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Using Immersive Video to Evaluate

Future Traveller Information Systems

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Abstract

We present an immersive video system that has been developed for the purpose of evaluating future traveller information system (F-TIS), in particular, F-TIS scenarios that rely on a pervasive computing infrastructure. Immersive video uses multiple video streams captured from a first person perspective at key locations in a scenario. By dynamically reconstructing a user's visual and aural experiences, the immersive video system creates a lab-based framework that captures a number of the contextual factors of real-world mobile information system use. Graphical user interfaces, displayed on a Wearable Display (WD) and a Personal Digital Assistant (PDA), are used in the evaluation. We present both the technical basis of the immersive video system and its application to the study of user perceptions and reactions to pervasive information services.

1 Background and previous work

The provision of traveller information, in the form of available travel options and other salient data, is generally acknowledged as having the potential to change traveller behaviour and mode choices. Such changes are expected to benefit the whole transport system, if the information provided is timely, reliable, and appropriate to travellers' needs [1-13]. Currently, traveller information, ranging from paper-based timetables and road atlases, to web-based dynamic journey planners and in-vehicle navigation systems, is widely available. However, integrated multimodal personal navigation and information systems, which provide bespoke and tailored travel assistance anywhere and at any time, remain an aspiration. An underlying information infrastructure is yet to be established that will allow real-time integration across all transport services and options.

Advances in information, computing and communication technology are ushering in the era of pervasive computing where computers will in essence disappear into the fabric of everyday life [14-16]. As a result, everything and everyone will be connected through wireless networks. The whole environments will be sensitive, adaptive and responsive to individual capabilities, needs, habits, gestures and even emotions [17-19]. Accordingly, pervasive computing have the potential to change transport infrastructure radically, allowing real-time monitoring of transport networks and services, and providing travellers with timely, personalised and accurate information services [20]. The user will no longer need to search disparate sources of information for the most appropriate travel option, but instead will receive context-aware and personalised travel information and support.

This vision of fully connected and pervasive information systems is a component of the future transport system envisaged by the recently published report by the Foresight Directorate of the UK governments' Office of Science and Technology, Intelligent Infrastructure Systems study which explored in detail the implications of science and technology over the next 50 years [21, 22]. To understand the potential impact of such future traveller information systems (F-TIS), we developed a methodology to investigate a number of key issues that need to be addressed and researched in an effort to better understand the effectiveness of future information delivery. These include: user perception, user acceptance and the impact on the use of public transport as an alternative to the car. Such issues are core elements of an ongoing debate between policy makers, system developers and transport service providers in relation to the benefits of investing in future traveller information services [23].

2 Evaluation through user participation

Evaluations of information systems can be conducted for a number of purposes: to explore the usability of a system and its interface [24-29], or as in this case, to assess the potential impact of a system on user attitudes and reactions. Rossi et al. [30] describe an effective evaluation as requiring an accurate description of the system performance and user participation as a means of assessing the potential value of the system. Though tests can be conducted with respect to defined specifications of system behaviour, evaluation through user participation permits the use of the system to be observed and user perceptions explored based on their actual experience of and interaction with the system in context. Here, we use the term *user experience* to capture the specific notions of knowledge and satisfaction gained through the use of traveller information systems (TIS). The evaluation of our notion of user experience requires the consideration of a number of factors: current use of TIS; current mode choices with respect to journey types; perceptions of F-TIS; likely use of F-TIS; and potential impact of F-TIS on the use of public transport.

2.1 A review of evaluation methodologies

Evaluation can be performed either in the relatively controlled environment of a development lab or in the field [31].

2.1.1 Field studies

In a field study, a minimally functioning prototype of the system needs to be deployed in the target environment (or one very similar) [7, 24, 32-37]. The principal advantage of field studies is that they allow the use of the real transport networks and direct observation of users within genuine travel scenarios. Hence, field studies have the advantage of *ecological validity*, both in the fact that users are less conscious of their participation in the study (and the impact this has on their behaviour) and in the spatial and temporal constraints to which they are subject. The term *ecological validity* indicates the degree of the closeness of the test environment to the actual environment in which the system is used. Hence field studies emphasise the importance of a *high-fidelity user experience* [12, 31] and admit the study of actual information needs, reactions to information provided, and genuine journey choices.

The term *high-fidelity of user experience* refers to a realistic representation of the factors that impact on user experience.

However, a consequence of *ecological validity* is that rigorous field studies are problematic to conduct. From a methodological perspective, due to the lack of control over certain elements of the study, significant effort is required to distinguish the root causes of journey-making choices. In addition to characteristics of the subjects and the journeys themselves, field studies incorporate many additional environmental and contextual factors (e.g. unexpected changes in weather condition, or incidental events such as receiving a phone call). Furthermore, the physical design of the information provided and a subject's past experience of travel information (and travel information systems) also influences the decision making process. Although each of these factors could influence traveller behaviour, resource constraints mean that experimenters must use their experience in judging which need to be considered in detail [12, 31]. Previously, even detailed studies of TIS took little account of environmental and contextual factors in the data collection and analysis [34].

