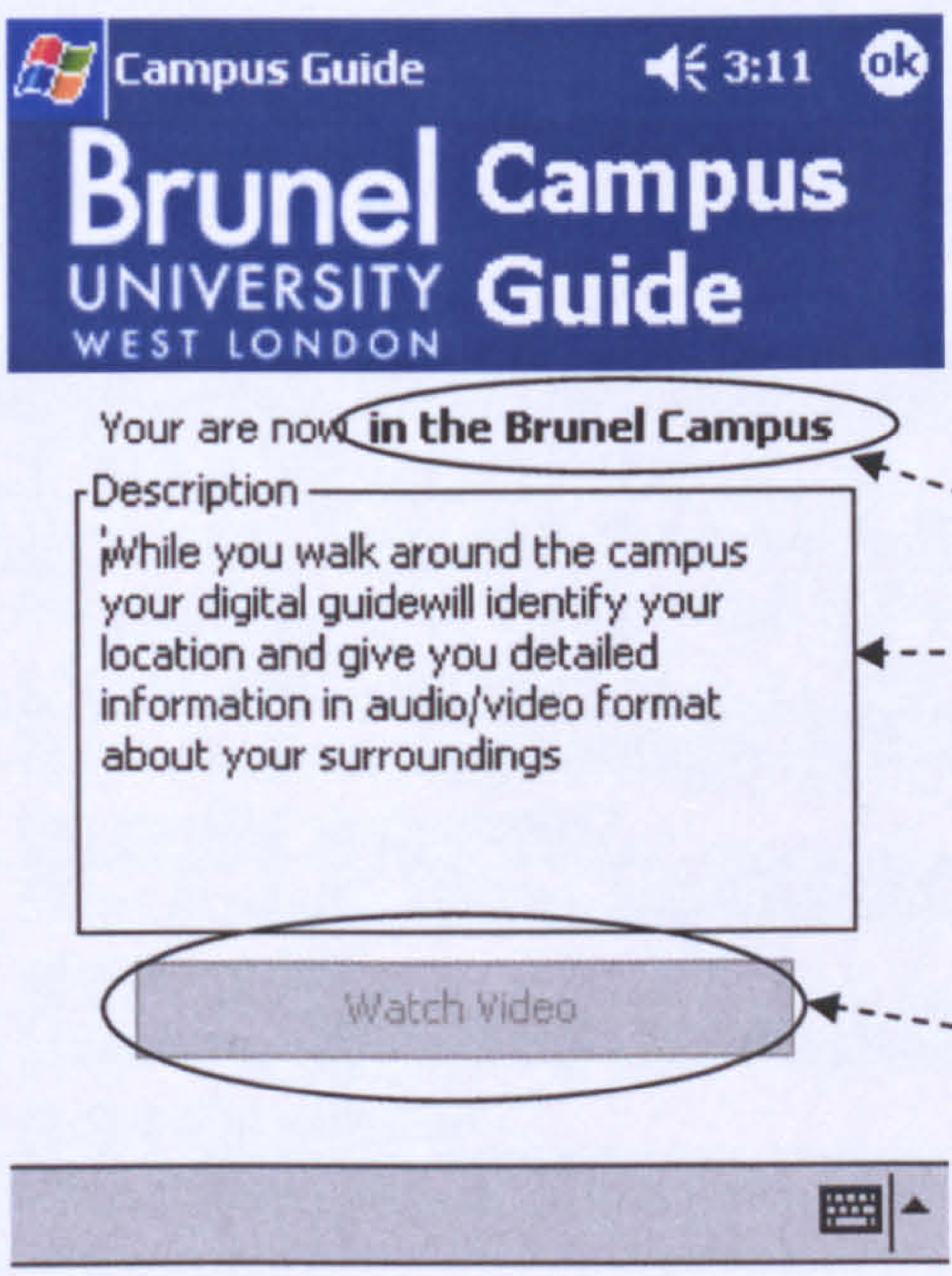
Device and Location Impact Evaluation Questionnaire

Digital Campus Guide Experiment Manual

The participants of this experiment are expected to make a tour of the Brunel University (Uxbridge) Campus using the designated device and watch the related video clips for each one of the building and locations. A participant should start his/her tour around Pink Building and finish around the Security Office by at least having watched 3 video clips.

The main objective of the Digital Campus Guide Experiment is to evaluate the location and device impact on user's information and entertainment assimilation. It is neither to measure the user's attention span nor abilities.

Experimental Application User Interface:



The initial screen is simplistic with a location indicator, description text box and *Watch Video* button.

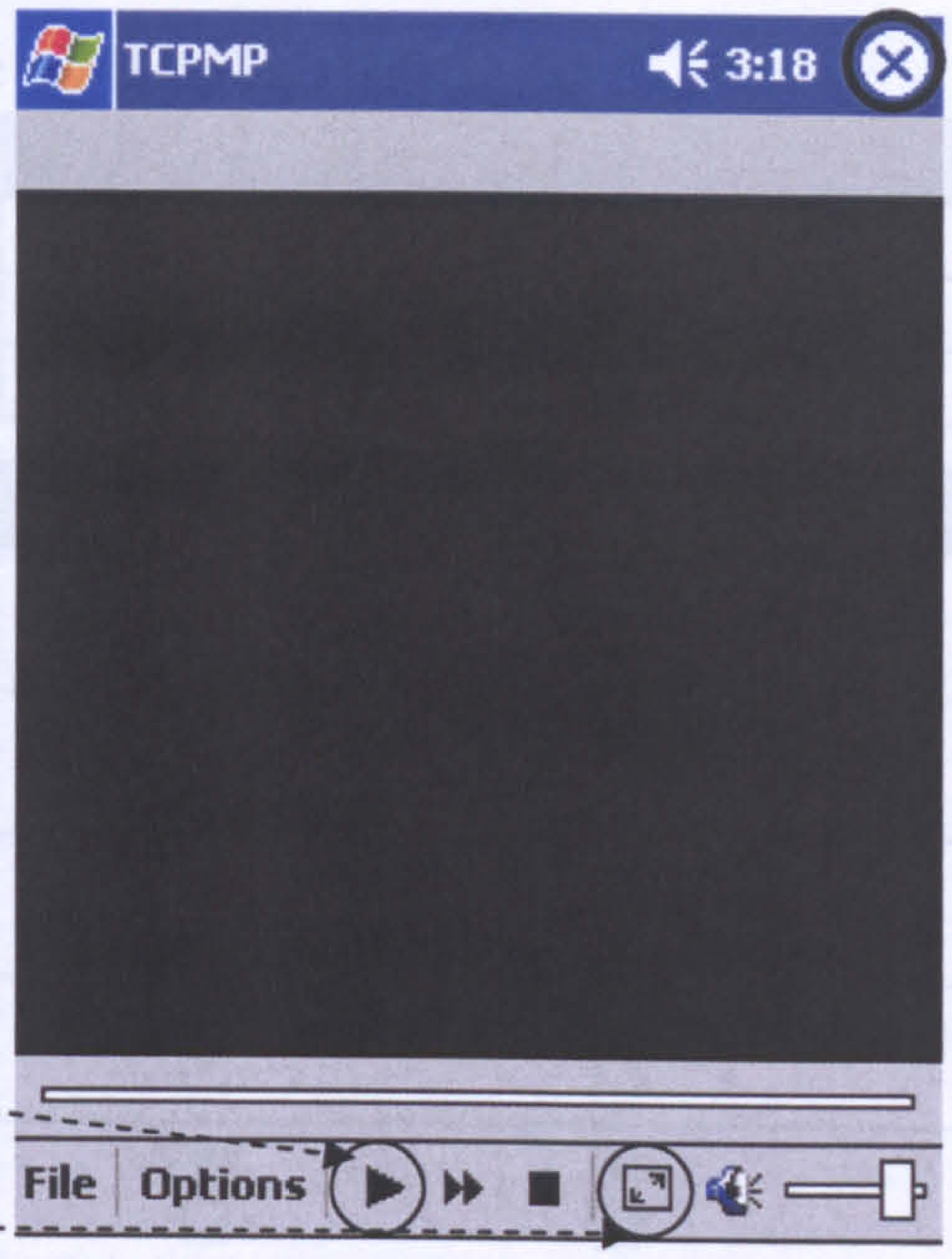
The indicator is located just below the main banner and the location is highlighted in bold characters. Whenever a building or location is recognised the location and description text is updated accordingly.

For the recognised buildings and locations the users can get further information by tapping on the *Watch Video* button. This action will bring up the video player and download the relevant clip.

On this interface users have to tap on the play button, which is located at the bottom centre of the application window, to start the video clip.

In order to improve the resolution problems caused by small screen device, the user can tap on full screen button to watch the clip in full screen mode.

The user can go to the main guide screen by just tapping on the **X** icon at the top right corner of the application window.



Campus Guide Questionnaire

Details	
Name:	**Age:**
Device: PDA / HMD / Laptop	**Sex: M / F**
Start Time:	**Finish Time:**

Computer Background	
How long have you been using desktop computer?	_____ Months _____ Years
How long have you been using mobile computers (Laptop/PDA)?	_____ Months _____ Years
Do you regularly use electronic mail (e-mail)?	Yes ☐ No ☐
Do you regularly use search engines (Google, AltaVista)?	Yes ☐ No ☐
Do you regularly use word processing applications (Ms Word, WordPerfect)?	Yes ☐ No ☐
Do you regularly use spreadsheet applications (Ms Excel, Lotus)?	Yes ☐ No ☐
Have you ever successfully installed software on a computer?	Yes ☐ No ☐
Have you ever written and successfully run a computer program?	Yes ☐ No ☐
Do you know how much RAM your computer has? (amount orally)	Yes ☐ No ☐
Do you know what a USB port is? (mention orally)	Yes ☐ No ☐

Location: Department	
Where is SISCM located?	....
How many floors does the building have?	....
What colour is the background of the ground floor corridors?	....
How many vending machines are there in the student study room?	....
What kind of monitors is used in the computer lab?	....
How many MPhil/PhD students are there in the department?	....
How many professors are there in the department?	....
On which are floor the lecturer offices and administrator offices located?	Lecturer offices:............................ Administrator Offices:......................
What was the RAE grade of the department in 2001?	....
What are the main research themes of Information Systems & Computing?	....
Quality: 0 – 1 – 2 – 3 – 4 – 5	Enjoyment: 0 – 1 – 2 – 3 – 4 – 5

Location: Bannerman (Library)	
What is the colour of the hat of the student who waves in the clip?	…………………………………………
How many computers were on the table in the clip?	…………………………………………
What colour were the office chairs next to the computer desk?	…………………………………………
What is the shape of the tables in the refectory/food court?	…………………………………………
What time does the library open and close on weekdays?	…………………………………………
Can you please name three services provided by the library?	………………………………………… ………………………………………… …………………………………………
On which areas do the Twickenham and Osterley libraries provide resources?	………………………………………… …………………………………………
How many days of the week is the library open during term-time?	…………………………………………
What facilities are there in the Student Union?	…………………………………………
Quality: 0 – 1 – 2 – 3 – 4 – 5	Enjoyment: 0 – 1 – 2 – 3 – 4 – 5

Comments……………………………………………………………………………………
……………………………………………………………………………………………

Location: Lawn	
What sort of character does the woman in the fur coat have?	…………………………………………
What do the man and the dog have in common?	…………………………………………
Is the woman in fur coat fat or slim?	…………………………………………
What is the weather outside like?	…………………………………………
How many insults does the woman in the fur coat use?	…………………………………………
How many characters talk in the clip? Which ones?	………………………………………… ………………………………………… …………………………………………
How many characters behave happily? Which ones?	………………………………………… …………………………………………
Does the woman in the fur coat get her bag when she leaves?	…………………………………………
Name an element of the clip, which is similar to the temperament of the woman in the fur coat?	…………………………………………
How many scared people are there in the clip?	…………………………………………
Quality: 0 – 1 – 2 – 3 – 4 – 5	Enjoyment: 0 – 1 – 2 – 3 – 4 – 5

Comments……………………………………………………………………………………
……………………………………………………………………………………………

APPENDIX E

Device and Location Impact Evaluation Prototype Application Source Code

1. GPS Coordinate Reader

```
#include <windows.h>
#include <string.h>
#include <stdio.h>



DWORD WINAPI GPSReadThreadFunc(LPVOID);
void Listing9_4();
void Listing9_5();
LPTSTR GetNextToken(LPTSTR, LPTSTR);
void ParseRMC(LPTSTR);

void ParseRMC(LPTSTR szSentence);

HANDLE hGPSPort = INVALID_HANDLE_VALUE;
//void ParseRMC(LPTSTR szSentence);


int WINAPI WinMain( HINSTANCE hInstance,
    HINSTANCE hPrevInstance,
    LPTSTR    lpCmdLine,
    int       nCmdShow)
{
// open the port
Listing9_4();

// read some data and write it to file
//GPSReadThread(NULL);
// close the port

GPSReadThreadFunc(NULL);

//Sleep(3000);

//Listing9_5();

return 0;
}




void Listing9_4()
{
      hGPSPort = CreateFile ("COM6:", // Port Name (Unicode
compatible)
                  GENERIC_READ | GENERIC_WRITE, // Open for Read-
Write
            0,             // COM port cannot be shared
            NULL,          // Always NULL for Windows CE
```

```
            OPEN_EXISTING, // For communication resource
            0,             // Non-overlapped operation only
            NULL);         // Always NULL for Windows CE
      if(hGPSPort == INVALID_HANDLE_VALUE)
      {
            //ReportCommError(_T("Opening Comms Port."));
            return;
      }
      // set the timeouts to specify the behavior of reads and
writes.
      COMMTIMEOUTS ct;
      ct.ReadIntervalTimeout = 1000;
      ct.ReadTotalTimeoutMultiplier = 0;
    ct.ReadTotalTimeoutConstant = 0;
    ct.WriteTotalTimeoutMultiplier = 10;
    ct.WriteTotalTimeoutConstant = 1000;
      if(!SetCommTimeouts(hGPSPort, &ct))
      {
            MessageBox(0, TEXT("Set Comm Time
Out"),TEXT("Test"),0);//ReportCommError(_T("Setting comm.
timeouts."));
            Listing9_5(); // close comm port
            return;
      }
      // get the current communications parameters, and configure
baud rate
      DCB dcb;
      dcb.DCBlength = sizeof(DCB);
      if(!GetCommState(hGPSPort, &dcb))
      {
            MessageBox(0, TEXT("Set Comm
State"),TEXT("Test"),0);//ReportCommError(_T("Getting Comms.
State."));
            Listing9_5(); // close comm port
            return;
      }

      dcb.BaudRate = CBR_9600;            // set baud rate to 9600
      dcb.fOutxCtsFlow  = FALSE;
      dcb.fRtsControl     = RTS_CONTROL_DISABLE;
      dcb.fDtrControl     = DTR_CONTROL_DISABLE;
      dcb.fOutxDsrFlow    = FALSE;
      dcb.fOutX           = TRUE; // XON/XOFF control
      dcb.fInX            = TRUE;
      dcb.ByteSize        = 8;
      dcb.Parity          = NOPARITY;
      dcb.StopBits        = ONESTOPBIT;
      if(!SetCommState(hGPSPort, &dcb))
      {
            MessageBox(0, TEXT("Set Comm
State"),TEXT("Test"),0);//ReportCommError(_T("Setting Comms.
State."));
            Listing9_5(); // close comm port
            return;
      }
      // now need to create the thread that will be reading the comms
port
      HANDLE hCommReadThread = CreateThread(NULL, 0,
                  GPSReadThreadFunc, NULL, 0, NULL);
      if(hCommReadThread == NULL)
      {
            MessageBox(0, TEXT("Create
Thread"),TEXT("Test"),0);//ReportCommError(_T("Creating Thread."));
            Listing9_5(); // close comm port
            return;
      }
      else
      {
            CloseHandle(hCommReadThread);
```

```
		}
}

// Thread function reads NMEA output from GPS device
DWORD WINAPI GPSReadThreadFunc(LPVOID)
{
	DWORD dwBytesRead;
	char szSentence[1000], c;
	TCHAR szwcsSentence[1000];
	int nc = 0;

	SetThreadPriority(GetCurrentThread(),
THREAD_PRIORITY_BELOW_NORMAL);
	while(hGPSPort != INVALID_HANDLE_VALUE)
	{
		if(!ReadFile(hGPSPort, &c, 1, &dwBytesRead, NULL))
		{
			//ReportCommError(_T("Reading comms port."));
			return 0;		// terminate thread on first
error
		}
		if(dwBytesRead == 1)
		{
			if(c == '\n') // LF marks end of sentance
			{
				szSentence[nc - 1] = '\0';// remove trailing
CR
				nc = 0;			// ready to read next
sentence
				if(strlen(szSentence) < 6)
					;//MessageBox(0, TEXT("Corrupt
Sentence"),TEXT("Test"),0);//cout << _T("Corrupt sentence") << endl;
				else if(szSentence[0] != '$')
					;//MessageBox(0, TEXT("No Start
Sentence"),TEXT("Test"),0);//cout << _T("Sentence did not start with
$") << endl;
				else
				{
					// have a sentence. convert to Unicode
					//mbstowcs(szwcsSentence, szSentence,
1000);
					// find sentence ID
					//if(wcsncmp(&szwcsSentence[3], "RMC",
3) == 0)
						ParseRMC(szSentence);
				}
			}
			else
				szSentence[nc++] = c;
		}
	}
	return 0;
}

// returns the next token from the sentence.
LPTSTR GetNextToken(LPTSTR lpSentence, LPTSTR lpToken)
{
	lpToken[0] = '\0';
	if(lpSentence == NULL) // empty sentence
		return NULL;
	if(lpSentence[0] == '\0') // end of sentence
		return NULL;
	if(lpSentence[0] == ',') // empty token
		return lpSentence + 1;
	while(*lpSentence != ',' && *lpSentence != '\0' && *lpSentence
!= '*')
	{
		*lpToken = *lpSentence;
		lpToken++;
```

```
            lpSentence++;
      }
      lpSentence++;  // skip over comma
      *lpToken = '\0';
      return lpSentence;
}

// Parses a RMC sentence which has the format:
// RMC,225446,A,4916.45,N,12311.12,W,000.5,054.7,191194,020.3,E*68

void ParseRMC(LPTSTR szSentence)
{


//TCHAR szToken[20];
//DWORD dwCheckSum = 0;
FILE* stream;
//TCHAR* u = _T("\n");
//LPCWSTR seps2 = (const unsigned short *) u;
//TCHAR* s = _T(",");
//LPCWSTR seps = (const unsigned short *) s;
//for(UINT i = 1; i < wcslen(szSentence) && szSentence[i] != '*';
i++)
 //dwCheckSum ^= szSentence[i];
// lpNextTok points at ID $GPRMS, ignore this
//szSentence = GetNextToken(szSentence, szToken);
//print to file
if (strncmp(szSentence,"$GPRMC",6)== 0)
{
      stream = fopen( "\\location7.txt", "w" );
      fputs( szSentence, stream );
   //fputws( seps, stream );
      fclose( stream );
}
// Time of Fix, convert to Unicode
//szSentence = GetNextToken(szSentence, szToken);
//write file Fix Time to file
//stream = fopen( "\\location7.txt", "a" );
  // fputws( szToken, stream );
//fputws( seps, stream );


// Navigation receiver (GPS) warning
//szSentence = GetNextToken(szSentence, szToken);
// write GPS Warning to file
  // fputws( szToken, stream );
//fputws( seps, stream );
// Latitude
//szSentence = GetNextToken(szSentence, szToken);

// write lat. to file
  // fputws( szToken, stream );
//fputws( seps, stream );
// Latitude N or S
//szSentence = GetNextToken(szSentence, szToken);

// write N/S. to file
  // fputws( szToken, stream );
//fputws( seps, stream );

// Longitude
//szSentence = GetNextToken(szSentence, szToken);

// write lon. to file
  // fputws( szToken, stream );
//fputws( seps, stream );
// Longitude W or E
//szSentence = GetNextToken(szSentence, szToken);
```

```
// write W/E. to file
  // fputws( szToken, stream );
//fputws( seps, stream );
//fputws( seps2, stream );
//fclose( stream );
}


// *** Listing 9.5
//
// Closes COM1 serial port used for reading GPS device.
//

void Listing9_5()
{
      if(hGPSPort != INVALID_HANDLE_VALUE)
      {
            CloseHandle(hGPSPort);
            hGPSPort = INVALID_HANDLE_VALUE;
            MessageBox(0, TEXT("Port Closed"),TEXT("Test"),0);//cout
<< _T("GPS port closed") << endl;
      }
      else
            MessageBox(0, TEXT("Port was not
open"),TEXT("Test"),0);//cout << _T("GPS port was not open") << endl;
}
```

