Sheffield Hallam University

Museum, Memories and Digital Stories

A Liminal Space for Human Computer Interaction

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STATEMENT

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ABSTRACT

Objects, material or digital, mediate memories: they act as anchors in between temporal notions and relations of past and present. Through those objects of memory, the act of remembering occurs neither completely relived in the mind, nor fully captured in the medium. Essential to personal memories, objects represent also our collective memory and capture our social history.

The papers submitted for this PhD by selected publications look at the design of innovative technology that can make remembering more evocative and affective. They look at both museums, where digital and material are combined in an augmented reality, and personal/family contexts, where the home and mundane objects can be technologically enhanced to encapsulate digital memories.

The museum was ideal to experiment with hybrid settings that combine material (the collection and the architectural space) and digital (the information) (papers 1 to 3). Personalization of information was used to augment the reality of rooms and exhibits: whole body interaction (i.e. physical movements in the space) was used to select and personalize the content and engage visitors with both material (the object) and digital (the information). Although the mobile technology is dated, these papers show the value of combining digital and physical to provide a holistic experience that made visitors wonder. Where the fusion occurs, however, is in the digital technology. To balance this perspective, paper 4 looks at the effect of taking the digital content out into the exhibition space.

My recent research (papers 5-9) looks at objects of memory in the personal realm, in particular in the family home. Starting from observing the role and function of mementos, I conclude that a more holistic and organic approach has to be taken to make personal digital objects of memory more present in people's life. Materialization can be achieved with digital devices designed for individual and family use, so that the product fits with the mundane aspects of life, is immediate, and stimulates affect, not efficiency.

Finally papers 10 and 11 provide evidence of the innovative methodologies I have developed and successfully used in iterative user studies and evaluations across different research projects and many years of research.

As a whole this submission shows that there is a huge design space to explore in looking at how technology could be used in public or private spaces to bring together the two aspects of memory: remembering in the mind and capturing through objects, in order to preserve our digital life as tangible interactive objects.

LIST OF PUBLISHED PAPERS SUBMITTED

1. E. Not, **D. Petrelli**, O. Stock, C. Strapparava and M. Zancanaro (1997) *Person-oriented guided visits in a physical museum.* The 4th International Conference on Hypermedia and Interactivity in Museums (ICHIM97), Paris, September 1-5.

   A speculative paper on the potential of artificial intelligence and personalization of digital content for cultural heritage. It explores how museum-goers can be supported before, during and after the physical visit. It shows how my personal research (detailed in papers 2 and 3) was positioned with respect to the current trends.

2. **D. Petrelli**, A. De Angeli and G. Convertino (1999) *A User-Centered Approach to User Modelling.* Proceedings of the 7th International Conference UM'99, 255-264.

   Awarded an Honourable Mention

   Personalization requires the system to hold and update a model of the interacting user: a large survey of museums goers was set up to find the core characteristics that would predict users' behaviour. This paper received a Honourable Mention as the first attempt to model users on the basis of a user study.

3. **D. Petrelli** and E. Not (2005) *User-centred Design of Flexible Hypermedia for a Mobile Guide: Reflections on the HyperAudio Experience.* User modelling and User Adapted Interaction UMUAI, 15, 303-338.

   This paper provides an overview of the whole project: its rationale, implementation, data creation and test. It shows how the results of the user study above affected the final system and the user interaction.

4. S. Reilly and **D. Petrelli** (2007) *Engaging with Books You Cannot Touch: Interactive Multimedia to Explore Library Treasures.* Co-Design, vol. 3, supplement 1, 2007, 199-210.

   A questionnaire distributed to the visitors of a mixed media-material exhibition is used to critically assess the achievement of the designers' goals of creating a multisensory experience that satisfies different tastes.

5. **D. Petrelli**, S. Whittaker and J. Brockmeier (2008) *AutoTopography: What Can Physical Mementos Tell us about Digital Memories?* CHI 2008, International Conference on Human Factors in Computing System, Florence, Italy, 53-62.

   Awarded an Honourable Mention

   An exploration of the role of objects in the home as means to autobiographical remembering. Inspired by previous research in social science, it looked at the personal relation with physical objects in the domestic space as inspiration for the design of technology for personal reminiscing.

6. **D. Petrelli** and S. Whittaker (2010) *Family Memories in the Home: Contrasting Physical and Digital Mementos*, Journal of Personal and Ubiquitous Computing, 14 (2), 153-169.

   This paper uses the data collected for [5] to compare and contrast physical and material mementos. It suggests design principles to address the shortcomings of digital mementos and move their design toward a better integration in people's life.

7. **D. Petrelli**, E. van den Hoven and S. Whittaker (2009) *Making History: Intentional Capturing of Future Memories.* CHI 2009, International Conference on Human Factors in Computing System, Boston : MA, USA.

While paper [5] looked back, this paper looks forward 25 years and investigates what should be captured today to be remembered tomorrow. Mundane activities and ordinary people were considered by participants worth preserving more than exceptional events.

8. L. Dib, **D. Petrelli** and S. Whittaker (2010) *Sonic Souvenirs: Exploring the Paradoxes of Recorded Sounds for Family Remembering*. International Conference on Computer Supported Cooperative Work - CSCW 2010, 6-10 Feb. 2010.

Awarded an Honourable Mention

Studies [5] and [6] showed how difficult it is for people to think in terms of digital mementos to represent their life and memories. This study set out to explore the most challenging media (it exists only in digital form, cannot be previewed, needs time and effort to capture and listen to) and its function in personal reminiscing compared to digital photography.

9. **D. Petrelli**, N. Villar, V. Kalnikaite, L. Dib and S. Whittaker (2010) *FM Radio: Family Interplay with Sonic Mementos*. CHI 2010, International Conference on Human Factors in Computing System, Atlanta, GE, USA.

On the basis of [8], this paper describes the design, implementation and evaluation of a radio for listening to the "sonic souvenirs" in a playful way and in a social context. It shows it is an engaging object that suits the aesthetic of the home and the social dynamic of a family.

10. S. Bowen and **D. Petrelli** (2011) *Remembering Today Tomorrow: Exploring the Human-Centred Design of Digital Mementos*. International Journal of Human Computer Studies, 69 (5), 324-337.

Focussed on methodology, this paper shows how the studies reported in [5] and [7] used creative activities to stimulate engagement and produce a richer set of data than would be collected through questionnaires or interviews. The empirical data then fostered design solutions that were very creative and provocative although addressing the issues of use identified in the studies.

11. **D. Petrelli** (2008) *On the Role of User-Centred Evaluation in the Advancement of Interactive Information Retrieval.* Information Processing and Management, 44 (1), 22-38.

A methodological paper written as reflection on four years of research in interactive information retrieval, it represents my shift from determinism to constructivism, from controlled in-lab experiments to observations of naturalistic uses.

These papers are cited in the text below using square brackets, e.g. [6]. Other papers I have published that are not submitted are cited using the standard format (Petrelli et al. 2009).

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1. INTRODUCTION

In my career I have researched multilingual and multimedia information access, information and knowledge management, intelligent interfaces and interaction with intelligent systems, data visualization and manipulation for sense-making, and personal digital memories. Despite the different topics, my research has always focussed on how people could interact with digital content in a way that harmonizes with the situational context they are in. This goal has pushed me to experiment with a wide range of research methods and seeking collaborations with experts in other disciplines (e.g., psychology, anthropology and philosophy). I have published about fifty full papers in refereed journals and conferences and I have more than seventy contributions overall. Given the variety and the span of my research, it was not easy to decide which papers better represent my story as a researcher in Human-Computer Interaction (HCI in the following).

Eleven papers[1] are submitted here, researched and written over a period of fifteen years. More than others, they illustrate the development of my research. Besides the specific findings, when considered in sequence these papers capture key points in the evolution and changes of direction in my research, starting from a positivistic position that considered HCI as a deterministic process, to a much more open, subjectivist approach that includes the environment surrounding the two agents, the human and the computer. Perhaps not surprisingly, my change of perspective, attitude and methodology seems to reflect the transformations HCI has gone through in the last 20 years, gradually moving the focus from cognitive psychology, to usability and finally creative practices.

These papers also capture my commitment to multidisciplinary research and my effort in "transplanting" practices from one discipline into another. They highlight my interest in combining material and digital to create a new interactive space situated in a specific socio-technical environment. The early work looked at creating a hybrid museum space where the digital content was dynamically composed on the basis of the movements in the physical space; more recent research focussed on materializing digital personal memories into physical objects to create digital mementos. In both cases, what the person experiences is neither completely physical nor completely material. I argue that by combining material and digital a new liminal space is created and that there is where interaction design should sit. Designing for this liminal space requires the ability to empathise with "users" and to deeply understand what the technology can do in order to shape experiences that are both emotional and effective.

2. AIMS

A PhD by publications is, by its nature, very different from a PhD by research in so far that the investigation does not necessarily evolve linearly, following a single research plan, with a progressive accumulation of new knowledge. Instead a PhD by Selected Publications gains its value from long term investigations with intermediate findings and experiences that influence and re-direct subsequent research. In my case it embraces quite a considerable lapse of time (fifteenyears); a substantial increase in expertise (from being a computer scientist only to a computer scientist *and* a social research practitioner *and* to embrace research by design); a new ability of analysis and synthesis across disciplines (by combining both my scientific and artistic background); and a new passion for experimenting with alternative choices and imagining the world from different perspectives.

As a result, my aims in writing this submission for a PhD by Selected Publications are:

1. *To reflect on the changes in my research attitude and practice*: from a positivistic belief that users studies provide scientific evidence for interaction design and that

[1] When I felt it would help a better understanding of my work, I cite papers I published other than those submitted here.

user evaluations give a definitive proof/disproof of the validity of a design solution, to an interpretative standpoint that recognizes the importance of understanding from within as a way of opening up to many more design possibilities.

2. *To make explicit my aim of combining material and digital into a liminal space that affords new interaction experiences*: when properly drawn together, material and digital complement each other instead of competing for human attention. On the basis of my publications I discuss how materiality and digitality (i.e., the quality of being digital) can be effectively combined to create new experiences for users in museums and at home.

3. *To reflect on integrated research as a driving force for innovation in HCI*: in my more recent research I have drawn on my skills as social researcher, my knowledge of computer science, and my interest in art and design. I discuss why a multidisciplinary background is important in HCI and how this can open up new possibilities for innovation.

This submission spans fifteenyears of research, quite a long time in terms of digital technology development. I feel it is therefore useful to look at my story in relation to the changes that have affected HCI since I became interested and involved in it. An outline is provided in the next section. I then progress to expanding points 2 and 3 above before discussing the contribution and the relevance of this research. A table with the papers presented as evidence for this PhD by publications, each commented with respect to its content and the contribution of the co-authors, is provided in the appendix.

3. HISTORICAL CONTEXT

Stemming from ergonomics, in the 80s HCI was shaped by both psychology and engineering: the first provided precise costs for human actions (i.e. the GOMS model, Card et al. 1983), the second would make a user interface that optimized the costs. By the late 80s the increased complexity of the interface made prescriptive methods impractical to use. WIMP (Windows Icons Menu and Pointer) became the user interface paradigm prompted by increasingly better screen graphics (e.g. NeXT Computer 1988-1990). User-Centred Design emerged as good practice (Norman and Draper 1986), and usability (Nielsen 1993) influenced software engineering (e.g. use cases entered the Unified Modeling Language for programming around 1995-96).

3.1. The initial curiosity of the early days

I became aware of HCI in my very first job. Although I have an art diploma that predates my university time, by education I am a computer scientist specialized in computer graphics and image processing. In 1989 I joined the Telecom Italia Research Lab to work on the design of the user interface of an experimental multipoint videoconference system for the MPEG standard, at that time under definition at ISO. In line with the ideas of the time (Shneiderman 1987), my aim was to design a graphical user interface to satisfy user's needs, e.g. how to share documents across computers and swap the speaking rights. Although we adopted a user-centred approach, the organization of the team was rigid with social scientists carrying out the user studies and feeding the computer scientists on (pre-selected and digested) user's needs. By the end of 1993, I was acutely aware of the difficulties a rigid organization of work poses to the effective sharing of knowledge and the development of new ideas: different disciplines can work side by side in the same team without crossing their individual discipline boundaries while interdisciplinary research requires a common goal and an integration of disciplines (Tress et al. 2005). I felt frustrated and unsatisfied by receiving only second-hand information and just being told what to do with little background information on the *why* a certain feature was needed. My interest in social research germinated here, from the need to see first hand what was going on and thereafter better understand the implications for my work on the user interface. I started to get out in the field, visiting the places where the interaction was expected to take place and observing the dynamics of the people involved.

One episode in particular marked a turn in my research path. For a project funded by the local authority, I had to design a kiosk aiming at unemployed people self-searching for jobs, the motivation being to preserve privacy on a sensitive matter. I asked to visit and observe some of the interactions the civil servants had with the job seekers. Listening in on very few conversations was enough to understand that the unemployed were often looking for a word of comfort, or directions on how to write a CV or the best way to hold an interview. No self-service information kiosk would have ever been able to substitute for the sympathetic clerk and there was no justification for a kiosk in that setting[2]. It dawned on me how misleading preconceptions could be and how fundamental it is to get a thorough understanding of the reality before any intervention is planned. This consciousness was clearly filtered by empathy but unsupported by any data collection of undisputable facts; it clashed with my scientific education where conclusions had to be motivated by objective, numeric evidence not by gut-feelings. The value of qualitative research was unknown to me and I looked for scientific evidence to motivate any user interface decision. The first chance to design on the basis of empirical evidence presented itself in 1996 in the context of the HyperAudio project discussed next (papers [1], [2] and [3]).

3.2. Growing an interest in tangible interaction

Digital innovation moved fast in the mid 90s and new visions of digital technology emerged: *ubiquitous computing*, ecologies of small reactive devices all communicating and embedded in space (Weiser 1991, Weiser 1993, Weiser 1994); *augmented reality*, overlapping digital content to physical objects and spaces to enhance human activities (Wellner et al. 1993); and *adaptive interfaces*[3] that dynamically change their appearance or behaviour to adapt to their users (Benyon 1993). HCI picked up the potentials and new interaction paradigms were put forward: *graspable interfaces* to interact with underlining computer technology (Fitzmaurice et al. 1995); *information appliances* designed to support one single task (Norman 1998); and *ambient technology* as information display (Ishii and Ullmer 1997).

In 1993, I joined IRST, a research centre in artificial intelligence and robotics and their work on adaptive interfaces (Stock 1993, Stock et al. 1996). Adaptation was achieved by modelling the user: some form of representation of the interacting user was kept in the system ("what they knew" and "what they liked" were popular features) and used to, for example, i) select the content that better fitted the user's knowledge (naïve vs. expert) and ii) deliver it using the user's preferred media (text vs. image). Cultural heritage was a favoured domain as the amount of information available could be properly selected and prepared for each individual user (Ardissono et al. 2011). My original contribution to the on-going project (paper [1]) was twofold: (i) to take the personalization of information into the physical space of a museum (paper [3]); and (ii) to study museum visitors and model the user on real data (paper [2]). The vision was that the information space (in the computer) would overlap the physical space (the museum) creating an augmented reality that offered interaction in both physical and digital domains (Fig. 1, top left): information selections were triggered by movements in the physical space (implicit input, Fig. 1, top right) or by clicking on the mobile interface (explicit input, Fig. 1, bottom left). By tracking both the physical and virtual paths the system was able to personalize the content (information) delivered to the visitor on the basis of the on-going visit.

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[2] The aim of the project was then diverted to support clerks providing information on pensions.

[3] Today this branch of computer science research, strongly connected to artificial intelligence, is better known as "personalization research". The same belief in computers being able to understand user's needs motivated research in software agents (applications able to carry out tasks on behalf of their users, Shneiderman and Maes 1997), and intelligent interfaces (interfaces able to interpret complex interactions, e.g. gestures, or extract core information from data analysis e.g. text, image or video analysis, Jameson 2008).

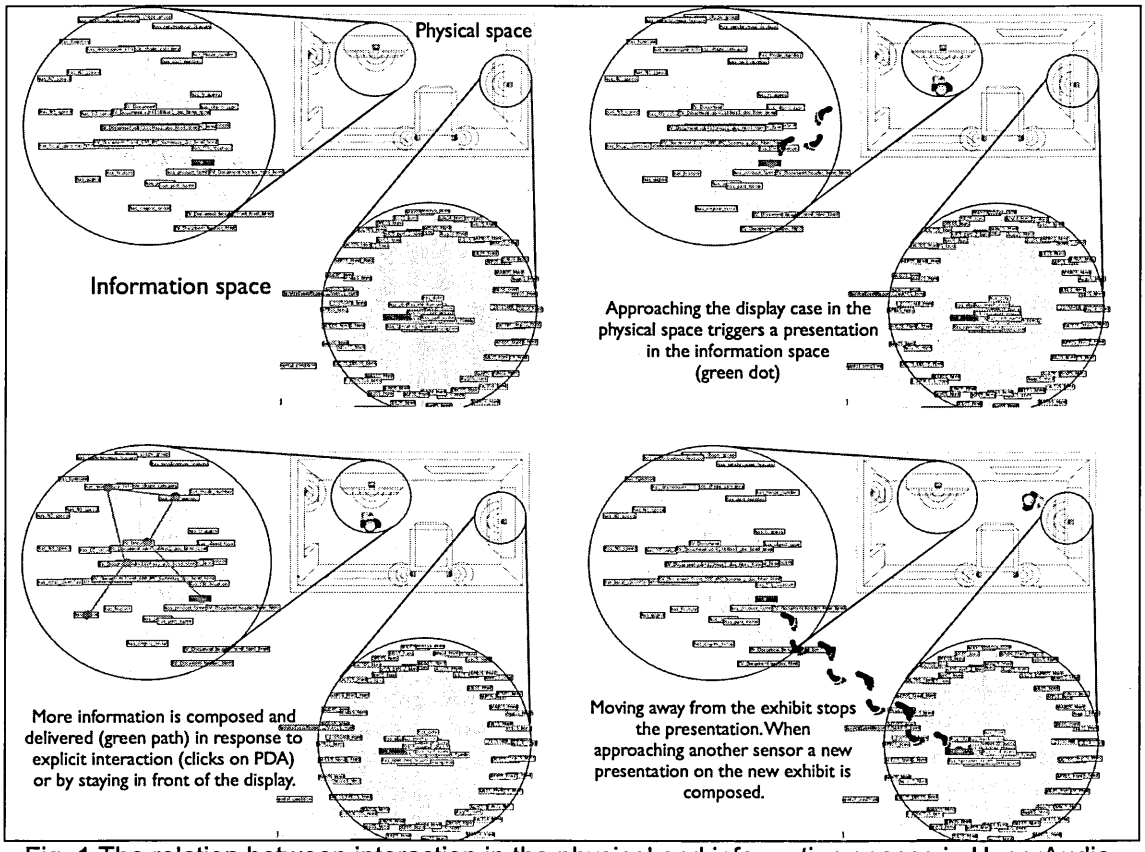

Fig. 1 The relation between interaction in the physical and information spaces in HyperAudio.

In line with the work of the time, the user model was expected to contain the features that the researchers assumed to be relevant, e.g. a model of the knowledge and of the interest [1]. How to capture the visitor's level of knowledge and the kind of interest was a task for the user interface. Equipped with my new awareness on the importance of understanding reality, I wanted to base the user model on real data. A large survey (250 participants) was set up to find correlations between personal features and visit behaviour [2]. The rationale was that if personal features were related to a visitor's style, then selecting a profile at the start of the tour would successfully control the adaptation process. The result of the survey and the extended statistical analysis clearly showed that personal features (e.g. education, age) did not correlate with a visitor's behaviour (e.g. length of the visit, items seen). Instead, factors like the social group, being the first visit or a further one determined the visit pattern (e.g. first time visitors wanted an overview, further visits deepened into few exhibits for longer). Moreover, while guidance was welcome, technology was not, even among young people. This deeply affected the user model, the system and the interaction design as it indicated that the majority of visitors might never actively engage with technology. The final interaction design (paper [3]) included a larger set of movements (e.g. standing in front of an exhibit for a long time was considered as an implicit request for more information, equivalent to a click on the PDA screen). Personalization could then occur on movements alone, without ever interacting with the PDA, a type of interaction today called *whole-body interaction.* The user experience was transformed from actively seeking information to walking around listening to the narrations that poured from the headphone in a natural responsive way to the physical movements.

This work was groundbreaking: it was the first attempt to model users on the bases of real data and not researcher-imagined personal traits. Although it could seem peculiar, no one before had ever studied the user to define a realistic user model and our work (paper [2]) received a Honourable Mention at the User Modeling international conference in 1999. It also anticipated some of the concepts later developed in HCI, e.g. reactive spaces and whole-body interaction.

Looking back, I ascribe to this episode my growing confidence in challenging the status quo and carrying out independent research. Between 2001 and 2006, I experimented with a number of methods to study complex work situations, e.g. aerospace engineering (Petrelli et al. 2006), or jobs that require the use of multiple languages, not necessarily known[4] (Petrelli et al. 2002). In those years I progressively moved away from a positivistic approach of HCI that looked for "unquestionable" evidence on the way to progress, as was the case in paper [2], toward a much more constructionist position open to the influence and importance of the social context. However, while my user studies were more and more qualitative and varied, I still believed the evaluation had to be rigid to be rigorous and scientific. I allowed myself to relax rigid conditions and evaluate my work in a more naturalistic way only at a second stage, after iterations and when supported by statistical evidence [11]. I needed the context of personal memories and a few more years of independent research to find the confidence for embarking upon a completely qualitative evaluation of my work, with the FM Radio described in paper [9]. The call to abandon an evaluation schema based on measuring performance on task for a more emotion-centred analysis was natural given the personal value of the content. This step changed the epistemology and methodology of my research, but did not diminish the rigour of data collection and analysis conducted with qualitative data.

3.3. Embracing interdisciplinary research

As my epistemological position shifted over the years from objectivism to constructivism, it seems to me so did HCI. Today HCI is very different from the deterministic science-and-engineering certainty that pervaded the early days. New methods of study emerged (e.g., cultural probes (Gaver et al. 1999, Gaver et al. 2004), technology probes (Hutchinson et al. 2003) or affective evaluation (Isbister et al. 2006)) blurring even more the boundaries between electronic engineering, social science, design and art (Norman 2004, Dunne 2005). The stimulus for changing practices was, for HCI, that digital technology was entering the wild territory of personal life and the home. The metrics of efficiency and effectiveness developed for usability in the office did not fit the practice at home and new methods had to be devised. In my case the drive was my research into personal digital memories that started in 2006.

By this time I was at the University of Sheffield, in the Information Retrieval Group at the department of Information Studies (now Information School). The problem our research team wanted to address was how to facilitate the access to digital content accumulated over a lifetime. We foresaw an advanced information retrieval system with an innovative graphical user interface, possibly one that embedded psychological principles of autobiographical memories (e.g. the hierarchical clustering of events as proposed by Conway and Pleydell-Pearce 2000). While my colleagues were focussed on retrieval tasks (e.g. Whittaker et al. 2010), I wanted to start from the values that people see in personal memories. While a digital collection is a recent acquisition and many[5] do not know how to handle it (Marshall 2007), everyone has material mementos that are cherished, looked after, preserved for the future and sometimes passed on to the next generation. I then looked at the existing practices with material objects to inspire the design of the user interface.

I wanted to gain an inside view, to look at family life through the eyes of the participants. I needed a compassionate method if I wanted my informants to feel emotionally involved and sustain their engagement, so I gave them traces for creative activities (papers [5], [7], [8]). My attempt was to go beyond the collection of data conforming to a researcher's plan (e.g. questionnaire or interview) or the scattered impressions provided by cultural probes (Gaver et al. 1999, Gaver et al. 2004): I needed methods that prompted my informants to overcome the natural resistance in recounting their intimate stories to a stranger. The three studies were very different to one another, but all three put participants in charge allowing me to see their

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[4] In the case of the Finnish Parliament librarians had to retrieve on behalf of MPs documents on laws passed in other countries without knowing the foreign language.