In addition to direct observation, field studies usually employ travel diaries in which participants self-report their travel choices and TIS usage. By comparing behaviour before and after the use, the impact of a proposed system can be isolated. However, the use of travel diaries can give rise to factors that interfere with the ecological validity of a field study, in that participants feel somewhat burdened by the reporting requirements which in turn lead to depressed TIS use as participants attempt to reduce the lengths of entries in their diaries [32].

In general, studies conducted in the field enable high-fidelity user experience and reliable and valid data collection, but tend to be time consuming, complex, costly and labour intensive. Therefore, alternative methodologies for conducting studies under controlled lab-based evaluation have been developed.

2.1.2 Lab-based studies

In lab-based studies, participants are taken out of their normal living environment to take part in controlled tests, often in a lab or simply a quiet room [31]. By standardising and controlling the environment, lab-based studies are deliberately designed to ensure that subjects are exposed to exactly the same experimental conditions [38]. In some situations, a lab-based study can be the only option. For example, if real-world implementations of new generation TIS technologies are impossible, or available resources are insufficient, this would limit the evaluation to be conducted in lab environments.

In lab-based studies, the performance of systems is normally demonstrated by either paper-based scenarios or computer-based simulations. These methods provide a low-cost but highly portable means by which to test specific issues of behavioural concerns that are difficult to capture with conventional survey techniques, or that cannot be adequately observed in the real world [39]. However, paper-based scenarios provide little dynamic context within which the system is intended to be used and thus there are few opportunities for subjects to interact with the system. Therefore, such methods are useful for exploring conceptual designs or to explore the impact of pre-trip information on travel choices [8], but they are not suitable for studies in which dynamic context and user interactions are important, such as when investigating the impact of en route, timely and context-based information delivery on travel choices. Computer-based simulations have been extensively developed to provide viable alternatives to create the intended contexts and demonstrate improved system performance in laboratories during the past decade, which provides a highly portable and easily reproduced platform to explore user experience [31, 39]. A physical visit to the target environment is no longer necessary for participants. However, the main disadvantage of such methods is that they require significant effort to generate content and high-level programming support (for the simulation to be efficient and robust). When compared with field studies, lab-based studies are generally easier to control, quicker and less expensive to establish. However, they are artificial and are perceived as such by subjects [40]. This may influence the way users behave. On balance, there is always a need to weigh the costs and benefits of a field study and a lab-based study.

The challenge of this research is to investigate user behaviour and perceptions to a technology that does not yet exist on the street. Conducting a field study with a fully-implemented or even just a partially implemented system would be extremely difficult, high-priced and time-consuming. Therefore, a home-built future environment to evaluate F-TIS has been developed and termed ‘immersive video’.

2.2 Methodology – Immersive Video

We have developed a system, namely *immersive video*, to facilitate all aspects of the evaluation required for this research. Immersive video system consists of three components: (1) an immersive display to recreate the sense of being in the target environment; (2) a demonstration of the F-TIS services; and (3) a wizard system.

2.2.1 Immersive display

Using an immersive display to provider viewers a sense of being at the site has been proposed on a number of occasions as an alternative form of presentations to traditional paper-based scenarios and computer-based simulations [41-44]. In our study, a scenario was firstly selected to be characteristic of the intended use of F-TIS; this included 16 decision-making points (key locations) along the route of a real public transport journey. At each of the key locations, three video cameras were lined up on a metal bracket to capture the actual scene and surrounding sounds from a first-person perspective (see Figure 1).