2. Digital Campus Guide Application for Pocket PC (Windows CE)

Form1.ebf

```
VERSION 5.00
Object = "{338D5EA5-4BBD-11D1-9A7D-00C04FAD5AEC}#1.0#0";
"mscepicture.dll"
Begin VB.Form Form1
   Appearance      =   0  'Flat
   BackColor       =   &H80000005&
   Caption         =   "Campus Guide"
   ClientHeight    =   3615
   ClientLeft      =   60
   ClientTop       =   840
   ClientWidth     =   3420
   ForeColor       =   &H80000008&
   ScaleHeight     =   3615
   ScaleWidth      =   3420
   ShowOK          =   -1  'True
   Begin VBCE.Frame Frame2
      Height          =   975
      Left            =   0
      TabIndex        =   7
      Top             =   0
      Width           =   3615
      _cx             =   6376
      _cy             =   1720
      BackColor       =   12257280
      BorderStyle     =   0
      Caption         =   ""
      Enabled         =   -1  'True
      BeginProperty Font {0BE35203-8F91-11CE-9DE3-00AA004BB851}
         Name            =   "Tahoma"
         Size            =   8.25
         Charset         =   0
```

```
      Weight          =   400
      Underline       =   0   'False
      Italic          =   0   'False
      Strikethrough   =   0   'False
   EndProperty
   ForeColor       =   -2147483643
   ClipControls    =   -1  'True
   Begin PictureBoxCtl.PictureBox PictureBox1
      Height          =   890
      Left            =   240
      TabIndex        =   8
      Top             =   40
      Width           =   1450
      _cx             =   2566
      _cy             =   1561
      AutoSize        =   0   'False
      BackColor       =   -2147483643
      BorderStyle     =   0
      DrawMode        =   13
      DrawStyle       =   0
      DrawWidth       =   1
      FillColor       =   -2147483640
      FillStyle       =   1
      ForeColor       =   -2147483640
      FontBold        =   0   'False
      FontItalic      =   0   'False
      FontStrikethru  =   0   'False
      FontUnderline   =   0   'False
      FontName        =   "Tahoma"
      FontSize        =   10
      FontTransparent =   -1  'True
      Object.Height          =   59
      Object.Width           =   97
      Object.Left            =   16
      Object.Top             =   3
      Picture         =   ""
      ScaleHeight     =   885
      ScaleWidth      =   1455
      ScaleLeft       =   0
      ScaleTop        =   0
      ScaleMode       =   1
      Enabled         =   -1  'True
   End
   Begin VBCE.Label Label3
      Height          =   855
      Left            =   1800
      TabIndex        =   9
      Top             =   0
      Width           =   1455
      _cx             =   2566
      _cy             =   1508
      AutoSize        =   0   'False
      BackColor       =   12257280
      BackStyle       =   1
      BorderStyle     =   0
      Caption         =   "Campus Guide"
      Enabled         =   -1  'True
      BeginProperty Font {0BE35203-8F91-11CE-9DE3-00AA004BB851}
         Name            =   "Arial"
         Size            =   18
         Charset         =   0
```

```
            Weight          =   700
            Underline       =   0    'False
            Italic          =   0    'False
            Strikethrough   =   0    'False
         EndProperty
         ForeColor       =   -2147483643
         Alignment       =   0
         UseMnemonic     =   -1   'True
         WordWrap        =   0    'False
      End
   End
   Begin VBCE.Frame Frame1
      Height          =   1815
      Left            =   240
      TabIndex        =   3
      Top             =   1320
      Width           =   3015
      _cx             =   5318
      _cy             =   3201
      BackColor       =   -2147483643
      BorderStyle     =   1
      Caption         =   "Description"
      Enabled         =   -1   'True
      BeginProperty Font {0BE35203-8F91-11CE-9DE3-00AA004BB851}
         Name            =   "Tahoma"
         Size            =   8.25
         Charset         =   0
         Weight          =   400
         Underline       =   0    'False
         Italic          =   0    'False
         Strikethrough   =   0    'False
      EndProperty
      ForeColor       =   -2147483640
      ClipControls    =   -1   'True
      Begin VBCE.TextBox DescriptionTxt
         Height          =   1455
         Left            =   120
         TabIndex        =   4
         Top             =   240
         Width           =   2775
         _cx             =   4895
         _cy             =   2566
         BackColor       =   -2147483643
         BorderStyle     =   0
         Enabled         =   -1   'True
         BeginProperty Font {0BE35203-8F91-11CE-9DE3-00AA004BB851}
            Name            =   "Tahoma"
            Size            =   8.25
            Charset         =   0
            Weight          =   400
            Underline       =   0    'False
            Italic          =   0    'False
            Strikethrough   =   0    'False
         EndProperty
         ForeColor       =   -2147483640
         Text            =   $"Form1.frx":0000
         Alignment       =   0
         HideSelection   =   -1   'True
         Locked          =   0    'False
         MaxLength       =   0
         MultiLine       =   -1   'True
```

```
         PasswordChar    =   ""
         ScrollBars      =   0
      End
   End
   Begin VBCE.Label LocationLabel
      Height          =   375
      Left            =   1395
      TabIndex        =   6
      Top             =   1080
      Width           =   2055
      _cx             =   3625
      _cy             =   661
      AutoSize        =   0   'False
      BackColor       =   -2147483643
      BackStyle       =   1
      BorderStyle     =   0
      Caption         =   "in the Brunel Campus"
      Enabled         =   -1  'True
      BeginProperty Font {0BE35203-8F91-11CE-9DE3-00AA004BB851}
         Name            =   "Tahoma"
         Size            =   8.25
         Charset         =   0
         Weight          =   700
         Underline       =   0   'False
         Italic          =   0   'False
         Strikethrough   =   0   'False
      EndProperty
      ForeColor       =   -2147483640
      Alignment       =   0
      UseMnemonic     =   -1  'True
      WordWrap        =   0   'False
   End
   Begin VBCE.Label Label2
      Height          =   615
      Left            =   1920
      TabIndex        =   5
      Top             =   240
      Width           =   1455
      _cx             =   2566
      _cy             =   1085
      AutoSize        =   0   'False
      BackColor       =   -2147483643
      BackStyle       =   1
      BorderStyle     =   0
      Caption         =   "Campus Guide"
      Enabled         =   -1  'True
      BeginProperty Font {0BE35203-8F91-11CE-9DE3-00AA004BB851}
         Name            =   "Tahoma"
         Size            =   12
         Charset         =   0
         Weight          =   700
         Underline       =   0   'False
         Italic          =   0   'False
         Strikethrough   =   0   'False
      EndProperty
      ForeColor       =   -2147483640
      Alignment       =   0
      UseMnemonic     =   -1  'True
      WordWrap        =   0   'False
   End
   Begin VBCE.CommandButton Command1
```

```
      Height            =   375
      Left              =   480
      TabIndex          =   2
      Top               =   3240
      Width             =   2535
      _cx               =   4471
      _cy               =   661
      BackColor         =   12632256
      Caption           =   "Watch Video"
      Enabled           =   0   'False
      BeginProperty Font {0BE35203-8F91-11CE-9DE3-00AA004BB851}
         Name              =   "Tahoma"
         Size              =   8.25
         Charset           =   0
         Weight            =   400
         Underline         =   0   'False
         Italic            =   0   'False
         Strikethrough     =   0   'False
      EndProperty
      Style             =   0
   End
   Begin VBCE.Label Label1
      Height            =   255
      Left              =   360
      TabIndex          =   1
      Top               =   1080
      Width             =   1110
      _cx               =   1958
      _cy               =   450
      AutoSize          =   0   'False
      BackColor         =   -2147483643
      BackStyle         =   1
      BorderStyle       =   0
      Caption           =   "Your are now"
      Enabled           =   -1  'True
      BeginProperty Font {0BE35203-8F91-11CE-9DE3-00AA004BB851}
         Name              =   "Tahoma"
         Size              =   8.25
         Charset           =   0
         Weight            =   400
         Underline         =   0   'False
         Italic            =   0   'False
         Strikethrough     =   0   'False
      EndProperty
      ForeColor         =   -2147483640
      Alignment         =   0
      UseMnemonic       =   -1  'True
      WordWrap          =   0   'False
   End
   Begin VBCE.Timer Timer1
      Left              =   120
      Top               =   3000
      _cx               =   847
      _cy               =   847
      Enabled           =   -1  'True
      Interval          =   2000
   End
   Begin VBCE.TextBox txtRead
      Height            =   255
      Left              =   3120
      TabIndex          =   0
```

```
      Top              =   3360
      Visible          =   0   'False
      Width            =   375
      _cx              =   661
      _cy              =   450
      BackColor        =   -2147483643
      BorderStyle      =   1
      Enabled          =   -1  'True
      BeginProperty Font {0BE35203-8F91-11CE-9DE3-00AA004BB851}
         Name             =   "Tahoma"
         Size             =   8.25
         Charset          =   0
         Weight           =   400
         Underline        =   0   'False
         Italic           =   0   'False
         Strikethrough    =   0   'False
      EndProperty
      ForeColor        =   -2147483640
      Text             =   "Text1"
      Alignment        =   0
      HideSelection    =   -1  'True
      Locked           =   0   'False
      MaxLength        =   0
      MultiLine        =   -1  'True
      PasswordChar     =   ""
      ScrollBars       =   0
   End
End
Attribute VB_Name = "Form1"
Attribute VB_GlobalNameSpace = False
Attribute VB_Creatable = False
Attribute VB_PredeclaredId = True
Attribute VB_Exposed = False
Option Explicit
Dim LocationID As interger


Private Sub Command1_Click()
Dim llResult As Long

  If LocationID = 0 Then
  llResult = Shell("\Program Files\TCPMP\player.exe", "\Storage
Card\PDADept25.avi")
  If llResult <> 0 Then MsgBox "Shell() error: " & llResult
  End If

  If LocationID = 1 Then
  llResult = Shell("\Program Files\TCPMP\player.exe", "\Storage
Card\PDABannermann15.avi")
  If llResult <> 0 Then MsgBox "Shell() error: " & llResult
  End If

  If LocationID = 2 Then
  llResult = Shell("\Program Files\TCPMP\player.exe", "\Storage
Card\PDALawn15.avi")
  If llResult <> 0 Then MsgBox "Shell() error: " & llResult
  End If

End Sub

Private Sub Form_Load()
```

```
PictureBox1.Picture = App.Path & "\brunel_bluelogo.bmp"
End Sub

Private Sub Form_OKClick()
    App.End
End Sub

Private Function ParseTXT(SourceTXT As String)
Dim N As String
Dim W As String

    If Len(SourceTXT) = 47 Then
        If Mid(SourceTXT, 1, 6) = "$GPRMC" And Mid(SourceTXT, 19, 1)
= "A" Then
            N = Mid(SourceTXT, 21, 9)
            W = Mid(SourceTXT, 33, 10)
            SelectLocation N, W
        End If
    End If

End Function

Private Sub Timer1_Timer()
 GetContentofFile
End Sub

Private Function SelectLocation(Ntxt As String, Wtxt As String)
    Dim N As Long
    Dim W As Long
    Dim Selection As Integer
    Selection = 3
    'LocationTxt.Text = Ntxt & " " & Wtxt
    N = Ntxt
    W = Wtxt

    If IsNumeric(N) = True And IsNumeric(W) = True Then
    'LocationTxt.Text = N2 & " " & N3
        If N < 5132.08 And N > 5132.03 Then
            If W > 28.09 And W < 28.225 Then
                LocationLabel.Caption = "around St John's"
                LocationID = 0
                Selection = 0
                DescriptionTxt.Text = "St John's Building is where
the School of Informations Systems & Computing and Mathematics
reside, for further information please tap on Watch Video button."
                Command1.Enabled = True
            End If
        End If
        If N < 5132.1 And N > 5131.93 Then
            If W > 28.4 And W < 28.46 Then
                LocationLabel.Caption = "around Bannermann Centre"
                LocationID = 1
                Selection = 1
                DescriptionTxt.Text = "Bannerman Centre is located in
the heart of the Brunel University Uxbridge Campus and is the
building where the main library is located. For further information
please tap on Watch Video button"
                Command1.Enabled = True
            End If
        End If
        If N < 5132.03 And N > 5131.97 Then
```

```
            If W > 28.47 And W < 28.52 Then
                LocationLabel.Caption = "around the lawn"
                LocationID = 2
                Selection = 2
                DescriptionTxt.Text = "This is the lawn area where
the students relax during the summer time"
                Command1.Enabled = True
            End If
        End If

        If Selection = 3 Then
        LocationLabel.Caption = "in the Brunel Campus"
        DescriptionTxt.Text = "While you walk around the campus your
digital guidewill identify your location and give you detailed
information in audio/video format about your surroundings"
        Command1.Enabled = False
        End If

    End If



End Function

Private Function GetContentofFile()
    Dim hFile As Long
    Dim FileSize As Long
    Dim Contents As String
    Dim dwRead As Long
    Dim i As Integer
    Dim output As String
    Dim output2 As String
    Dim outbuffer As String



    ' get file size
    hFile = CreateFile("location7.txt", GENERIC_READ + GENERIC_WRITE,
_
                        0, 0, OPEN_EXISTING, 0, 0)

    If hFile <> -1 Then
        FileSize = GetFileSize(hFile, 0)


        If FileSize > 0 Then
            ' allocate space for contents
            Contents = String(FileSize, 0)

            ' get contents
            ReadFile hFile, Contents, FileSize, dwRead, 0

            ' display contents
            'If optASCII.Value Then
                'txtRead.Text = UnicodeToAnsi(Contents)

            'Else
               txtRead.Text = ""
               output2 = ""
               For i = 1 To FileSize
```

```
                    output = Right("0" & Hex(AscB(MidB(Contents, i,
1))) & " ", 3)
                    outbuffer = ChrB("&H" & output)
                    txtRead.Text = txtRead.Text & outbuffer

                Next i
                output2 = txtRead.Text

                txtRead.Text = output2 '& outbuffer 'hex2ascii(output)

            'End If
        End If

        CloseHandle hFile
    End If
    ParseTXT (output2)

End Function
```

Comm.bas

```
Attribute VB_Name = "Communication_module"

Option Explicit

Public Declare Function CreateFile Lib "coredll" Alias "CreateFileW"
( _
    ByVal lpFileName As String, _
    ByVal dwDesiredAccess As Long, _
    ByVal dwShareMode As Long, _
    lpSecurityAttributes As Long, _
    ByVal dwCreationDisposition As Long, _
    ByVal dwFlagsAndAttributes As Long, _
    ByVal hTemplateFile As Long) As Long

Public Declare Function ReadFile Lib "coredll" ( _
    ByVal hFile As Long, _
    ByVal lpBuffer As String, _
    ByVal nNumberOfBytesToRead As Long, _
    lpNumberOfBytesRead As Long, _
    ByVal lpOverlapped As Long) As Long

Public Declare Function WriteFile Lib "coredll" ( _
    ByVal hFile As Long, _
    ByVal lpBuffer As String, _
    ByVal nNumberOfBytesToWrite As Long, _
    lpNumberOfBytesWritten As Long, _
    ByVal lpOverlapped As Long) As Long

Public Declare Function CloseHandle Lib "coredll" ( _
    ByVal hObject As Long) As Long

Public Declare Function SetFilePointer Lib "coredll" ( _
    ByVal hFile As Long, _
    ByVal lDistanceToMove As Long, _
    lpDistanceToMoveHigh As Long, _
    ByVal dwMoveMethod As Long) As Long

Public Declare Function GetFileSize Lib "coredll" ( _
    ByVal hFile As Long, _
```

```
    lpFileSizeHigh) As Long

Public Declare Function GetLastError Lib "coredll" () As Long

Public Const FILE_BEGIN As Long = 0
Public Const FILE_CURRENT As Long = 1
Public Const FILE_END As Long = 2
Public Const READ_CONTROL = &H20000
Public Const READ_WRITE = 2
Public Const FILE_READ_DATA = (&H1)
Public Const FILE_READ_ATTRIBUTES = (&H80)
Public Const FILE_READ_EA = (&H8)
Public Const FILE_WRITE_ATTRIBUTES = (&H100)
Public Const FILE_WRITE_DATA = (&H2)
Public Const FILE_WRITE_EA = (&H10)
Public Const FILE_APPEND_DATA = (&H4)
Public Const SYNCHRONIZE = &H100000

Public Const CREATE_ALWAYS = 2
Public Const OPEN_EXISTING = 3
Public Const OPEN_ALWAYS = 4
Public Const STANDARD_RIGHTS_WRITE = &H20000
Public Const STANDARD_RIGHTS_READ = &H20000
Public Const GENERIC_READ = &H80000000
Public Const GENERIC_WRITE = &H40000000
```

Application_shell.bas

```
Attribute VB_Name = "App_shell"


Option Explicit

Declare Function MyCreateProcess Lib "coredll" Alias "CreateProcessW"
(ByVal lpApplicationName As String, ByVal lpCommandLine As String,
ByVal lpProcessAttributes As Long, ByVal lpThreadAttributes As Long,
ByVal bInheritHandles As Long, ByVal dwCreationFlags As Long, ByVal
lpEnvironment As Long, ByVal lpCurrentDirectory As Long, ByVal
lpStartupInfo As Long, ByVal lpProcessInformation As String) As Long
Declare Function MyGetLastError Lib "coredll" Alias "GetLastError" ()
As Long
Declare Function MyCloseHandle Lib "coredll" Alias "CloseHandle"
(ByVal hObject As Long) As Long
Function Shell(ByVal Application As String, ByVal Parameters As
String) As Long

  Dim lsPI As String, llResult As Long, lhProcess As Long, lhThread
As Long

  lsPI = LongToBytes(0) & LongToBytes(0) & LongToBytes(0) &
LongToBytes(0)
  llResult = MyCreateProcess(Application, Parameters, 0, 0, 0, 0, 0,
0, 0, lsPI)
  If llResult <> 0 Then
    lhThread = BytesToLong(MidB(lsPI, 5, 4))
    Call MyCloseHandle(lhThread)
    lhProcess = BytesToLong(MidB(lsPI, 1, 4))
    Call MyCloseHandle(lhProcess)
    llResult = 0
  Else
    llResult = MyGetLastError()
    If llResult = 0 Then llResult = -1
  End If
```

```
  Shell = llResult

End Function
Function LongToBytes(ByVal Value As Long) As String

  Dim lsHex As String, i As Integer

  lsHex = Right("00000000" & Hex(Value), 8)
  For i = 1 To 7 Step 2
    LongToBytes = ChrB(CInt("&H" & Mid(lsHex, i, 2))) & LongToBytes
  Next

End Function
Function BytesToLong(ByVal Value As String) As Long

  Dim lsHex As String, i As Integer

  For i = 1 To 4
    lsHex = Hex(AscB(MidB(Value, i, 1))) & lsHex
  Next
  BytesToLong = CLng("&H" & lsHex)

End Function
```

2. *Digital Campus Guide Application for Windows 98/2000/XP*

User_Interface.vbp

```
Type=Exe
Form=UI.frm
Reference=*\G{00020430-0000-0000-C000-
000000000046}#2.0#0#..\..\..\..\..\..\WINDOWS\System32\stdole2.tlb#OL
E Automation
Object={6BF52A50-394A-11D3-B153-00C04F79FAA6}#1.0#0; wmp.dll
IconForm="Form1"
Startup="Form1"
ExeName32="CampusGuide.exe"
Path32="..\..\.."
Command32=""
Name="Project1"
HelpContextID="0"
CompatibleMode="0"
MajorVer=1
MinorVer=0
RevisionVer=0
AutoIncrementVer=0
ServerSupportFiles=0
VersionCompanyName="Brunel University"
CompilationType=0
OptimizationType=0
FavorPentiumPro(tm)=0
CodeViewDebugInfo=0
NoAliasing=0
BoundsCheck=0
OverflowCheck=0
FlPointCheck=0
FDIVCheck=0
UnroundedFP=0
StartMode=0
Unattended=0
Retained=0
ThreadPerObject=0
MaxNumberOfThreads=1

[MS Transaction Server]
```

```
AutoRefresh=1
```