[5] Professionals in digital libraries are well aware of the problems and actively searching for the best solutions (Deegan and Tanner 2006; Manoff 2006).

individual realities through their eyes: in the Memory Tour participants walked their home telling the stories of their mementos (papers [5], [6]); for the Time Capsule the families composed a representation of their life to be opened in 2033 (paper [7]); and in the Sonic Souvenirs they recorded the sound of their family Summer holiday (paper [8]). Participants were so excited about the studies that, for the first time in my career, I had friends of participants asking to take part themselves (two psychiatrists heard of the Memory Tour from a colleague – "*I thought it was a fascinating study and an opportunity to reflect*" - while two families discovered a friend was making the Time Capsule – "*it commits us to an interesting family project*"). The results exceeded any expectations: data was particularly rich and evocative because of the personal involvement and the emotional investment of participants (paper [10]). While the first was a reflective exercise, that indeed attracted psychiatrists as volunteers, the other two were fun for all: the possibility of creating a collection (of objects or sounds) for their own personal use was the key for self-appropriation of the creative task.

The findings were much more articulated than anything I had ever collected before indicating a design path towards concepts that were not "obviously digital" but that blended with the nuances and intimacy of personal spaces and personal life. My data captured the imagination of a designer who went on to propose a number of concepts for *digital mementos* (in and out of the computer) and discussed them in workshops with potential users (paper [10]). Reflecting on Bowen's ideas and observing the workshops helped me in rediscovering my training in fine arts and building my confidence as a creative person. My effort in imagining how sonic souvenirs could be made more accessible and part of family lives became the FM Radio (paper [9]). The evaluation set up was as naturalistic as possible: the family who recorded the sounds listening back to their own recordings with no task or timing (paper [9]). This broke my last taboo and completed my transition from quantitative to qualitative research.

I have finally reconciled different parts of my past: computer science, social inquiry and art, into a single and individual approach to HCI research. My trajectory in HCI shifted from deterministic to objectivistic without abandoning essential understanding of computing but integrating and mitigating it with my understanding of human values and design for them. I combine empathy and intuition (from social science) with a strong analytical approach to maintaining rigour within narrative data analysis; as a consequence my design is based on empirical data collected in a sympathetic way but analysed scientifically. The many twists and turns made me a 'design thinker' (Brown 2008), a person able to see the world from many perspectives, who doesn't rely on analytic thinking alone, who trusts a better solution can be found, is experimental and collaborative. Interestingly, this seems to be where HCI is now: pulling together the many souls from design to engineering, experimenting as never before with pragmatic as well as improbable ideas, pushing further the limit of digital technology into personal life.

4. MATERIALITY AND DIGITALITY

4.1 The Museum as a Place for Storytelling

As outlined above, in the mid 90s I was among the first researchers experimenting with mobile technology and the physical context. The standard framework was that of ubiquitous computing: nomadic interaction on screen. The user interface to cultural heritage content was essentially designed as a browser displayed on mobile technology to be used within the cultural site, e.g. a tablet PC (Cheverst et al. 2000), a WAP phone (Ardissono et al. 2003).

The same concept of a browsing interface on a PDA was my starting point when designing the interaction with the Apple Newton, the device used for the adaptive museum guide. The extended study of museum visitors carried out through 250 questionnaires in three different exhibition sites [paper 2] clearly showed that interacting with digital technology was not of interest while visitors appreciated a guided tour. The overwhelming evidence pushed me to re-think the interaction and seek a better integration of the technology within the visit. The design was influenced by three factors:

- The study showed *visitors might never interact with the technology* so the guide needed to work even without any explicit intervention from the visitors, i.e. no tapping on screen. The physical movement (implicit input) became the focus of the interaction design, much more than tapping on the screen (explicit input). The range of movements initially limited to approaching an exhibit expanded to include: entering a room, spending more time in front of the same exhibit, walking without stopping, and moving away. It was an embryonic form of whole-body interaction.

- Visitors' *interest is toward the exhibition* so the guide should not compete for the visitor's attention but instead complement and integrate the evocativeness and the affordance of the physical space. The whole-body interaction released the attention channel (sight and action) that was now completely devoted to the museum space. As the narrative was delivered to the visitors in audio format the interactive experience was composed by the museum (physical space) on the visual channel and the information (digital space) on the auditory channel.

- While the museum setting is fixed, digital content can be dynamically recombined and tuned on the visitor's individual path to *create a personalized experience*. The flexibility provided by the digital medium allowed for deeply personalizing the content and the form of the narrative on the basis of the visitor's behaviour: the guide would not repeat content already delivered (even if returning to an already visited exhibit); it would provide generic information to visitors who do not stop in front of any item while it would deliver progressively detailed content to those spending time in front of the same exhibit; it would lengthen the narrative for a slow pacing visitor and shorten it for a faster one. Linguistic rearrangements of the content were added to reinforce cohesiveness and coherence, e.g. by making comparisons to previously seen objects or referring to objects in the surrounding space, e.g. "the lizard in front of you".

The interaction design then started with the analysis of the space and extended to incorporate the digital content in a way that complements and reinforces the sense of place. Indeed the effect of the physical space on visitors and its relation with the level of engagement with the exhibits is well-researched in museum studies: position and lighting has the power to attract and hold visitors' attention (Boisvert and Sletz 1995); different visitors show different visit patterns, e.g. looking at every single exhibit vs. selecting a few in each room (Veron and Lavasseur 1983; Serrell 1997); and the individual pattern changes over time when fatigue intervenes (Falk and Dierking 1992). Acknowledging that the exhibition space has an effect on visitors and that the visiting style changes over time suggested a design concept that was closer to interactive storytelling (Murray 1998) than to Internet browsing practices. Interactive storytelling combines artificial intelligence and interactive games: although there is the schema of a plot, the next step in the story is dynamically created on the basis of the user interaction. For HyperAudio the interactive storytelling was composed through movements: the museum space, composed by rooms and objects, provided the general structure; the content dynamically instantiated depending on the visitor's path provided the details in the on-going narrative. The story existed only as a combination of the individual path in the physical space with the specific path in the information space (Fig. 1). Space and information are interwoven in a unique experience where the digital component cannot be distinguished any more from the physical. The interactive space created in this way is more than the overlapping of the digital over the physical as advocated, for example, by augmented reality: it exists only while the experience lasts. I will argue in the next section that this space is liminal, in between sensorial and virtual.

HyperAudio was demonstrated at UM99 and CHI99 (Petrelli et al. 1999) and broadcast by national Italian television[6] but never reached the museum: Apple stopped producing it in early

[6] A video clip of the popular program TG2 Dossier broadcast by Italian TV featuring HyperAudio can be seen at http://dagda.shef.ac.uk/daniela/Daniela_Petrelli/Show_off.html

1998 and the Palm Pilot, launched in 1997, did not have enough computational power for the sophisticated software with the result that the ideas initially tested were never fully explored. The chance to continue this line of investigation presented itself in 2006 with the opening of the exhibition "The life and works of William Butlers Yeats"[7] at the National Library of Ireland set up by the professional firm Martello Media [paper 4]. The exhibition uses a combination of digital content, material objects, space arrangements and media to create highly evocative niches that appeal to different people in different ways: a small gazebo to sit in and listen to poems; videos displayed in recreated settings, e.g. the poet's study; extra-large interactive tables to inspect the digitized manuscripts; pairs of physical and digital cases to get information; and personal artefacts reproduced from digitized originals. Although the exhibition did not have any form of bodily interaction or personalization it provides an interesting case study on how an exhibition space can be purposefully designed to combine digital and material to create a new hybrid space for affective interaction.

The affordance of the material world created evocativeness and composed the right context; it uses the potential of the digital to expand beyond the limitation of the physical, e.g. zooming in, acquiring further content or displaying objects for which there is not enough physical space. The result of the study clearly showed how the appreciation of different settings is highly individual. The exhibition then becomes a shared space for collective heritage and individual interests mediated by the (material or digital) artefacts: the objects allow for crossing the boundary between personal and collective, cognition and emition (Dudley 2010). In this perspective, the concept of heritage is very close to that of collective memory: "collective frameworks are [..] the instruments used by the collective memory to reconstruct an image of the past which is in accord, in each epoch, with the predominant thoughts of the society." (Halbwachs 1992, p. 40). Inevitably, the digital culture is pushing curators to reconsider the function of digital technology, moving away from being functional learning tools toward social media and public participation, reinforcing the tangle between material-digital and personal-social. A setting where personal and social are tightly connected but still understudied with respect to the potential of combining material and digital culture is the home. The next section reports my investigation on the domestication of digital technology.

4.2 There Is no Place Like Home

The home is a special place: "A house is not a home. A house [....] is a physical structure. Home is the rich set of evolving cultural, demographic, and psychological meanings we attach to the physical structure. Thus, despite real estate advertisements to the contrary, you cannot buy a home. You can buy (or rent) a residence and, with luck, time, and effort, turn it into a home." (Gifford 2002, p.236) At home people cultivate their identity, they can be themselves, sheltered from the effort of keeping their status in society, by imposed formalities and by the pressure of work duties (McCracken 2005). Home has its own moral order that changes over time depending on the changed circumstances of its inhabitants or by an increased awareness of possibilities, e.g. online banking or shopping (Strain 2003). Ideally, digital technology should be purposefully designed for being used in the social context of the home. As different rooms have different affordance on individual and social activities, the position of digital technology in the home can facilitate or hamper their use, e.g., a PC in the basement, far from where the domestic life is, requires an intentional effort with respect to a PC in the family room (Frohlich and Kraut 2003). The 'sociopetal' (bringing together) or 'sociofugal' (setting apart) function of the computer in the family home could be controlled by designing its functionalities for shared places and tasks (Frohlich and Kraut 2003).

Although a design of computer functionalities that fits the home is essential, a true domestication of digital technology will happen through a shift of focus from cognition to emotion. In my research of technology in the domestic space I look at the affect and emotion people feel toward objects and use this to achieve a better integration of digital in the home; I aim at "a sensual approach to introducing technology into the home, building on what is already there, and exploring the overlap between material and immaterial world from an

[7] The exhibition, still open in Dublin, has a virtual counterpart http://www.nli.ie/yeats/

aesthetic and anthropological point of view". (Dunne 2005, p. 4) In my research I used ethnography-inspired studies to understand the domestic context from within, while with my design I want to provoke an aesthetic judgement that prompts reflection through sensory experience.

My investigation into sensual and empathic design develops in the context of personal digital memories in the home. Autobiographical memories are narratives reconstructed in today's social and temporal context (Brockmaier 2010, Halbwachs 1992). To me the technology-centred total-recall approach adopted in lifelogging (Bell and Gemmel 2007) is inadequate: solving the problem of "the storage and retrieval of innumerable memory-infested files" ignores the act of remembering. "Memories are narratives as well as artifacts, performances as well as objects – things that work in every day lives and culture of people." (van Dijck 2007, p. 168). It was inside this new framework of mediated memories that I started my research, looking for the human value of remembering beyond the user needs and retrieval systems.

I felt that the change of perspective, from *user* to *human,* called for a more creative field research, beyond querying digital recording and viewing practices. In three studies (papers [5], [7], and [8]), participants appropriated the proposed activities, they described and represented their own lives, unknowingly implementing the ethnographic principle of 'observing from within' (Blomberg et al. 1993). They found the activities valuable, not because of the given rewards (a gift), but because they were doing something engaging and satisfying and it is this mechanism, I believe, that made the data collected so insightful. This data may be more difficult to account for in the design process, as countable factual evidence is not there. Indeed, the understanding emerged from an empathetic interpretation of personal experiences providing inspiration for innovative design of technology in the home.

To find inspiration for interaction design of digital memories I looked into material culture and the way people related with their mementos, objects kept in memory of someone or something (papers [5] and [7]). Material and digital mementos are similar insofar that they are both heterogeneous, idiosyncratic and highly affective, but material mementos around the house prompt reminding and meaning making, whereas files in the computer, despite their affective value, get forgotten. The stories of objects of memory in the home are pockets of compressed time in space (Bachelard 1969), a feature completely missing in digital objects. To realize my vision of materializing digital objects of memory, I collaborated with a designer, Dr. Simon Bowen, who produced critical artefacts to capture the essence of digital mementos (paper [10]). The design concepts did not optimise technology for use but put at the fore human values, thus changing the balance on which features are important, e.g. efficiency is meaningless when revisiting memories occurs once a year or even less. For the owner, the value is not the frequency of access but the emotional investment captured by old mementos rarely visited [10].

My own exploration of emotional design for personal memories is in papers [8] and [9]. While the field studies in papers [5] and [7] looked at both material and digital, the capturing of audio (as sonic souvenirs) during family holidays (paper [8]) directly addressed the challenge of evocative but immaterial content that is the essence of digital objects of memory. Recording was playful, drawn by both curiosity and intentionality; listening and reminiscing as a family gave great pleasure and showed the potential of digital content when it cannot be replicated in any material form. The tension between the material world and digital content pushed me to explore how to provide access to personal digital belongings that are easy, playful and social. The Family Memory Radio (paper [9]) reconciles material and digital by embodying the sounds into a familiar object, and old radio from the 70s, and allowing users to socially browse through their sonic collection via tangible interaction. One year after the recordings of the sonic souvenirs I took the radio to the families and invited them to listen to it, try it out and discuss its potential role in the family life. The unusual look for a digital technology device was much discussed and appreciated for both its aesthetic suitable for the home, its ubiquity and the possibilities it offered to tune in and out of the memory flow while involved in other activities. The radio is a material presence, a physical reminder, but it acts as a portal for the

digital content. It has a hybrid nature, both material and digital; it is an "[object] designed to straddle both material and immaterial domains [and] arouse curiosity about the fit between these worlds." (Dunne 2005, p. 111). Seen in this perspective, it is not a new software that better organizes files that is needed, but a whole new device, or set of devices, that have a material presence and act as threshold for the digital content. The double nature of the radio creates a space apart, that is not fully material neither fully digital, it creates a liminal space. This interpretation is supported by the feedback I received when the radio was exhibited for two weeks at a public event[8]: visitors commented upon the experience of being transported into the life of others through listening to their personal recordings.

5. THE LIMINAL SPACE OF HUMAN COMPUTER INTERACTION

The two strands of research submitted for this PhD explore the space created by the intersection of material with digital in public and private environments. The concept of intersection is important. Although 'digital' is often used as synonymous to virtual, non-existing, digital has a material dimension dictated by the device used to access, store or manipulate it: '[the] medium shapes [the] content' (Manoff 2006). Content and container form a particularly interesting pair for interaction design as new devices can generate new practices, for example the materiality of the mobile phone (small screen and keys) paired with the possibilities of sending text messages has generated a new (pigeon) language rich in abbreviations that does not exist in any other electronic medium (Manoff 2006).

The synergy between physical and digital achieved in the two projects I discussed above creates very different user experiences. In the work in the museum the digital component led the interaction and narrative "magically" started as reaction to movements in the space; with the radio the engagement is driven by the physical clicking and turning of buttons and knobs[9]. The design of places and devices can exploit this dual nature and create experiences that are not completely material neither fully digital but midway, a *liminal space*: a "privileged place and time set off from the areas and periods of work [or mundane activities]" (Turner 1987, p. 23).

The concept of liminality, of being betwixt and between, was introduced by the anthropologist Victor Turner to explain rituals as performative acts (Turner 1987). A liminal space is not necessarily a dedicated physical place, but it has something, e.g. a decoration, that sets it apart from the context, that makes it special, privileged. Its main function is that of boundary crossing. People may enter a liminal space to exit it changed, as in rites of passage, or to experience a different dimension, as while watching a theatre piece.

In the context of personal digital memory, a liminal space is where the process of remembering occurs, triggered by mnemonic aids (material or digital mementos) and supported by creative instruments (e.g., the FM Radio). When remembering, a person is not fully in today neither completely in the past. As it is unlikely to be a completely solitary experience, remembering is in between the self and the other(s).

In the context of an augmented museum, a liminal space is where the sensory and cognitive explorations occur combined in a new visitor experience. While my research was rooted in the curatorial culture of the time that favoured information and stories over objects, we are currently witnessing a cultural shift toward physical and emotional interaction following evidence that encounters with material objects has a higher learning impact on visitors (Dudley 2010). HCI actually rediscovered the importance of materiality in museums earlier than curators did (Ferris et al. 2004) and a few but very interesting experimentations occurred

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[8] The Inhabiting Space Exhibition http://www.inhabitingspace.org/index.html (accessed 11.8.2011)

[9] A video of one of the participant families interacting with the radio can be found at http://dagda.shef.ac.uk/daniela/Daniela_Petrelli/Research.html or at http://portal.acm.org/citation.cfm?id=1753683 (accessed 11.8.2011)

in recent years (e.g. a whole-body and social interaction with Constable's paintings (von Lehn et al. 2007), or the use of RQ-codes paired with material souvenirs given as gifts and part of the experience of visiting an exhibition (Ciolfi et al. 2011)).

The purposeful design of 'digitality' into 'materiality' holds much potential for HCI. A new place for interaction requires considering the place people live in not just designing for the tasks. A liminal interactive place includes the space as well as the emotional and social aspect of being there. The design then becomes specific for that space, that people, doing that activity (Harrison and Tatar 2007). This takes a step beyond the support of mental construction (interaction as built in the mind of the user) but as firmly rooted in the physical affordance of materiality.

My experience of designing a liminal interactive space is that the researcher must understand both the socio-cultural context (material side) and the potential of technology (digital side). This dual knowledge is then embedded in the affective and emotional process of creative design. Emotions play a pivotal role in creative processes (Sas and Zhang 2010), but the teaching of creative practices to computer scientists is still experimental (Sas and Dix 2009). Indeed, although HCI is inherently interdisciplinary with computer science, engineering, social science and design constantly "crossing subject boundaries to create new knowledge and theory and solve a common research goal" (Tress et al. 2005) their integration is not commonly pursued and is rarely achieved. One possible reason is that each discipline requires different attitudes: computer programming is rooted in logic and rationality; social research needs empathy and observational skills; and for design imagination and experimentation are essential. The ability to combine observational skills, empiric data, reflection and analysis, and cross disciplines is essential for reaching innovation (Leonard and Rayport 1997). HCI as a liminal space in between a social context and digital technology requires the integration of these different knowledges and skills. During years of research I have accumulated knowledge in different disciplines and developed new skills: I have integrated my computer science theoretical and practical knowledge with ten years of social field research and recently with creative design practice. This integrated knowledge fosters intuition and makes my research innovative and relevant both within and outside the HCI community, as discussed next.

6. COHERENCE, CONTRIBUTION AND RELEVANCE OF WORK

My continuous search for new forms of interaction that combines material and digital in an organic and human-centred way gives coherence to the papers discussed in this submission for PhD by publication. These papers demonstrate my attempt to overcome the common practice and experiment with alternative methods to reach my vision. The need to understand before designing is another trait that pervades all my research, including the projects not discussed here.

My original contribution lies in exploring aspects of hybrid research across disciplines that, at times, resembled a diplomatic negotiation (Petrelli et al. 2009 (b)). The cross-fertilization has gone both ways: from other disciplines into HCI and from HCI into other disciplines. In the first case, I encountered people and ideas that inspired my HCI research:

- the modelling of visitors' behaviour through empirical data (paper [2]) heavily used techniques of data collection and analysis suggested by my co-authors[10], both psychologists;
- the study on personal memories in the home was inspired by Csikszentmihalyi and Rochberg-Halton's book "the meaning of things", suggested to me by my co-author

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the philosopher and linguist Jens Brockmeier[11] (paper [5]) in one of our stimulating conversations;
- the design of the time capsule (paper [7]) was influenced by work in material culture (Turkle 2007), autobiographical studies and anthropology (Hoskins 1998);
- the argument I put forward on HCI as a liminal space, was prompted by Turner's discussion on rituals and performance (1987).

I have also, with some success, brought HCI principles and practices into hard-core computer science niches where the user interaction is often seen as the display of a pretty GUI. In particular the use of user-centred design in user modelling (paper [2]) and semantic web (Petrelli et al. 2009 (b)) both received the Best Paper Nomination, and a study of computer vision techniques applied to historical video archive was highly commended for an Emerald Literaty Award for excellence in 2008 (Petrelli and Auld 2008).

Paper [2] stirred user-modelling research community attention toward the need for looking at users first and it is still cited more than ten years after its publication[12]. More substantial is the relevance of my recent work on personal digital memories (papers [5], [6], [7], [8], [9]) that, it seems, is helping to shape the emerging area of digital technology for personal memories[13]. Notably, papers [5] and [8] received a Best Paper Nomination respectively at CHI08 and CSCW10. I see my work in this area as particularly relevant for its critical questioning of the value of lifelogging and other technology-centred research into personal digital memories with core questions deeply rooted in human values.

Although this submission is, by its essence, a retrospective narrative on a finite time, I feel it is important to mention how my research is progressing as it shows how my contribution, as outlined above, is expanding. My curiosity on the mechanisms underlining the "domestication of digital technology" is taking me toward anthropological studies in secular rituals seen as means to reinforce elements of social belonging (Bell 2010), particularly within a family. My impulse for cross-pollinating other disciplines is taking me into a new area, Organization and Management. With a colleague from business studies, I have started to investigate the tensions and conflicts in organizational processes that require management and decision-making as well as considerations for aesthetics and user-centred design (Spedale et al. 2011).

SUMMARY

In this submission I initially briefly introduced the papers before stating my aims, namely i) to contextualize my fifteen years of research career in the proper historical context; ii) to discuss my exploration of the intersection of digital and material; and iii) to outline the importance of integrated research for effective interaction design. I have then provided an historical summary of my research career and an articulated discussion of the implications of combining material and digital in public (museum) and private (home) contexts to better capture the richness of personal and collective ememories. In the museum I experimented with digital content nested in the physical space (rooms and exhibits) and revealed by whole-body interaction that transformed the visit into a personal experience. In the home affective digital recordings have been embedded into a physical device, a radio, that functions as a reminder and facilitates appropriation and meaning building. Finally I have described my contribution to both HCI and other disciplines as my ability of crossing boundaries and integrating different disciplines facilitating and fostering cross-fertilization and innovation.

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[12] Source: Google Scholar citation list (as at 19.8.2010).

[13] The cumulative number of downloads of the four papers [6] (published in 2008) to [9] (published in 2010) is 2110, source ACM Digital Library (as at 19.8.2010).

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APPENDIX

The list of papers presented for this PhD by selected publications. A short description and the contribution of co-authors is given. For each paper two citation indices are provided under the Ref.N., one from Google Scholar (indicated as Gh) and one from Web of Science (WoS). My overall citation indices from Google are: 826 citations (of 80 papers); h-index 16; i10-index 21. My most cited paper (127 citations) is not included as it belongs to that part of my research that is not represented here.

Ref.N.	Details of the Published Work	Description	Role of co-authors
1 Gh: 3 WoS: 3	E. Not, **D. Petrelli**, O. Stock, C. Strapparava and M. Zancanaro (1997) *Person-oriented guided visits in a physical museum*. The 4th International Conference on Hypermedia and Interactivity in Museums (ICHIM97), Paris, September 1-5.	A speculative paper on the potential of artificial intelligence and personalization of digital content for cultural heritage. It explores how museum-goers can be supported before, during and after the physical visit. It shows how my personal research (detailed in papers 2 and 3) was positioned respect to the current trend.	Co-authors Stock, Strapparava, Zancanaro had developed a previous project on natural-language interaction for the exploration of cultural heritage, referred in the paper as 'before and after the visit'. Elena Not explored with me the personalization situated in the museum, she looked after the linguistic core for composing the narratives.
2 Gh: 59 WoS: 2	**D. Petrelli**, A. De Angeli and G. Convertino (1999) *A User-Centered Approach to User Modelling*. Proceedings of the 7th International Conference UM'99, 255-264. Awarded an Honourable Mention	Personalization requires the system to hold and update a model of the interacting user: a large survey of museums goers was set up to find the core characteristics that would predict user's behaviour. This paper received a Honourable Mention as the first attempt to model users on the bases of a user study.	Co-authors De Angeli and Convertino are psychologists, they constructed a balanced questionnaire (based on of my questions), distributed and collected it, statistically analysed the data. Mine was the idea to study visitors to model the user on real data, the questions, the qualitative analysis for user model and the personalized guide.
3 Gh: 63 WoS:22	**D. Petrelli** and E. Not. (2005) *User-centred Design of Flexible Hypermedia for a Mobile Guide: Reflections on the HyperAudio Experience*. User modelling and User Adapted Interaction UMUAI, 15, 303-338.	This paper provides an overview of the whole project: its rationale, implementation, data creation and test. It shows how the results of the user study above affected the final system and the user interaction.	My co-author Elena Not was responsible for the natural language component that determined the segmentation and re-composition of the narrative. I was responsible for the user interaction, the interface, and the project overall.
4 Gh: 0 WoS: 0	S. Reilly, **D. Petrelli** (2007) *Engaging with Books You Cannot Touch: Interactive Multimedia to Explore Library Treasures*. Co-Design, vol. 3, supplement 1, 2007, 199-210.	A questionnaire distributed to the visitors of a mixed media-material exhibition is used to critically asses the achievement of the designers' goals of creating a multisensory experience that satisfy different tastes.	This paper derives from Susan Reilly's Master dissertation. As supervisor I advised on: the multi-methods approach, the questionnaire and interview structure, the data analysis. I wrote the paper and expanded the analysis/discussion.