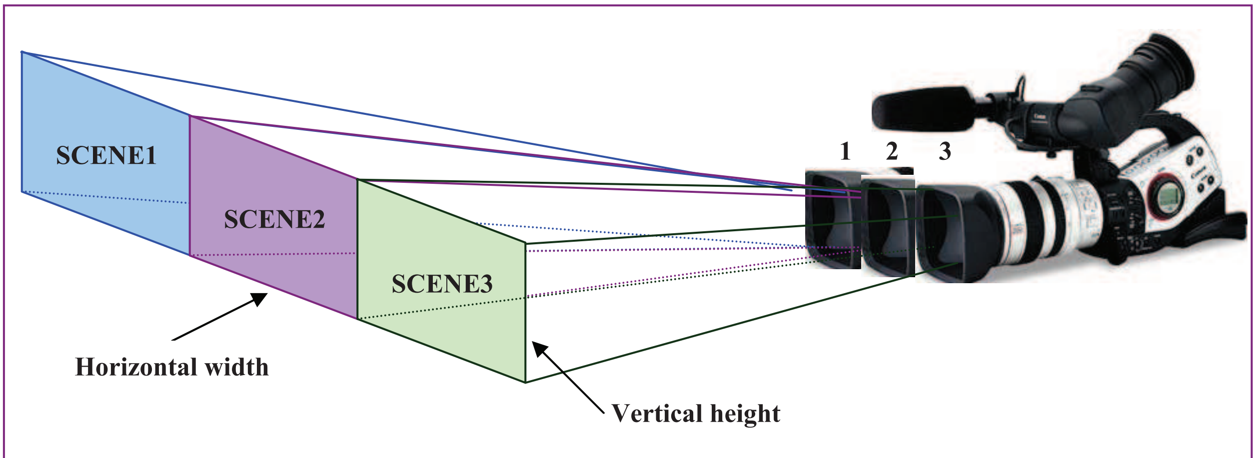

Figure 1: Locating cameras

Then we replayed the 16 sets of footage captured at each key location on the same number of screens set up in the lab. Each set of footage represented a realistic mock-up of one key location and gave the subject a feeling of being surrounded by pedestrians, streets, vehicles, buildings, urban animals and ambient sounds (see Figure 2). This enabled a test subject in the lab to experience the sights and sounds of the key locations he or she was being taken to on his/her virtual journey. Corresponding F-TIS information services were provided to the subject on a personal device at the same time.

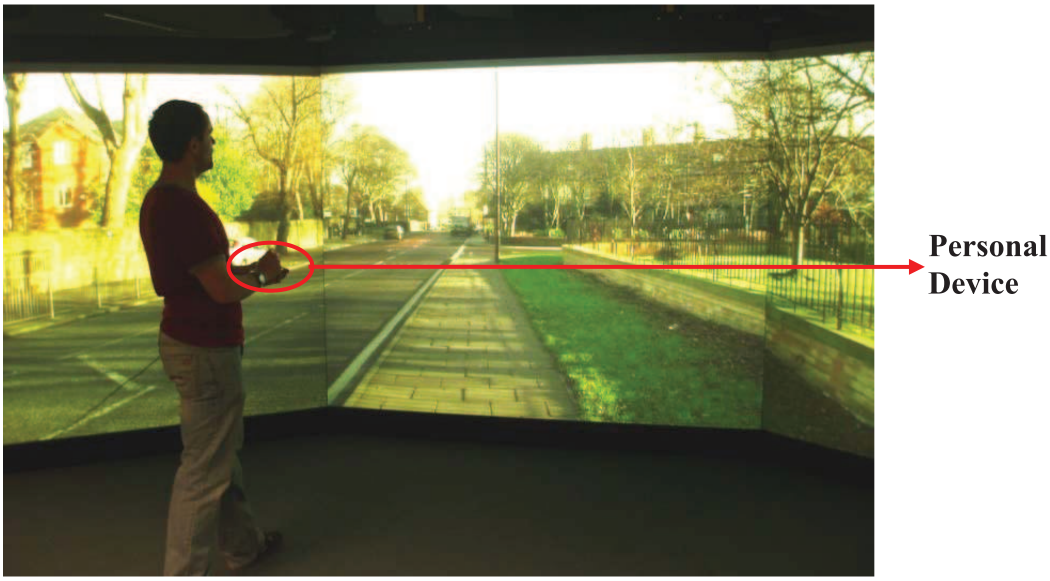

Figure 2: A subject stands in the middle of the cave-based immersive display formed by three screens

2.2.2 Demonstration of F-TIS

The corresponding F-TIS information services were pre-defined in the scenario and detailed for each key location, which included: (A) journey duration; (B) walking time; (C) in-vehicle time; (D) travel costs; (E) context-based travel alerts; (F) personal navigation; (G) image of the route and public transport vehicles; (H) information on comfort; (I) information on convenience; (J) information on events, point of interests; and (K) automatic journey re-planning when change occurs. The changes in the subject's contexts were also pre-understood. Hence, it was decided that, instead of physically implementing sensors to actually respond to the users' requests in the lab, the input and feedback mechanisms were prepared beforehand. Graphical user interface (GUI) using text, pictures, graphics and icons were designed to represent F-TIS types of services at each of the 16 key locations (see Figure 3 – the image on the right hand side is a video shot of the set of footage captured at 13th key location whilst the image on the left hand side is the GUI which represents the corresponding F-TIS information services for 13th key location).