UI.frm

```
VERSION 5.00
Object = "{6BF52A50-394A-11D3-B153-00C04F79FAA6}#1.0#0"; "wmp.dll"
Begin VB.Form Form1
   BorderStyle     =   1  'Fixed Single
   Caption         =   "Brunel University - Digital Campus Guide"
   ClientHeight    =   4455
   ClientLeft      =   45
   ClientTop       =   435
   ClientWidth     =   10065
   LinkTopic       =   "Form1"
   MaxButton       =   0   'False
   MinButton       =   0   'False
   ScaleHeight     =   4455
   ScaleWidth      =   10065
   StartUpPosition =   3  'Windows Default
   Begin VB.Frame Frame1
      Caption         =   "Video Panel"
      Height          =   3975
      Left            =   4680
      TabIndex        =   0
      Top             =   240
      Width           =   5295
      Begin WMPLibCtl.WindowsMediaPlayer WindowsMediaPlayer1
         Height          =   3650
         Left            =   240
         TabIndex        =   1
         Top             =   240
         Visible         =   0   'False
         Width           =   4885
         URL             =   ""
         rate            =   1
         balance         =   0
         currentPosition =   0
         defaultFrame    =   ""
         playCount       =   1
         autoStart       =   -1  'True
         currentMarker   =   0
         invokeURLs      =   -1  'True
         baseURL         =   ""
         volume          =   50
         mute            =   0   'False
         uiMode          =   "none"
         stretchToFit    =   0   'False
         windowlessVideo =   0   'False
         enabled         =   -1  'True
         enableContextMenu=   -1  'True
         fullScreen      =   0   'False
         SAMIStyle       =   ""
         SAMILang        =   ""
         SAMIFilename    =   ""
         captioningID    =   ""
         enableErrorDialogs=   0   'False
         _cx             =   8625
         _cy             =   6429
      End
```

```
   End
   Begin VB.Frame Frame2
      Caption         =   "Information Panel"
      Height          =   3975
      Left            =   240
      TabIndex        =   2
      Top             =   240
      Width           =   4215
      Begin VB.TextBox SatTimeTxt
         Height          =   285
         Left            =   1320
         TabIndex        =   12
         Text            =   "Receiving..."
         Top             =   1080
         Width           =   1815
      End
      Begin VB.TextBox LonTxt
         Height          =   285
         Left            =   1320
         TabIndex        =   11
         Text            =   "Receiving..."
         Top             =   720
         Width           =   1815
      End
      Begin VB.TextBox LanTxt
         Height          =   285
         Left            =   1320
         TabIndex        =   8
         Text            =   "Receiving..."
         Top             =   360
         Width           =   1815
      End
      Begin VB.CommandButton Command1
         Caption         =   "Play Vi&deo"
         Height          =   495
         Left            =   720
         TabIndex        =   4
         Top             =   3360
         Width           =   2415
      End
      Begin VB.TextBox txtMain
         Height          =   1575
         Left            =   120
         MultiLine       =   -1  'True
         TabIndex        =   3
         Top             =   1680
         Width           =   3975
      End
      Begin VB.Label Label4
         Caption         =   "Satellite Time:"
         Height          =   255
         Left            =   240
         TabIndex        =   10
         Top             =   1080
         Width           =   1215
      End
      Begin VB.Label Label3
         Caption         =   "Longitute:"
         Height          =   255
         Left            =   240
         TabIndex        =   9
```

```
         Top              =   720
         Width            =   1095
      End
      Begin VB.Label Label2
         Caption          =   "Latitude:"
         Height           =   255
         Left             =   240
         TabIndex         =   7
         Top              =   360
         Width            =   735
      End
      Begin VB.Label Label1
         Caption          =   "You are now"
         Height           =   255
         Left             =   120
         TabIndex         =   6
         Top              =   1440
         Width            =   975
      End
      Begin VB.Label LocationLabel
         BeginProperty Font
            Name             =   "MS Sans Serif"
            Size             =   8.25
            Charset          =   0
            Weight           =   700
            Underline        =   0    'False
            Italic           =   0    'False
            Strikethrough    =   0    'False
         EndProperty
         Height           =   255
         Left             =   1080
         TabIndex         =   5
         Top              =   1440
         Width            =   2295
      End
   End
   Begin VB.Timer Timer1
      Interval        =   3000
      Left            =   4080
      Top             =   0
   End
End
Attribute VB_Name = "Form1"
Attribute VB_GlobalNameSpace = False
Attribute VB_Creatable = False
Attribute VB_PredeclaredId = True
Attribute VB_Exposed = False
Option Explicit
Dim LocationID As Integer
Dim ButtonDisabled As Integer


Private Sub Command1_Click()

If LocationID = 0 Then
WindowsMediaPlayer1.Visible = True
WindowsMediaPlayer1.URL = "C:\Laptop_Video\LaptopDept25.avi"
Command1.Enabled = False
ButtonDisabled = 1
End If
```

```
If LocationID = 1 Then
WindowsMediaPlayer1.Visible = True
WindowsMediaPlayer1.URL = "C:\Laptop_Video\LaptopBannerman5.avi"
Command1.Enabled = False
ButtonDisabled = 2
End If


If LocationID = 2 Then
WindowsMediaPlayer1.Visible = True
WindowsMediaPlayer1.URL = "C:\Laptop_Video\LaptopLawn25.mpg"
Command1.Enabled = False
ButtonDisabled = 3
End If


End Sub

Private Sub Form_Load()
Command1.Enabled = False
ButtonDisabled = 0
End Sub

Private Sub Timer1_Timer()
'lblTeam.Caption = "Red Sox"
'iWins% = 78: iLosses% = 84
'Open App.Path & "\myFile788.txt" For Output As #1
'     Write #1, lblTeam.Caption, iWins%, iLosses%
'Close #1
'MsgBox App.Path

'Open App.Path & "\location7.txt" For Input As #1
'     txtMain.Text = Input(LOF(1), #1)
'Close #1

Dim Selection As Integer
Dim lon, lan
Selection = 3
Dim Longtit As Double, Langtit As Double
Dim ProtType As String, LinkStability As String, NSVal As String,
WEVal As String, string5 As String, string6 As String, SatTime As
Long, LonVal As Long, LanVal As Long, number4 As Long, number5 As
Long, number6 As Long
Open "\location7.txt" For Input As #1
     If LOF(1) > 60 Then
         Input #1, ProtType, SatTime, LinkStability, Longtit, NSVal,
Langtit, WEVal, number5, number6, string5, string6
     End If
Close #1

'txtMain.Text = ProtType & "," & SatTime & "," & LinkStability & ","
& lon & "," & NSVal & "," & lan & "," & WEVal

'Longtit = lon

'Langtit = lan


If IsNumeric(Longtit) = True And IsNumeric(Langtit) = True Then
```

```
LonTxt.Text = Longtit & " " & NSVal
LanTxt.Text = Langtit & " " & WEVal
SatTimeTxt.Text = ReFormatTime(SatTime)


'MsgBox Longtit & " " & Langtit
'LocationTxt.Text = N2 & " " & N3
        If Longtit < 5132.08 And Longtit > 5132.03 Then
           If Langtit > 28.09 And Langtit < 28.225 Then
                LocationLabel.Caption = "around St John's Building"
                LocationID = 0
                Selection = 0
                txtMain.Text = "St John's Building is where the
School of Information Systems & Computing and Mathematics reside, for
further information please tap on Watch Video button."
                If ButtonDisabled < 1 Then
                    Command1.Enabled = True
                End If
            End If
        End If
        If Longtit < 5132.1 And Longtit > 5131.93 Then
            If Langtit > 28.4 And Langtit < 28.46 Then
                LocationLabel.Caption = "around Bannermann Centre"
                LocationID = 1
                Selection = 1
                txtMain.Text = "Bannerman Centre is located in the
heart of the Brunel University Uxbridge Campus and is the building
where the main library is located. For further information please tap
on Watch Video button"
                If ButtonDisabled < 2 Then
                    Command1.Enabled = True
                End If
            End If
        End If
        If Longtit < 5132.03 And Longtit > 5131.97 Then
            If Langtit > 28.47 And Langtit < 28.52 Then
                LocationLabel.Caption = "around the lawn"
                LocationID = 2
                Selection = 2
                txtMain.Text = "This is the lawn area where the
students relax during the summer time"
                If ButtonDisabled < 3 Then
                    Command1.Enabled = True
                End If
            End If
        End If

        If Selection = 3 Then
        LocationLabel.Caption = "in the Brunel Campus"
        txtMain.Text = "While you walk around the campus your digital
guidewill identify your location and give you detailed information in
audio/video format about your surroundings"
        Command1.Enabled = False
        End If

End If

End Sub

Private Sub WindowsMediaPlayer1_StatusChange()
```

```
    If WindowsMediaPlayer1.Status = "Finished" Then
        WindowsMediaPlayer1.Close
        WindowsMediaPlayer1.Visible = False
    End If

End Sub

Public Function ReFormatTime(CurrentTime As Long)


Dim szCurrentTime As String
szCurrentTime = CurrentTime

If Len(szCurrentTime) < 6 Then
szCurrentTime = "0" & szCurrentTime
End If

ReFormatTime = Mid(szCurrentTime, 1, 2) & ":" & Mid(szCurrentTime, 3,
2) & ":" & Mid(szCurrentTime, 5, 2)


End Function
```