5 Gh: 37 WoS: 1	**D. Petrelli**, S. Whittaker, J. Brockmeier (2008) *AutoTopography: What Can Physical Mementos Tell us about Digital Memories?* CHI 2008, International Conference on Human Factors in Computing System, Florence, Italy, 53-62. Awarded an Honourable Mention	An exploration of the role of objects in the home as means to autobiographical remembering. Inspired by previous research in social science, it looked at the personal relation with physical objects in the domestic space as inspiration for the design of technology for personal reminiscing.	Prof. Brockmeier talks and our discussion opened up my horizon on new findings in autobiographical memories, i.e. the shortcoming of the archival model and the evidence in favour of reconstructive narratives. I, autonomously, designed the study and the method for the data analysis. With Prof. Whittaker I discussed some aspects of the analysis; he also helped me in structuring and refining the paper. I presented the paper at CHI 2008.
6 Gh: 13 WoS:	**D. Petrelli**, S. Whittaker (2010) *Family Memories in the Home: Contrasting Physical and Digital Mementos*, Journal of Personal and Ubiquitous Computing, 14 (2), 153-169.	This paper uses the data collected for [5] to compare and contrast physical and material mementos. It suggests design principles to address the shortcomings of digital mementos and move their design toward a better integration in people's life.	Inspired by the detailed analysis on material objects and the home space reported in paper [5], I led the comparison with digital mementos. With Prof. Whittaker I discussed the findings and the implications for design. I was the major contributor to the writing with help from Prof. Whittaker.
7 Gh: 21 WoS: 3	**D. Petrelli**, E. van den Hoven, S. Whittaker (2009) *Making History: Intentional Capturing of Future Momeries.* CHI 2009, International Conference on Human Factors in Computing System, Boston : MA, USA.	While paper [5] looked back, this paper looks forward 25 years and investigates what should be captured today to be remembered tomorrow. Mundane activities and ordinary people where considered by participants worth preserving more than exceptional events.	I originated the study, carried out the vast majority of the data collection and the whole data analysis. Dr. van den Hoven and Prof. Whittaker were valuable in refining the initial idea, planning the study, and discussing the results. We co-authored the paper that Dr. Hoven and I presented.
8 Gh: 8 WoS: 0	L. Dib; **D. Petrelli**, S. Whittaker (2010) *Sonic Souvenirs: Exploring the Paradoxes of Recorded Sounds for Family Remembering.* International Conference on Computer Supported Cooperative Work - CSCW 2010, 6-10 Feb. 2010. Awarded an Honourable Mention	Studies [5] and [6] shoed how difficult is for people to think in terms of digital mementos to represent their life and memories. This study set out to explore the most challenging media (it exists only in digital form, cannot be previewed, needs time and effort to capture and listen to) and its function in personal reminiscing compared to digital photography.	I inspired this research and substantially contributed to the design of the study. The data collection and analysis was carried out entirely by Ms. Lina Dib, PhD student in anthropology. I co-designed the study, participated in the discussion of the emerging results and contributed to the writing. I presented the paper at CSCW 2010.
9 Gh: 6 WoS: 0	**D. Petrelli**, N. Villar, V. Kalnikaite, L. Dib, S. Whittaker (2010) *FM Radio: Family Interplay with Sonic Mementos.* CHI 2010, International Conference on Human Factors in Computing System, Atlanta, GE, USA.	On the bases of [8], this paper describes the design, implementation and evaluation of a radio for listening to the "sonic souvenirs" in a playful way and in a social context. It shows it is an engaging object that suits the aesthetic of the home and the social dynamic of a family.	I led the group and put forward the idea of an old radio as device (although my vision was a radio of the 50s not the 70s). I co-designed the interface, conducted the user evaluation and data analysis. I led the writing and presented the paper at CHI 2010.

10 Gh: 0 WoS: 0	S. Bowen, **D. Petrelli** (2011) *Remembering Today Tomorrow: Exploring the Human-Centred Design of Digital Mementos*. International Journal of Human Computer Studies, 69 (5), 324-337.	A methodological paper, it shows how the studies in [5] and [7] used creative activities to stimulate engagement and produce a richer set of data than questionnaires or interviews. This fostered design concepts that were creative and provocative although addressing the issues of use identified in the studies.	The paper writing clearly distinguishes the work done by the two authors: mine is the design of the studies and the associated reflection that fed Dr. Bowen's creative effort.
11 Gh: 26 WoS: 6	**D. Petrelli** (2008) *On the Role of User-Centred Evaluation in the Advancement of Interactive Information Retrieval.* Information Processing and Management, 44 (1), 22-38.	A methodological paper written as reflection on four years of research in interactive information retrieval. It represents my shift from determinism to constructivism, from controlled in-lab experiments to observations of naturalistic uses.	

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Person-Oriented Guided Visits in a Physical Museum

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Abstract

The "ideal guided visit" to a space (as an exhibition, a museum, an open-air exposition distributed in different areas of a city, an archaeological site and so on) allows the visitor to organise the tour throughout the different areas according to their own needs or preferred criteria: for example, looking for paintings coming from the same geographical region rather than paintings produced in the same period (following a geographical thread rather than a chronological one). However, when organising the physical layout of the exposition areas a specific criterion for items placement has to be chosen, according to a "default" perspective of information presentation, either chosen by an architect or imposed by geographical constraints. It may happen that the default physical organisation does not meet directly the visitor's expectations, possibly making it difficult to build a personal route.

We shall discuss the development of a system able to organise the presentation of a museum contents taking into account the visitor's needs and the layout of the physical space. The system guides the visitor through the museum and provides information by means of audio messages: the visitor can get instructions for finding the objects of interest, hear descriptions with references to other interesting objects in the museum, ask for additional information and receive suggestions on next steps. Therefore, the visitor is provided with a personalised guide for exploring the physical and information space.

Keywords

adaptive hypertext; intelligent interfaces; user models; portable digital assistants

1. Introduction

Artificial Intelligence, and in particular intelligent interfaces, may open new scenarios for tourism and fruition of cultural heritage. The main prospect made possible by the adoption of these technologies is to move from the current mass-oriented approach to an approach oriented toward the individual. This has at least two facets: on the one side systems will have to take into account the specificity of the user with his own interests, idiosyncrasies, and so on; on the other the user will be the main agent in his exploration, he will take the initiative and exploit the high level of interactivity that will be available in intelligent interfaces.

With this vision of the future, at IRST we have worked for several years at developing a prototype in which some advanced research concepts were put together in a complex system demonstrable in a realistic context. Before focusing on the specific object of the present article, we would like to briefly review the characteristics of that project, called AlFresco [ST93], [Sto94].

The AlFresco system is a natural language dialogue system for a user interested in Fourteenth Century Italian frescoes and paintings with the aim not only of providing information, but also of promoting other masterpieces that may attract the user. It runs on a workstation connected to a videodisk unit and a touch screen. The particular videodisk in use includes images of frescoes and monuments. The system, besides understanding and using natural language, integrates it with hypermedia both in input and output. The user can interact with the system by typing a sentence, navigating in the underlying hypertext, and using the touch screen. In input, our efforts have been focused on combining the interpretation of linguistic deictic references with pointing to images displayed on a touch screen. In output, images and generated text with buttons offer entry points for further hypertextual exploration. The result is that the user communicates linguistically and by manipulating various entities, images, and text itself. In sum AlFresco yields an environment suited for exploration of a large information space where the user may integrate moments of goal-oriented investigation and browsing.

A system like AlFresco can constitute the basis for exploration at home. But we believe nothing can take the place of a visit to the "real thing". The emotion is different. So the whole cultural

experience can be seen as encompassing three phases, each of which can take advantage of technology: support before the visit, during the visit and after the visit.

Here we shall describe an approach to support the visitor *during* his visit. The perspective is that the visitor moves in the physical space while seeking information and guidance. The user is not moving in virtual space but in a real space (such as a museum) augmented with a personalised informational dimension. The two spaces are integrated, producing a new way of exploring the culture heritage. The solutions presented in the paper are currently being developed inside a project called HyperAudio [HA]. Further challenging research issues emerging in this interaction scenario will be investigated inside the HIPS [HIP] European project.

2. The Ideal Guided Visit

Usually, a tourist experience begins before reaching the actual cultural/tourist site. In fact, the interest for a particular place or masterpiece often begins with reading a book or an advertisement or talking to a friend; it grows by reading preparatory material; it may continue after the visit by purchasing and reading the catalogue or related books. The knowledge acquired before the visit is used to better enjoy the actual tour and is completed later on by further study.

Information technology can support the visitor's thirst for information in different ways either before, during and after the actual cultural/tourist visit, helping the visitor to get the best out of this experience.

2.1 Preparing for the Visit

At present, the most common way of acquiring knowledge on cultural exhibitions or tourist sites still consists in reading books on the subject or advertisement material prepared by the organisers, talking with more informed friends or consulting experts. However, these traditional forms of knowledge acquisition have also technological counterparts that are becoming more and more used: for example, CD-ROM based systems; digital libraries accessed through Internet; intelligent information-providing systems. Within this latter class, many systems have been developed exploiting the more advanced findings of the AI field, especially in the context of adaptive and adaptable systems. In the cultural domain related to museums, for example, we find systems like the before mentioned ALFresco, ILEX[1] [KMOO96], [MOOK97] or PEBA-II[2][DM96], just to mention a few.

More generally, the use of technology has a lot of obvious advantages, e.g. world-wide access and adaptive presentation of information [Fle97]. But, there is more than that: the information exploration performed at home by the visitor-to-be can be used to collect information on his previous knowledge and preferences which will be effectively exploited during the visit. For example, to allow on-site systems (inside the real museum or the actual place visited) to be more effective in proposing interesting information.

2.2 Continuing Exploring Information After the Visit

Usually, visitors bring home books, CD-ROM or video catalogues related to what they have seen. And they often browse through the collected material in search for what they have learnt, what they liked most and further material to enrich the knowledge they have acquired. These types of traditional *static*[3] catalogues usually gather a lot of interesting information related to all the objects displayed in the exhibition. The material is typically organised by domain experts according to a chosen perspective (the leitmotiv that inspires the conceptual and physical organisation of the exposition) and possibly educational strategies.

Recent advances in the field of Artificial Intelligence provide valuable background for the development of new-generation catalogues, complementary to the more traditional ones, summarising the information explored by the visitor according to a meaningful presentational structure and tailoring it to the single visitor's personal traits. This new type of catalogue could be automatically created on the basis of a user-model, built before and during the visit, and completed by interacting with a workstation connected to a multimedia data base. Opposite to the traditional one, we call this type of catalogue *dynamic*.

2.3 The Actual Visit: Moving in an Augmented Space

In an "ideal guided visit" to a space (as an exhibition, a museum, an archaeological site, a city, and so on) what a visitor would like to have is a flexible companion that helps him in visiting the museum or town as an information space. Of course, museums or exhibitions (or towns) are physically organised in some rigid way. When organising the physical layout of the exposition areas a specific criterion for items placement has to be chosen, according to a "default" perspective of information presentation, either chosen by an architect or imposed by geographical constraints. It may happen that the default physical organisation does not meet directly the visitor's expectations, possibly making it difficult to build a personal route. In the case of a museum, paper maps, provided at the entrance, may help visitors navigate through the different rooms to find those items that meet their own interests. Written and tape recorded guides can provide useful description of the objects displayed but they do not guarantee flexibility, either because of technological constraints (i.e. audio tapes force a predefined path) or because the descriptions are not coherently related to each other (e.g., CD-ROMs support free movements but not connected presentations).

On the other hand, virtual museums (implemented for example as hypertextual resources browsable from the World Wide Web) may offer a more flexible (dynamically computed) object display determined by the visitor's individual preferences. The visitors can play around a clickable representation of the museum rooms and objects, getting informative cards on what they are most interested in. However, with purely virtual spaces the visitor may perceive objects differently (e.g., different dimensions and colours) and miss the emotional involvement experienced with real objects (e.g., being in front of Mona Lisa at the Louvre is quite a different experience from looking at its reproduction on the Web).

New hardware technology allows the fruition of virtual repositories of information while enjoying the physical space: for example, kiosks or portable devices may allow the access to a portion of the virtual information space relevant for the object in front of the visitor. More generally, information technology can be exploited to modify the li environment, helping to augment the functional of every-day things, therefore enlarging hu possibilities in interacting with objects. Figu suggests one possible scenario of this kind, w visitors of a museum or an exhibition may enj personalised tour through the interaction "augmented objects". Each visitor is equipped a palmtop computer endowed with headphones which an infrared receiver is mounted. E meaningful physical location has a small (po autonomous) infrared emitter, sending a code uniquely identifies it (see fig. 2).

Exploiting the infrared signals, the system is abl identify when the visitor reaches a certain phys location and can activate a relevant portion of information repository loaded on the palmt Meaningful information are selected and organi to be played as audio messages or displayed on palmtop screen. Adaptive and dynamic hyper technology is exploited to tailor a presentat according to the visitor interests, the actual cont of the visit and so on. In this way, the system gui the visitor through the museum and provi information by means of audio messages: the visi can get instructions for finding the objects of inter hear descriptions with references to other interest objects in the museum, ask for additio information and receive suggestions on next ste Therefore, he is provided with a personalised gui for exploring the augmented physical spa [NPS+97].

We are currently investigating the features of tl scenario inside the HyperAudio project, a proj IRST is developing in collaboration with the Ci Museum of Rovereto (Italy). The results gain inside HyperAudio will contribute to more advanc research efforts towards a richer interaction scenar to be explored jointly with other partners inside t HIPS European project [HIP].

In the following sections we describe the critic research issues involved in HyperAudio and tl approach that has been adopted for the developme of the final prototype. In particular we focus on ne opportunities opened by the use of this tool for acti visiting.

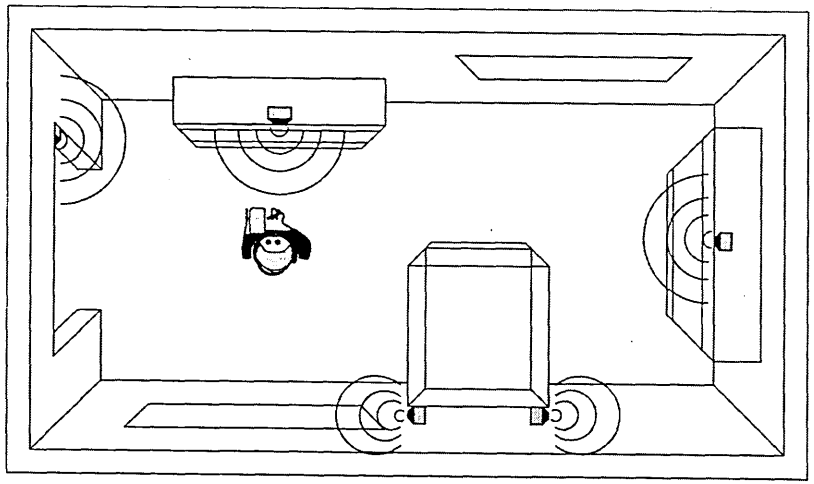


Figure 1: A visitor exploring an augmented room in a museum.

3. Physical and Virtual Museum vs. Augmented Museum

The peculiarity of integrating a virtual information space (e.g. a hypertext) onto a physical space goes beyond the simple juxtaposition of the two spaces; what we get is an *augmented space* with new interaction modalities and new navigation problems:

- Moving around the physical space, approaching meaningful physical locations, the visitor implicitly "clicks" on corresponding points in the information space.
- After getting information about an object (navigation in the information space), the visitor may decide to move in a direction that was explicitly or implicitly suggested by the message as a next interesting step. But the visitor may also decide to ignore the suggested tour thread. Therefore, the navigation in the informative and in the physical space do not necessarily coincide.
- Physical hints may attract the visitor's interest more than the proposed follow-up hypertextual links: he may be distracted by interesting objects close by or he may have personal intuitions about semantic relations between objects that make him stray from the chosen path.

Exploiting the features of the augmented space the system can play a new role in the information-providing task: not only can the system provide the visitor with information tailored to his own interests and interaction history (as it happens with adaptive hypermedia, [cf. Bru96], but it can also support the visitor in his own exploration of the physical space, helping him to find what he is looking for, suggesting new interesting physical locations, trying to avoid his getting lost in the physical space or misunderstanding what he sees.

As an example of how an augmented museum would assist a personalised visit, let us suppose that the visitor is in front of a case containing a stuffed squirrel. The system may provide a description of the animal, suggesting additional explorable information about its predators. If the visitor asks for this type of proposed exploration (by clicking a button on the palmtop screen), the system may provide a description of animals like eagles, foxes,

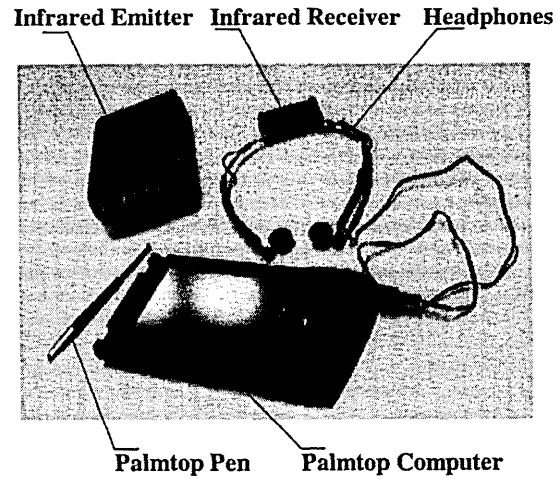


Figure 2: Equipment for a visitor in an augmented space.

etc. If the cases containing the predators are close by, the system could suggest looking at them, explaining how to reach the new location. However, if the shown predators are very far away orthe visitor has displayed interest only in rodents, the system may decide not to propose the site.

Figure 3 illustrates the scenario in which a flexible hyperspace is created taking into consideration both the semantic relations between concepts, the physical constraints as well as the user model and the interaction history.

The nodes in the virtual space are created on the fly in order to adapt to the preferences of the current visitor and to what he has already seen: the message contained in the node created for the current physical location is played as an audio description; additional explorable links to relevant portions of the (dynamic) virtual space are displayed on the palmtop screen.

3.1 The Notion of Path in an Augmented Space

When a physical space is coupled with a virtual space the notion of path is twofold:

- it has a semantic dimension because the purpose of the movement is to get information and not simply to walk around: visiting new points in the space implies that new information is gathered;
- it has the usual spatial dimension in which the visitor moves from one point to another. The spatial dimension itself is twofold:
- the movement can be in the physical space, involving perceptual experiences with real objects and physical strain, or
- the movement can be in the virtual space, i.e. browsing and jumping in the hyperspace.

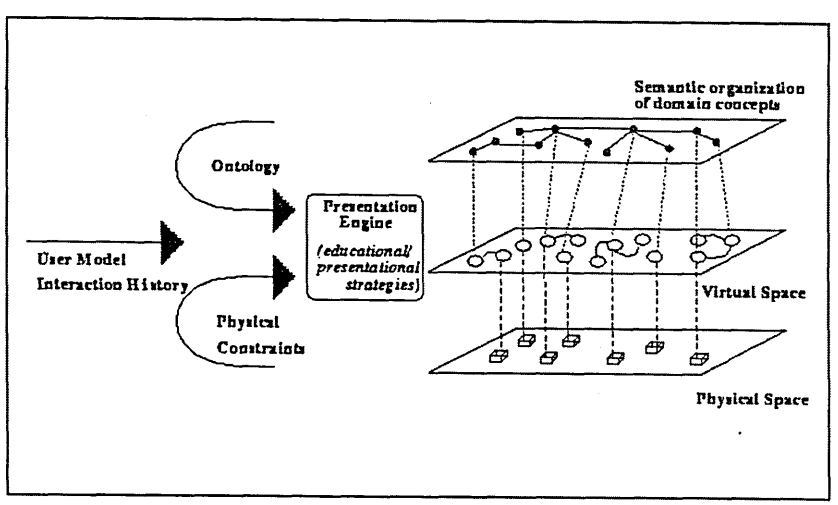
In an information space there may exist *predefined paths*, i.e. sequences of physical/virtual locations preselected by the designer, that offer particular perspectives on the content. In any case the visitor is not compelled to follow a predefined path, but may take diversions, both in physical and virtual space: we will call the actual sequence of undertaken steps the *actual path*.

Moreover, in an augmented information space, a portable system can suggest at any physical/virtual location next alternative steps, dynamically determined according to the visitor interests, the previous steps and possibly educational strategies. To carry out this active role, the system has also to take into consideration the peculiarities of the two dimensions (semantic and spatial). One key element is the different notion of *distance*: there is a *semantic distance* as a measure of how much two concepts are related to each other and there is a *spatial distance* as a measure of how many points need to be touched before getting to a certain destination. The paths that the system suggests to the visitor should not involve big distances between steps, to limit the mental and physical effort in the navigation and the risk that the visitor gets lost in the physical and information space. To produce coherent information presentations, the system should build object descriptions that involve only "close" semantic concepts. The semantic distance depends on many factors: not only on proximity in an ontological representation of the world but also on contextual saliency [Mil97b]. Therefore the semantic distance of two concepts may vary during the presentation[4]. Distances in the spatial dimension depend instead on the structure of the space. In the physical space the metric used to compute distances should consider the presence of obstacles (walls, stairs, lifts), possibly assigning weights to their negative effect (e.g. stairs involve much more strain that lifts, changing room usually involves less burden than changing floor, and so on). In a virtual space, instead, (e.g. a hypertextual informative space) distances are computed in terms of links you need to traverse. In the optimal situation of a dynamic hypertext in which the relevant hypertextual links available to the user are computed on the fly, distances could be reduced by the system in an automatic way.

4. System Architecture for a Person-Oriented Electronic Guide

The most suitable hardware for a portable device intended to guide the visitor flexibly throughout an augmented space is a mobile platform of reduced size (e.g. palmtop computer) together with some devices used for position localisation. The more sophisticated the localisation mechanism is (from

Figure 3: How a virtual space is dynamically created in an augmented space



the simple confirmation of the visitor's presence in front of the object, up to the determination of his distance and orientation in the room) the more effective the system guiding can be.

In HyperAudio we are currently using a Newton equipped with an infrared sensor. Small infrared transmitters are placed in meaningful points of the museum rooms, without damage to the building, since no cabling is required (each transmitter has an internal battery for power supply). Each transmitter emits an infrared signal that encodes a number uniquely identifying it. Whenever the palmtop enters in the area of a transmitter, the receiver (located on the headset) catches the identifying code and locates the visitor's position (the system is provided with a map of the transmitters placement). The maximum area affected by a transmitter can reach 10 metres in distance with an angle of 30 degrees. The covered area can be reduced in order to increase the precision of the localisation method when many transmitters may interfere with each other.

4.1 Implicit and Explicit Input

The ability of the system to track the visitor's movements in the physical space allows the system to propose information relevant to the visitor's needs and interests even without an explicit request. Sensors provide an implicit[5] input for system decisions. The visitor is free to look around in the room and focus his attention on the objects displayed: he is not compelled to check on the palmtop screen if and where[6] relevant information can be found. If he stops in front of an interesting object a descriptive audio message is automatically played. It is up to the system to decide if the visitor's movements have to be intended as a relevant input or not. For example, if the system has suggested to go to a given location, sensors activated along the route will not trigger presentations (although the information that the visitor has passed through other locations will be retained for other purposes).