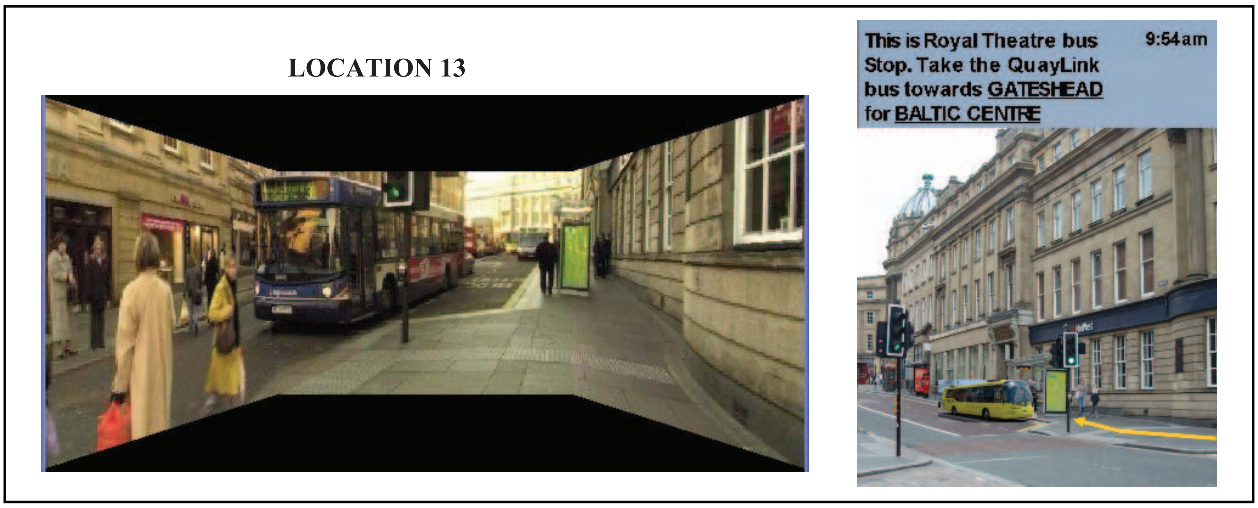

Figure 3: Immersive display and demonstration of F-TIS services at Location 13

Traveller information services and personal travel support for the videoed scenarios were demonstrated to subjects through two personal devices: a Wearable Display (WD) and a Personal Digital Assistant (PDA) based on the availability of equipments (see Figures 4 and 5). A WD was used in the evaluation of travel information in a more ambient manner. The information displayed on the mini-screen of the WD was determined by a subject's location (in the video simulation) alone. By contrast, the PDA is not only an information source, but is a fully interactive tool that allows the user to gain more information by using the onscreen prompts and clickable icons.

Figure 4: The Wearable Display

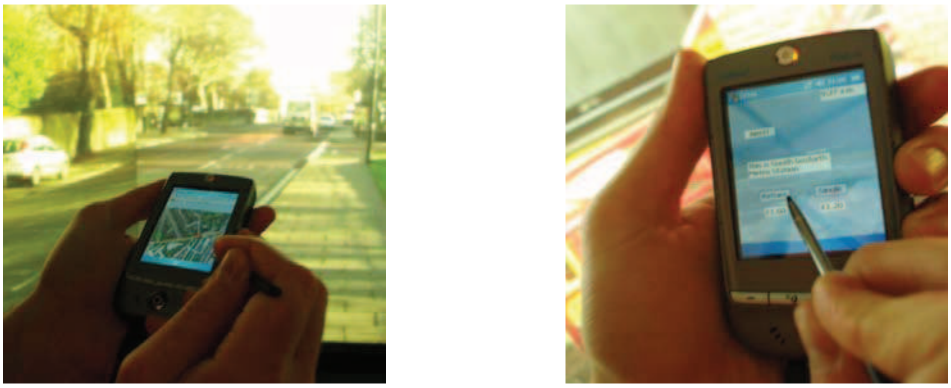

Figure 5: The Personal Digital Assistant

2.2.3 The wizard

Positional information was collected using sensors such as Global Positioning System (GPS) and Bluetooth tags to define each of the key locations, as well as the corresponding traveller information (i.e. the GUIs) at each location. Bluetooth values were used for indoor locations (e.g. home, on-board). GPS values were used for outdoor locations. One eXtensible Markup Language (XML) file was created for each location by specifying its unique sensor value(s) and the reachable locations from this state.

The 16 sets of video footage were arranged into the correct sequence as one undertook the journey in the real world and were fed into a wizard system via XML files. The subject's location was controlled by the experimenter through the use of a wizard control panel (see Figure 6) which changed the video being played according to the notional location of the subject. Traveller information displayed on the PDA at each location was synchronised with the video footage through the use of same sensor values for each location.