APPENDIX F

Experimental Multimedia Content

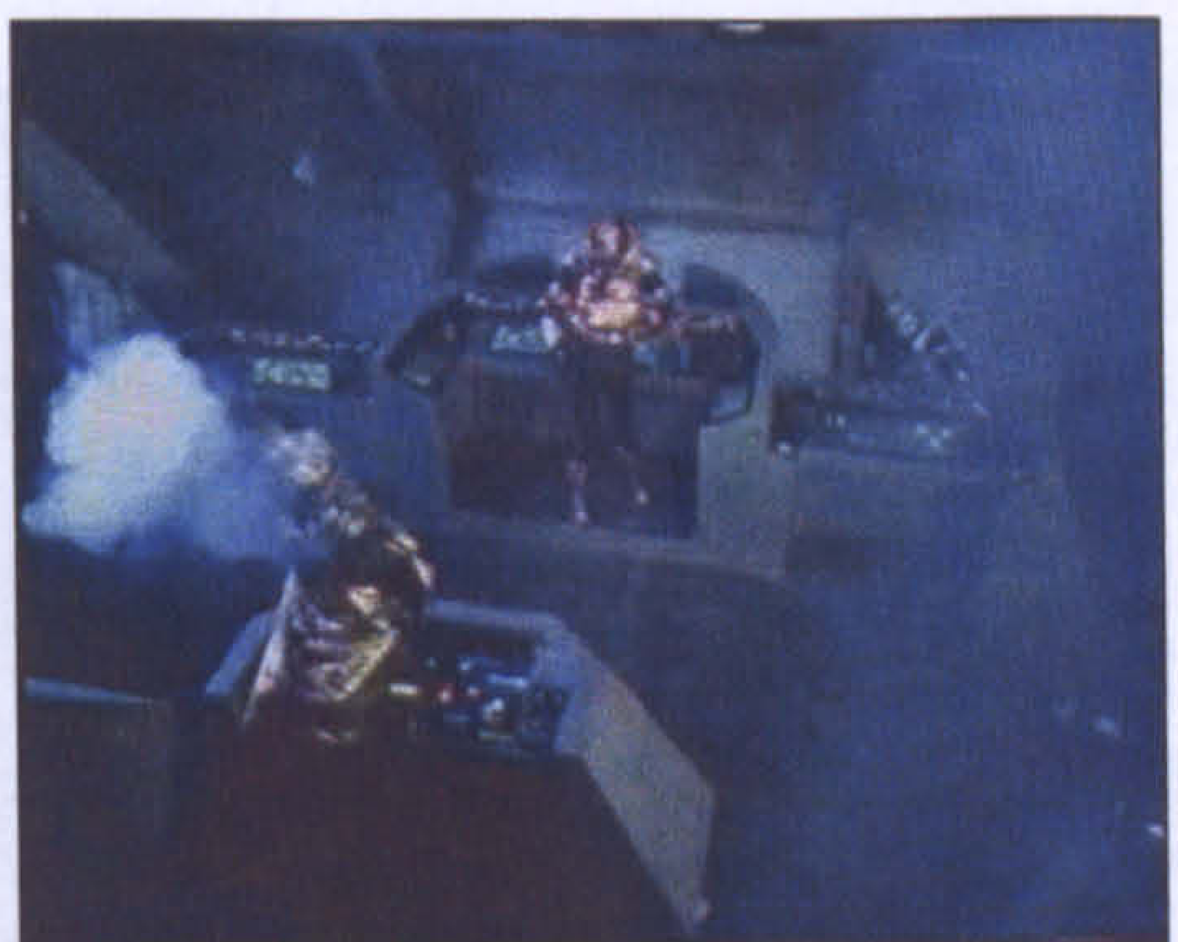
Action Movie

Action Movie

Action Movie

Action Movie

Action Movie

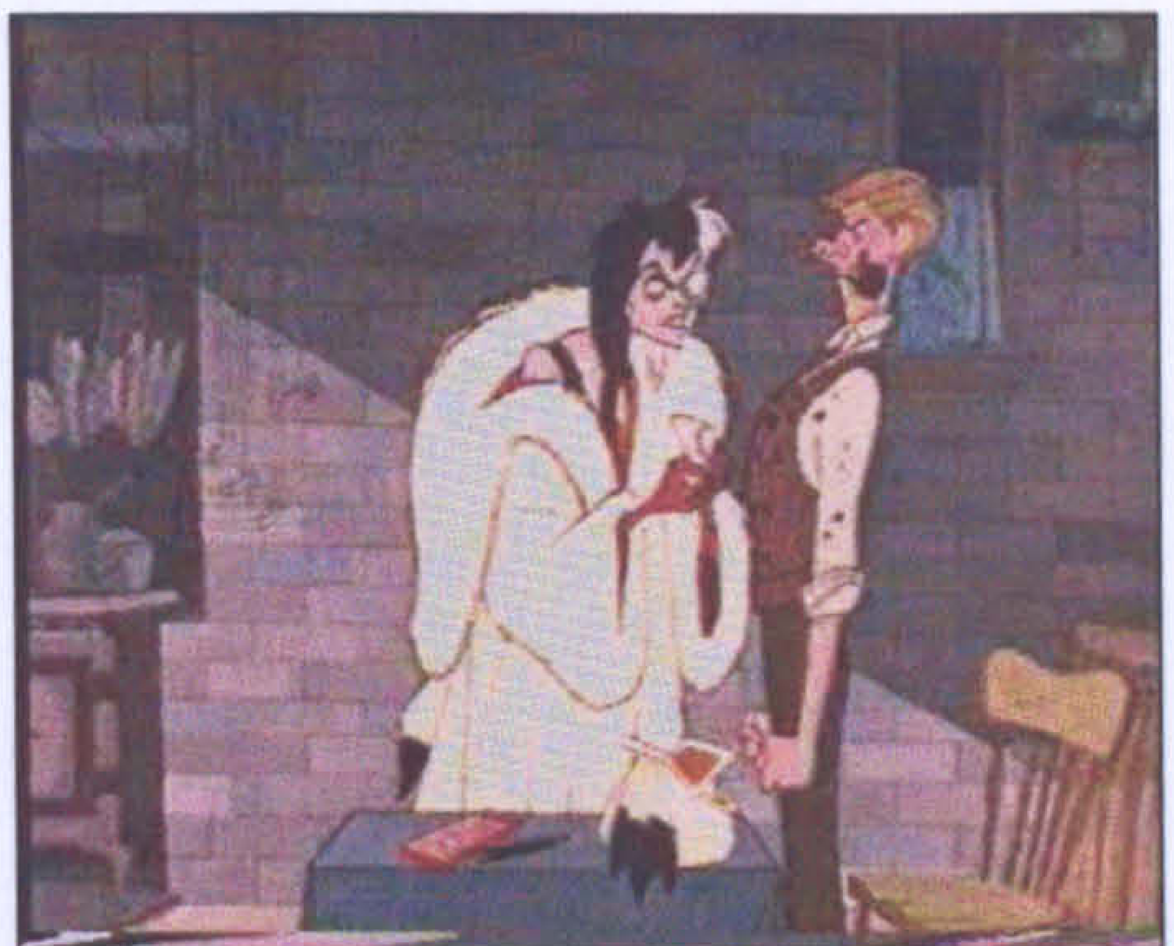


Action Movie

Action Movie

Action Movie

Animation Movie

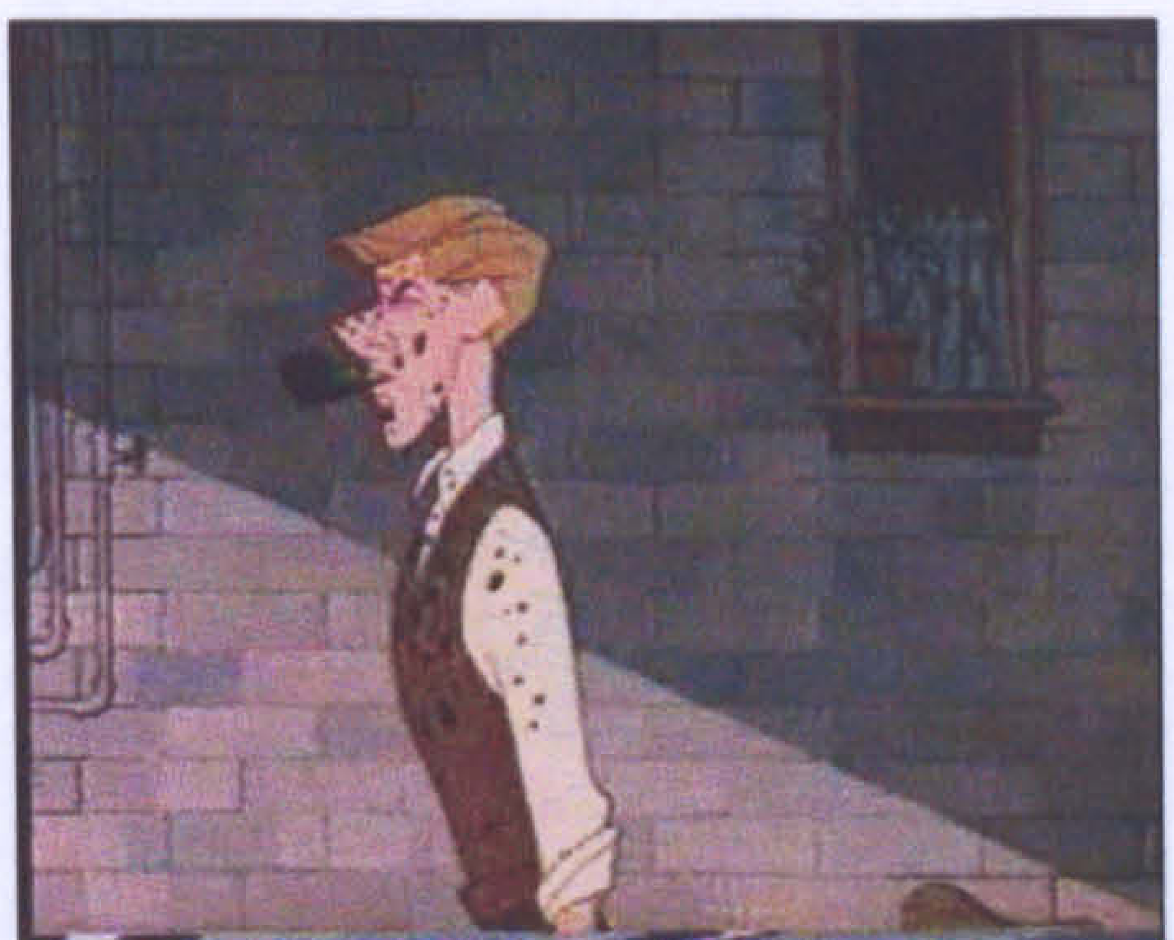


Animation Movie

Animation Movie

Animation Movie

Animation Movie



Animation Movie

Animation Movie

Animation Movie

Band Clip

Band Clip

Band Clip

Band Clip

Band Clip

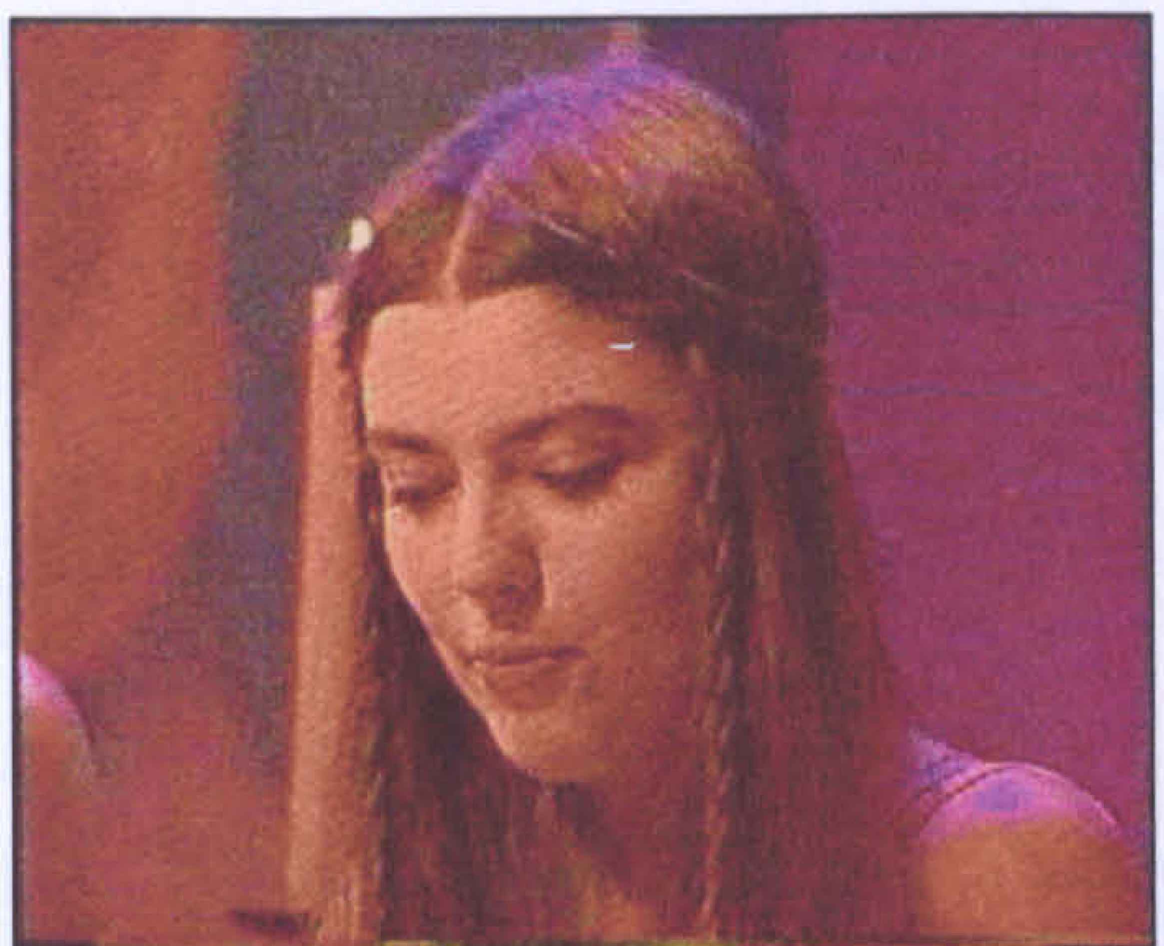
Band Clip

Band Clip

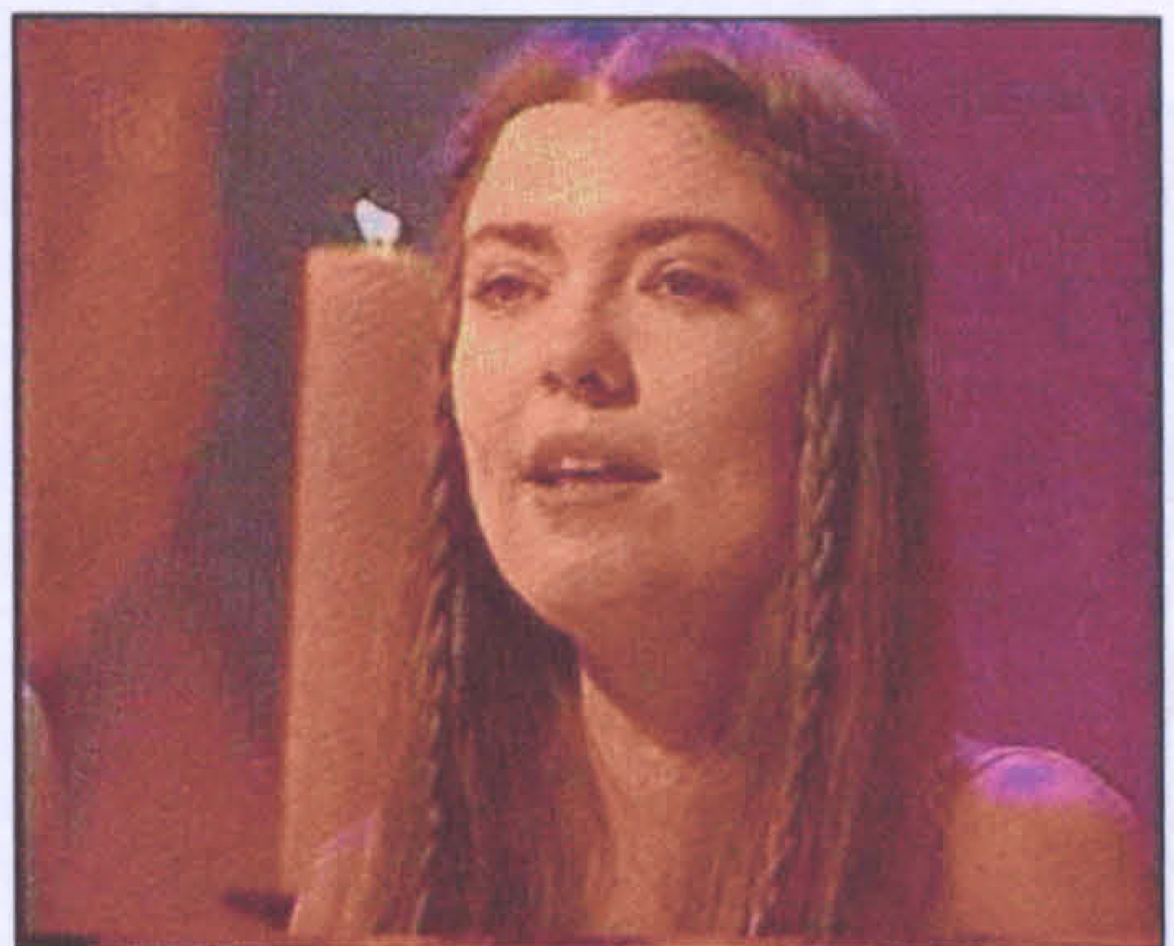
Band Clip

Chorus Clip

Chorus Clip



Chorus Clip



Chorus Clip

Chorus Clip

Chorus Clip

Chorus Clip

Chorus Clip

Commercial Clip

Commercial Clip

Commercial Clip

Commercial Clip

Commercial Clip

Commercial Clip

Commercial Clip

Commercial Clip

Cooking Clip

Cooking Clip

Cooking Clip

Cooking Clip

Cooking Clip

Cooking Clip

Cooking Clip

Cooking Clip


Documentary

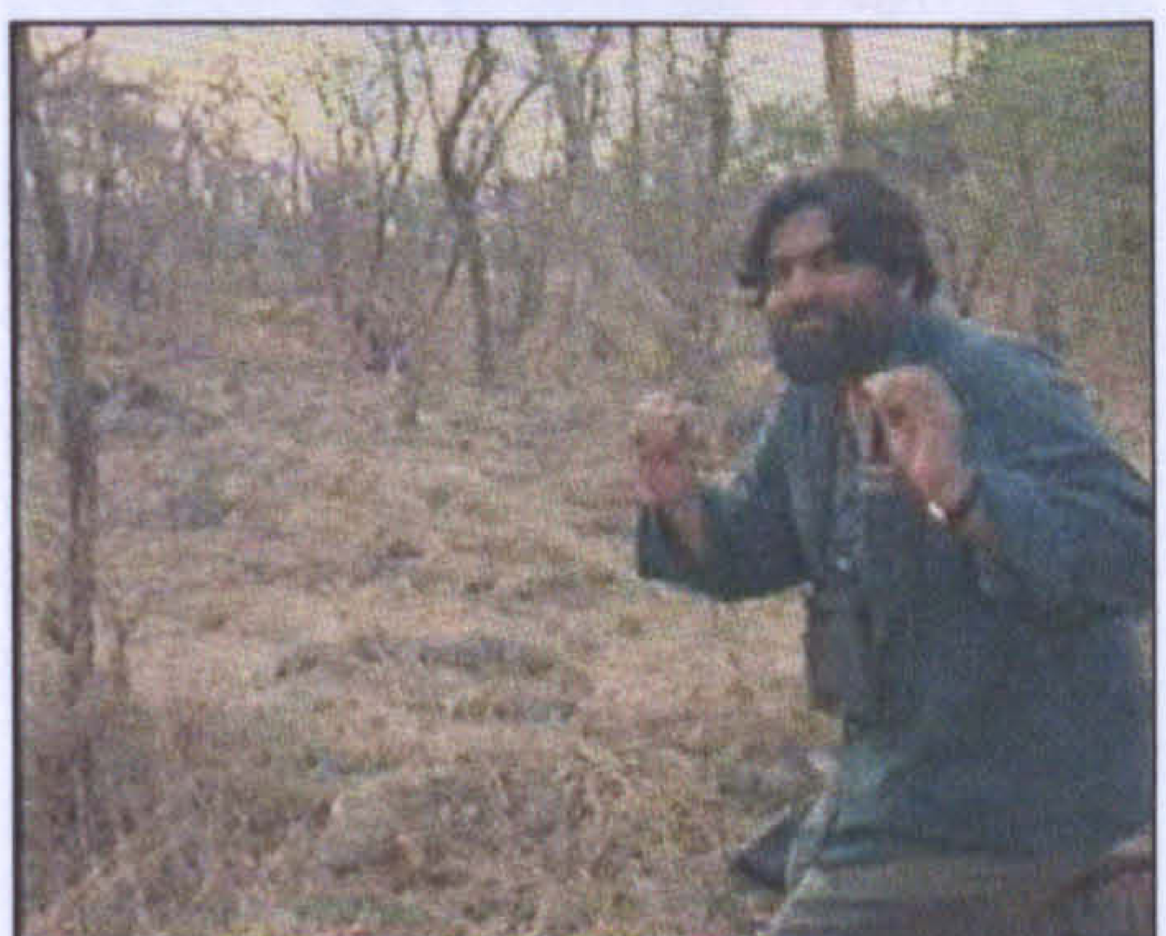

Documentary


Documentary


Documentary


Documentary


Documentary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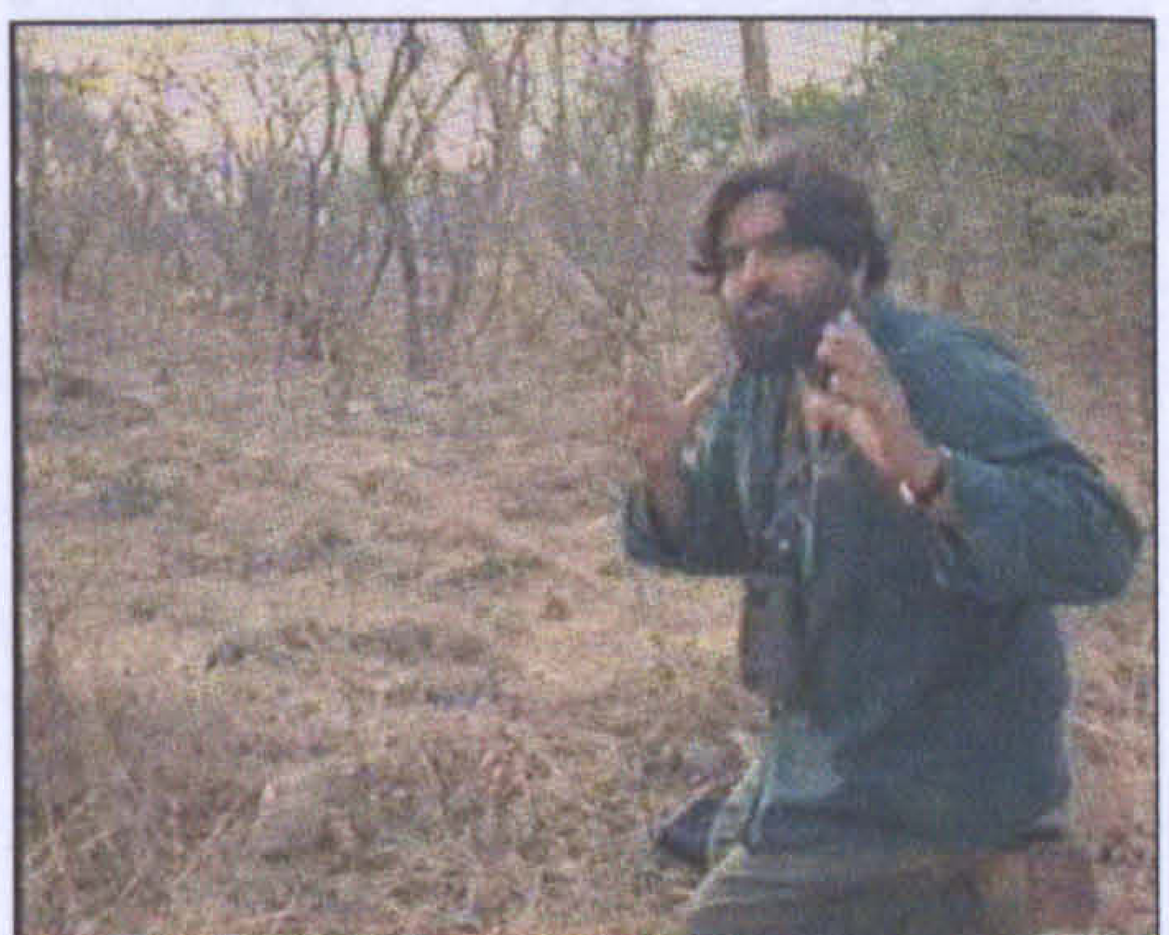