Furthermore, the visitor has also means to explicitly interact with the system, exploiting its suggestions for studying in more depth interesting topics. The palmtop screen displays virtual buttons the person can click on to get additional information that elaborate on the audio message content. For example, buttons can fire comparisons to similar objects (paintings of the same author, paintings of the same period, etc. ...)(cf. [Mil97a] or can activate the presentation of instructions (with maps and verbal directions) on how to reach related interesting objects mentioned in the initial audio message.

4.2 Output

System output includes either content presentation and next steps suggestion. In our HyperAudio project the content is mainly presented in linguistic form through an audio device. Pre-recorded audio messages, appropriately assembled together, are played either on user request or automatically when the system identifies this is suitable. Museum maps, follow up browsable links and system commands (e.g. to stop the audio play or to show a global map of the museum with the current position of the visitor) are presented as clickable icons or text.

In the following, we will also point out how adaptivity can be enhanced in the output presentation by exploiting the achievements in the field of natural language generation and speech technology.

4.3 Modules and Knowledge Sources

The HyperAudio architecture is mainly organised as sketched in figure 3 above. The core of the system is a *presentation composer* that determines the relevant information to be presented: it actually builds the nodes of the virtual space the visitor can (implicitly or explicitly) click onto, giving rise to a dynamic, adaptive virtual space. The nodes are built on the fly as the interaction progresses and contain an audio file to be played, clickable links displayed on the palmtop screen pointing to follow-up content, clickable icons corresponding to interesting following steps in the suggested path. To produce the most effective information presentation, the presentation composer accesses different knowledge sources:

Ontology: An ontology reflecting the semantic organisation of the most relevant domain concepts is maintained to allow the computation of semantic distances and attribute saliency.

Macronodes: Information is organised in a network of macronodes (see fig. 4). Each macronode includes a set of linkable audio files (among which the ones actually played are chosen), pointers to other related macronodes (also expressing the particular rhetorical

relation occurring between the macronodes' content[7]), the type of text (e.g. general description, historical information, and so on), a pointer to the associated semantic concept, and possibly a link to the physical locations for which the macronode is relevant.

Museum maps: The system has also a set of maps of the physical space and the capability of limited reasoning about spatial relationships both linguistically and graphically.

User Model: The system maintains a model of the particular user with whom it is currently interacting. Our user model has two kinds of information: what the user has been exposed to or is assumed to know, and what the user seems to be interested in. The user's knowledge model is based on an initialisation (depending on a user profile, e.g. expert or novice) and on a modelization of what the user has become aware of. The user's interest model provides a model of the potential interest of the user and consists on an activation/inhibition weighted network whose nodes are associated with ordered sets of individual concepts.

The user model is exploited during the process of content generation in order to avoid repetitions and false assumptions, and to promote other objects potentially relevant from the user point of view. The updating of the user model depends on both what the user really chose and what he rejected (i.e. stopping an audio play, not clicking a particular choice, unexpectedly changing the physical path, and so on).

Interaction History: The system also maintains a history of the interaction, keeping track of what the visitor has seen, heard and asked for. This information is used to effect further output, for example reminding preceding presentation sequences.

To generate presentation nodes, the composer first chooses the most appropriate subset of audio files from the current macronode and plays them. Secondly, it decides which rhetorical relations to other macronodes are relevant in the present context and displays them as clickable links to related information. Finally, if needed, it integrates the presentation with maps and spatial directions, for example instructions on how to reach a certain location or relevant rooms.

The system adaptivity therefore emerges in different forms, both in the information provided and in the further steps suggested. Adaptivity in the information is not limited to content selection but may also affect the choice of language style: the context of interaction may suggest different linguistic choices, for example the selection of deictic referring expressions (instead of indefinite or definite ones) in case an audio message describing an object is heard when the visitor is in front of the object[8]. Adaptivity in the selection of following steps to suggest consists in the identification of "locally" interesting links, according to user model and interaction:

- new virtual locations to visit are suggested depending on rhetorical structure and text typology;
- new physical locations to visit are suggested depending on ontology relevance and physical constraints.

Adaptivity can be further enhanced when the system pursues more ambitious goals concerning educational strategies and has to negotiate between the visitor's initiative and its own promotion constraints. A simple example of this is that a system attracts the visitor toward a predefined path when this is compatible with the visitor's interests.

5. Further Developments

In this paper we have presented a system that produces informative guidance through an exposition area by exploiting data coming from the physical world (the movements of the visitor inside the space), the history of the interaction up to the current moment (descriptions already given and requests made) and a repository of information related to the domain. The actual presentation of information is:

- dynamically assembled;
- adaptive, taking into account the user's interests and knowledge;

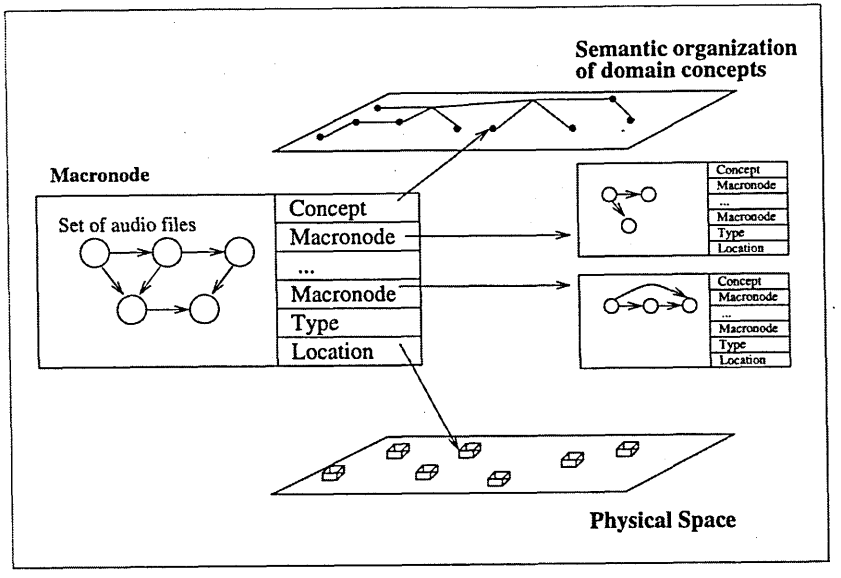


Figure 4: The macronode structure.

- multimodal, integrating audio information with a display on the screen;
- integrated with maps and spatial directions;
- used interactively, with the user allowed to explicitly request for new information.

The solutions adopted in HyperAudio for the accomplishment of these features can be improved in important ways. For example, for the assembling of the audio presentation we adopt the simple solution of selecting and concatenating pre-existing audio files, since our main initial research concern was especially focused on other navigation issues. However, we believe that more sophisticated techniques developed in the field of natural language generation could be profitably exploited in this context. The content of the message, in fact, could be produced with different degrees of complexity, yielding increasingly flexible presentations, for example by:

- modifying existing audio/text files through the introduction of cohesive devices that improve the fluency of the final message (anaphora introduction, introduction of linking sentences that signal comparisons, prosody adjustments, choice of cue-phrases, and so on) [O'D97];
- generating the messages from scratch, with a flexible content selection and organisation, starting from the knowledge represented in the ontology [KMOO96], [MOOK97]. Note that not always this is the most appropriate solution even if you do not consider the technical difficulty: pre-existing texts prepared by critics or domain experts can be good material to exploit.

This and other challenging research issues emerging in the interaction scenario described here are currently being investigated inside HIPS (Hyper-Interaction within the Physical Space), a new large European project under the Esprit programme Intelligent Information Interfaces (I³) [HIP][9].

Notes

1. ILEX (Intelligent Labelling EXplorer) generates personalised descriptions of artifacts in a (virtual) gallery adapting the information conveyed according to the features of the particular visitor and to the interaction history.

2. PEBA-II takes an underlying knowledge base containing information on the animal kingdom and produces from it adaptive textual descriptions for the animals similar in content to encyclopedia entries.

3. By 'static' here we mean that the content of the catalogue is a-priori fixed, even though the user is free to browse around it.

4. For example, when describing the lion -a carnivorous animal- we should avoid describing the flora of its living environment, unless this is motivated by the particular user interests.

5. Here *implicit* means that there is no intentionality on the part of the visitor to communicate his position to the system.

6. If the system automatically computes the relevant portion of the information repository to activate according to the visitor's position, the visitor is not compelled to browse through the information in search for what he is looking at.

7. For the modeling of the rhetorical relations expressing how text spans coherently relate to each other we have adopted the well known Rhetorical Structure Theory (RST), widely used in many generation systems, cf. [MT87].

8. In the simplest case, alternative audio messages may be available presenting the same information with different language style.

9. The HIPS consortium includes: University of Siena (coordinating partner), CB&J (France), GMD (Germany), IRST (Italy), SIETTE-Alcatel (Italy), SINTEF (Norway), University of Dublin and University of Edinburgh.

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A User-Centered Approach to User Modeling

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Abstract. Generally, user modeling concerns a person interacting with a standing console. This scenario does not represent the *HyperAudio* system in use: a visitor freely moves in a museum, gathering information from an adaptive and portable electronic guide. To provide designers with presumptive user behavior, data about visitor profiles and visit styles were collected through a questionnaire. The study pointed out unpredicted situations (e.g., the importance of social context) and confirmed some working hypotheses (e.g., the relevance of visit span). This paper reports on this experience, describing how to go from designer questions to guidelines for user modeling, making the best use of empirical data.

1 Introduction

The design of information systems is more and more user-centered: final users are involved from the very beginning of the planning stage. Early involvement of users has the potential for preventing serious mistakes when projecting innovative systems. Indeed, it compels designers to think in terms of utility and usability. Benefits of the user-centered approach are mainly related to time and cost saving during development, completeness of system functionality, repair effort saving, as well as user satisfaction (Nielsen, 1993). Involving users from early stages allows basing the system core on what is effectively needed. It is acknowledged that approximately 60-80% of interaction difficulties, including lack of facilities and usability problems, are due to poor or inadequate requirement specifications. Even if late evaluations are useful to assess the usability of final systems, it is unrealistic to expect that these results bring about a complete redesign.

Despite its importance, the motto *know the user* seems to be somehow neglected when planning how the system is to interpret user actions. As soon as user-modeling technology moves from research labs to real field usage, the need for a precise idea on how the interaction will evolve becomes increasingly important. The user model can manage only some dimensions (e.g., knowledge or interest) of that complex universe the human being is. Thus, these dimensions have to be the most meaningful and representative of users and uses. Moreover, an advanced sketch of the user is a key point when designing adaptive systems for completely new scenarios, such as computer augmented environments and mobile devices. This paper discusses the usefulness of a user-centered design for user modeling and reports the experience gathered in the HyperAudio project, where empirical foundation were sought to start-up an adaptive and portable electronic guide to a museum.

* We thank the HyperAudio project team for valuable suggestions throughout the design of the study, Museum staff for assistance with data collection, and all the visitors for filling out the questionnaire.

2 Know the User: Why and How [1]

To be effective in use, an information system has to be faithful to the real context. This implies that the system has to be in keeping with the employment the final users will make of it. Unfortunately, "users have infinite potential for making unexpected misinterpretations of interface elements and for performing their job in a different way than you imagine" (Nielsen, 1993). In other words, "a designer's best guess is not good enough". To cope with this, the Human-Computer Interaction community developed methodologies to design systems incrementally, in order to reach the implementation step with a design that is worth succeeding.

Adaptive systems have been proposed as a solution for usability problems (Benyon, 1993). Nevertheless, even if they greatly improve interaction, their effectiveness and their correspondence to user needs are not straightforward (Dieterich et al., 1993). Well-founded hypotheses are fundamental for a successful interaction, because they represent the basis for system reaction to user behavior. We claim that a user-centered approach enhances the probability that the model to be implemented will satisfy user needs.

Designing with a user-centered approach requires that the user be involved from the very beginning. The relative engagement and influence of users on the final design suggest splitting the approach into two classes depending on the user's role. *Consultative design* leaves decision-making power to technicians: users are simply sources of information with little to no direct influence. Designers turn to users to test their ideas and receive specific hints on the system being developed. On the opposite, *cooperative design* strongly involves selected users giving them the possibility of affecting the final system. Users have an active role: they have to understand problems and to propose solutions. A big effort is needed to create a common background, as well as to organize and lead design sessions. Here consultative design is discussed; interested readers in cooperative design can refer to Communication of the ACM, June 1993.

First of all, a user-centered approach requires understanding reality: who will use the system, where, how, and to do what. Then, the system is designed iterating a design-implementation-evaluation cycle. In this way it is possible to avoid serious mistakes and to save re-implementation time since the first design is based on empirical knowledge of user behavior. To collect it, many different techniques can be applied, among them direct observation, interviews and questionnaires. *Direct observation* is the most reliable and precise method, especially valuable for identifying user classes and related tasks. Moreover, it allows identifying critical factors, like social pressure, that can have a strong effect on user behavior when the system will be used in the field. Unfortunately, direct observation is very expensive, because it requires experimenters to observe each user individually. For this reason, it is useful when a reduced number of observations is enough to generalize behavioral predictions or when hypotheses have to be tested rather than generated. *Interviews* collect self-reported experience, opinion, and behavioral motivations. They are essential to finding out procedural knowledge as well as problems with currently used tools. Interviews cost a bit less than direct observations, because they can be shorter and easier to code. However, they still require skilled experimenters to be effective. By contrast, self-administered *questionnaires* can be handed out and collected by untrained personnel allowing to gather a huge quantity

[1] Here fifteen years of HCI are summarized. It is impossible go give references. Interested readers can refer to the valuable commented list of current HCI literature by Andrew Sears ("An HCI Reading List", SIGCHI Bulletin, Jan. 1998, vol. 30, n. 1) available at http://www.acm.org/sigchi/ bulletin/ .

of data at low cost. They allow statistical analyses and stronger generalizations than interviews. Questionnaires provide an overview on the current situation as well as specific answers. Which combination of these methods is worth applying depends both on requirements and budget. The ideal situation, where all of the above are used as in Vassileva (1996), is rarely justified. Nevertheless, as described in this work, the cheapest solution can give rise to interesting results.

Elaborating the outcome of the knowledge phase, designers define a first version of the system. At this stage, design techniques (e.g., task centered or scenario based) and expert reviewing (e.g., heuristic evaluation or cognitive walkthroughs) do provide satisfying solutions. Among the many methods used in HCI, probably the most suitable for systems that have a user model is parallel design. The goal is to explore different design alternatives before settling on a single proposal to be further developed. Possibly, in this way designers will propose different solutions (what to model) and different interaction strategies (what the user can control).

Then, one or more solutions can be tested with users. This step, called *formative evaluation*, aims at checking some choices and getting hints for revising the design. Techniques like paper mock-ups, prototyping and Wizard Of Oz simulations can be applied. *Paper mock-ups* are the cheapest: pieces of the system interface are drawn on paper and the interaction with a user is simulated by an experimenter. Despite its trivial appearance, this technique allows collecting reliable data which can be used for parallel reviewing. *Prototyping* allows testing some functionalities in depth (vertical prototyping) or the whole interface (horizontal prototyping). Both paper mock-ups and prototyping can be empowered by methods like focus group (i.e., many users solve a task together) or think-aloud (i.e., the user expresses verbally what he/she is doing), that clarify user behavior and understanding. They also succeed in finding misunderstandings and false presuppositions. Since no system is needed, they can be valuable tools in user modeling early testing. They can easily test the relative advantage of system self-adaptation versus user controlled adaptation (Dieterich et al., 1993), or user general understanding of interface dynamic changes. By contrast, *Wizard Of Oz simulations* require a sophisticated system to help the wizard perform as the final system will do. This technique is expensive and is justified only when a corpus of reliable interactions has to be collected (e.g., for future training or testing in dialogue systems).

At the end of the design cycle, *summative evaluation* are run. They concerns the test of the final system with effective users performing real tasks in their working environment. Therefore, a summative evaluation should be considered as the very last confirmation of the correctness of the hypotheses stated during the design process.

3 A Quick Overview of HyperAudio

The basic idea of HyperAudio arose upon observing that each museum can be coupled with a hypertext the visitor might wish to explore during the visit. Each exhibit corresponds to a sub-net. For example, a stuffed crocodile can be described by general features, evolution, life cycle etc. Entering the reptile room, approaching the crocodile, visitors explore the hypertext through their movements. Combining portable computers and physical exhibitions, coupling exhibits and hypertext structure, HyperAudio provides a new way of navigating information:

- moving in the physical space, approaching a case, the visitor implicitly selects a node of the hypertext as relevant;

– as in a "traditional" hypertext, the visitor can explicitly explore the sub-net connected to the current node (i.e., the object the visitor is facing) before moving in the physical space towards a new object.

In this way, the visit becomes a path among physical sites (rooms, objects) and semantic sites (descriptions, contents).

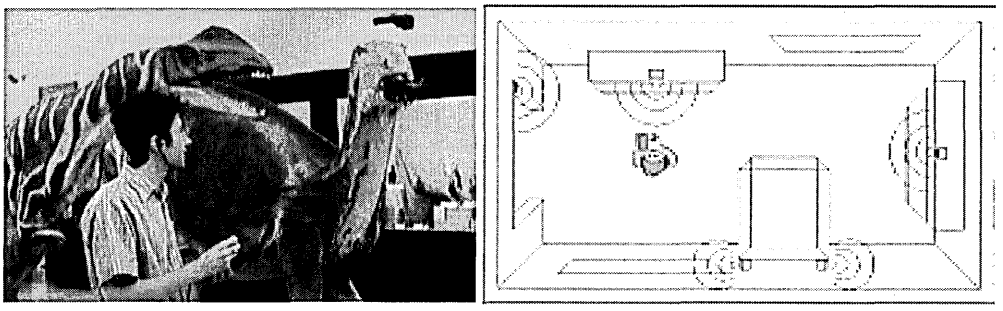

Figure1. A visitor equipped with a palmtop computer and headphones in the augmented museum.

HyperAudio stands where location aware systems and adaptive systems overlap. Exploiting position data, it provides personalized information to a user carrying a palmtop computer. The system follows the moving user and provides information at the right time (Figure 1). HyperAudio adapts to a single user, who is following a personal path in a physical context[2]. Each of these three facets (the visitor, the actual visit, and the museum) influences the process of dynamically building presentations in different ways and with different strengths (Not and Zancanaro, 1998, and Petrelli et al., 1999). A presentation is created on the fly. It is composed of an audio message (generated by assembling pieces of messages), a set of potentially interesting links, and a map or a picture valid for the discussed object. A presentation can vary in terms of: (i) the selected content; (ii) the proposed links; (iii) the language used (style and form); and (iiii) the system initiative (ranging from a fully guided tour to delivering information only upon explicit request). Selecting the proper content and links, using the most suitable language, and proposing the right level of visiting support depend on the guesswork the system makes observing visitor behavior. As described above, physical and hypertextual steps compose a visit path. The system has to interpret both steps as user input. While the link selection using a pen on the palmtop screen is explicit, moving towards, stopping, and moving away from an exhibit are signs of visitor's attitudes, but they are not straightforward. They have to be interpreted.

[2] HyperAudio is at the basis of a richer scenario that is being exploited, jointly with other partners, in HIPS, a European project of the Esprit I3 program, (http://marconi.ltt.dii.unisi.it/progetti/HIPS/). The HIPS consortium includes: University of Siena (Italy, coordinating partner), CB&J (France), GMD (Germany), ITC-IRST (Italy), SIETTE-Alcatel (Italy), SINTEF (Norway), University College Dublin (Ireland), and University of Edimburgh (Scotland).

4 Getting Off on the Right Foot

Good initial hypotheses are instrumental when the interaction is far from the well-known direct manipulation paradigm. When the HyperAudio project team tried to imagine visitor-system interaction, they did not receive any support from the literature, nor from previous experiences. Moreover, the peculiar scenario further complicated the task. In a museum, the attention of a visitor is mainly focused on exhibits. Therefore, the time spent interacting is possibly low and distributed all along the visit. This means that HyperAudio guesses have to be based on a few details: a moving, a stop, and a single click. Thus, a reliable profile is vital. To overcome the gap between current knowledge and design needs, a case study was planned. An interdisciplinary group, involving people with background in psychology, human computer interaction, and artificial intelligence, was set up. Applying a consultative design methodology, a survey study was planned. Requirements were of preliminary data on visitor's attitudes toward and behavior in museums. In that case, reliable results required a broad sample of observations. Thus, the questionnaire was selected as the more suitable tool to collect relevant information on visitor profiles.

The aim of the study was to get a precise idea of how people visit museums and of what their feelings are. The final goal was to draw stereotypes (Rich, 1983) identifying the major dimensions affecting visitor behavior, feeling and attitudes. The study was not intended to be a survey of museum visitors, describing for instance the average age or profession. On the contrary, here personal data are of interest if (and only if) they match a typical behavior. Age, for example, may explain variations in attitude towards technology if elderly visitors prefer human guides, while younger ones enjoy using computer guides. This information would affect interaction preferences, a major aspect of the initial user profile. Accordingly, the system is set for a completely guided tour or, alternatively, it proposes a highly interactive visit.

As a working hypothesis, we assumed that through stereotypes, we could identify visitors categories by analyzing a short questionnaire (10 items at most) the user would be required to fill in at the beginning of the visit. This because we expected that visitors would be easily categorized using "classical" dimensions such as age, profession, education, specific knowledge or background. Such a categorization would allow setting important features in the user profile, such as language style (expert vs. naive), preferred interaction modalities (led by the system vs. the user), verbosity (depending on the available time). As a typical scenario, we imagined an individual visitor, going to the museum to visit it as a whole. We also assumed that the behavior should affect the dynamic part of the user model, i.e., user knowledge and user interest. Thus, jumps, skipping and staying in front of an exhibit would update the interest model, while the request for information would affect interests and knowledge. Finally, the rate of interaction would be a measure of preferred modalities.

5 The Questionnaire and the Case Study

The design of the questionnaire was guided by several constraints arising from field research. In particular, an accurate and quick way to collect reliable, self-reported information from visitors

was needed. Questionnaire topics were defined on the basis of the literature relevant to museums. The five topic areas are listed and commented below.

- **Personal data profile** contains questions about age, sex, education, job, etc. It has the purpose of providing a sketch of the compiler.
- **Museum habits** collects information about frequency of museum visits and preferences (e.g., visiting alone or with a partner). It was introduced to complete the personal profile in the museum visit perspective.
- **Context of the current visit** moves the focus to the visit just finished. Information on general motivations for the visit was collected here.
- **Course of the current visit** was intended to clarify the use of guides (from labels to human guides) as well as the duration and the purpose of the visit.
- **Styles of visit** aims to clarify different dimensions of visiting styles, to say how people behave (e.g., stay with the companion all the time), how they feel after (e.g., afraid of having missed something important), or their attitudes towards guided tours.

The final version, as derived by a pilot study, was composed of 26 items, requiring around 10 minutes to be filled out. A page describing the purpose of the study introduced the questionnaire. For most of the items, participants were required to tick the appropriate answer from a set of given alternatives. In the "styles of visit" section participants had to express their level of agreement with 11 statements describing different behaviors or attitudes. Answers were modulated on a 5-point Likert scale. The survey was conducted from October to December 1997. Data were collected in three museums focusing on topics related to the natural sciences: *Museo Tridentino di Scienze Naturali* in Trento (Natural Science); *Museo Civico di Storia Naturale* in Verona (Natural History); *Museo dei Fossili* in Bolca (Fossil Museum). The heterogeneous sample should increase the external validity of the study, allowing to generalize findings to the class of Natural Science/History Museums. In total, 250 questionnaires were collected: 97 in Trento, 102 in Verona, and 51 in Bolca.

When leaving, visitors where asked to take part in the study by museum staff. This procedure was convenient, on the one hand, because it did not required experimenters to stay at the museum, but, on the other hand, it did not allow for any control over sampling. For instance a bias might affected the sample of Verona where teachers and professors seemed to be a preferred target. Nevertheless, we considered the whole sample reliable since we are not interested in museum statistics: we are interested in finding out if and how personal characteristics are relevant to predicting visitor behavior.