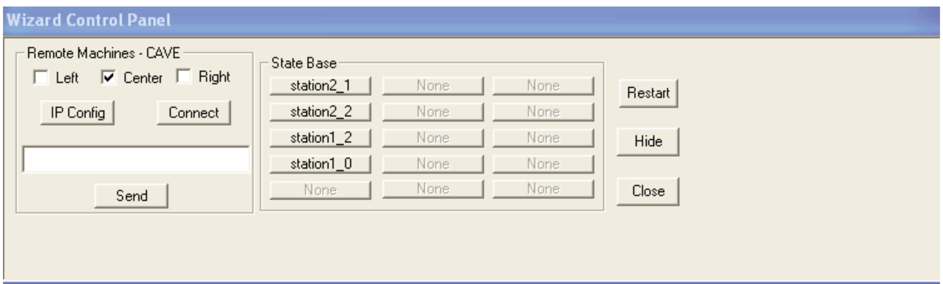

Figure 6: The Wizard Control Panel

3 The study

Twenty-one local people were recruited as participants, eight male and thirteen female. The participants included a representative mixture of ages and economic status (see Figure 7), with some qualifications: (1) there were more female participants than male in the study; (2) female participants were relative younger than male; (3) female participants had higher level of education than male participants.

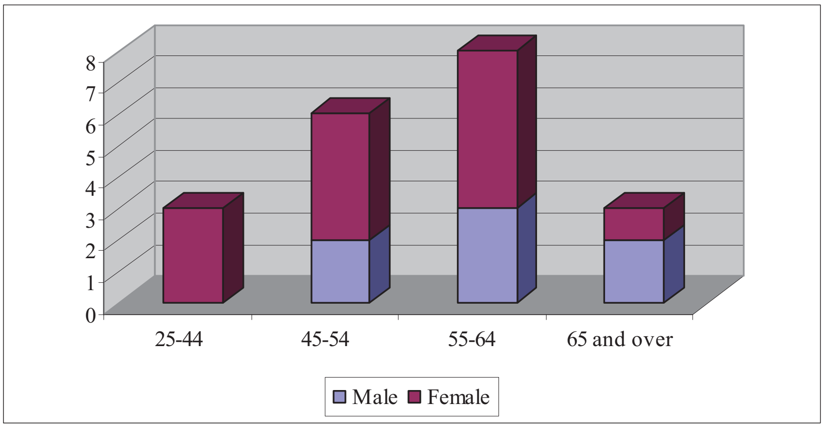

Figure 7: Participants' Age and Gender

3.1 The perceived usefulness of F-TIS types of services

Participants were presented with the list of services provided by F-TIS. In the immersive video trials, participants used most of these services whilst making a virtual journey. A face-to-face interview using a pre-designed questionnaire was carried out. Participants expressed their perceived usefulness of the information services immediately after their use of the demonstrated F-TIS. All participants emphasised that the usefulness of the services mainly depended on their familiarity with the journey. Due to a small sample size, we have to admit that differences among various age groups, levels of education and economic status are unlikely to be recognised. This will be testified in some additional trials in 2008. Gender differences emerged on the attitudes towards F-TIS services. Female participants expressed the need for more assistance in travelling or were more open to the use of additional information than male participants (see Table 1).

Table 1: Mean value of participants' perceived usefulness of the future TIS services

Sex	Value	A	B	C	D	E	F	G	H	I	J	K
M	valid	8	8	8	8	7	8	8	8	8	8	7
	missing	0	0	0	0	1	0	0	0	0	0	1
	Mean	**3.14**	**3.00**	**2.71**	**3.00**	**3.43**	**2.86**	**2.14**	**2.29**	**2.86**	**2.71**	**3.57**
	Std. D	1.07	1.00	1.25	.577	.55	.690	1.21	.951	.378	.756	.516
F	valid	13	13	13	13	12	13	13	13	13	12	12
	mission	0	0	0	0	1	0	0	0	0	1	1
	Mean	**3.23**	**2.92**	**3.31**	**3.38**	**3.31**	**3.00**	**2.62**	**1.77**	**3.00**	**3.15**	**3.85**
	Std. D	.725	.862	.751	.650	.99	1.29	1.12	1.01	1.08	.835	.389

Examples of services that are delivered in response to a user's context include 'automatic re-planning of journeys when changes occurs', 'personal navigation information based upon current location' and 'travel alerts'. Such services require a system to collect detailed contextual information about a user, and as a result there is a debate over the significance of privacy concerns. In fact, a lively discussion with participants arose in relation to the trade-off between privacy and the level of bespoke services available to them. Participant broadly accepted that a system should be aware where they were, where they were heading, what the purpose of the journey was, and what the constraints were in order to receive such timely and unprompted travel assistance.

Participants were positive about the automatic journey re-planning capabilities, which simply requested the user to confirm his/her new destination. Indeed, this service was considered 'useful' or 'very useful' by all participants regardless of their familiarity with the journey. Participants were further questioned about whether they would like to receive information on 'delays and alternative departure times and mode/route choices'. All considered that information on 'delays and alternative departure times' was 'useful' or 'very useful' because they allowed better time management. All but one stated that information on 'delays and alternative mode/route choices' was 'useful' or 'very useful' only if they were travelling by public transport, particularly those who travelled by car most of the time. Most stressed that if they had started a journey with the car, they would prefer to stay with their car, and alternative mode choices would only be considered acceptable in the event of severe delays and the alternative was 'extremely' convenient.