Documentary

News Clip

News Clip

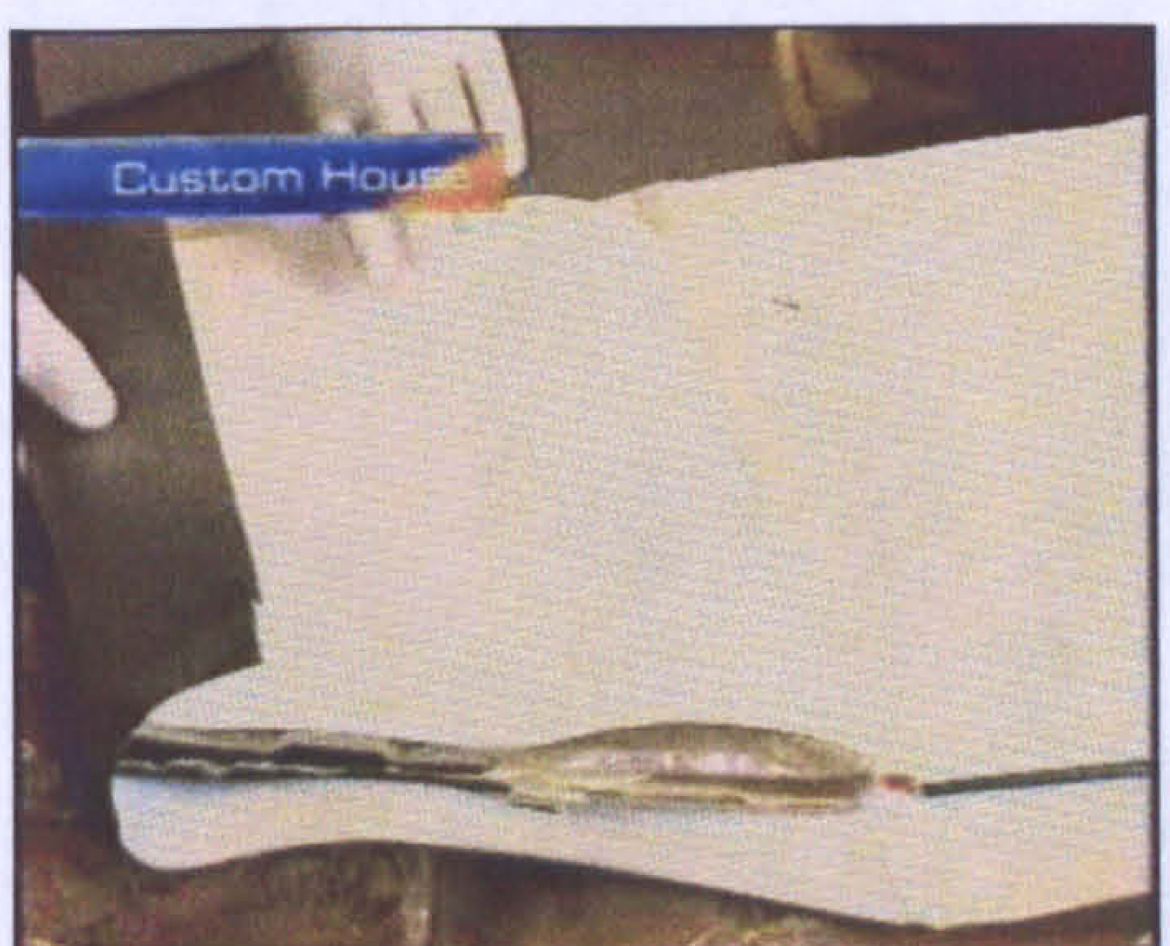
News Clip

News Clip

News Clip

News Clip

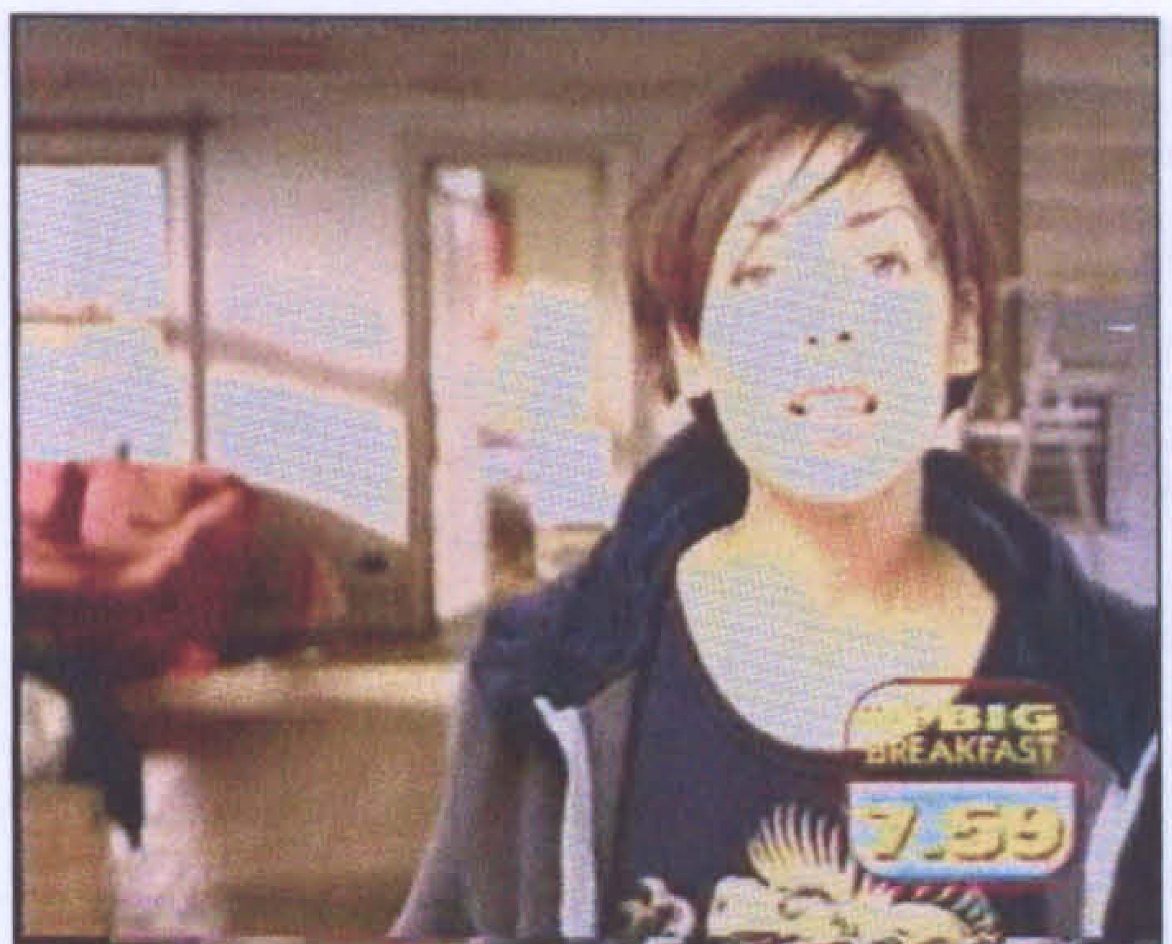
News Clip


News Clip

Pop Clip

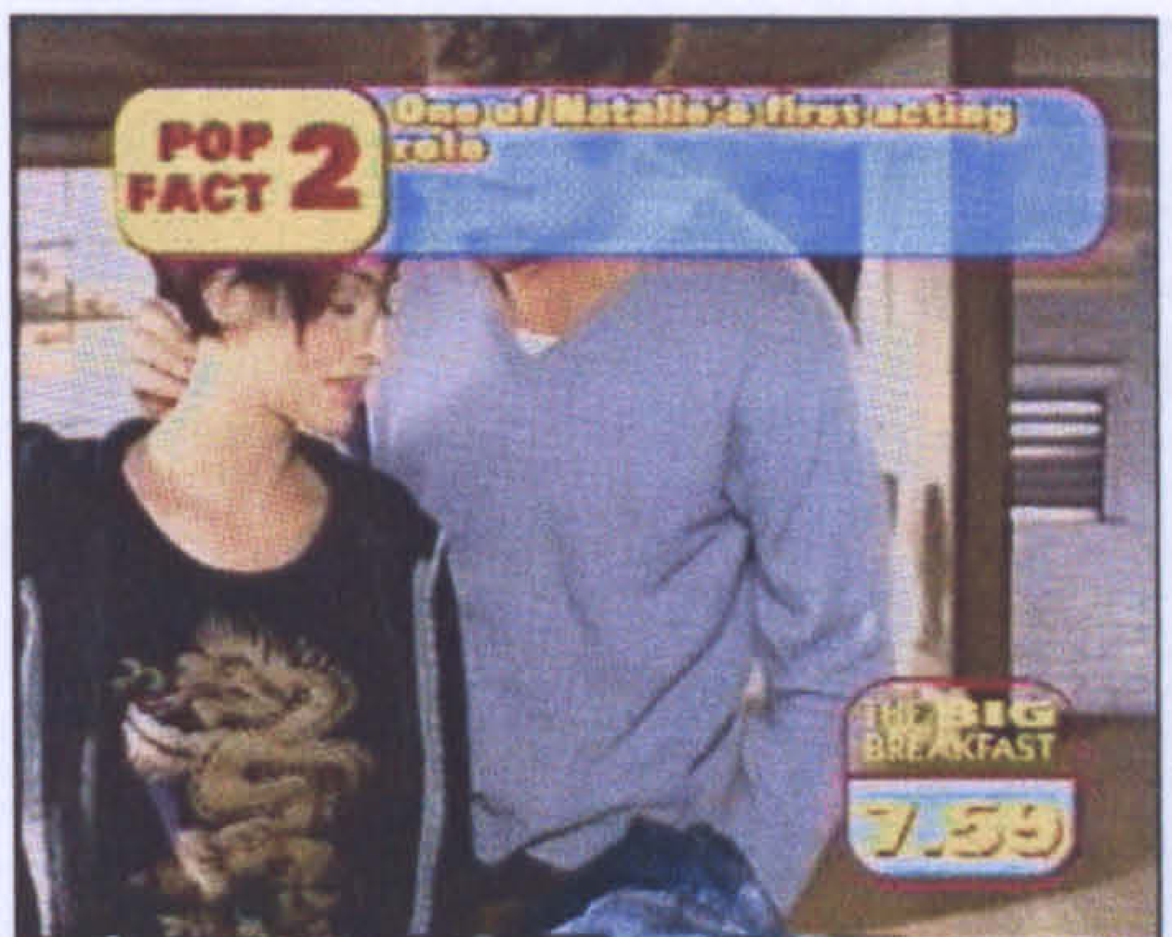
Pop Clip

Pop Clip

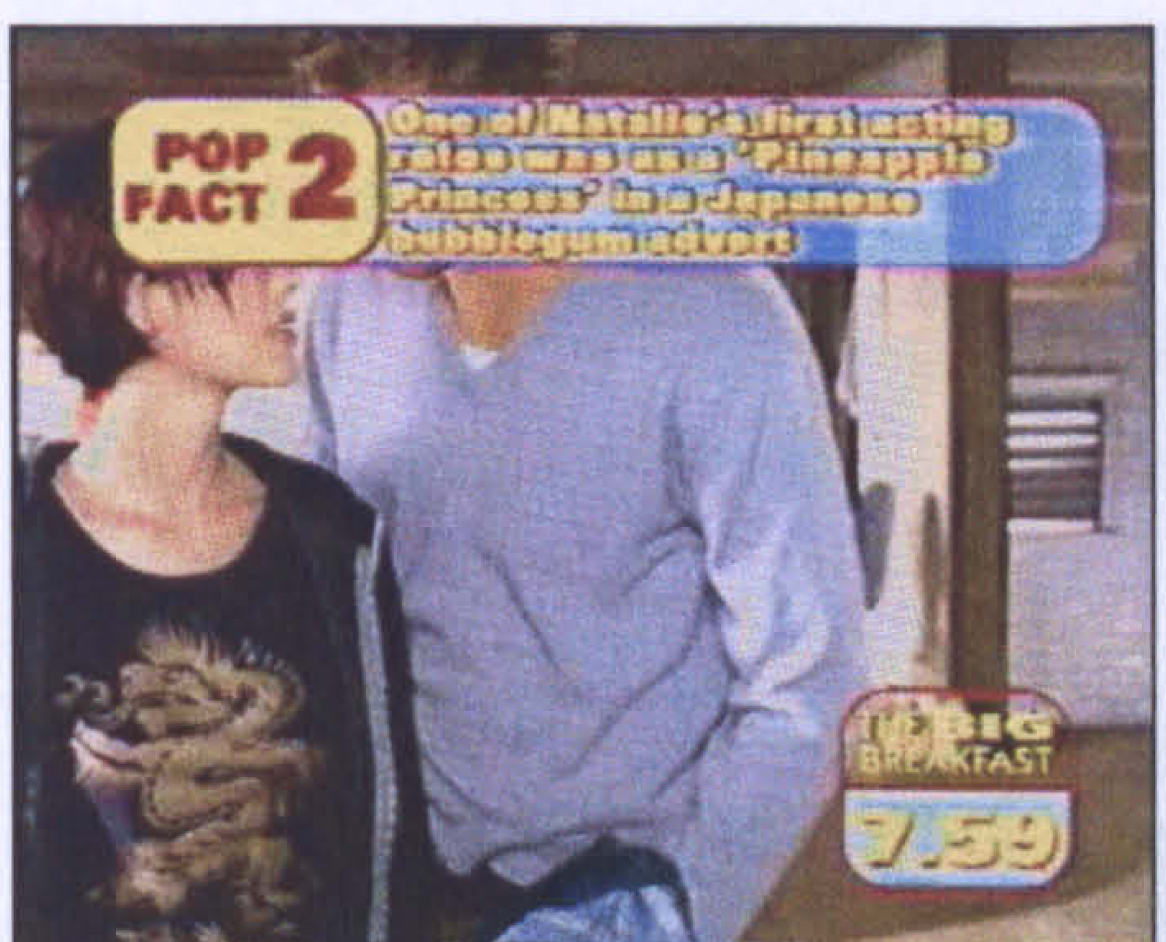


Pop Clip

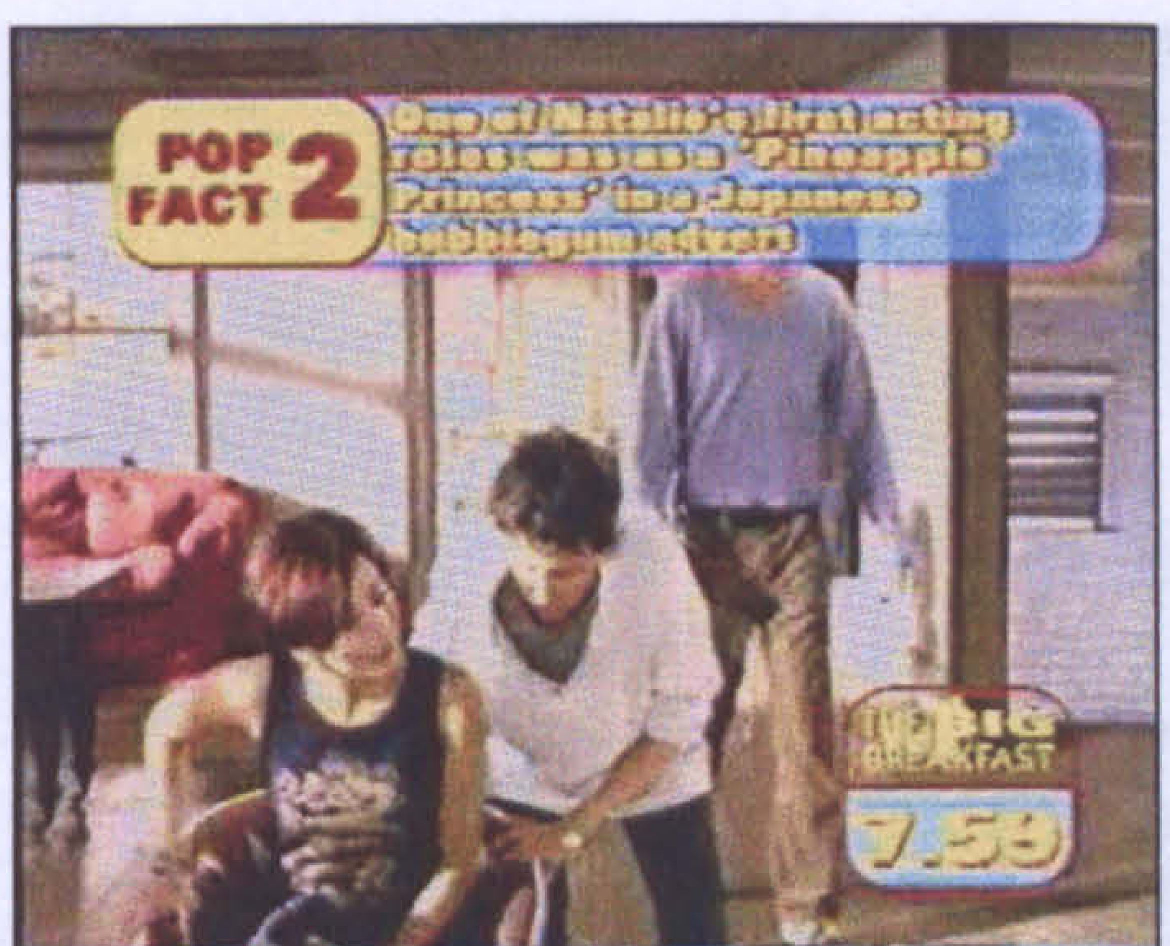
Pop Clip



Pop Clip



Pop Clip



Pop Clip


Rugby Clip

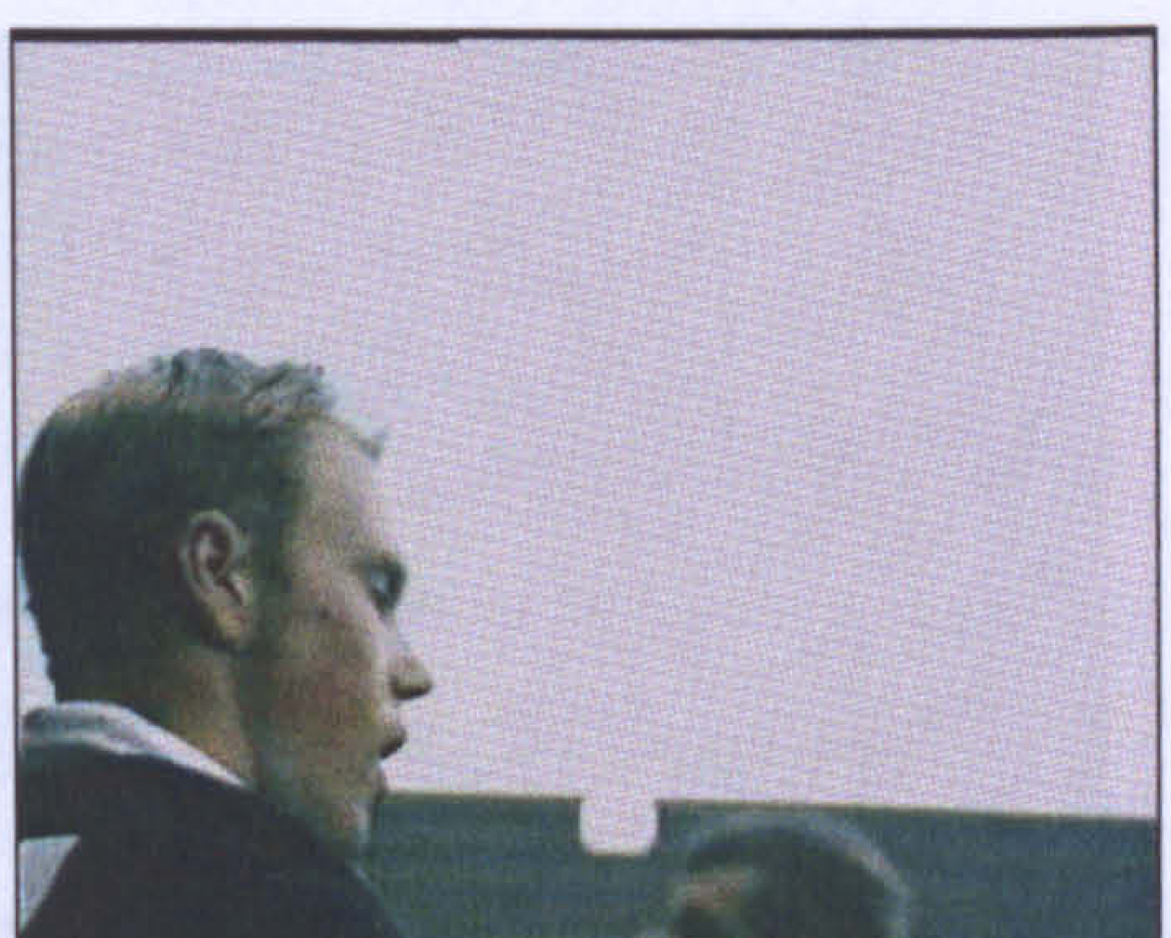

Rugby Clip


Rugby Clip

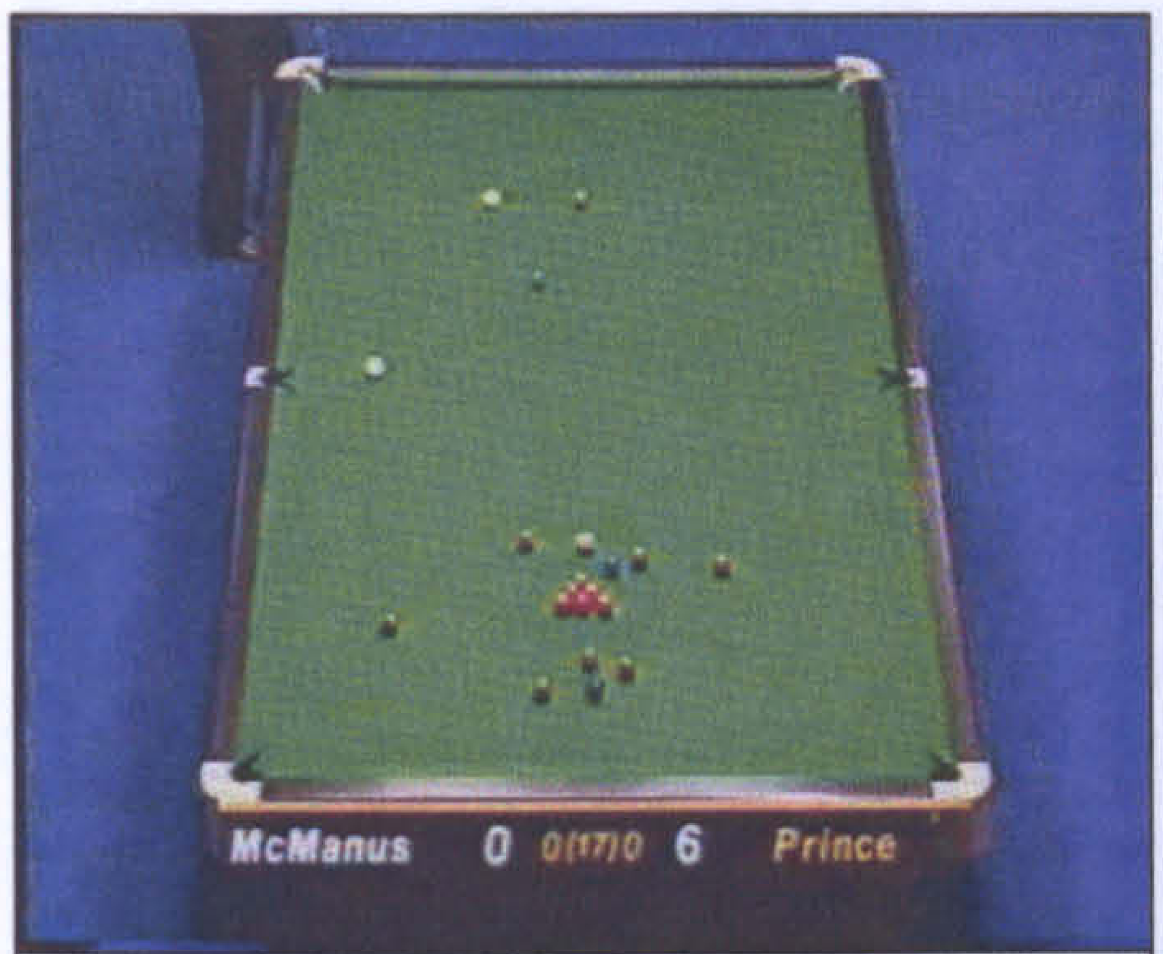

Rugby Clip


Rugby Clip

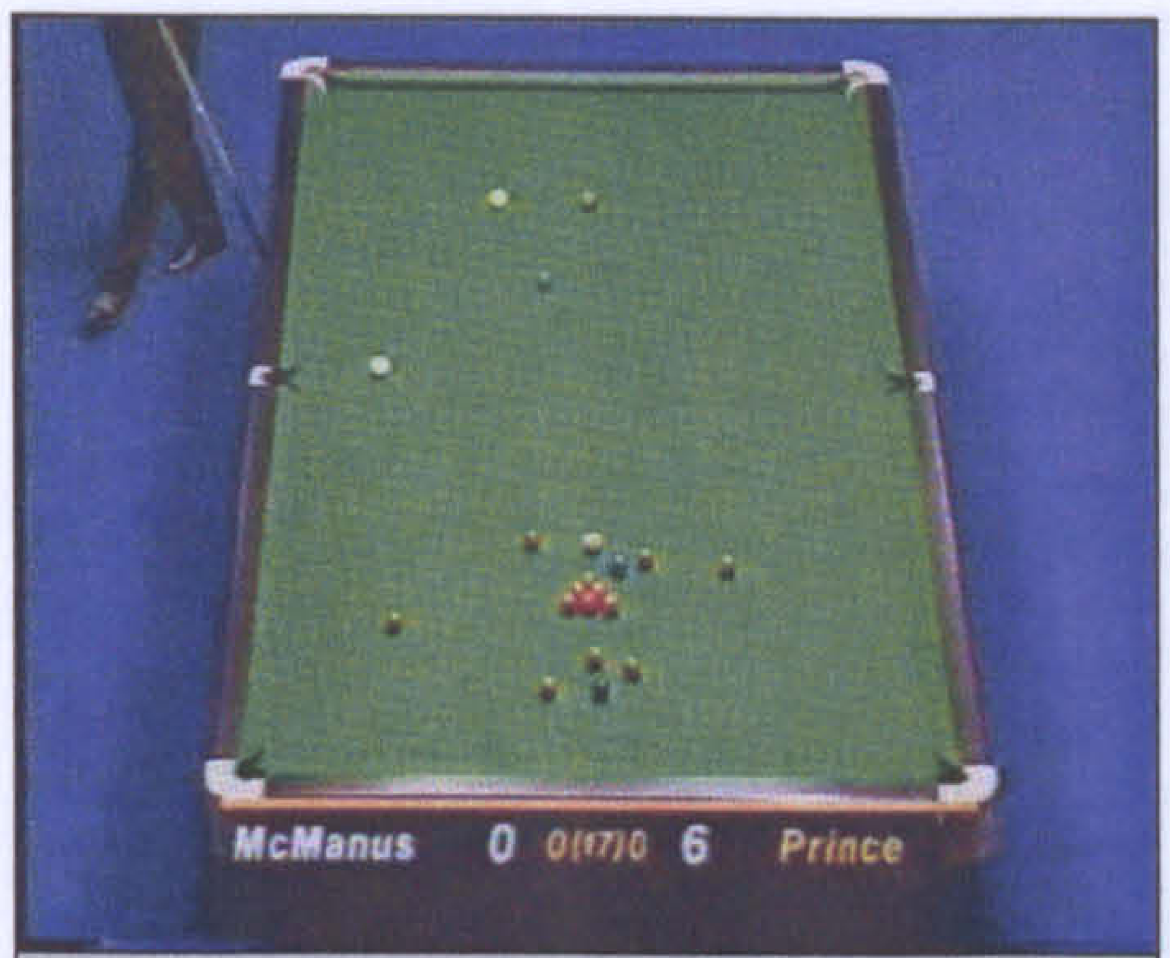

Rugby Clip


Rugby Clip