6 From Empirical Results to Briefings

Empirical results pointed out relevant and unexpected aspects that urge designers to rethink the system. In the following the main outcomes are presented and discussed. The focus is on result interpretation and on user modeling guidelines. The experiment and analysis report (Petrelli et al., 1998) is available at http://ecate.itc.it:1024/petrelli/publications.html.

6.1 Museums are Social Places

The major unexpected result regards the importance of the social dimension. This clearly emerges analyzing either self-reported behavior or preferences. Only 5% of visitors went to the museum all alone. The majority participated in a guided tour (45%), while 20% went to the museum with friends. Moreover a high percentage of people came with children (30%), showing that families are an important target for natural science museums. From these results, it appears that visiting a museum is mainly a 'social event', an experience to share with important others. Family, friends and partners play an important role in making the visit a valuable experience. This finding clearly contradicts our hypothesis stating that visiting a museum is mainly a personal experience. As a consequence, the user model has to become a group model too, because needs, expectations and behavior of groups are very different from those of individuals. Indeed, our data confirm Falk and Dierking (1992): persons tend to behave differently when visiting museums with friends or family. When visiting museums with friends, adults are mainly concerned with the nature and the content of the exhibits. Even if discussion is stated as a very important point, their attention is more focused towards what they see than towards their own social group. On the contrary, adults with their family typically focus on their children, on making the exhibition understandable and the visit enjoyable. Before the visit, they are used to gather information significantly more often than adults with friends. This finding has a strong impact on user modeling. Indeed, it is plausible that the family profile has a higher background than the most part of single visitors. Moreover, it is known that family visit depends on what attracts children and that family learning (i.e., when adults and children learn together) derives from family discussions (Borun and Dritsas, 1997). Therefore, the system has to support family discussion besides proposing a standard comment on the exhibit. The content could be organized as question-answer, because this format stimulates discussion and self-exploration. System proposals (e.g., presenting further information when a visitor remains in front of the same object) should be reduced in number and form, so as not to hamper family discussion and exploration. In terms of user modeling, a new attribute of linguistic style has to be introduced (question-answer vs. narrative presentation), and system initiative (i.e., preferred interaction modality) has to be fine-tuned.

Our data suggest also that museums play an important role in pupils learning. In the sample 36% of participants were teachers who came with the class. This experience is very different from that of being taught in a classroom: since exhibits replace the teacher as the central medium of instruction, museum learning is self-directed rather than directed by the teacher. In this context, the main purpose of a guided tour should be to have the pupils stay in the exhibits longer, learn more, and return to the museum frequently throughout their lifetimes (Falk and Dierking, 1992). Moreover, children learn well together. As a consequence, an electronic guide should take most of the group visit. It should stimulate students in working together, have them solve problems in groups, and share their solutions. Therefore, the system should shift from a guiding style to an "informal" tutoring style, proposing quizzes and problems as well as suitable explanation of the exhibits. This is of course a completely new and exciting scenario.

6.2 Guide without Dominating

Another important result is the positive attitude towards guidance. On the average, participants reported to strongly appreciate guided tours. Attitudes were found to be consistent with reported

behavior. More than half of the sample (58%) used a guide during their actual visit. One of the major goals of the survey was to evince factors influencing the decision of using a guide. Such a decision appears to be correlated with familiarity with the specific museum. The more visitors are used to going to a museum, the more they will use a guide. In addition, we found that the major part of people who came to see specific objects used a guide, while people who came to visit the museum in general did not. These results are counterintuitive. Indeed, we expected that familiarity with museums should reflect an autonomous style and self-sufficiency.

Other interesting results regard the number of non-first-time visitors. It is surprisingly high (68%). This variable was found to affect the time of the visit. Contrary to our expectations, those who came to see specific objects stayed in the museum longer than those who wanted to see the museum in general did. Again these results have strong impact on user modeling. They support the idea that each visitor comes to the museum with a personal agenda in mind. Some come to get an overview, others to see specific objects, or to learn, or to relax. An accurate user model has to take these aspects into account because they change the meaning of behavior. For example, when a visitor is not coming for the first time, skipping objects has not to affect the interest model decreasing the weight of the object. Similarly, pondering an object for a long time is a sign of interest, but the system should not interrupt self-exploration with further explanations. A *beep* may be enough to signal interested visitors about available information. First-time visitors have to be considered apart because they have to be motivated and engaged if they want to learn and return. One way to stimulate first-time visitors is to create expectations (Finn, 1985). For this purpose, the system may use the very beginning of the visit, when people spend a few minutes in finding direction, to give a sketch of the possible visit. Then, each visitor would follow his/her preferences adopting a personal path and rhythm for the visit. Some visitors will have a systematic and intensive look, others will select objects to look at, and many will "cruise" the museum (Falk and Dierking, 1992). By monitoring this behavior, the system can identify relevant aspects to modify the user model.

6.3 Technology Must Be Hidden

Results show that the most liked museum visit is guided by a member of the museum staff (53%). Almost 21% of the sample prefer catalogues or books, and 19% to visit museum without any support. Only 7% reports to like using technological devices. These data lead to several important considerations. First of all visit aids are highly appreciated. Secondly, the preferred solution is still represented by human experts. This can be due to the social aspect of the situation and to the possibility of interacting with the source of knowledge to obtain the most appropriate information. It can also suggest that listening to a human guide is the easiest way (i.e. less tiring and constricting) to get information.

To conclude, the low percentage of people who prefer technological devices has to be taken into account. It can be partially explained by the reality of Italian museums, where technology is still underrepresented, or by the comparison with human guides, but it could also reflect a negative attitude towards technology in the context of a museum visit. This suggests that some visitors may never explicitly interact with the system. Thus, the user model has to take into account the possibility of facing a completely passive visitor: the system has to rely on a default setting that actively proposes a visit. This also fits the requirement that systems for public use have to be "walk-up and use", i.e., no training phase is needed to operate them. However, active users can take the initiative

getting the most from HyperAudio support. For those visitors who like to interact with computers, the system has to adopt appropriate strategies, since the attraction lasts only for few minutes (Serrell and Raphling, 1992). For example, it could propose a game to measure background knowledge, a user characteristic particularly important and that is difficult to self report about.

6.4 Ask Only the Essential

Another unexpected outcome is that personal data, like age, profession, education etc., do not characterize the visitor. For example older people do not show different preferences than younger one; education is high for almost all museum visitors (91%); professional interest does not influence visit behavior. This means that personal data are not as important as expected and should be ignored in the initial questionnaire.

Secondly, a relative dislike for technology suggests reducing the explicit interaction to the very minimum, possibly even eliminating it. Filling out a questionnaire at the beginning of the interaction, a technique widely adopted in user modeling community (Fink et al., 1997, Strachen et al., 1997, Murphy and McTear, 1997 just to mention a few), does not seem to be the best solution in this context. Indeed, the negative attitude towards technology, the strong attraction of the exhibits, the small amount of time devoted to computer interaction suggests limiting system requests as much as possible. Furthermore, the four attributes that explain the most of visit and interaction variability and that the system must know to start can be inserted by museum staff when the HyperAudio guide is handed out. They are:

- **Family, school or adult**: user modeling does not only concern a single person but also has to address groups of people with a common goal. This attribute affects language style (narrative vs. question-answer) and complexity (simple terms vs. complex ones to stimulate discussion) as well as the system reaction level (high initiative of the system vs. user explicit request).
- **First-time visit**: this distinction affects content selection. For first-time visits an overview is proposed, while for following visits a deepening is preferred. This attribute also affects the dynamic part of the user model, mainly the interest, because some behavior does not have the same meaning in the two cases, e.g., skipping objects will not be interpreted as disinterest in follow-up visits, while it is one of the best guesses for a first-time visit. It also has an impact on the next attribute evaluation.
- **Foreseen visit duration**: the more time available the broader the visit can be. It affects system verbosity in terms of numbers of objects proposed or in-depth descriptions.
- **Interaction preferences**: this is an important attribute of the visitor's profile since it is used to describe passive visitors. Unfortunately it does not appear to be related to any personal or visit characteristics. Partially it can be inferred by previous attributes, for example family visitors may prefer a smooth interaction, while adults on their first-time visit could appreciate a very active guide.

Note that this questionnaire does not portray the isolated user but, better, it describes user, visit and context, the three components relevant for an effective usage of the electronic guide.

7 Conclusions

The outcome of this study has demonstrated the high level feedback that a user-centered approach can provide, even with low cost methods. The results incited designers to rethink some basic assumptions. Indeed, the idea of using stereotypes had to be set aside in favor of a broader view, where user, visit, and context were the key points. It is worth noting that no prototype was developed for the study. Hence the whole system could be easily redesigned. A sketch of the current user model implementation is given in Sarini and Strapparava (1999), in the poster section of this volume. Given the very interesting results, we are going to follow the user-centered design approach exploring games to measure background knowledge through paper mock-ups.

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User-centred Design of Flexible Hypermedia for a Mobile Guide Reflections on the HyperAudio Experience

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Abstract. A user-centred design approach involves end-users from the very beginning. Considering users at the early stages compels designers to think in terms of utility and usability and helps develop the system on what is actually needed. This paper discusses the case of HyperAudio, a context-sensitive adaptive and mobile guide to museums developed in the late 90s. User requirements were collected via a survey to understand visitors' profiles and visit styles in Natural Science museums. The knowledge acquired supported the specification of system requirements, helping defining user model, data structure and adaptive behaviour of the system. User requirements guided the design decisions on what could be implemented by using simple adaptable triggers and what instead needed more sophisticated adaptive techniques, a fundamental choice when all the computation must be done on a PDA. Graphical and interactive environments for developing and testing complex adaptive systems are discussed as a further step towards an iterative design that considers the user interaction a central point. The paper discusses how such an environment allows designers and developers to experiment with different system's behaviours and to widely test it under realistic conditions by simulation of the actual context evolving over time. The understanding gained in HyperAudio is then considered in the perspective of the developments that followed that first experience: our findings seem still valid despite the passed time.

Keywords: User Centred Design, Flexible Hypermedia, Mobile Guides, Content Adaptation, Development Support Environments.

1 Introduction

To guide the design of information systems towards actual user needs and expectation, human-computer interaction researchers have developed appropriate methodology and techniques. The user-centred system design (UCD) approach revolves around end-users. Potential users are involved from the very beginning and are regularly consulted for the evaluations of incremental prototypes (Preece et al., 2002). Though, a rigorous user-centred design does not start with a prototype, but with an extensive analysis of potential users, tasks, and environment (Hackos & Redish, 1998). Multiple techniques can be used and the analysis of the data collected

[1] The work discussed in this paper was carried out when the author was at ITC-irst in Italy.

should specify user requirements and system features. This starts an iterative process of user evaluation, redesign, and prototyping that ends when the system satisfies usability criteria (Nielsen, 1993; Harston, 1998).

UCD principles have been rarely applied throughout the whole design of adaptive systems. When adopted, user studies have affected the design of the user model, sometimes the interface layout (for example Bontcheva, 2001; Vassileva, 1996), but a pervasive user-centred design has hardly ever influenced the information organization or adaptation rules[2]. Instead, a deep understanding of user, usage, and environment is instrumental in identifying what is the most appropriate content for each user class and can help in deciding where simple or complex adaptive mechanisms have to be applied. As a matter of fact adaptive systems can be implemented by using very simple techniques (e.g. triggers associated with users' actions) or highly sophisticated ones (e.g. deductive and inductive system reasoning) (Kobsa et al., 2001). Deciding about the needed complexity is a design decision and should be driven by the knowledge acquired on users and tasks during preliminary studies.

However, a good starting is not enough to assure the final adaptive systems would be user-compliant. UCD advocates an iterative process where incremental prototypes are developed and tested. Applying this principle in the context of adaptive systems requires the adoption of a modular architecture to support experimenting with different options. Indeed designing an adaptive system is not limited to working out a single solution; rather "the designer [of an adaptive system] specifies a number of solutions and matches those with the variety and the changeability of users and the environments" (Benyon, 1993). Conceiving different solutions implies for the designer a wide exploration of the range of alternatives in an iterative testing process. Moreover the more complicated the scenario the more difficult the exploration, given that adaptivity is then not limited to adjusting to users: factors such as where the action takes place, the device the person is using, and the communication infrastructure are all suitable subjects for adaptivity (Petrelli et al., 2001).

To assure that the adaptation is working as expected tests have to be done on real data. Indeed the effectiveness of an adaptive system can be judged only by assessing the actual format that is delivered to the user. In mobile and adaptive hypertext, for example, predicting how a page is composed at run time can be challenging: content and links included do not depend on the actual status of the user model only, but also on the current *interaction context* (where the user is, whether she is moving or not, what she is looking at,...). An extensive testing becomes mandatory to assure a smooth and coherent flow of information. Authoring data and extensive testing have then to be done in pairs. Although authoring support for adaptive hypermedia has always been considered important, only recently it has received the needed attention from both practical and theoretical perspectives (Calvi & Cristea, 2002; Cristea & Aroyo, 2002; Weber et al., 2001; De Bra et al., 2003). Still, data creation and rules testing are kept apart, possibly because content creation is considered the task of domain experts while rule testing is developers' responsibility. When the scenario of the interaction is not limited to screen, keyboard, and mouse, as in the case of mobile guides, an environment for testing how each context component contributes to the final adaptation is a valid support for system development. Designers of adaptive systems would benefit from a tool that supports fast prototyping and testing of new promising ideas. The same environment should then be used to produce the annotated data and for testing its adapted form as delivered to the user.

As discussed above, applying UCD to the design of adaptive systems is particularly challenging because the behaviour of the final system is intended to dynamically adjust according to multiple parameters, i.e. user preferences, knowledge and behaviour, and interaction context.

When, in the mid 90s, we first started working on one of the first prototypes of adaptive and mobile museum guide (called HyperAudio, Not et al., 1997a), not much experience was available in the Adaptive Hypermedia community on how to export principles of adaptivity to mobile applications, nor much skill was available on the application of UCD to adaptive systems. In the initial critical phase of the project we faced problems like envisaging credible scenarios of use, identifying parameters for adaptivity, designing content and adaptation rules in a suitable way. The initial aim we had in mind was to offer the visitor personalized information centred on his/her current standing position. The envisaged interface was a web-based layout with an active involvement of browsing users. What the final development of HyperAudio offered instead was an experience of freely moving in an information space and automatically receiving tailored information. We

[2] Exceptions are web-based recommendation systems that make use of massive logs of user profile/behavior to select the most appropriate information and in general to implement adaptivity (Kobsa et al., 2001).

started with the idea of an adaptive hypermedia displayed on a PDA for browsing and ended with an intelligent system that was respective of social and relational conditions, of visiting pace, of visitor's interests. It was intended to be a guide; it ended being a companion.

This deep change in how the adaptation should be manifested was due to an extensive survey of museum visitors coupled with an explorative design, as explained in the rest of this paper. The deep analysis was not limited to descriptive statistics (e.g. the percentage of visitors who arrive at the museum already informed) but also included correlating different data (e.g. those more likely to be families) and ultimately designing solutions (e.g. consider families as a separate user class). Results supported the decision to go for a simpler and lighter architecture but a more sophisticated data structure than originally conceived.

The experience we gained in the small scale HyperAudio project contributed ideas to HIPS, Hypernavigation In the Physical Space (Benelli et al. 1999), a broader European project funded in the i3 (Intelligent Interactive Interfaces) framework, where we further explored the UCD approach by creating a workbench for fast prototyping and off-line testing. The use of such development environment closed the cycle of UCD applied to adaptive systems: we could test different solutions by simply "plug-and-play" different modules (e.g. different user models, different adaptation rules), and we could verify the system was behaving (i.e. adapting) as expected by performing a set of off-line tests.

Since HyperAudio initial implementation, many other systems have been developed according to the principles of seamless and personalized interaction with the surrounding space (see section 7 for some references), however, as an insight in the evolution of design, we consider our experience still valuable and unique after all these many years. This paper reports on HyperAudio experience of applying the UCD approach when developing a handheld museum guide that adapts its behaviour to users, their position in the space, and their interaction with both the guide and the environment. The architecture of the HyperAudio system and its sophisticated adaptive mechanisms are discussed in section 2. The user study conducted to understand Science Museums and their visitors is described in section 3; the redesign of the first ideas of user model, data structure, and adaptation rules follow in section 4 together with some scenarios of use. A discussion of the importance of an interactive environment for fast prototyping and component testing for design purposes follows in section 5, while section 6 discusses the use of the same environment for data editing. Finally, section 7 presents related work in immersive and adaptive mobile guides.

2 HyperAudio: Location Awareness and Adaptivity

2.1 The History

The late 90s saw a substantial increase in the work done in adaptive hypermedia towards the most diverse domains (Brusilovsky, 2001). That was also the time when the idea of adapting an existing hypertext to the interacting user by means of a user model came into contact with research into natural language text generation. Researchers in natural language processing were developing dynamic hypertext, where pages are generated on the fly on the basis of some domain knowledge representation, according to a user model (Oberlander et al., 1998; Milosavljevic et al., 1996). The First Flexible Hypertext Workshop (Milosavljevic et al., 1997) was a forum for discussing and comparing the two approaches and other hybrid solutions.

At the same time, the human-computer interaction community was exploring the new world of mobile devices (Johnsons, 1998). The ideas of augmented reality and ubiquitous computing of the early 90s (CACM, 1993) were maturing into exciting experimental systems able to locate the user's position via sensors, and to react accordingly, e.g. by switching on/off electronic devices or transferring data to support the user's task (Bederson, 1995; Abowd et al., 1997).

Our project started in 1997 with the aim of fusing these hot issues in the areas of Adaptive Hypermedia, Natural Language Generation and Human Computer Interaction. The challenge was to create a *smart* location-aware system for delivering personalized hypermedia to an itinerant user. Museums were chosen as a promising application test-bed because visitors move in the physical space looking for interesting exhibits and wishing to acquire information, deepening their knowledge and interests. The museum was then thought as a sort of augmented environment, sensitive to visitors' movements, where an information hyperspace can be associated to each exhibit; the visitors explore that hyperspace during the physical visit (Not et al., 1997a,

1997b). The envisaged system would automatically play an audio comment as soon as the visitor approached an exhibit. Since the main communication channel was intended to be audio and the information was presented with a hypertextual paradigm we chose *HyperAudio* as the project name (Not et al., 1998). However prominent, audio was not indented to be the sole presentation medium: a dynamically created hypermedia page would display images, text, and links potentially interesting to the visitor. The presentation (audio message and hypermedia page) would be adapted to the interacting user but also to the broad interaction context, including the physical space, the visit so far, the history of interaction, and the narration.

2.2 The Challenge

In the HyperAudio project we interpreted the term "adaptation" in its broadest sense. The system had to adapt its behaviour to serve at best the visitor's goal of enjoying the museum, finding it rewarding and useful. Thus the system had to adapt the presentation content and navigation hyperlinks to each visitor, but also had to take into account the prominence of the physical space, the objects of interest, and the visitor's position with respect to them. The guide had to select content about the object in sight or apply strategies to attract the visitor's attention towards other objects. Moreover what the visitor has already seen (in the physical space) or heard (from the hypermedia space) had to be considered: a properly designed adaptive guide would not propose the same information twice to a visitor coming back to an already seen object.

However, the user model, the space model, and the visit history were not considered sufficient for assuring a smooth interaction with HyperAudio. The sequence of messages delivered to the user had to be a single smooth narration, thus the composition of the presentation had to consider rules for effective content structuring and linguistic realization according to the current discourse context. For example, during a presentation, a deictic reference to an object in the physical space, like "*this is* the fossil of an ancient crocodile", is valuable to reinforce coherence between vision and text. On the other hand, other appropriate lexico-grammatical patterns may be used to manifest certain kinds of semantic relations between text units which reinforce *texture*, i.e. the property of a text of being perceived as coherent (Halliday & Hasan, 1985). This happens for example when appropriate anaphoric referring expressions are used, like the pronoun "it" in "*it* was found under a thick rock stratum.", or when markers are used to make explicit the rhetorical relations between content units, like "conversely" in the following example "Reptile skin is covered by keratin or horn scales. Their position and thickness prevent desiccation. *Conversely*, amphibians have naked skin that lacks protective devices.".

The overall HyperAudio challenge was therefore to select the most appropriate content and links with respect to the current visitor's interests, the environment, and the interaction so far, and to polish the final presentation by adjusting the narration. The following section discusses the adopted solution.

2.3 The Hardware and Software Architecture

In the HyperAudio scenario, the visitor is provided with a palmtop (an Apple MessagePad) equipped with headphones on which an infrared receiver is mounted (Figure 1). Visitors are asked to position the infrared receiver under their chin, in order to ensure that only signals coming from the front are detected. Each meaningful physical location (e.g., exhibit, door, or passage) has a small power-autonomous infrared emitter that continuously sends a uniquely identifiable code. Thus the physical space is partitioned into sensitive zones allowing the system to identify the visitor's position and orientation (the *Space Model* in Figure 2).

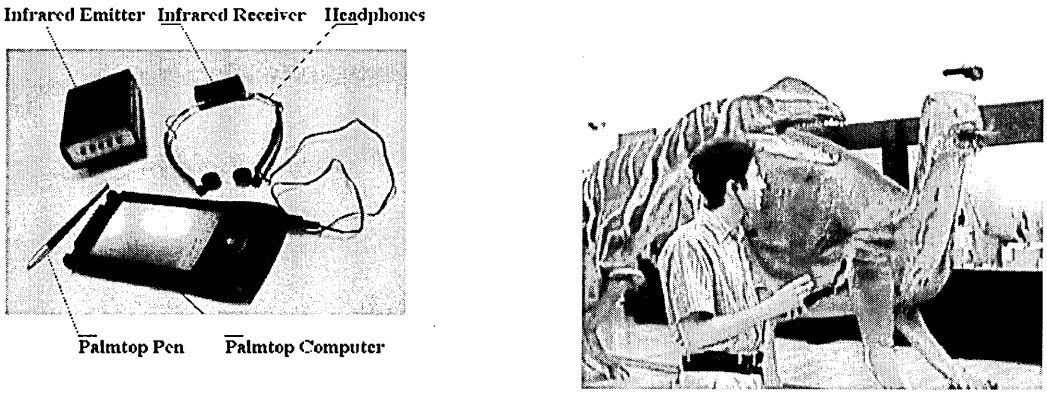

Figure 1. HyperAudio hardware.

When the user approaches an exhibit, the corresponding infrared signal is detected (*implicit input*), the system is triggered and a description (*presentation*) of the object in sight is dynamically composed. The presentation has an audio message and an image relevant to the object described, plus a set of suggested links. The pointing of the pen on a displayed link (*explicit input*) activates the system as well, as outlined in Figure 2.

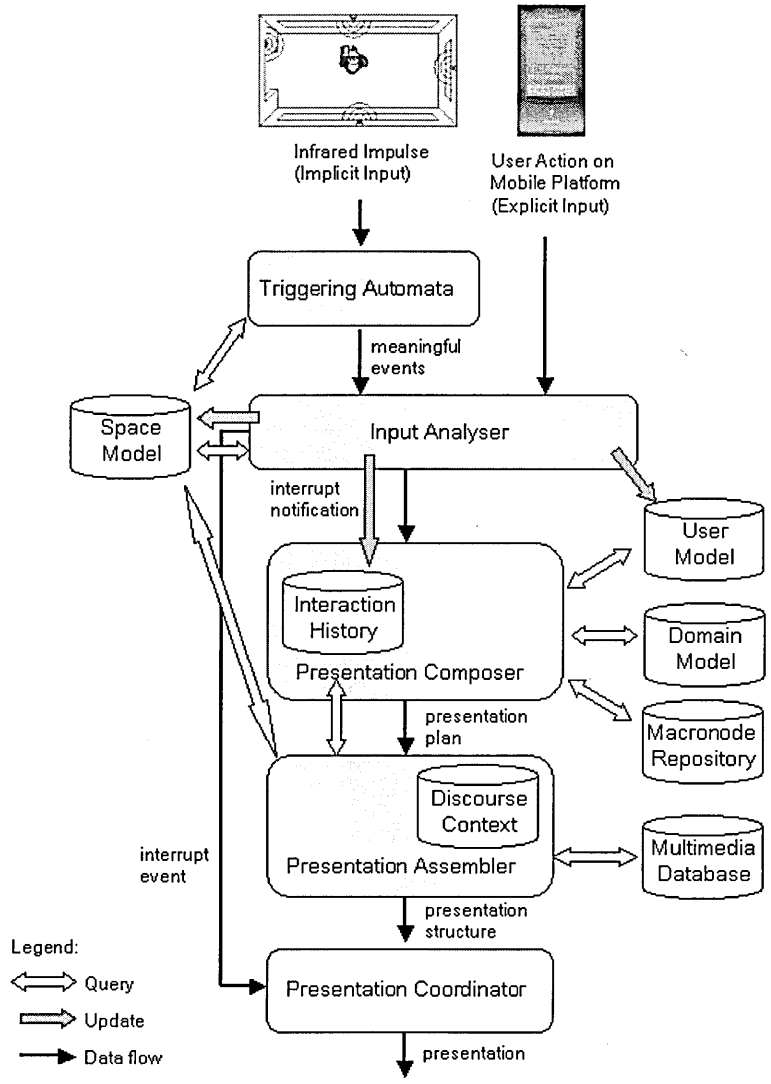

Fig. 2 The HyperAudio software architecture.