All participants stated that personal navigation was only ‘useful’ or ‘very useful’ for travelling in unfamiliar areas, but not in familiar areas. However, its utility was clearly observed during the participants’ use of the system. For example, one travel option, which the majority of participants had never used in reality, was the QuayLink bus. As a result there was a general uncertainty about where to take the bus upon leaving one of the metro stations (Monument metro station). The route (from the Monument metro station to the Theatre Royal bus stop) and the locations (of the metro station and the bus stop), were clearly marked on the map and were used by all participants.

Participants were surprised by the timely and context-based ‘travel alerts’. All but two female participants considered it a useful service even for travelling in familiar areas, particularly for public transport journeys. Further discussions raised the possibility that timely and targeted travel alerts could allow participants to concentrate on non-travel activities without the anxiety that they sometimes suffer at present (with regard to missing buses and trains). Participants clearly recognised and welcomed these advantages. Information on ‘journey duration’, ‘walking time’, ‘in-vehicle time’, ‘travel costs’ and ‘real-time traffic conditions’ have already been assessed for web-based TIS. However, in this scenario, such information was delivered to a mobile personal device and updated in real-time. Most participants thought such information would be useful when unexpected changes occur; though others questioned its basic utility since once a journey was embarked upon it had to be completed regardless of the delay.

Over half the participants stated that they were not interested in receiving ‘information on comfort’, ‘images of the route/vehicle’ and ‘information on events and points of interest’ when deciding how to travel. They were more concerned about ‘information on convenience’. Once again, this demonstrates that the ease and efficiency of making the journey is a more important factor in travel choice than issues such as comfort, the weather and type of vehicle used.

3.2 The likely use of F-TIS

The participants reported that their use of F-TIS, in general, would depend on two factors: journey familiarity, and journey constraints. They believed that they would be more likely to use the services for undertaking an untypical journey in a familiar area, a familiar journey with time-constraint, or when travelling in an unfamiliar area. However, some information services were regarded as useful regardless of the familiarity and the constraints of the journey.

Three of fourteen participants claimed they would use the system for commuting to work, one of seven for going to school/college, seven of eighteen for personal business trips, seven of twenty for visiting friends and family and eight of twenty for travelling to a leisure or entertainment event.

Of those participants who were in employment, all stated that they would use the system for work-related business trips. One female participant believed that she would use the system for every journey and the use of such a system whilst travelling could become a habit. However, one male participant thought that he would not use the system for journeys at a national scale (due to his personal familiarity with the national transport networks). Another male participant claimed that he would only use the system for work-related business trips. The majority of participants believed that they would use the system for going on holiday and going on a day trip because very likely they would not be familiar with the area. Most participants also believed that they would use the system for travelling to public transport terminals due to the time-constraints or a better time management.

3.3 The potential impacts on the use of public transport

The trials have established a framework for evaluating user perceptions of future traveller information by establishing a synthetic environment in which F-TIS can be tested before full prototype systems are built. From the evaluations, it can be seen that about half of the participants believed that the services provided by the F-TIS, as illustrated in the immersive video environment would be likely to encourage them to make more use of public transport locally. Most of the other half of the participants stated that they did use public transport regularly. However, the majority of participants considered that F-TIS would certainly encourage them to make more use of public transport when travelling in unfamiliar areas. Furthermore, the following benefits of F-TIS were recognised by participants: (1) enhance their confidence in using public transport; (2) make public transport journey easier and less stressful; and (3) always allow them to be aware of the relevant public transport options. Nevertheless, participants pointed out that if they had started their journey with their car, they would prefer to finish the journey with the car, particularly for a chained journey combined with a number of purposes or intermediate stops before arriving at the final destination. They would switch to public transport choices only when information on delays or congestions could be received before they got into the traffic jam and if the alternative options were extremely convenient.

4 Conclusions

The Transport Operation Research Group at Newcastle University is developing a significant number of technologies and scenarios to investigate how and what future ITS technologies could have a significant impact on our next generation transport systems and networks. In developing a new approach to prototyping such systems for pervasive information delivery in a way that the user is immersed in the journey whilst in the lab – a new potentially powerful tool for rapidly texting new ICT technologies and their transport applications has been presented here. Our experience has shown that many useful insights can be gained both from user feedback about future traveller information services and the immersive video system. In the reported trial, twenty-one participants were taken through the immersive video experience of a public transport journey using a hypothetical F-TIS scenario. Significant advantages were apparent in the manner that the immersive video contextualised the tasks (as confirmed in reports by the participants) and the design of graphical user interfaces sufficiently demonstrated the performance of F-TIS services (without the need to deploy a sensor infrastructure in the lab). The use of the information system to support personal travel has been achieved. Subjects reported their opinions, attitudes and likely use of F-TIS based on their own experience, whist the experimenters directly observed user reactions towards the system. Our experience has shown that immersive video has the potential to become a promising evaluation and design tool for future systems.