Rugby Clip



Snooker Clip



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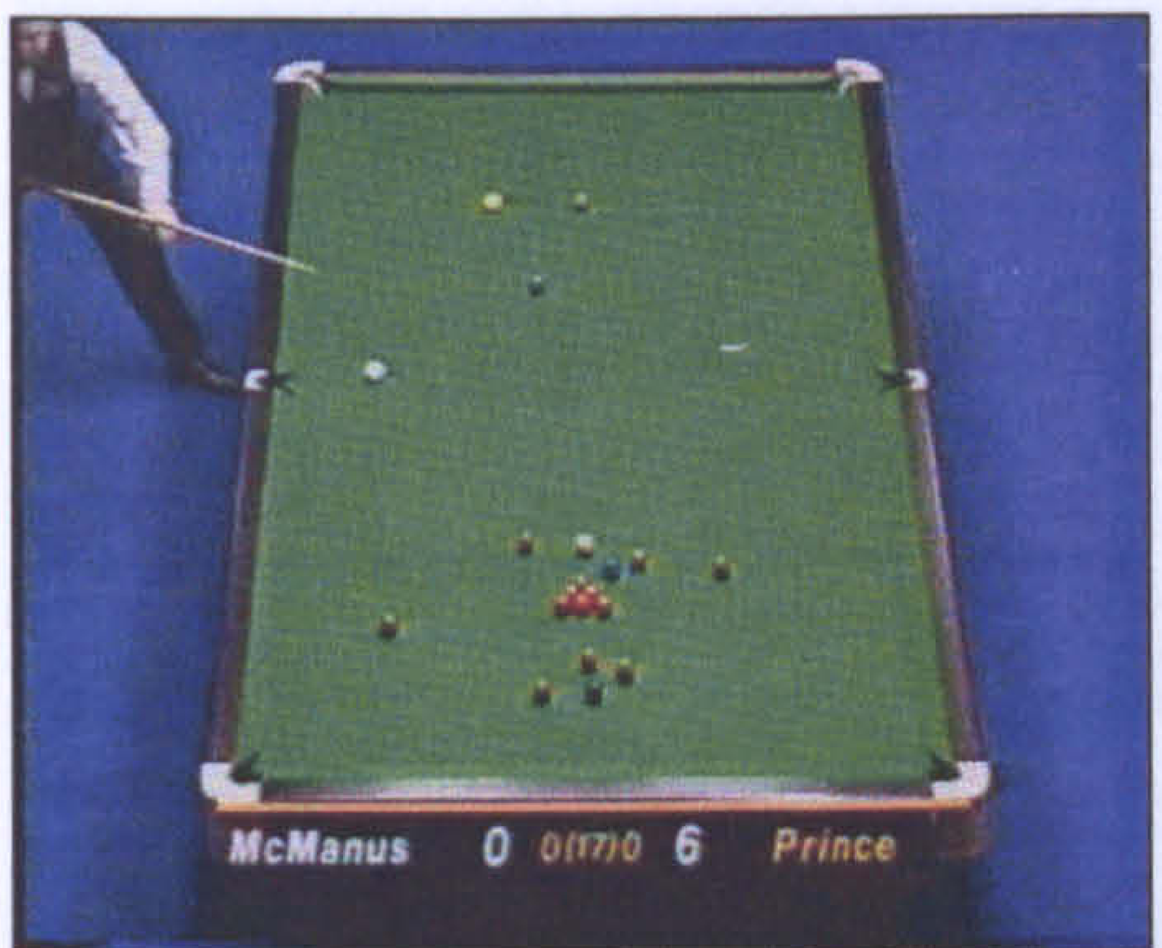

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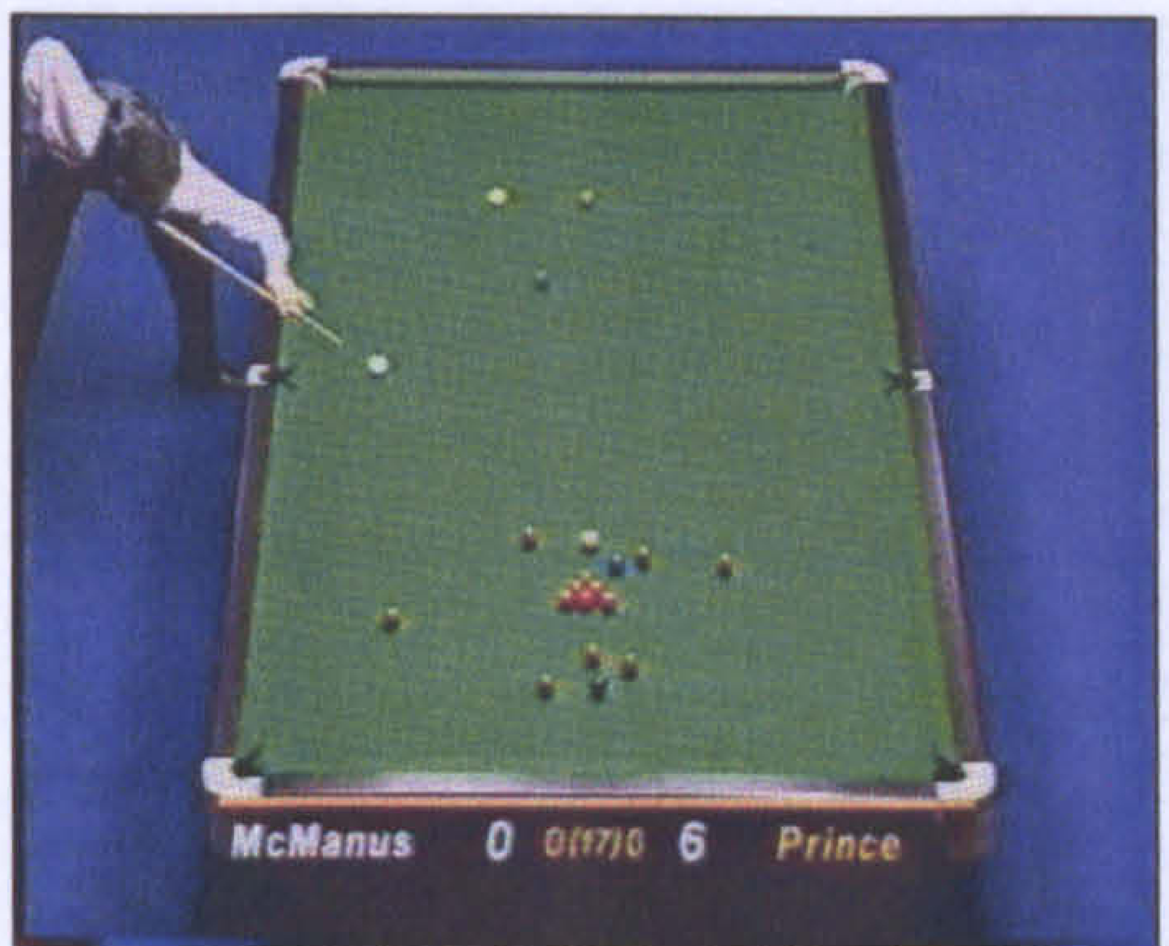

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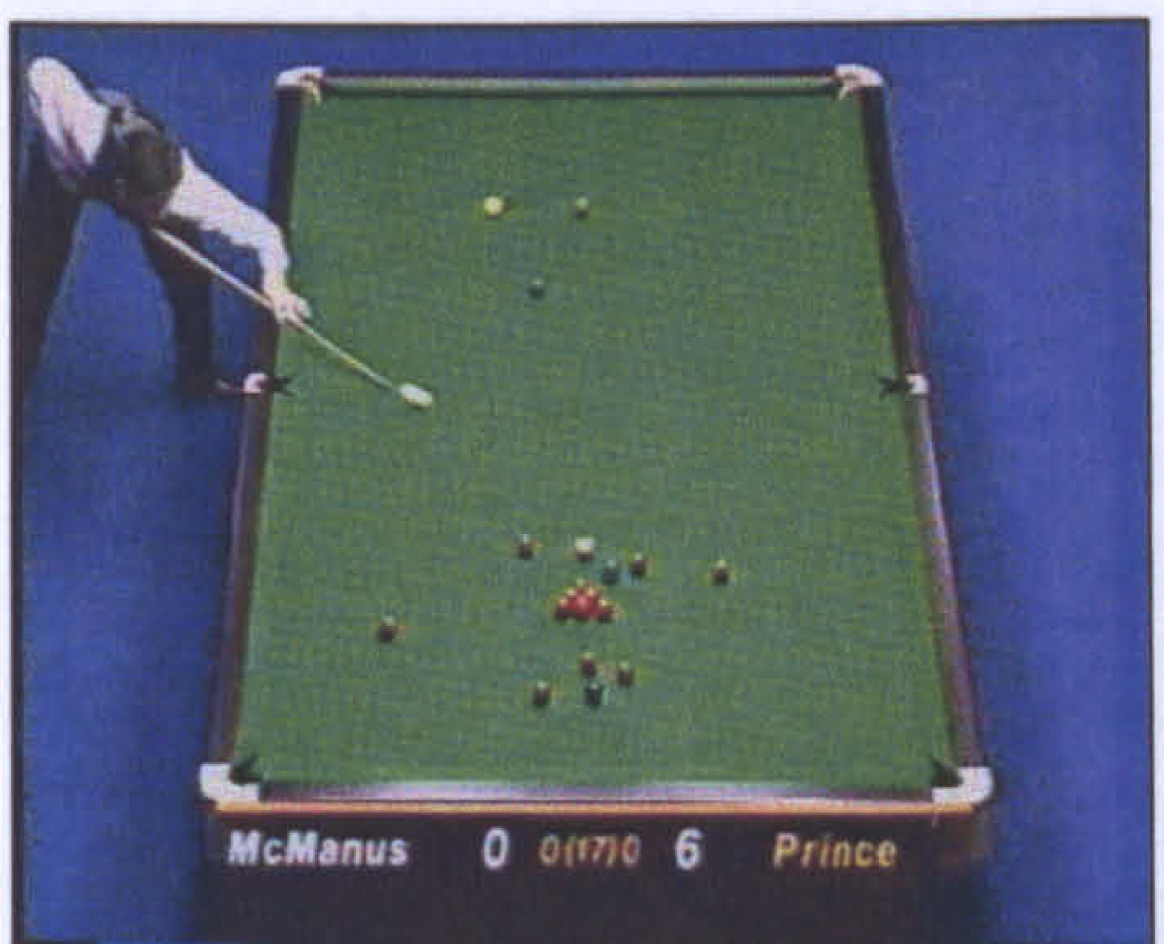

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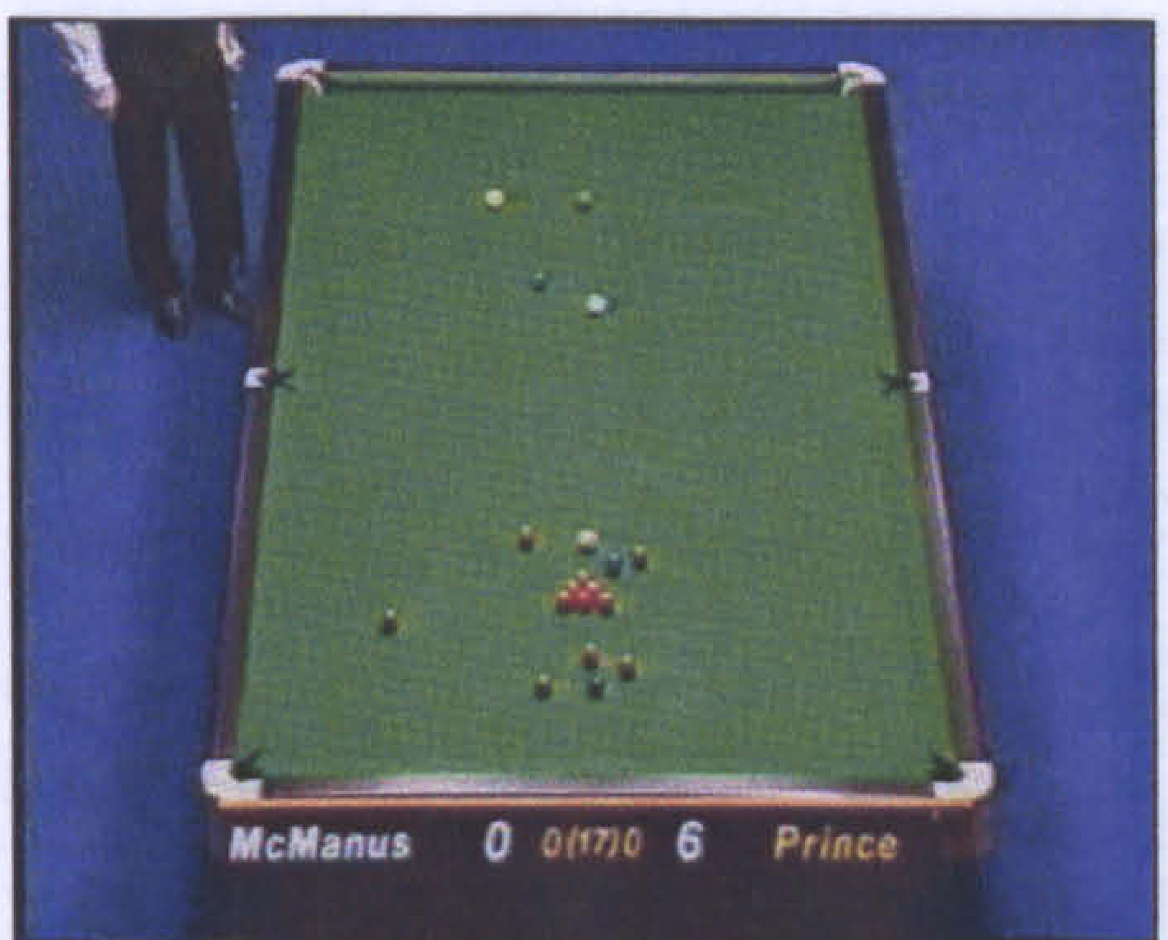

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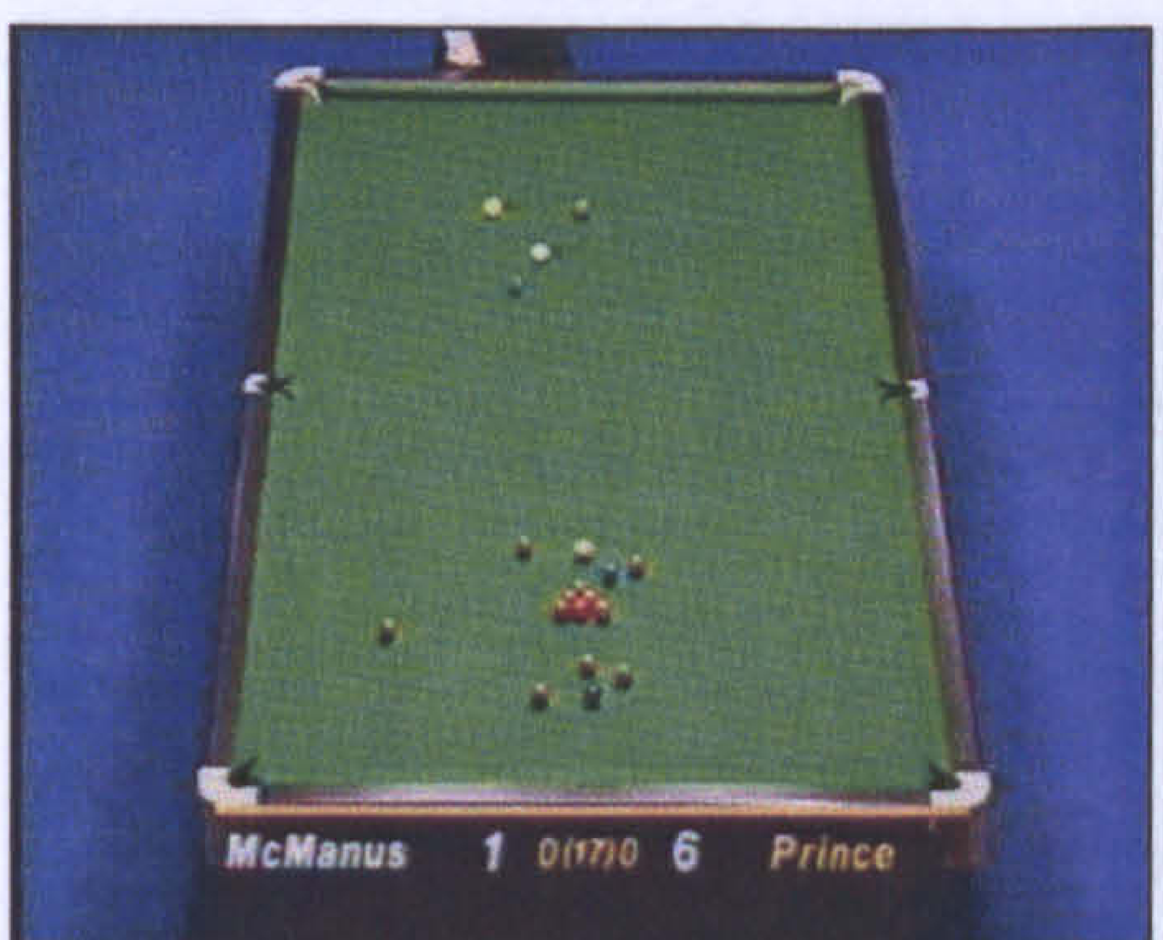

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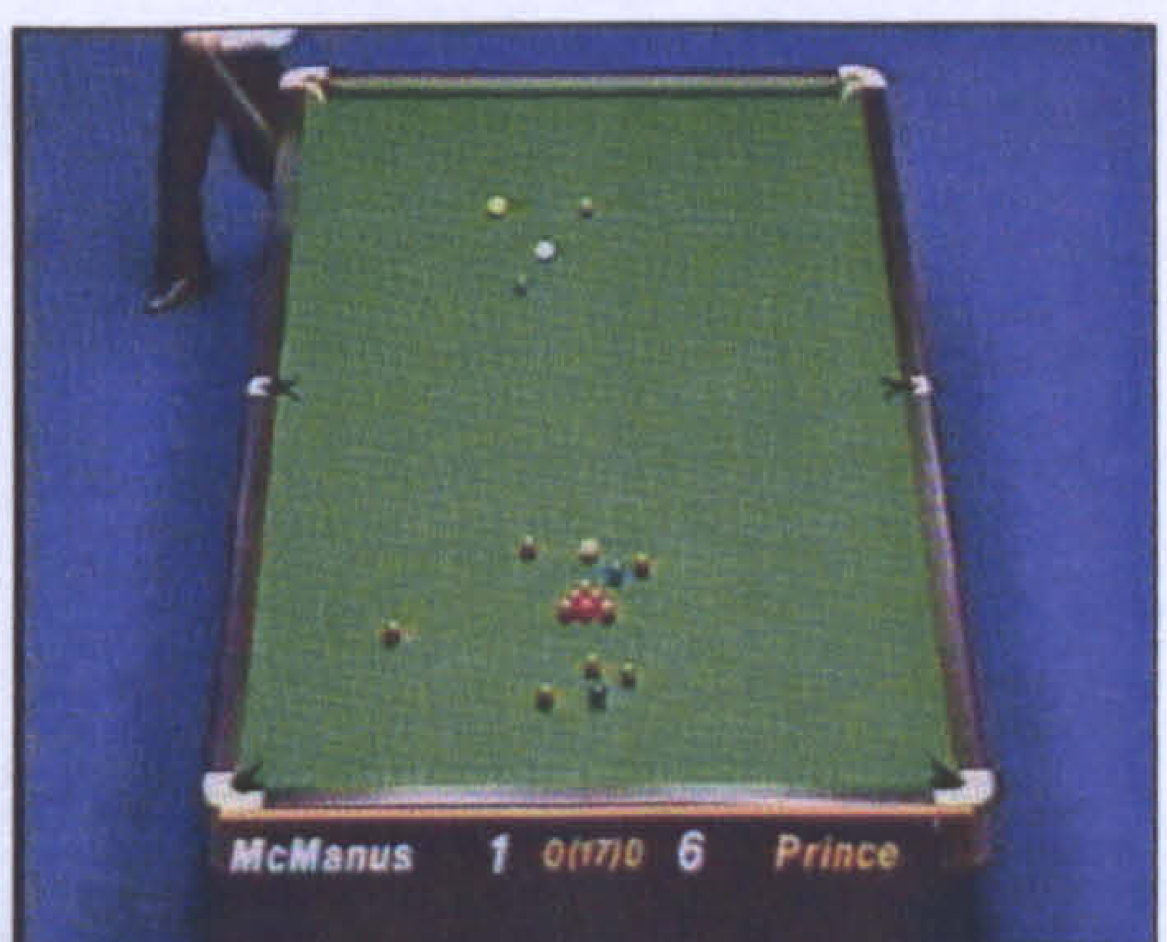