While the selection of a link on the interface is clearly a request, the implicit interaction generated by a movement has to be validated. When an infrared signal is detected, the *Triggering Automata* queries the *Space Model* for the user's current and previous positions. By comparing the two it determines whether the user entered/exited a sensitive area and how much time she spent in each cell of the augmented environment; quick changes of positions (i.e. different signals received in a fast sequence) are discarded as noise, others are passed on to the *Input Analyser* as *meaningful events*.

The *Input Analyser* decides the most appropriate reaction to implicit and explicit inputs. For example it sends an *interrupt event* to the *Presentation Coordinator* if a different cell is entered (i.e. the visitor significantly changed her position) and asks the *Presentation Composer* for a *new presentation* appropriate to the new position. It also updates the *User Model* following the visitor's actions; for example, stopping a presentation shows negative evidence and the interest model is updated accordingly.

The *Presentation Composer* is responsible for planning the overall presentation that integrates (where appropriate) object descriptions, images, links for follow-up information requests, and oriented maps. To create a *presentation plan* the composer traverses an annotated multimedia network stored in the *Macronode Repository* and uses the knowledge in the *Domain Model,* the *User Model,* and the *Interaction History* to

decide which nodes will be included in the audio presentation, which will become links and which will simply be ignored (see sections 2.3.1 and 2.3.2). The sequence of presentation plans is cumulated in the *Interaction History,* which keeps track of what has been presented to the user so far.

The *Presentation Assembler* takes the presentation plan and actually assembles the final message. Here is where the linguistic arrangement takes place with respect to the current *discourse context*, as explained in 2.3.2. Finally the assembler substitutes symbolic names with the appropriate multimedia data (audio files, images and maps) and asks the *Presentation Coordinator* to physically deliver the presentation to the user.

2.3.1 The Annotated Data Structure: Macronode Formalism

Adaptive hypermedia are based on the idea that pages and links are appropriately annotated so that personalization can be computed at run time. The amount and the type of annotation depend on the system (Brusilovsky, 1996). For example an HTML page can be annotated with structured comments that indicate when a piece of information (text or link) has to be included (De Bra & Calvi, 1998). However dynamic hypermedia do not keep any underlying network, but generate each page on the fly from some knowledge representation (as in ILEX (Oberlander et al., 1998)). The solution adopted in HyperAudio is hybrid: there is a richly annotated network of information units from which presentations are built, but nodes do not correspond to pages but rather to fragments of a page (Not & Zancanaro, 1998). Strategies borrowed from the field of natural language generation are used to select and structure information units and properly assemble multimedia pages (where audio plays a major role), adjusting the linguistic realization of the message to guarantee coherence and cohesion of the final presentation.

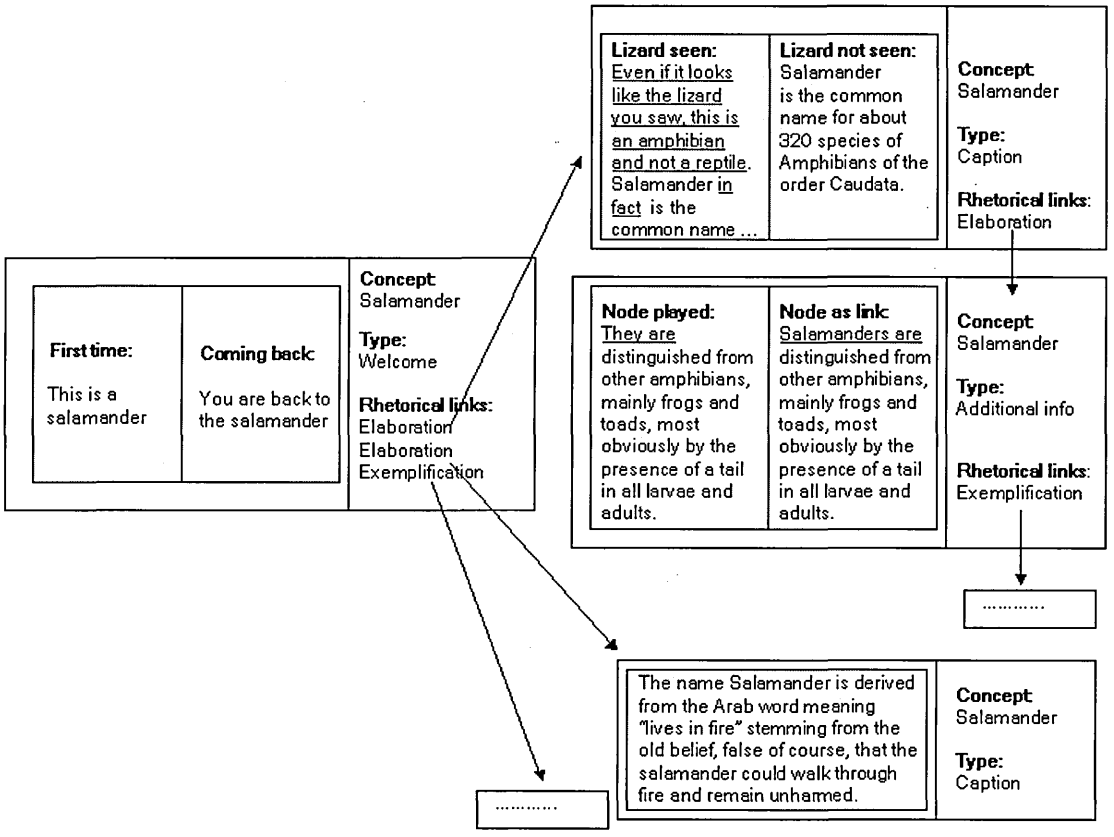

Figure 3: A network fragment of (simplified) Macronodes: in the content part (left) linguistic variations are underlined.

Content selection is enabled by the fact that each information unit, which we call a *macronode*, contains a shallow semantic annotation that describes its main topic (i.e., what the node is about) and its function in the

narration (i.e., introduction, core information, or additional details). Macronodes in the repository are related to each other by rhetorical relations (Mann & Thompson, 1988) that help describe the semantic relations between the various information units and how they could be textually integrated coherently. A macronode is internally organized to allow for some linguistic variation. Figure 3 shows a sample fragment of macronode network. The linguistic adjustements are actually computed at run time by the Presentation Assembler which selects from a conditional graph (see Figure 4) the most effective realization according to constraints over the space model, the discourse context and the interaction history.

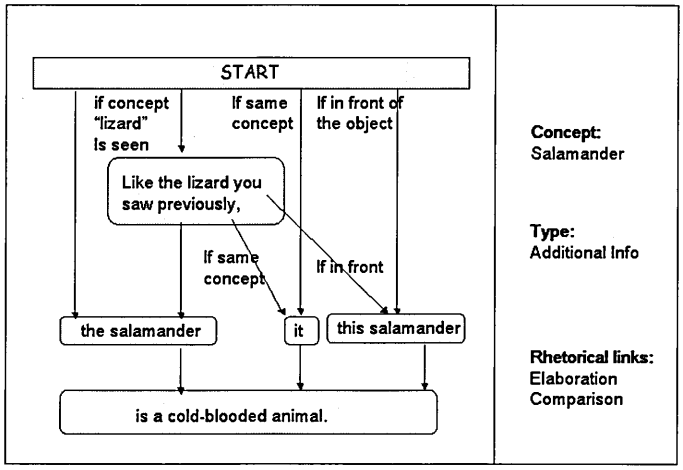

Figure 4. The macronode internal structure.

The content of the macronode shown in Figure 4, for example, could result in the following alternative sentences:

- "like the lizard you saw previously, the salamander is a cold-blooded animal"
- "like the lizard you saw previously, it is a cold-blooded animal"
- "like the lizard you saw previously, this salamander is a cold-blooded animal"
- "the salamander is a cold-blooded animal"
- "it is a cold-blooded animal"
- "this salamander is a cold-blooded animal"

In the original implementation of macronodes, all linguistic adjustments of the macronode's surface form were realized through conditional text, manually specified by the content author with the aid of a macronode editor (Petrelli et al., 2000). The text was then to be read and recorded by a human actor. Further research has investigated the integration of this manual approach with the automatic generation of sentences or portions of sentences (e.g. the insertion of pronouns or deictic references, or the reference to previously seen objects), to relieve the author's burden when a speech synthesizer is available (Not & Zancanaro, 2001).

2.3.2. The Adaptation Techniques: Input Analyser, Presentation Composer, and Presentation Assembler

As described above, HyperAudio has three points where adaptivity is realized. Different sets of rules are used by the different modules for deciding (i) if a presentation has to be composed, (ii) eventually composing it, and lastly (iii) tuning its final linguistic form.

The first set is used by the Input Analyser and includes rules such as "if the visitor is leaving an object, then interrupt the running presentation" or "if the visitor approaches a new object but the current presentation is general, then let it finish".

Rules applied by the Presentation Composer decide about content and links selection, as well as the length and the inclusion of new concepts. Strategies are encoded to avoid presenting already known information, to choose the kind of information for which the user's interest is high, to present new information when the user goes back to a previous topic. In addition, rules checking the rhetorical links between macronodes control the

length of an elaboration chain or the inclusion of background information to clarify a topic.

The Presentation Assembler takes care of tuning the linguistic form of the presentation considering the current status of the Space Model, the Discourse Context, and the Interaction History; it applies rules such as "if the user is in front of the object, then select the text containing a deictic reference (e.g., 'this is') " or "if a concept has been already introduced (e.g., the object has been seen), then include an explicit reminder (e.g., 'you saw previously') ".

2.4 User Interface

The design of the interface was based on two basic constraints: (i) the MessagePad screen has low definition; and (ii) visitor's attention is devoted to the exhibition. As a consequence, the audio channel mediates the descriptions of the exhibits whereas the graphical interface is reduced to the minimum. Figure 5 shows a typical screenshot: a central picture provides the context of the current description, and links to concepts related to the object in sight are displayed as buttons. Those above the picture lead to other related concepts, those below the picture lead to elaborations of the same concept. By clicking on the buttons the user can explore concepts related to objects located elsewhere in the exhibition. A map, displayed by clicking a further button, shows the position of the object currently described, whether in the room or elsewhere. Finally a "back" enables repeated listening to previously played presentations.

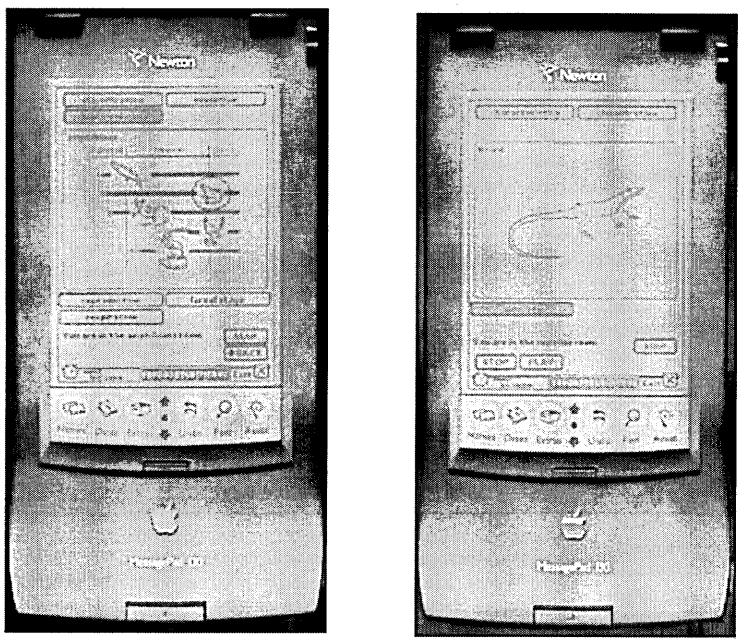

Figure 5. The interface layout as displayed (a) in the reptiles room, and (b) in front of the lizard.

3. User Requirements Elicitation

As mentioned in section 1, UCD typically starts with an extensive analysis of potential users, tasks and environment that feeds the design of the first prototype. However given the novelty of the topic we decided to test the actual feasibility of the system at the same time as the user study was going on. A first functional prototype was implemented in Spring 1997 as a proof of concept. A user study was then set up to elicit user requirements and obtain ideas for the design of the user model and adaptation rules. The main purpose was to identify user characteristics that would compose the profile to be implemented as stereotypes (Rich, 1989). That seemed the best choice considering the constraints of using a PDA: adaptation had to be simple and light, quick and effective from the very beginning.

Visitors' behaviour has been studied for long and a whole museum literature is devoted to this topic. However this extensive knowledge was of limited help in defining stereotypes and adaptivity, since the focus is generally on how exhibition layout affects moves and how to make it effective. Since data on how personal traits relate to behaviour were not available, a user study was set up. We hypothesized that visitors' behaviour could be predicted using "classical" dimensions such as age, profession, education, specific knowledge or background. This categorization would allow setting features in the user profile, such as language style (expert vs. naive) or preferred interaction modalities (led by the system vs. led by the user). The study was not intended to be a survey of museum visitors; personal data were of interest if (and only if) they correlate with a predictable behaviour. The objective was to discover, for example, whether aged people have a negative attitude toward technology and would prefer to be guided; this would militate for a non-interactive setting of HyperAudio; conversely, a positive attitude expected from younger people would motivate a highly interactive mode.

3.1. The Case Study

To find out if relations between personal facts (e.g. age, specific interests) and the way museums are visited do exist, a survey was conducted. A questionnaire was organized around five topics:

- **A personal data profile section** asked for demographic information: Age, sex, education, job, and residence were selected as having potential for discriminating attitudes towards museums.
- **A museum habit section** complemented the personal profile. It collected data on how often the respondent visit museums and what are their preferred ways of visiting, e.g. alone, with a partner, with the family, or within a guided tour.
- **A context of the current visit section** focused on the just finished visit and asked if it was the visitor's first time in the museum, with whom they came, and the general motivation for the visit.
- **A course of the current visit section** collected opinions on the use of guides (from books to human guides) as well as the duration and the purpose of the visit.
- **A styles of visit section** collected general attitudes and opinions on different ways of visiting museums.

The final version of the questionnaire was composed of 26 questions, tested by a pilot study. It required around 10 minutes to fill in and was introduced by a page describing the purpose of the study. The survey was conducted from October to December 1997 in three museums focusing on topics related to natural science. As they exited, visitors were asked to take part in the study by museum staff and a total of 250 answers were collected.

3.2. Discovering Visitors' Attitudes

Empirical results revealed relevant and unexpected facts that required the designers to rethink their initial assumptions. The main findings are summarized in this section (for details see Petrelli et al., 1999).

The most unexpected and disappointing outcome was that personal data, like age, profession, education etc., did not account for respondents visit attitudes. Older people did not show preferences different to those of younger ones; education was high for almost all museum visitors (91%); professional interest had no impact. Thus, personal data would not predict visitor's behaviour and would not help in the adaptation process. As a consequence, asking for personal details in the initial form is of no use. Fortunately, other attributes were discovered which accounted for visit and interaction variability.

The social dimension emerged as an unpredicted important factor. Only 8% of visitors like to visit the museum alone; 24% prefer friends and partner; 20% choose organized tours; and a big 42% go with the family. Visiting a museum is mainly a 'social event' and being in a group changes the visiting pattern. Indeed, our data confirm Falk and Dierking (1992): people tend to behave differently when visiting museums with friends or family. When visiting museums with friends, adults are mainly concerned with the nature and content of the exhibits. Even if discussion is stated as a very important point, their attention is more focused on what they see than on their own social group. Conversely, adults with their family typically focus on their children, on making the exhibition understandable and the visit enjoyable. Family visits are led by children, and family learning (i.e., when adults and children learn together) derives from discussions (Borun & Dritsas, 1997). Our data showed also that families are more likely to arrive at the museum already informed than adult

groups. This indicated that classes of users had to be considered, with their different needs, expectations, and behaviours.

Another surprise was the number of non-first-time visitors, accounting for 68% of the sample. Being a frequent visitor was related to the type of visit and to the time spent visiting. Returning visitors came to see specific objects and stayed in the museum longer than those who came for the first time and wanted to see the museum in general. From this perspective the same behaviour may have a different meaning, e.g. skipping an object may indicate lack of interest, but this may not be the case for frequent visitors who have seen the object before. Thus a long-term user model (e.g. some kind of profile stored between visits) would be useful in such a context.

Visitors have a positive attitude towards guidance and use it if available (58% of our sample used a guide during their actual visit), regardless of personal attributes (e.g. age or knowledge). What accounts for the use of a guide seems to be familiarity with museums: the more visitors are used to going to museums, the more they use a guide. In addition, those who came to see specific objects used a guide, while people who came to visit the museum in general did not. These results are counterintuitive; we expected that familiarity with museums would reflect an autonomous self-sufficient style.

To reinforce the previous finding, only 7% reported liking using technological devices as museum guides. Most people liked visits guided by a member of the museum staff (53%), while 21% of the sample preferred catalogues or books, and 19% preferred to visit the museum without any support. These data led to several important considerations. First of all visit aids are highly appreciated. Secondly, the preferred solution is still human experts. This may be due to social factors and to the possibility of interacting with a source of knowledge, but it also suggests that listening to a human guide is still the easiest way to get information. Finally the general dislike of technology suggests that some visitors may never explicitly interact with the system. This completely passive behaviour of some users has strong implications, therefore the possibility for the system to provide a completely automatic visit was considered.

3.3. User Requirements and System Design

The survey study provided a deeper understanding of which are the important aspects of visiting a natural science museum. From this knowledge a set of user requirements were extracted:

- **Museum visit is a social activity**: groups have to be accommodated as well as single visitors.
- **Families (and schools) are important targets** and must be considered as distinct classes of users.
- **Families behave differently from adult groups**: families arrive with some background knowledge, the visit is driven by the children and learning comes from adult-children discussion.
- **Frequent visitors are important targets** and must be considered as a class.
- **Frequent visitors behave differently from first time visitors**: they see fewer objects and stay in the museum longer; this behaviour has to be accommodated.
- **First time visitors want a general overview**: they are not interested in details and have to be engaged if they are to return.
- **Attention is devoted to the exhibit or to the group** and not to the computer: the interaction has to be reduced to the minimum.
- **Guidance is welcome**.
- **Technology is disliked**.

The list was very different from the one expected, one where personal details would account for visiting attitudes; it became a tool for driving the interaction design and for generating new ideas. The anticipated interaction was also reconsidered. Before the study, the envisaged interaction was browser-based with text, image and links dynamically selected and composed; the audio message would direct the user's attention towards the PDA. Discovering that guided tours are well accepted and, more important, that interacting with technology is not a favoured activity changed our view. In this context[3], a system that autonomously decides

[3] In other scenarios this principle may not hold and control over the adaptive mechanism may be appropriate; however each solution has its own advantages and has to be considered in respect to each application (Jameson & Schwarzkopf, 2002). For example, when a proactive adaptive system is used to support activities in a daily working environment,

what to do (i.e., a self-adaptive system, Dietrich et al., 1993) was expected to have a greater appeal than one that asks for the user's assistance (a user-controlled self-adaptive system, Dietrich et al., 1993). This design decision seems also supported by Cheverst et al. (2002) findings that during the evaluation of GUIDE, the vast majority of users wanted to invest as little effort as possible in navigating for the retrieval of information. The HyperAudio final prototype supported also a proactive modality that automatically provides information, thus allowing for no interaction at all. Although a formal user evaluation never took place[4], we observed many people using HyperAudio in a small museum simulation installed in ITC-irst: all were impressed by the reaction of the environment to their movements and virtually nobody took any notice of the device they were carrying. We had implemented the idea of *information appliances,* small devices dedicated to a single task (Norman, 1998): the action of visiting is kept as natural as possible and interaction with the computer disappears.

3.4. On Results Generalization

In the follow-up experience we did together with the European partners of the HIPS project, a wider study on user requirements was conducted (Broadbent et al., 1998). Besides questionnaires distributed to visitors, focus groups with stakeholders (e.g. museum curators, art experts, custodians) were held to more precisely depict the needs of both visitors and managers. The study was carried out in four different places, three different countries (Norway, Germany, and Italy), and focussed on art museums (modern art in Norway and Germany, historical palaces in Italy[5]). The goal of the questionnaire in this study was not precisely the same as in HyperAudio: HIPS questionnaire was focussed on which art features visitors appreciate[6] more than on discovering actual behaviour and attitudes. However, despite the differences in the two questionnaires some degree of comparison is possible[7].

The first sensible difference is in the type of visitors (Table 1) with a strong dominance of family and group in the science museums versus partner and friends in art museums.

	Alone	Partner	Friends	Family	Group
HyperAudio	8%	14%	10%	42%	20%
HIPS	12%	39%	25%	19%	6%

Table 1. Preferred visit companion.

A second difference is in the preferred guide (Table 2 summarises the data). While human or audio guide account for the majority of preferred supports in science museums, participants definitely preferred a more autonomous visit in art museums. Interestingly in both studies technological supports (the audio guide) were equally disliked.

	Maps	Guidebook	Leaflets	Human	Audio	Desk	Friends	None
HyperAudio		20%		52%	7%		6%	12%
HIPS	25%	21%	5%	13%	4%	3%	10%	21%

Table 2. Preferred visit support (not all the options were included in both questionnaires; multiple choice

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even the possibility for the user of scrutinising/modifying the inner user model and system inference rules might be important as discussed by Cheverst et al. in this issue (Cheverst et al., 2005).

[4] By the time the prototype was ready the MessagePad was no longer being produced or supported by Apple, thus the planned porting in the museum setting never took place.

[5] The museums were (websites assessed 30.9.2004):

- Edvard Munch Museum in Norway – Munch's paintings and drawing http://www.munch.museum.no/
- Kunst Museum Bonn in Germany – modern and contemporary paintings http://www.bonn.de/kunstmuseum/
- Castello del Buonconsiglio in Trento (Italy) – a noble XIII-XVI palace http://www.buonconsiglio.it/
- Palazzo Pubblico in Siena (Italy) – the medieval townhall http://www.comune.siena.it/museocivico/

[6] This was done to feedback with realistic data the design of the user interest model.

[7] The original data is no more available to perform the same analysis done for HyperAudio and see if behavior and attitudes in art museums differ from those in science museums.

was allowed for the HIPS one and each % is calculated respect to the total number of answers).

Both tables above clearly show how the two contexts (science and art) are different and underline how assumptions based on somebody else's result can be risky. For example, caring particularly for family or group visitors seems not justified in art context. The need for a direct investigation on the reality is reinforced by some findings in the HIPS study: the questionnaire deeply considered the many facets of interest in art (e.g. technique, composition, theme, artist, social or political context, history, etc.) and showed a contrasting polarization of interests between the two clusters, namely historical vs. modern.