The results indicate that, in general, F-TIS was perceived as a useful system and the demand for F-TIS types of services could be high – willingness to pay will be tested in a future round of evaluation. Some of the functionalities of F-TIS were appealing to a majority of participants. Moreover, it has been recognised that F-TIS has the potential to successfully sell public transport services since it would enhance the confidence in using public transport, ease travelling with public transport and enable people to be aware of the relevant and viable public transport options all the time. The results also suggest that F-TIS need to cooperate with traffic management policies and local transport plans, such as road use charge, parking restriction, public transport priority, e-ticketing via smart card, or better facilities on public transport vehicles and terminals to be more effective. Obviously one limitation of this research is that we provided the triallists with our vision of what pervasive future traveller information could incorporate. As we understand the power and potential for embedded, pervasive and personal computing devices, the vision of what a F-ITS scenario could be will alter, however the framework for the evaluation of this using rapid prototyping and immersive video ensures we have a tool to evaluate these diverging futures.

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References:

1. Chorus, C.G., et al., *The value of travel information: Decision strategy-specific conceptualizations and numerical examples.* Transportation Research Part B: Methodological, 2006. **40**(6): p. 504-519.
2. Eastman, R., *The Strategic Framework for Network Control on English Trunk Roads*, in *Road Transport Information and Control*. 1998.
3. Guo, W. and P. Blythe, *Future Traveller Information Systems and Travel Behaviour*, in *5th Moving On Conference*. 2006a: Glasgow, UK.
4. Guo, W. and P. Blythe. *Intelligent Personalised Traveller Information: Impacts on the Choice of Travel Mode*. in *12th World Congress on Intelligent Transport Systems and Services*. 2005. San Francisco, USA.
5. Edwards, S., et al., *Tourist Information Delivered through Mobile Devices: Findings from the IMAGE Project.* Information Technology & Tourism, 2006. **8**: p. 31-46.
6. Kanninen, B.J., *Intelligent transportation systems: An economic and environmental policy assessment.* Transportation Research Part A: Policy and Practice, 1996. **30**(1): p. 1-10.
7. Khattak, A.J., J.L. Schofer, and F.S. Koppelman, *Commuters' enroute diversion and return decisions: Analysis and implications for advanced traveler information systems.* Transportation Research Part A: Policy and Practice, 1993. **27**(2): p. 101-111.

8. Kenyon, S. and G. Lyons, *The value of integrated multimodal traveller information and its potential contribution to modal change.* Transportation Research Part F: Traffic Psychology and Behaviour, 2003. **6**(1): p. 1-21.

9. Lyons, G., et al., *Traveller Information Systems Research: a review and recommendation for Transport Direct*, in *Final Report*. 2001, TRG, DTLR.

10. Lyons, G., *Transport Direct Market Research Programme: Findings and Implications from Phase 1*. 2003a, Transport Direct, Department for Transport.

11. Polydoropoulou, A. and M. Ben-Akiva, *The effect of ATIS on travellers' behaviour*, in *Behavioural and network impacts of driver information systems*, R.H.M. Emmerink and P. Nijkamp, Editors. 1999, Aldershot: Ashgate.

12. Schofer, J.L., A. Khattak, and F.S. Koppelman, *Behavioral issues in the design and evaluation of advanced traveler information systems.* Transportation Research Part C: Emerging Technologies, 1993. **1**(2): p. 107-117.

13. Lyons, G., *The role of information in decision-making with regard to travel.* IEE preceedings: Intelligent Transport Systems, 2006. **153**(3): p. 14.

14. ERCIM, *Byond the Horizon: Anticipating Future and Emerging Information Society Technologies.* 2006.

15. Weiser, M., *The computer of the 21st century.* Scientific American, 1991. **265**(3): p. p66-75.

16. Tully, A., *Pervasive tagging, sensors and data collection: a science and technology review for the foresight project on intelligent infrastructure systems.* Intelligent Transport Systems, IEE Proceedings, 2006. **153**(2): p. 129-146.

17. Gates, B. *The Disappearing Computer*. 2002 [cited Nov. 2006]; Available from: http://www.microsoft.com/presspass/ofnote/11-02worldin2003.mspx.

18. Stanford, V., *Pervasive computing goes the last hundred feet with RFID systems.* Pervasive Computing, IEEE, 2003. **2**(2): p. 9-14.