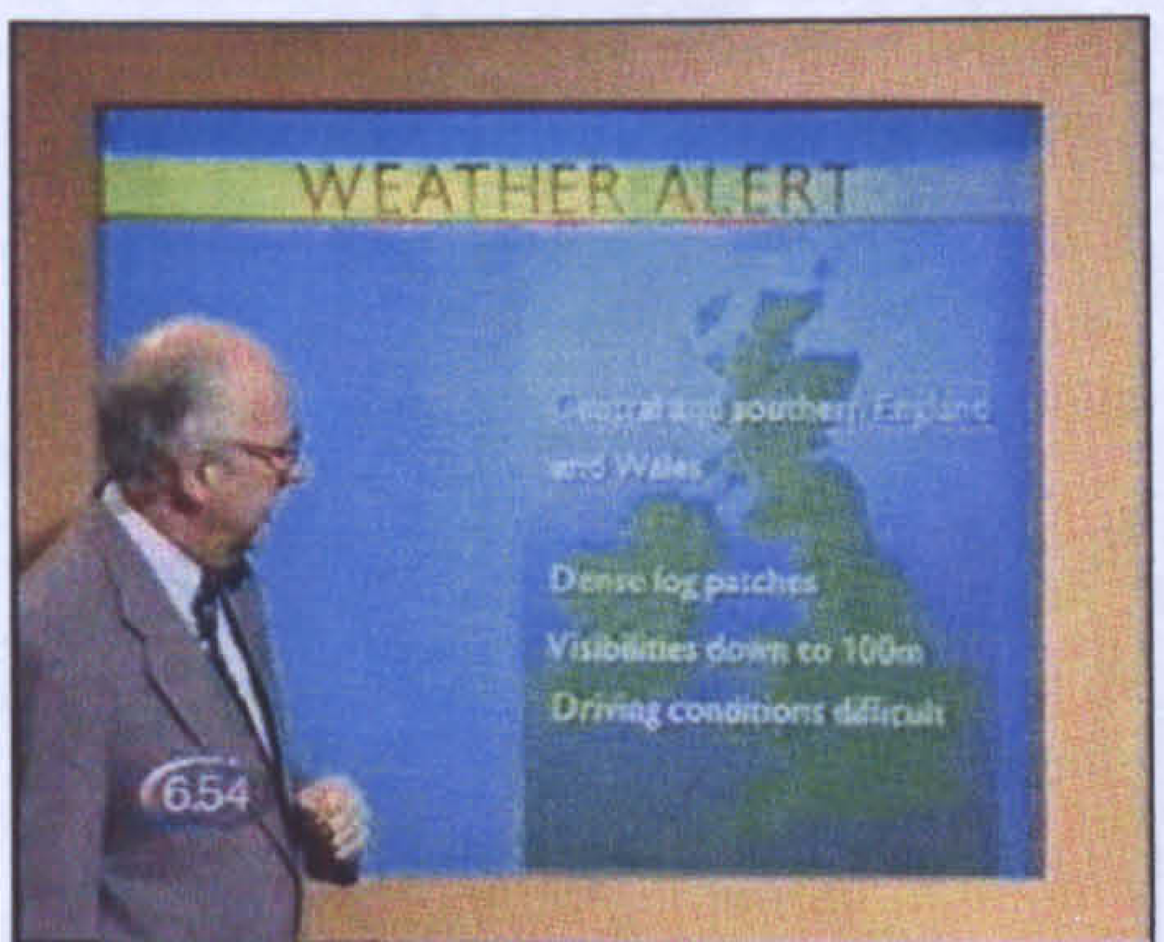
Snooker Clip

Weather Forecast

Weather Forecast

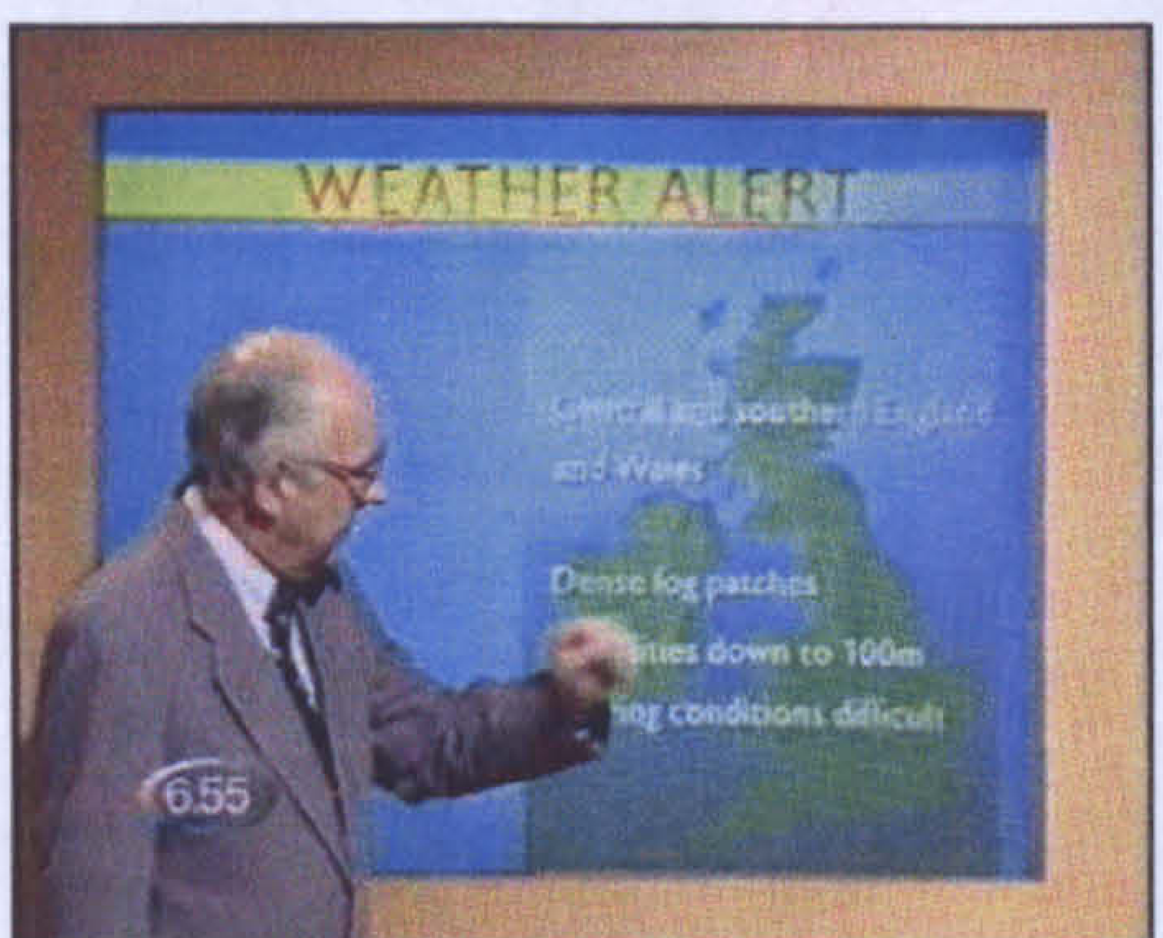
Weather Forecast

Weather Forecast



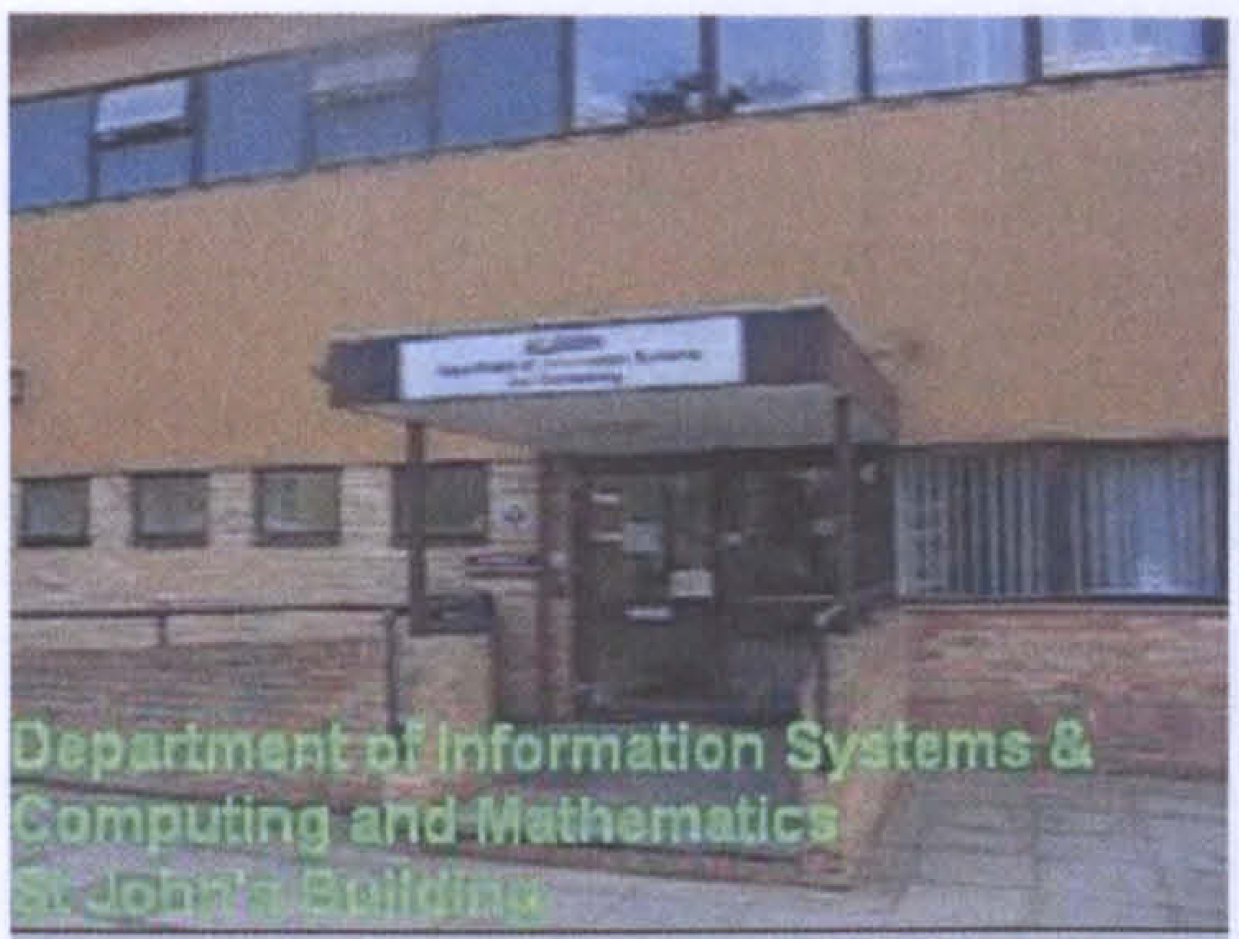
Weather Forecast

Weather Forecast

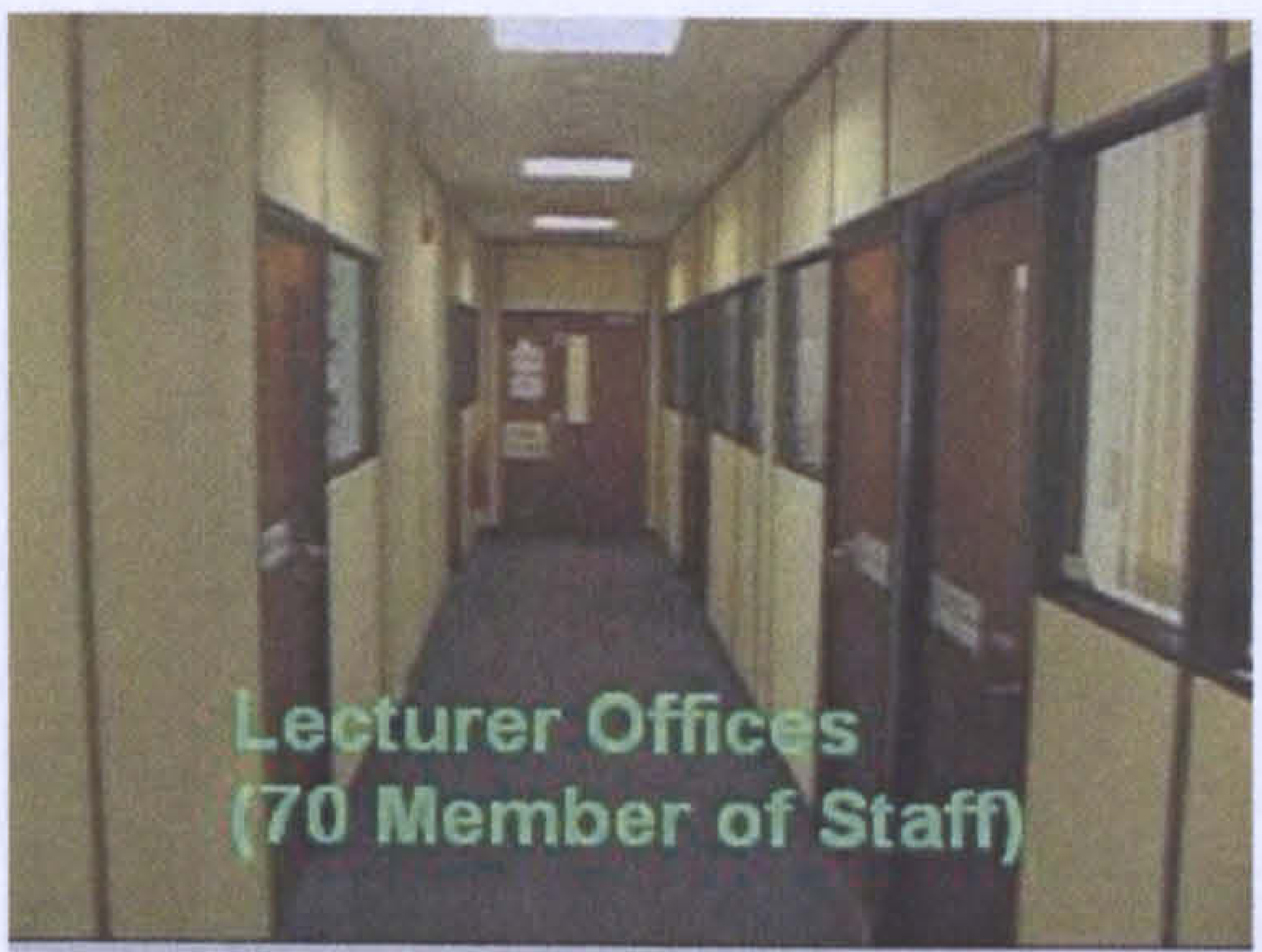


Weather Forecast

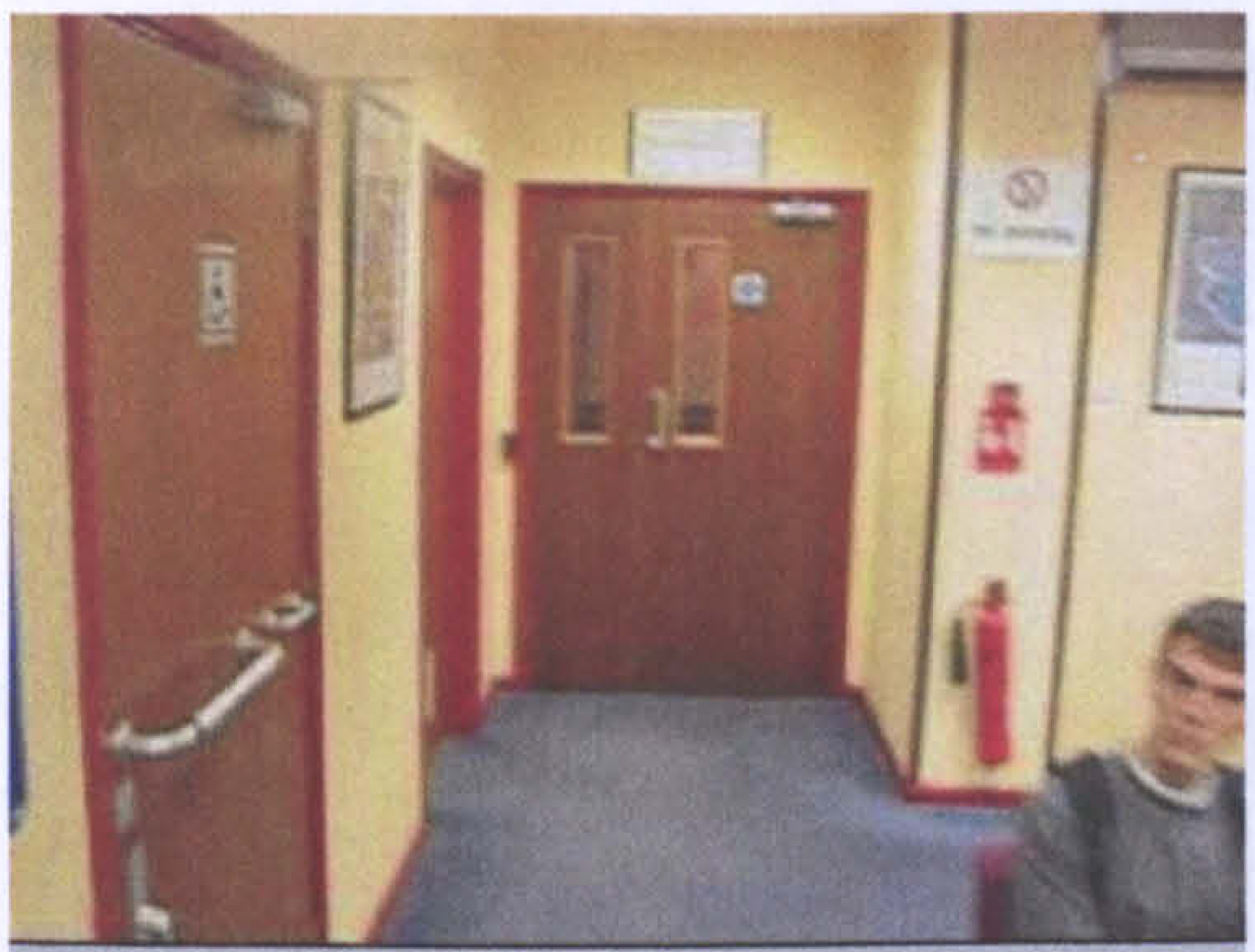
Weather Forecast



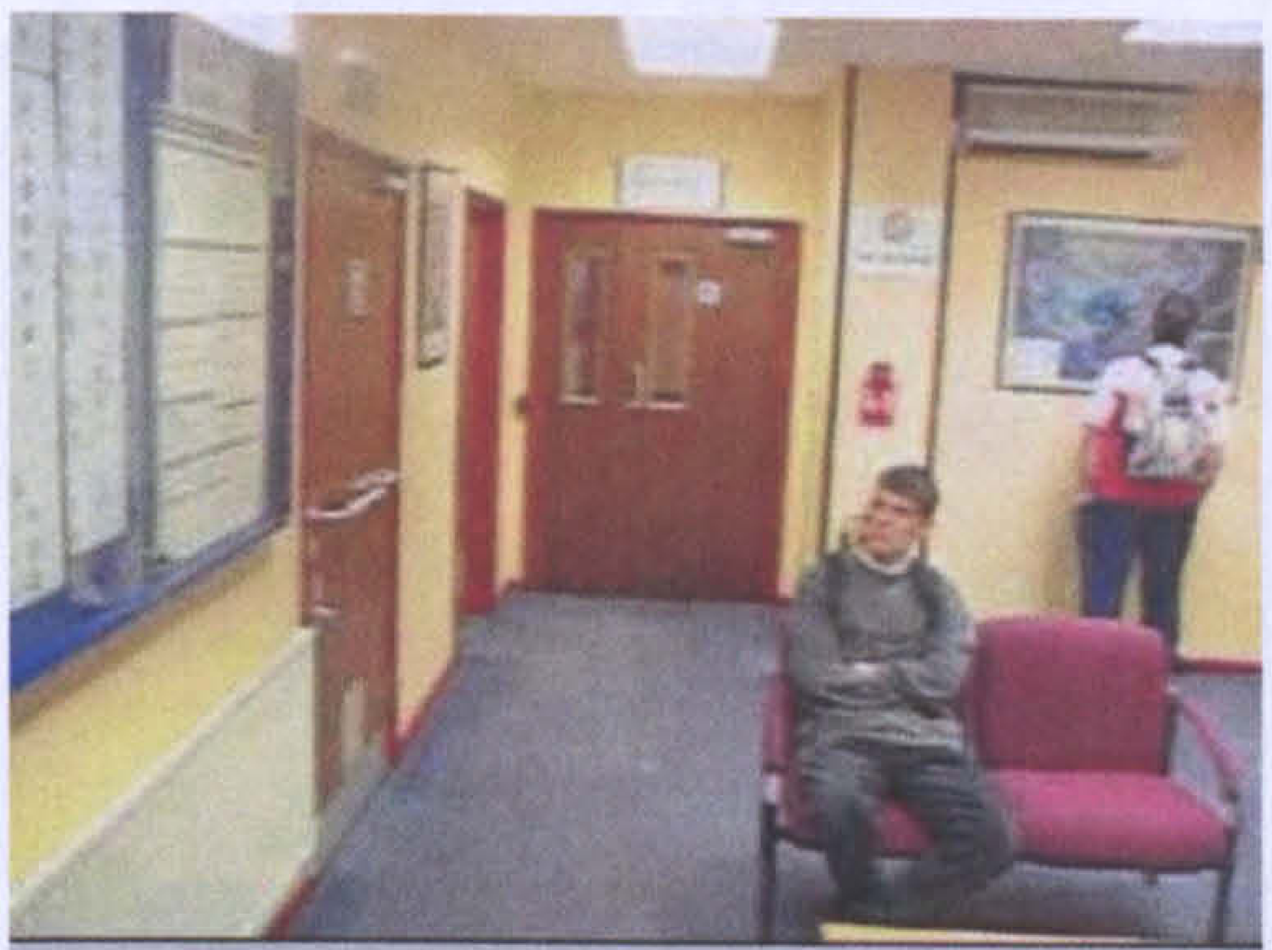
St John's Building Movie



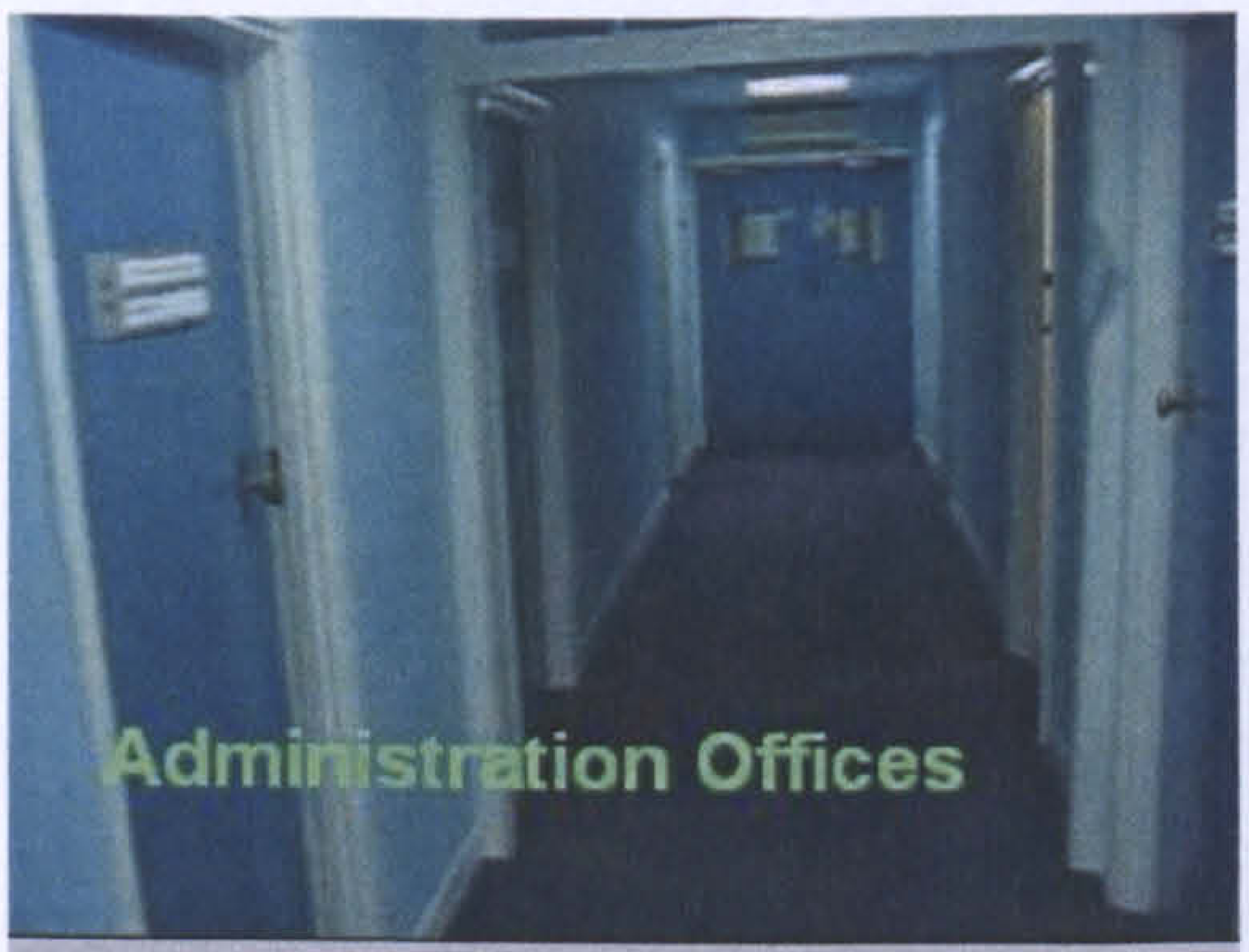
St John's Building Movie



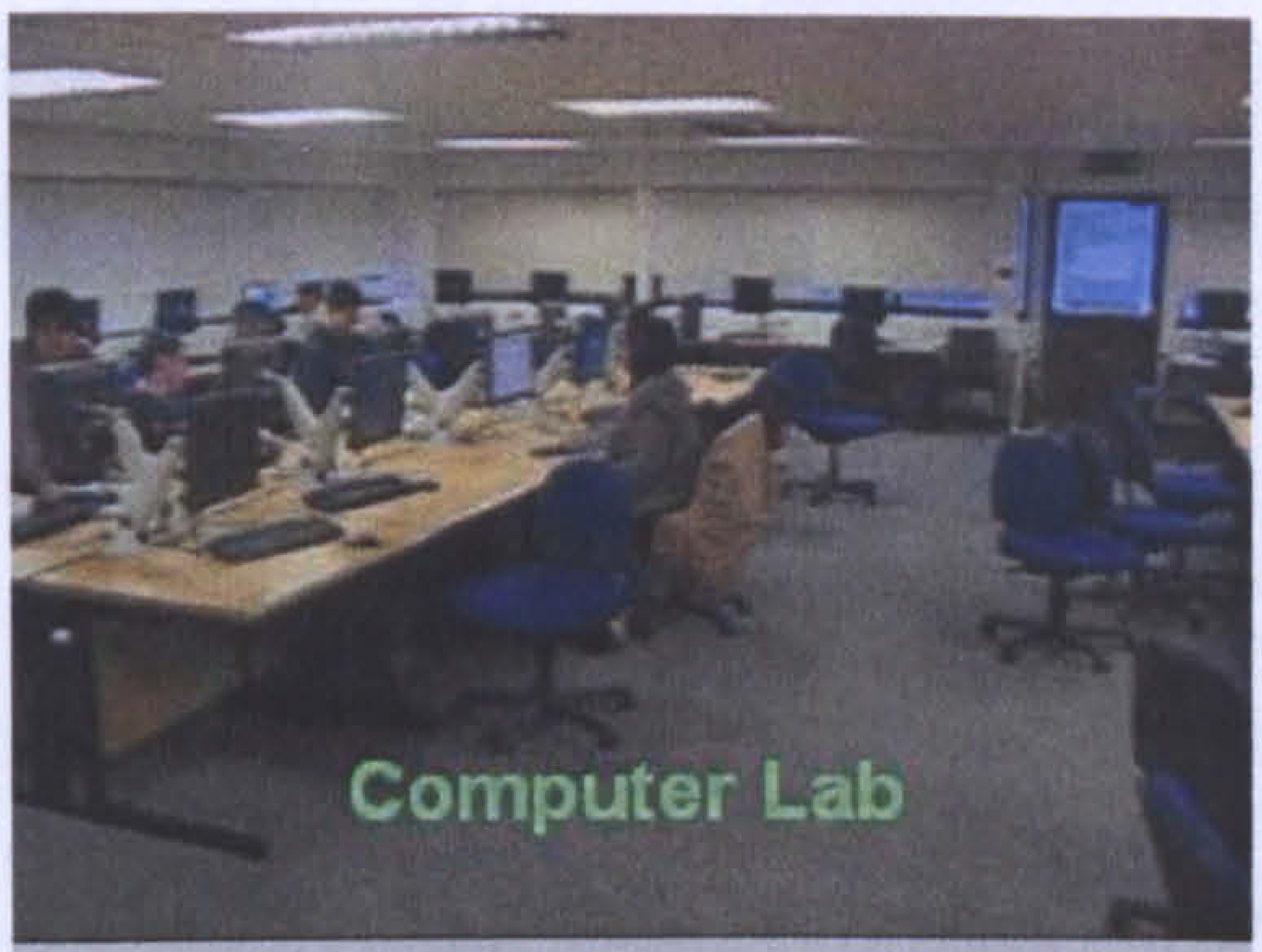