Although some results can be generalized and imported, e.g. the suggestion of including maps or guided tours in museum mobile guides (Broadbend et al., 1998; Broadbend & Marti, 1998), the information that can influence adaptation needs to be collected by the designing team and targeted toward the open questions that need direction. Undeniably the user requirements elicitation done for HyperAudio provided fundamental rationale for designing the adaptive behaviour, and for defining the appropriate internal data structures and adaptive rules.

4. System Redesign Based on User Requirements

Empirical evidence is used in UCD to direct redesign and adjustment. In HyperAudio this meant reconsidering the functionalities and adaptive behaviour the system was to support on the bases of the requirements collected in the previous phase. By analysing the requirements list we recognized how much of the flexible behaviour of the system could be implemented by simple adaptation techniques, like explicit triggers, instead of more complex reasoning. The user model, the data structure, and the matching rules, were revised from this perspective, as discussed below.

4.1. From a User Profile to a "Visit" Model

The strongest effect of the user study was on the user model. The original design of the User Model was based on a thorough study of the existing literature on how visitors typically behave in museums (e.g. Falk & Dierking, 1992), conversations with museum curators, and studies on how exhibition layout affects visitors' behaviour (Lozowski & Jochums, 1995). We intended to keep a detailed user profile to be collected via an initial detailed questionnaire. The questionnaire data was intended to be integrated with predicted attractive and holding power of each exhibit[8] and used to initialize a model of the user's background knowledge, interest, and interaction preferences (Sarini & Strapparava, 1998).

As soon as the analysis of the user studies became available it was clear that some of our initial hypothesis about interest and knowledge modelling had to be revised. The idea of stereotypes based on personal features was abandoned while others were considered. Actually there has been a shift from a user model to a *visit model*. In relation to this, four features emerged as important and were included in the initial questionnaire:

- **Family, school or adult(s)**: the three groups are different in interests, previous knowledge and ultimate goals. By knowing which group a visitor belongs to, the system can select different content for the presentation (e.g. classification vs. curiosity), can adopt a specific presentation style (e.g., narration vs. question-answering), and can automatically set an interaction mode (e.g., interactive for families, automatic for schools and adults).
- **First-time visit**: first-time and frequent visitors are differentiated. This affects content selection as well as the length of the presentation. For first-time visits the preferred content is introductory, actually an overview, while for subsequent visits a deeper content is preferred. The fact that frequent visitors spend more time and see fewer objects motivates the decision to use this information for setting the interest model to high so that longer presentations are composed from the very beginning.
- **Anticipated visit duration**: the more time is available, the broader the visit can be. This affects system verbosity in terms of numbers of objects proposed or depth of descriptions.
- **Interaction preferences**: proactive behaviour is the default mode; however it is considered

[8] Attracting, and holding power are the probability that the visitor stops and observes the exhibit, and the average time spent by visitors in front of it (Lozowski & Jochums, 1995).

important to allow visitors to change from fully automatic (i.e. the system plays the message automatically as soon as the visitor reaches an active area) to interactive (i.e. the system announces that new information is available with a "beep" but it is played only when the user explicitly clicks) since this is a preference that cannot be easily inferred.

The neutral nature of those questions would allow museum staff to fulfil it on behalf of the user when the guide is handed out, thus providing personalized information also to passive visitors, people who would never explicitly interact.

The dynamic part of the user model was also revised. Initially conceived as a complex weighted activation network over domain concepts (Sarini & Strapparava, 1998), user interest was finally implemented as an array of boolean values, each item associated to a concept: an item is set to true for returning visitors or when visitors stay in front of the corresponding object for more than two seconds after a presentation has finished; It is reset when the presentation is stopped. The user knowledge model simply ticks already heard macronodes: when the Presentation Composer traverses the network for collecting macronodes for the new presentation those already heard are discarded. Finally a boolean value to regulate system verbosity was introduced; it would be on for long visits or returning visitors. This very simple implementation of the dynamic user model had the advantage of making computation efficient even with limited computational power as when using only a PDA. As a consequence the HyperAudio reaction to user moves was very fast and the natural pace of visit was not affected by the system.

4.2. Revisiting the Data Formalism

The macronode formalism discussed in 2.3.1 was refined on the basis of the results of the survey. In particular the fact that visitors belong to different groups with different goals, e.g. families vs. adult groups, suggested a richer information space and a finer description of the node content. The *perspective* field was added to the macronode structure in order to better describe how the main *concept* of the macronode was elaborated in the content unit (classification, curiosity, characteristic...). Adaptation rules would then prefer different macronodes with different perspectives on the same concept depending on the selected user class, as shown in the scenarios in section 4.4.

A broader range of text types was introduced as a further data refinement. The purpose was to better support frequent visitors in the in-depth exploration of a limited number of objects. Thus a distinction was made between linked information that must be played immediately (e.g. for frequent or interested visitors) and elaborations that can be added to the message or included as links (for an example see section 4.4).

A further alteration to the original data structure was the *presentation style* to distinguish different forms, such as narrative, question-answer or dialogues. As before, a different style can be associated with a user class preferring narration for adults, question-answering for families and dialogue between characters for pupils.

4.3. The Adaptive Rules

As discussed in 2.3.2, HyperAudio adaptivity is realized by different sets of rules directed to different objectives. All rules were revised as a result of considering the found requirements. Discovering that visitors might never interact suggested reinforcing system reactivity to physical actions; for example "if the presentation has finished and the visitor does not move for a further two seconds, then prepare a new presentation".

Rules applied by the Presentation Composer were the subject of more revision. For example, the requirement to engage first time visitors suggested the rule "if a first-time visitor has a long time available, then propose visiting a new exhibit related to the current one". It is worth observing that these rules are designed on the bases of few context elements (mainly the questionnaire and current interaction) but provide a wide range of flexibility.

New composition rules were also derived from the revision of the data structure described above. For example "if a frequent visitor, than choose the longest chain of macronodes available for the topic", or "if family, then prefer a 'curiosity' perspective for the concept in focus" (similarly prefer 'characteristic' for adults and 'classification' for pupils). It should be noted that the association between user class and a specific

perspective is based on the inferred user intention, having fun for the family, learning basics for pupils, and acquiring generic knowledge for adults. However this association is quite arbitrary: different perspectives and associations would have been equally valid.

4.4. The Resulting System Behaviour

The following scenarios exemplify particular cases of visits and show how the macronode network shown in Figure 3 can be instantiated for different presentations using the rules that emerged from system redesign.

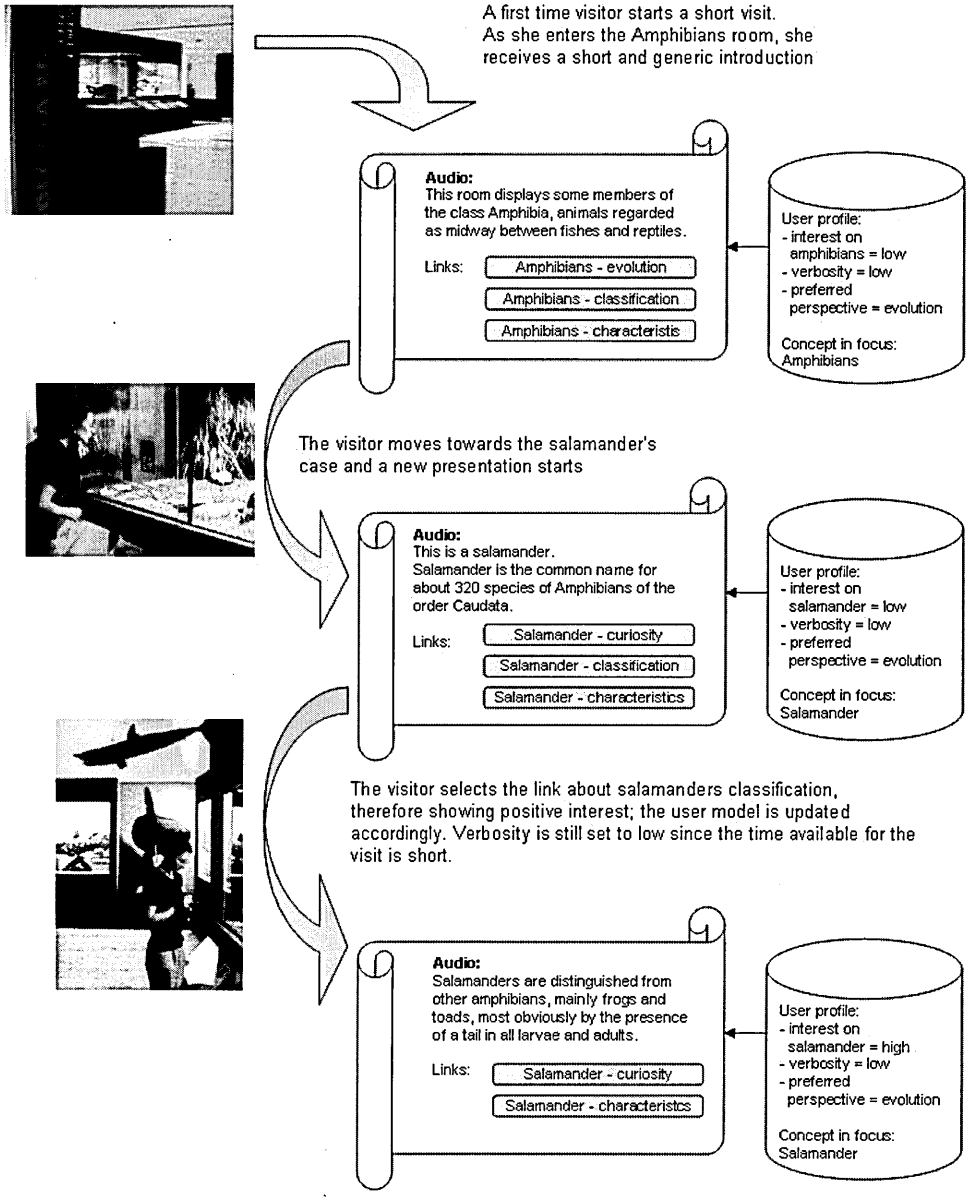

Figure 6. Scenario 1 for user interaction with HyperAudio.

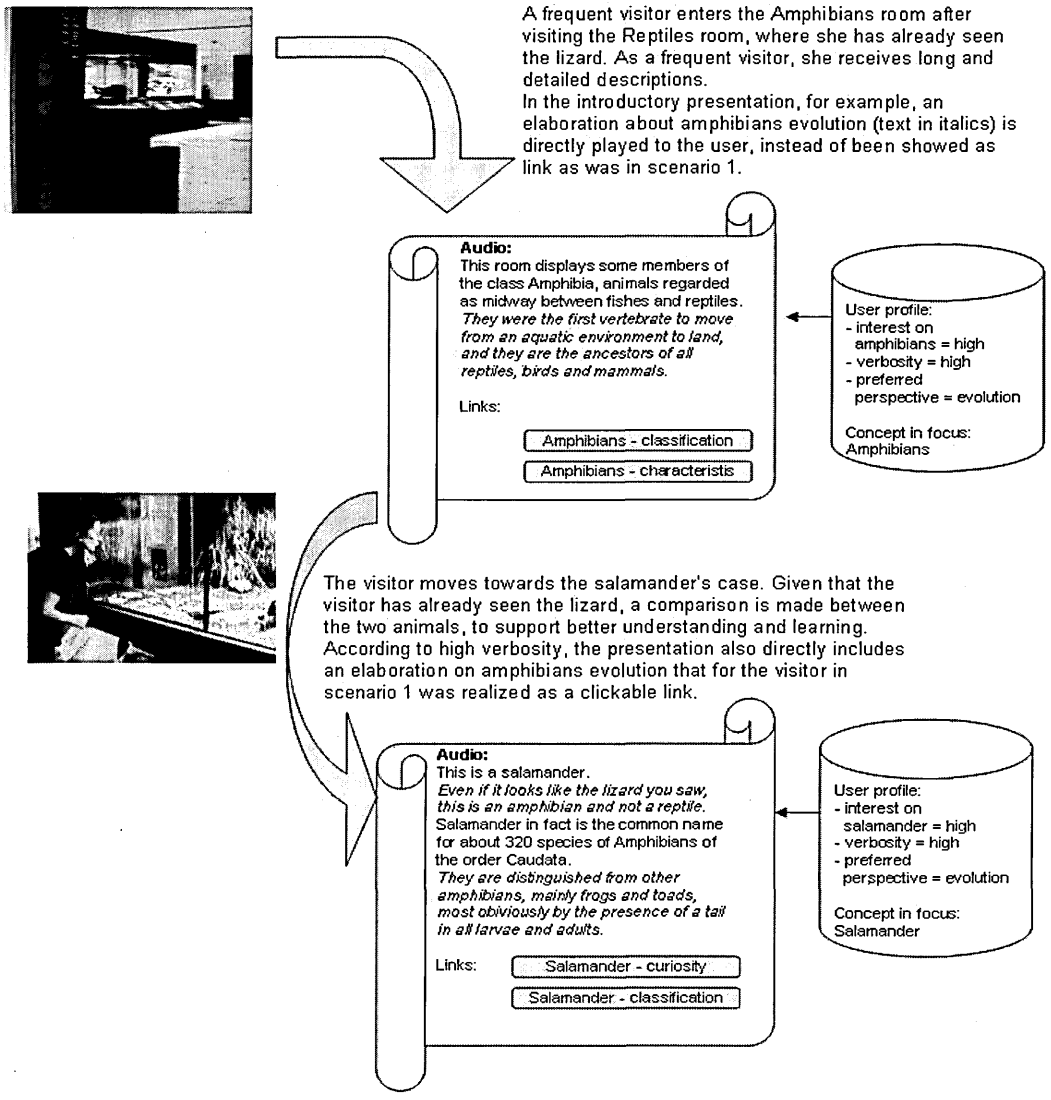

Figure 7: Scenario 2 for user interaction with HyperAudio.

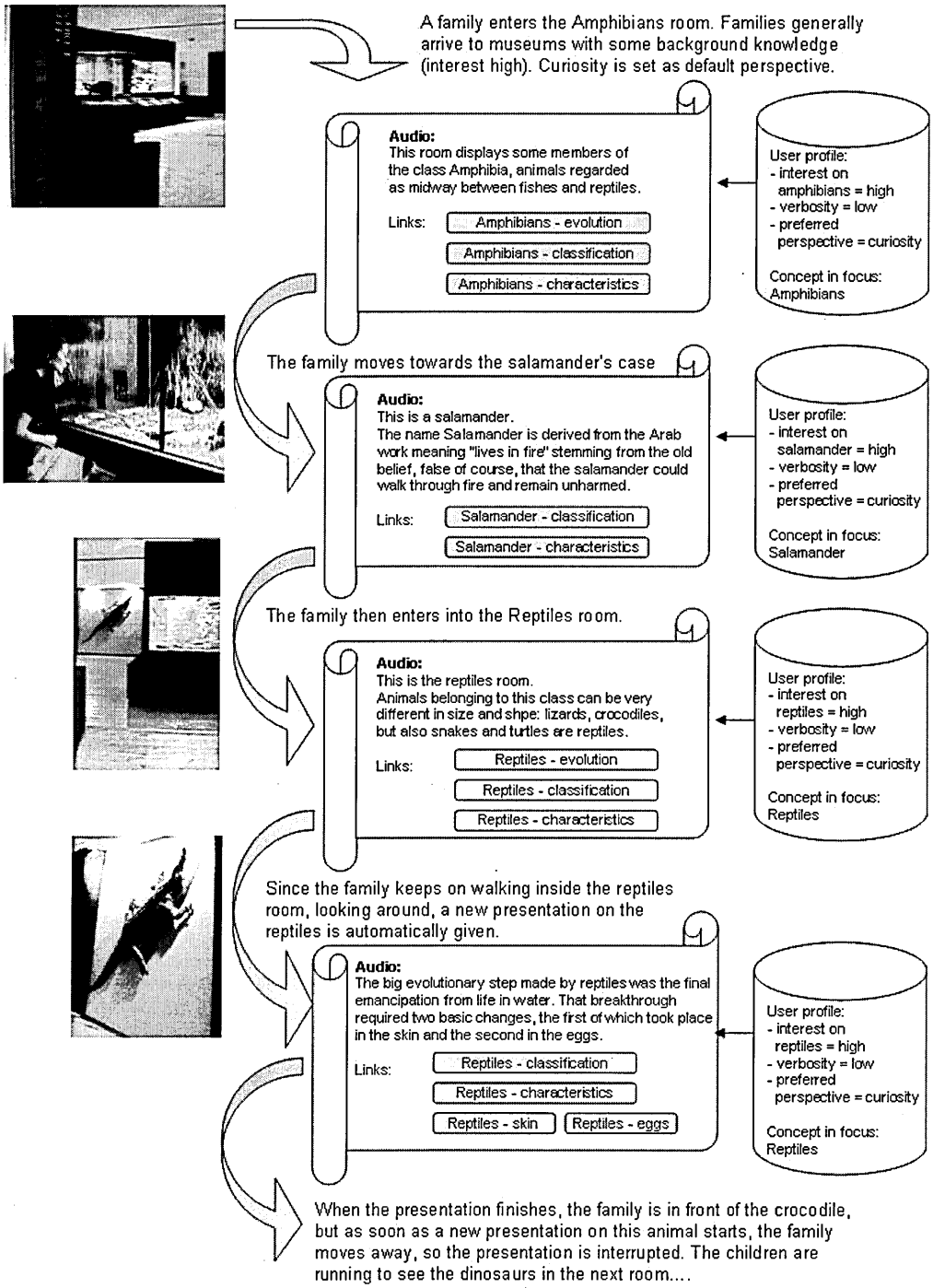

Figure 8: Scenario 3 for user interaction with HyperAudio

5. Rapid Prototyping and Testing

To assure a smooth interaction between the user and the final system, UCD advocates the application of an

iterative process of design, prototype, and test. Prototypes can be of different kind and are done for testing different system concepts; Houde and Hill (1997) have identified the following:

- a **role** prototype is used to test the function of the artefact in user's life;
- testing the **look and feel** means to concentrate on the interface and interaction;
- focussing on the **implementation** aspect would prototype techniques and components of the final system;
- finally, an **integration** prototype combines aspects of all the three prototypes above and moves the project towards its final form.

Although an integration prototype must be developed lastly, there is no particular order for the others that can be also done in parallel, e.g. testing the look-and-feel via paper mock-ups while testing how robust the localization is with an implementation prototype.

The more complex the system, the more important is to test each component separately before the integration step. Indeed a single-component test helps in focussing on only one aspect of the adaptive system. A multi-layer evaluation approach has been proposed for adaptive systems (Karagiannidis & Sampson 2000) and has demonstrated its power in localizing problems, i.e. in the interaction or else in the adaptation mechanisms (Brusilovski et al., 2001). Our approach is slightly more complex as we needed to take into account mobility as well as adaptivity.

When the implemented system is mobile and adaptive, testing the interaction in a multi-layer mode is more complicated as, for example, the evaluation should be delayed until the overall localization and communication infrastructure is fully functioning. However, an extensive testing of adaptive mechanisms can be done without involving the user, i.e. excluding the localization. To speed up the process of prototyping and testing, we developed an environment where components could be plugged in and tested while simulating others not-yet-ready modules. This approach was particularly useful in the HIPS project as different partners developed different components: using the development environment we were able to autonomously work on rules and data (the macronode network) while simulating the user model and the localization mechanism[9]. From that experience a set of guidelines can be proposed (Petrelli et al. 2000 reports the work in full, here only the most relevant points are discussed); Figure 9 visually summarizes the guidelines using HIPS as contextual example:

- **Modular architecture**: the adaptive hypermedia system and the development environment have to be designed simultaneously. The two architectures have to be similar if the environment has to support simulation of modules as well as component testing.
- **Plug and play:** adding or removing components should be easy. Plug-and-play finished components as well as easy disconnection of modules in need of the developer's attention is a very important feature when a team is involved. In HIPS during the tuning of macronodes and rules, the user model inquiry was simulated by manually setting different parameters; at a later stage the real modules were plugged in and the system was tested in full.
- **Component simulation via GUI:** to better support component simulation, a graphical interface should be offered for the easy setting of core values. This is particularly important if the values of the simulated modules are likely to change very often, as it was in our case for the location and orientation of the user.
- **Quick test-revise cycle:** since extensive testing is essential, setting a test should require just a few clicks. We have found useful a graphical panel for setting the hypothetical interaction context conditions, running the system and collecting the produced output.
- **Support localized testing:** besides manually setting the context values, it should be possible to manually set the data to be used in the test. The macronode to start with could be explicitly selected. This "localized testing" was very useful to discover specific problems in complex situations, e.g. how a specific adaptation rule works with a certain data configuration.
- **Cumulate the results:** it is useful to cumulate the output in a dedicated panel to support the monitoring of the behaviour of the system over time. This feature is essential for checking the

[9] A quite elaborated knowledge and interest model (Oppermann & Specht, 2000) was developed at GMD and was later integrated with a dynamic visiting style model (Gabrielli et al., 1999) developed at the University of Siena. The University of Siena was also responsible for the localization sub-system (Bianchi & Zancanaro, 1999).

adaptive system as a whole and to grasp what the user would experience while interacting.

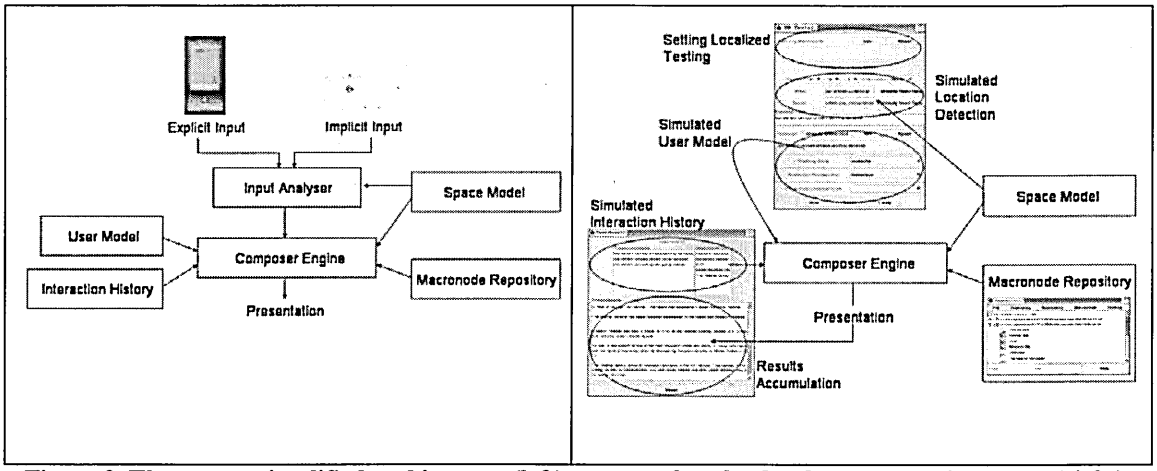

Figure 9. The system simplified architecture (left) compared to the development environment (right).

A development environment as outlined above allows considering and evaluating many context features at the same time as well as focussing on a single aspect of the complex adaptive mechanism (e.g. testing different user models while keeping the rest of the system fixed). The more complex the context the more valuable the help provided by the environment as all aspects of the context are related and can influence each other in negative and unwished ways. Consider a visitor listening to a presentation and moving toward an exhibit. Deciding if the presentation has to be stopped and a new one played may depend on factors other than the visitor's movements, for example the type of presentation currently playing: if it is about a specific object previously in focus it has to be interrupted (or better shortened to the end of the current sentence) as the references to the space are no longer valid, but if the content of the presentation is generic, then a full delivery is appropriate (the new presentation is queued). Using the environment it is easy to test different rules or combination of rules and evaluate the final effect thus shaping the adaptive behaviour precisely as the designer intended.

6. Content Editing and User Evaluation

A development environment that is to effectively support the overall UCD cycle for adaptive hypermedia cannot neglect the issue of content editing support. Content creation must be coupled with immediate testing and revision to guarantee coherent system behaviour. The macronode network used in the HyperAudio prototype was developed without any support and writing, connecting, and testing the 98 macronodes (for 7 objects, 2 rooms and 5 exhibits) proved to be error prone and time consuming. The cost of hand-writing was prohibitive for the bigger scale project HIPS and a editing support was deemed necessary.