19. Streitz, N. and P. Nixon, *The Disappearing Computing.* Communications of the ACM, 2005. **48**(3): p. 33-35.

20. Miles, J. and J. Walker, *Science Review: The potential application of artificial intelligence in transport*, in *Foresight Intelligent Infrastructure Systems Project*, POST, Editor. 2006, www.foresight.gov.uk.

21. Foresight. *Intelligent Infrastructure Future - Project Overview*. 2006 [cited Nov. 2006]; Available from: http://www.foresight.gov.uk/Previous_Projects/Intelligent_Infrastructure_Systems/Reports_and_Publications/Intelligent_Infrastructure_Futures/Index.html.

22. Blythe, P.T. *Intelligent Infrastructure*. in *Proc. IEE International Conference on Automotive Electronics* 2006a. London.

23. Blythe, P.T. *Intelligent Infrastructure: A Smart Future with Smart Dust and Smart Markets*. in *IFAC Conference on Transport Automation and Control*. 2006. Delft, The Netherlands.

24. Jeffery, D.J., *Driver Route Guidance Systems: State of the Art*, in *Telematics-Transportation and Spatial Development International Symposium*. 1988: Hague.

25. Cheverst, K., K.a. Mitchell, and N. Davies, *Exploring context-aware information push.* Personal and Ubiquitous Computing, 2002. **6**(4): p. 276-281.

26. Kjeldskov, J., et al., *Evaluating the usability of a mobile guide: the influence of location, participants and resources.* Behaviour & Information Technology, 2005. **24**(1): p. 51-65.

27. Lee, Y.S., et al., *Systematic evaluation methodology for cell phone user interfaces.* Interacting with Computers, 2006. **18**(2): p. 304-325.

28. Ojala, T. and A. Lumiaho, *Final Evaluation Report of PROMISE Demonstrations*, in *PROMISE: Personal Mobile Traveller and Traffic Information Service*. 1999, Nokia Mobile Phones.

29. Luff, B., *MR05 - Evaluation of Transport Direct portal prototypes*. 2004.

30. Rossi, P.H., M.W. Lipsey, and H.E. Freeman, *Evaluation: a systematic approach*. 7th ed. 2004: Sage Publications, Inc.

31. Dix, A., et al., *Human-Computer Interaction*. 3rd ed. 2004: Pearson Education Ltd.

32. Peirce, S. and J.E. Lappin, *Acquisition of traveller information and its effects on travel choices: evidence from a Seattle-area travel diary survey*. 2003, Volpe National Transportation.

33. Boyce, D., A. Kirson, and , and J. Schofer. *Design and implementation of ADVANCDE: the Illinois dynamic navigation and route guidance demonstration program*. in *2nd Annual Vehicle Navigation and Information Systems Conference*. 1991. Dearborn, MI: IEEE and SAE.

34. Chatterjee, K. and M. McDonald, *Effectiveness of Using Variable Message Signs to Disseminate Dynamic Traffic Information: Evidence from Field Trails in European Cities.* Transport Reviews, 2004. **24**(5): p. 559-585.

35. Gartner, N.H. and R.A. Reiss, *Congestion control in freeway corridors: The IMIS system*, in *Flow Control of Congested Networks*, A. Odoni, Editor. 1987, Springer-Verlag. p. 113-132.

36. Rillings, J.H. and J.W. Lewis. *TravTek*. in *Proceedings of the 2nd Annual Vehicle Navigations and Information Systems Conference*. 1991. Dearborn, MI: IEEE and SAE.

37. Smith, J.C. and K. Russam, *Some Possible Effects of AUTOGUIDE on traffic in London*, in *IEEE international conference on Vehicle Navigation & Information Systems*. 1989: Toronto, Canada.

38. De Vaus, D., *Research Design in Social Science*. 2001: SAGE Publications.

39. Adler, J.L. and M.G. McNally, *In-laboratory experiments to investigate driver behaviour under advanced traveller information systems.* Transportation Research Part C: Emerging Technologies, 1994. **2**(3): p. 149-164.

40. Eachus, P. *Research Methods for Health Sciences*. 2000 [cited Nov. 2006]; Available from: http://www.chssc.salford.ac.uk/healthSci/rem99/resmeth/field.htm.

41. Guo, W., et al. *Future Traveller Information Systems: impacts on modal shift*. in *ASK-IT Conference*. 2006c. Nice, France.

42. Guo, W. and P. Blythe. *Assessing Future Traveller Information Systems*. in *13th World Congress on Intelligent Transport Systems and Services*. 2006b. London.

43. Moezzi, S., et al. *Immersive Video*. in *VRAIS'96*. 1996: IEEE.

44. Singh, P., et al. *Rapid Prototyping and Evaluation of Intelligent Environment Using Immersive Video*. in *8th Conference on Human-computer Interaction with Mobile Devices and Services*. 2006. Espoo, Finland: ACM.