St John's Building Movie



St John's Building Movie



St John's Building Movie

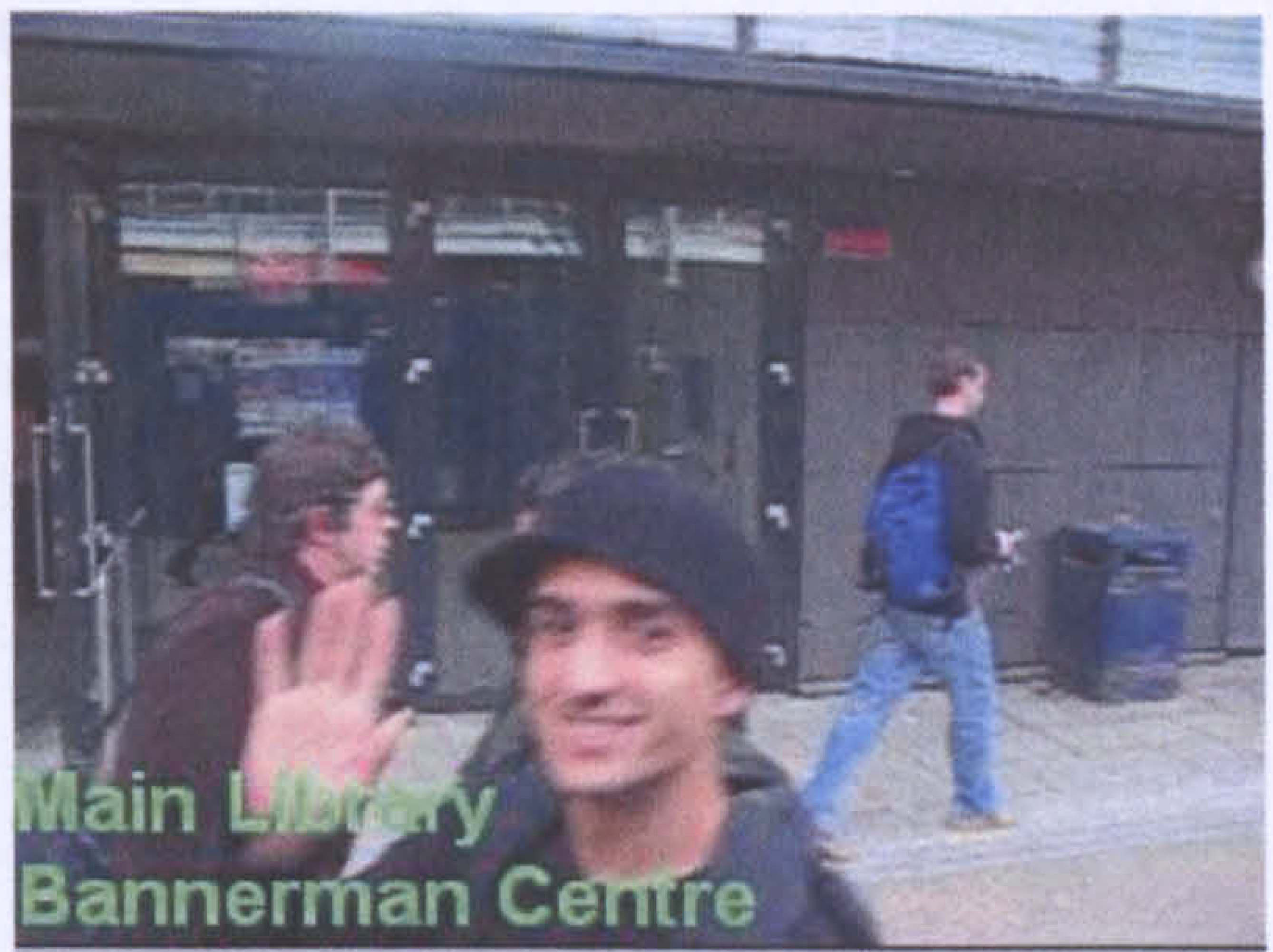


St John's Building Movie

St John's Building Movie

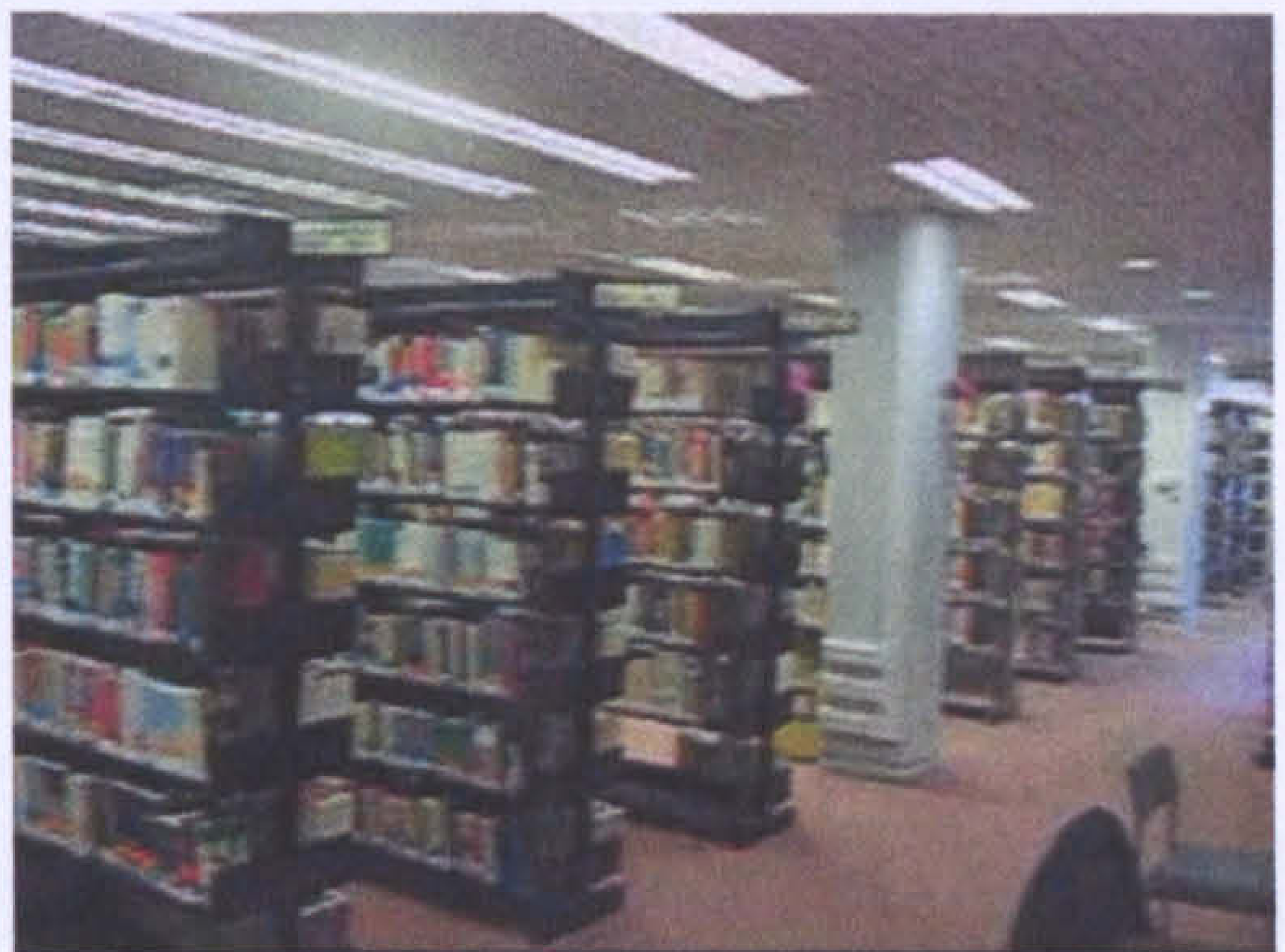
St John's Building Movie

Bannerman Centre Movie



Bannerman Centre Movie

Bannerman Centre Movie

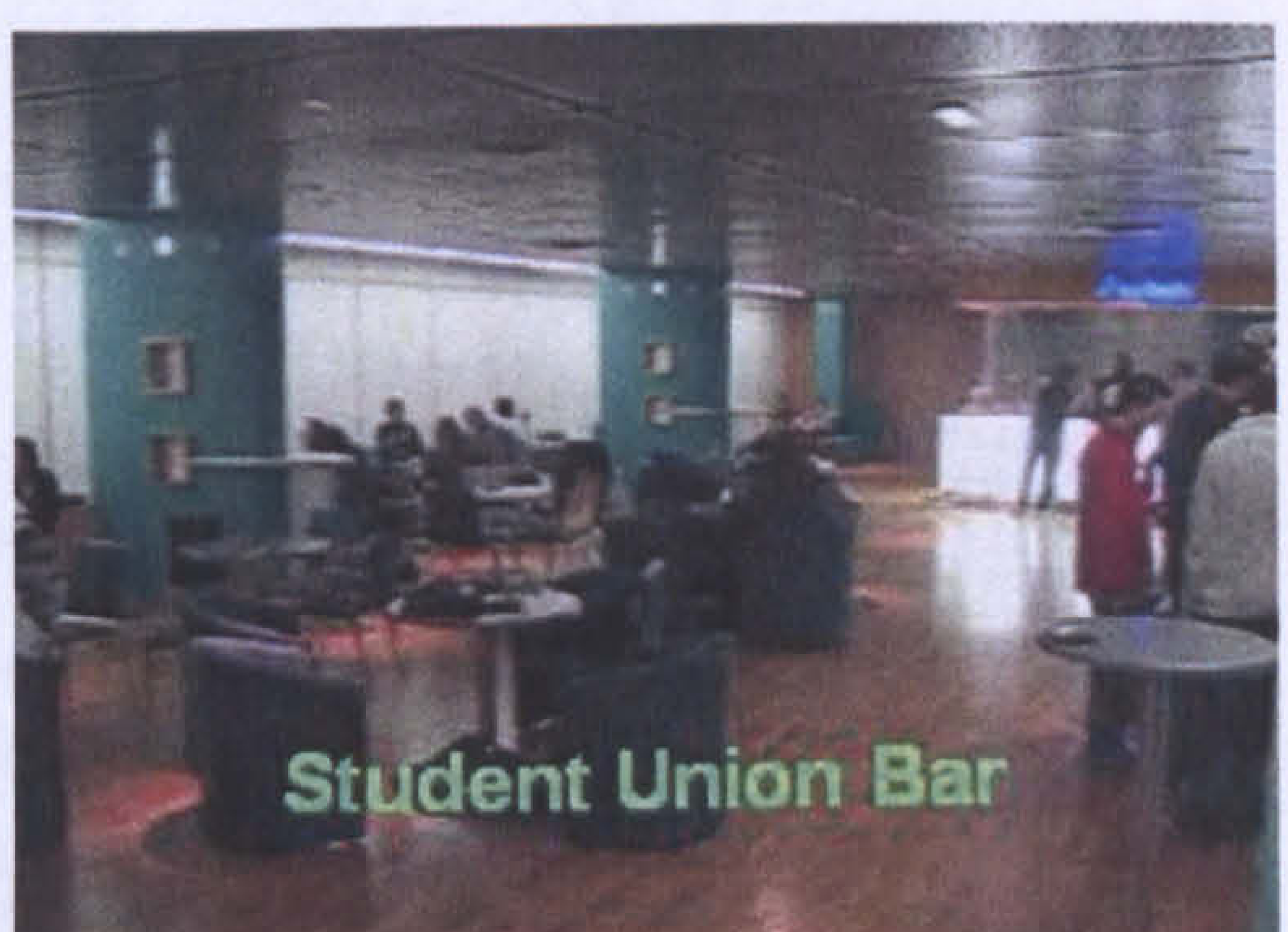


Bannerman Centre Movie

Bannerman Centre Movie

Bannerman Centre Movie

Bannerman Centre Movie



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