The need for some editing support when authoring content for adaptive systems has been recognised in the past and recently addressed as an integral part of the development of adaptive hypermedia (Weber et al., 2001; De Bra et al., 2003). While the usefulness of graphical support has been recognized as complexity increases, the checking has only been considered at the level of graph consistence and rules propagation (Calvi & Cristea, 2002). Unfortunately this is not enough when linguistic adaptation is involved: checking for graph correctness would not say if a deictic reference was properly applied or the narration was fluent. A human has to systematically check the data structure and how the adaptation process uses it. The environment described in the previous section can be used to support an author in correctly creating content, by properly supporting the editing of the annotated network, and testing how the adaptive rules work on it. For one of the HIPS prototypes (the one used in the Museo Civico in Siena) a network of 170 macronodes was prepared to cover 31 exhibits in the museum; the total number of audio files created to support linguistic variation was 344. The same environment was later used in the M-PIRO project (Androutsopoulos et al., 2001): 69 macronodes were created to cover 8 exhibits.

Using the environment has improved efficiency and effectiveness of adaptive hypertext editing. Lessons

were learnt, and suggestions can be given with specific reference on deploying an editing environment to adaptive hypertext authors external to the system development team, as it was done in the HIPS project. Figure 10 shows the components commented below and visually describes the relation between editing and testing.

- **Templates of (optimal) data organization:** developers should create templates of sub-networks that implement predefined directives to guide authors towards the correct compilation. The author can then concentrate on the content filling and the checking tasks. This feature is particularly important when the responsibility of creating the data is on the domain experts, i.e. museum curators. Through templates the developers can pass the basic knowledge on how the content had to be structured for optimal performance; by using examples of well-formed sub-networks authors can also gain a better understanding of the adaptive system.
- **Editing and testing the content network through a visually rich interface:** a basic display of the macronode network was available: the author could see at a glance the connections and the general content structure. Different views (by list or graph), searching facility, and user-defined data files turned out to be very handy features for network composed of hundreds of nodes. The possibility of getting at a glance an idea on, for example, the length of a presentation (i.e. length of a path in the network) or the type of content delivered (e.g. anecdotal or historical) was very useful for creating a balanced network where all the nodes got the chance to be selected and listened. A further improvement of the graphical interface is the progressive highlighting of the nodes used; this way the author can quickly check that all the nodes can be reached.
- **Quick test-revise cycle:** as for testing adaptivity, an extensive testing is essential in content editing as well. Simple test run, quick problem identification, and immediate fixing have to be supported. The features discussed in the previous section, namely a graphical panel for setting the hypothetical interaction context conditions, selecting the node to start with, running the system, and collecting the produced output, proved to be a valuable support for fast testing and problem identification. To support immediate fixing, the testing panels must be integrated with the editing ones so that the author can just turn her attention to the editing facilities for updating, switching then back for another test run.

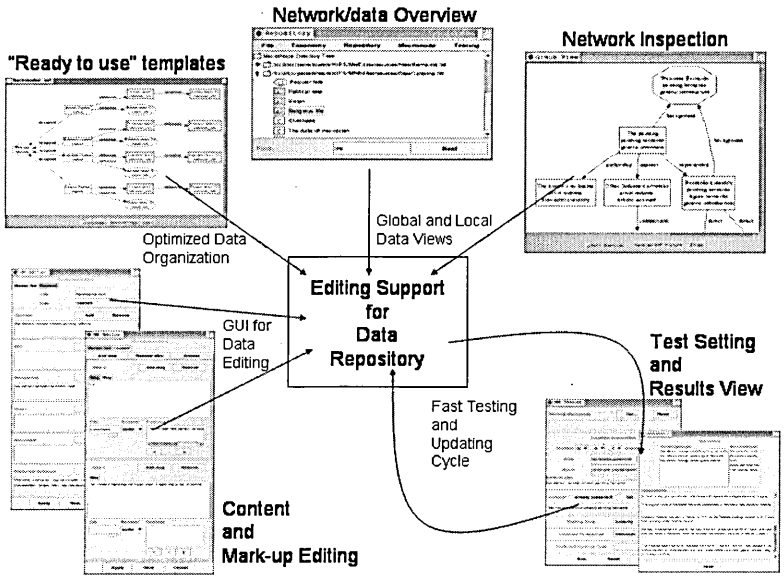

Figure 10. The editing supports components as related to the testing.

As discussed above, a comprehensive off-line/in-lab testing is essential to assure that the adaptive system is robust enough to go into users hands for a full evaluation. But this is just the first step. Indeed testing adaptive systems in real conditions is not trivial and the empirical evaluation of adaptive systems is a research

topic in itself (Weibelzahl & Paramitys, 2004). However as the number of adaptive systems implemented on mobile technology increases, there is the need of enlarging the context to location and device (as discussed by Gupta & Grover in Weibelzahl & Paramitys, 2004). New user evaluation methodologies are then needed to test adaptive and mobile guides, particularly when the use is not work-based but a leisure one (Marti, 2000; Marti & Lanzi, 2002). A first step in this direction can be found in this issue (Hatala & Wakkary, 2005): Hatala and Wakkary explore different dimensions of evaluating adaptive and mobile systems; they suggest, as we do, that an initial part of the evaluation (the "validation") can be done off line (in the lab) to determine the most appropriate parameters to be used in, for example, the user model; the second phase, the "verification", must be done with real users and should consider dimensions like variability, sustainability, and evolvability.

7. Related Work on Adaptive Mobile Systems

Adaptive mobile information systems for tourists and travellers is a popular topic[10]. It seems so promising that a generic user modelling system for tourist applications has been recently proposed (Fink & Kobsa, 2002). It is used by the WebGuide system to provide tourists in Heidelberg (Germany) personalized tours tailored to the user's interests and preferences, transport facilities (e.g. car or bicycle), geographical distance, and specific user constraints (e.g. limited time) (Fink & Kobsa, 2002).

INTRIGUE (Ardissono et al., 2002) is another tour scheduler. It helps visitors in planning tours in Torino (Italy) and its surrounding area adapting to the needs of a group of people travelling together, e.g. parents and children. Users have to fill an initial "registration form" that provides the system with information on day and time of the visit, categories and geographical areas of interest: on the bases of this data INTRIGUE schedules a tour taking into account transfer time. It also adapts its layout according to the display device, desktop PC or WAP phone.

CRUMPET (Poslad et al., 2001) uses a handheld computer (a iPAQ) to provide personalized recommendations of services and attractions for city tourists, tour planning, proactive tips for nearby sites of potential interest, interactive maps and automatic adaptation to network services. Adaptation is based on a dynamic user interest model calculated from positive examples. The user can directly access and modify her user model. Stereotypes are mentioned as means for fast adaptation but it is not clear if the empirical studies alluded to for identifying the typical interest profile have ever been conducted (Poslad et al., 2001). The interface layout is simple and has been designed with computer-web literate users in mind.

GUIDE (Cheverst et al., 2000) implements a location-aware adaptive guide for tourists visiting the city of Lancaster (UK); it selects sites nearby the current user position, that are open, and are compatible with the user profile. It can also plan a tour of the city arranging sites selected by the user: the order depends on sites' opening and visiting times, on distance and on the scenic route between sites. The user interface resembles a Web browser and new information is provided only after user interaction. Initially users are required to fill in a form asking for name, age, language, and interests. GUIDE also offers additional services such as booking accommodation, retrieving information (e.g. restaurants), and messaging with other tourists.

Hippie (Oppermann & Specht, 1999) is one of the preliminary prototypes developed inside the HIPS project. Conversely from the previously discussed applications, it is for inside use. It provides the visitors of an art exhibition with comments specific to the objects in sight; it adapts to user interests and knowledge calculated on the basis of actual behaviour. Hippie has a browser based interface that shows when new information is available by displaying a small blinking icon and playing a "earcon": by clicking on the icon the new information is delivered as a hypermedia page with image, text and speech. Tours are generated and proposed to the user on the basis of her assumed interests. An initial setting of user's interest profile is

[10] See also Baus et al. (2004) for a selected critical comparison of map-based mobile guides offering services like helping users in orienteering in an unfamiliar city or accomplishing simple tasks, e.g. find a hotel nearby in Lol@, booking theatre tickets in Smartkom. Note, however, that none of the systems reviewed by Baus and colleagues seems to emphasize dynamic and adaptive content delivery: just a few can filter information on the bases of the user's current position but no adaptation is applied. This can be due to the outdoor context where truly reliable localization and communication cannot be guaranteed: a correct localization and a continuous communication are mandatory for systems that aim at telling stories on the bases of the user's movements. As a consequence, aspects related to narration and interactive environments have especially been exploited by projects devoted to inside use, particularly in museums and exhibitions.

available but not mandatory.

Besides having different domains, the applications above share the same idea of active users interacting with an adaptive guide within a browser paradigm: Initially users set their own profiles, later they can request adapted information (tours or descriptions) and access the result. However, with small devices, like those of PDA, the interface design is particularly critical and new interaction paradigms need to be explored, as noted by Cheverst (2002). HyperAudio attempted to overcome the limit of the screen and explored the idea of interacting with the space. Our system fuses adaptive information with the environment surrounding the user to create an adaptive immersive environment. Adaptation is done in respect to the user but also in respect to her actual position and current movement in the physical space, and is realized in terms of content selection, linguistic realization and appropriate synchronization. This idea was fully exploited inside HIPS, where a more sophisticated architecture was experimented for very fine linguistic adaptation. A better adaptation to the space and the narration was possible because of a new space model[11] and a deeper discourse context. The space model was finer grained (Bianchi & Zancanaro, 1999) thus allowing for deictic reference to near or far objects ("this is" vs. "in front of you"), as well as to objects located beside or behind the visitor. Similarly the macronode formalism was revised to support a richer discourse context for controlling the narration at the word level (Not & Zancanaro, 2000; Not & Zancanaro, 2001). A new way of modeling users solely on the basis of their movements was used in HIPS to adapt presentation length (Marti et al., 2001) while content selection used full models of user interest and knowledge (Opperman & Specht, 2000). Finally a new graphical interface to help users in locating artworks in the room by highlighting them on a 3D user-centred perspective reproduction of the room was implemented (Gabrielli et al., 1999).

The concept of the disappearing computer has been extended by Zancanaro et al. (2003) who have enhanced the idea of adapted audio presentation built into HyperAudio and HIPS with a synchronized visual track for the described fresco: the pictures shown on the screen are animated via camera movements and shot transitions using cinematic techniques driven by the underlying content and rhetorical structure of the audio message (Zancanaro et al., 2003; Rocchi & Zancanaro, 2003; Callaway et al., 2005). The video-clips enhance the presentation, helping the visitors in locating described details in a complex and vast fresco, and demonstrate how computer technology can empower and enrich everyday activities, implementing the vision of augmented environments (CACM, 1993).

Monitoring user's free movements for adapting presentations has inspired research in the area of wearable devices. In the system developed by Sparacino (2002) the user wears a private eye (a small transparent screen positioned in front of a single eye) where additional information for the object in view are displayed producing in this way a visual augmentation of the museum space. A Bayesian network is used to model both the user (interest and style -busy, selective, or greedy visitor-) and the appropriateness of the content (length and order). A set of video clips derived from 2 hours film on the exhibition represent the content. The video clip to be delivered is conditionally selected respect to the user model, the appropriate order of delivery, and its length. The selected video clip is displayed on the private eye with textual and pictorial details.

The LISTEN project (Zimmermann et al., 2003) instead explores the audio channel: the user carries only headphones and moves freely in an adaptive 3D-audio art museum. LISTEN merges technology developed in virtual reality (3D audio environments) and adaptive interfaces. Data mining techniques are used to model user interests, preferences and movements; the adaptation affects the presentation style (e.g. music, spoken text, and sound effects), the presentation content (e.g. facts, emotions, overview), length and volume. Clues for the user modelling are derived from the time, the position (of user and object), and the object of focus. Within LISTEN a unified framework for context-management was experimented to integrate the modelling of the user and the modelling of the context (Zimmerman et al., 2005).

[11] A fine-grained and robust space model is essential to build up a sophisticated content adaptation system. Indeed being able to model the user, the space, and the objects in the same system (as proposed by Carmichael et al. in this issue (Carmichael et al. 2005)) open ups a spectrum of interesting new possibilities.

8. Conclusions

The examples discussed in the previous section show how adaptive hypermedia are branching out from the narrow path of adapting content and links to users sitting in front of a screen towards a broader way of adapting to the interaction context of users immersed in an augmented environment at a certain time and place. As scenarios of use for adaptive systems overcome the limit of desktop applications, system complexity will continue to increase. A robust methodology and appropriate development tools will increasingly be fundamental for successful designs particularly when mobile and ubiquitous computing is associated to adaptivity. HyperAudio has been one of the few adaptive projects where a user-centred approach was used to design the system and likely the first in the area of adaptive and ubiquitous guides. From that experience we have learnt how a deep understanding of users and uses is essential when designing adaptive systems to be used in highly-constrained conditions, as running efficiently on a PDA; in this context each design choice has to be evaluated and motivated. In this paper we have shown how the most sophisticated and advanced techniques could fail when compared with real use, and how a simpler solution can be equally effective. From our experience an effective design is based on few, relevant assumptions derived from actual user needs that spread on all the aspects of the adaptive system, i.e. user model, adaptive rules, and annotated data. Designers' creativity is then instrumental for deciding how flexibility should be implemented, i.e. which adaptive techniques can better support an effective and efficient use of the system. With this respect, the support of a dedicated environment is mandatory for an iterative development and testing of the final adaptive behaviour. In this way designers can explore and test different technical solutions and authors can be supported in the creation of the data.

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Engaging with Books You Cannot Touch: Interactive Multimedia to Expose Library Treasures

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Interactivity has proved a successful way to engage visitors of science museums. However it is not a common practice when the objects to exhibit are artefacts or, as in the case of this paper, books. A study was set up to investigate the driving criteria for the "The Life and Work of William Butler Yeats" exhibition at the National Library of Ireland and compare those with the visitors' opinion. Books, notebooks and personal belongings of the poet have been digitized and used to create a rich and varied exhibition that used both interactivity and multimedia. The result of visitors' survey showed that the variety was a key factor for the success of the exhibition: different people engaged with different contents and different medium to different degrees. The design of the ambience is critical: dim lights and the use of audio as a medium have to be carefully planned to avoid annoying instead of engaging.

Keywords: digital imaging; library exhibition; interactive multimedia.

1 Introduction

Many different kinds of technology have been used or experimented in museum settings: from traditional stationary multimedia kiosks, to mobile and adaptive guides (Petrelli & Not, 2005, Zancanaro et al. 2003), wearable devices (Sparacino et al. 1999) and virtual reality (Sparacino 2003, Rousseauu 2001). Each of them has advantages and disadvantages: multimedia kiosks are rich in information but limited by their location that can be away from the artefacts being described (Ciolfi & Bannon, 2003); PDAs are less physically constrictive than kiosks and have similar functionality, however as they are designed for individual use can disrupt the social nature of museum visits (Vom Lehn & Heath, 2003); wereable and virtual reality have a novelty factor, but to be effective for learning they have to hold visitors' attention beyond the initial surprise (Rousseau 2001).

However different in the technology used, each of the above offers a single interactive point. This contrasts with the evidence coming from evaluating visitors' experience that a multi-sensory mixed medium strategy is the most successful (but for the very quiet and solitary visitor (Davison et al. 1994)). Indeed evidence shows that a mixture of traditional presentations (cases with artefacts, dioramas, graphic panels, labels) supported by hands-on sensory components (touch, listen, smell) and interactive problem solving is the most successful solution for audience engagement in science museums (Davison et al. 1994). An open, non-didactic information structure that includes multiple views and activities can be successfully applied to interactive technology (Leslie & Gleeson 2005). The challenge is to plan the whole exhibition (not just one interaction point) and assure that each part is self contained but at the same time integrates and complements the others (an excellent example of such an approach is in Ferris et al. 2004). The role of a modern museum is not any

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more that of exhibit significant artefacts, but the one of creating experiences for visitors (Cauton 1998). Pushing the boundary further, constructivist museum theory emphasises the learning process over the actual body of knowledge: a visitor does not merely absorb information, but constructs new knowledge by interacting with content and assimilating it into what is already known (Leslie & Gleeson, 2005). To be effective an exhibition has to allow individuals to explore multiple narratives and construct knowledge through exhibits which present multiple scenarios and outcomes (Leslie & Gleeson, 2005).

In line with the transformation museums are experiencing, the library is less important as a physical place that provides access to books (as collections and catalogues can be used online) and more as a space to facilitate accessing and acquiring knowledge. The possibility of digitizing precious books and made then available to the public through interactive technology (like Turning the Page[1]) is core to this transformation. However, while museums had been the focus of much research (for an overview of recent trends see Ciolfi et al. 2005), little has been done in libraries as it is much harder to engage visitors with what are primarily text-based artefacts. The National Library of Ireland has recently experimented with interactive and multimedia technology in two exhibitions based on the lives of the prominent Irish literary figures Joyce and Yeats. While the Joyce exhibition, the first of the kind, was limited in scope and technology used, in Yeats' one the principle of a multi-sensory open-ended interaction guided the design. Technology has been used not only to present rarely seen artefacts (e.g. manuscripts), but to interpret them in different contexts supporting the visitors in a wider exploration of the writer and his work.
This paper reports a study done in during the initial opening of 'The Life and Work of William Butler Yeats' in early Summer 2006 and carried out to investigate if the intentions and aims of the curators and the designers have been received by the visitors and how. One of the curators and two exhibition designers have been interviewed to specifically identify the driving criteria for the exhibition; questionnaires were used to collect visitors' opinion and a tour guide was interviewed to better understand the questionnaire result.

2 'The Life and Work of William Butler Yeats' at the National Library of Ireland

The Life and Works of William Butler Yeats exhibition opened at the National Library of Ireland in May 2006. Put together over a period of two years, it was intended to promote and illuminate the Library's burgeoning collection of Yeats manuscripts, notebooks and correspondences, as well as his own personal library. The exhibition benefited from the work of five dedicated exhibition staff in the Library, a team of designers from Martello Media, input from several scholars, artworks by various artists, and the guidance of a film producer.
Given the material is mainly paper-based, the exhibition makes great use of digitalized images and interactive computer technology to provide depth and detailed content. More traditional communication methods like graphic boards and cases, audiovisual installations and replicas of places and artefacts are used to complete the visit experience. This result in a variety of different but inter-related zones designed to engage the audience at intellectual, interactive and visceral level.

2.1 Structure and Layout

Best known to the Irish public as a poet and playwright, Yeats is one of Ireland's most important literary and cultural figures. The structure of the exhibition is biographical, beginning with Yeats' origins and family tree and ending with his death and funeral in 1936. Visitors are not explicitly directed (no arrows or maps); the

[1] http://www.bl.uk/onlinegallery/ttp/ttpbooks.html

layout invites to naturally move from one phase to the next in a circular way. The general setting is dark with the lightened elements (cases, interactive points, audiovisual settings) to attract visitors' attention.
Aspects and periods of Yeats' life and work are presented in separated "islands", each represented by a 'Signature Image' and a different colour theme. Signature images are reproduced on large wall boards and are displayed as screensaver on interactive touch screens (Fig. 1). Four evocations (reproductions of rooms) with the associated four films focus on particular aspects of Yeats' life, while the replicas (reproduction of artefacts), the cases and the turning the pages focus on particular objects. The two interactive installations in the centre of the circle, The Tower and Poetry in Print, provide in depth understanding of Yeats' work and complement each other. The technology used in each of these islands is described in more detail below.

2.2 Audiovisual Experience

The welcome to the exhibition is the 'Verse and Vision' space, a circular reflective area where people can sit and listen to Yeats' poetry and watch the words and related images appear on four large high screens (Figure 2).

Figure 1. Signature Image and touchscreen.

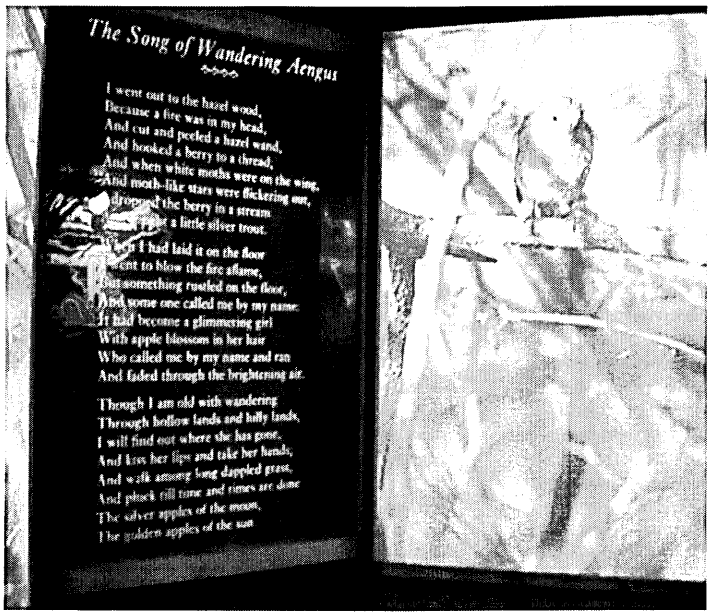

Figure 2. Verse and Vision installation.

Four significant locations in Yeats' life are recreated in the 'Evocations', small curved enclosures located in different points of the exhibition and related to specific periods in his life. Each Evocation has an associated documentary film describing: important women in the poet's life (Affaire of the heart), the relation with theatre (Players and Painted Stage), the interest in the esoteric (The other world) and his public and political role (The Mask).

2.3. Information Points

Touch-screens and interactive points are distributed all around the exhibition with different functions depending on the context. Touch-screens placed under Signature Images (Fig. 1) provide an overview of the

period. A selection of manuscripts from the library's collection is on show in display cases together with photographs and artefacts lent by the family. The touch-screen nearby (Fig. 3) provides a means to examine the contents of the display cases more closely. Each display case and its contents are exactly represented on the touch-screen: by touching an object visitors can view it in more detail (zoom in) as well as get information on it.

2.4 Digital Reading Points

Following the public success recorded during Joyce's exhibition, two Turning the Pages[2] installations are available to enable the audience viewing Pail (Fig. 4) and Rapallo notebooks at such as high level of detail that even the grain of the paper is apparent on the screen. The installation uses a book metaphor for interaction: users turn the page by dragging its corner across the screen. A side description introduces the page and visitors can zoom in a page to read Yeats' personal notes.

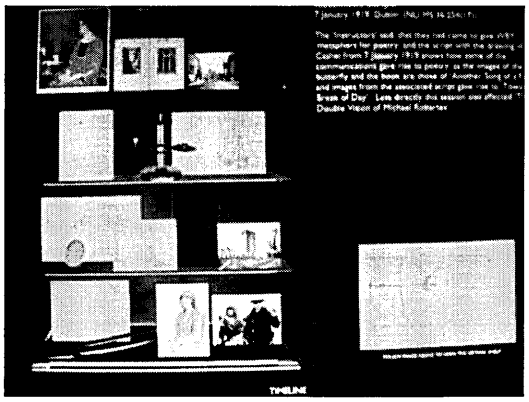

Figure 3. A display case and the related touchscreen.

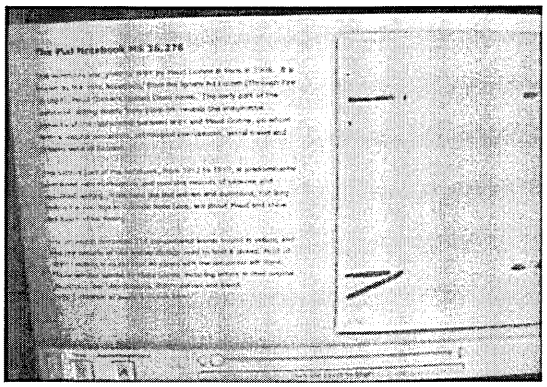

Figure 4. Turning the Pages Installations

2.5 Interactive points

Two further installations aim at supporting a deeper exploration of Yeats' work: the evolution of the collection of poems The Tower and the poet direct involvement with the production and publication of his books.

The Tower is a semicircular structure (Fig. 5) displaying a map of the process leading up to the creation of the Tower, from the writing of the first poem, to the intermediary stages and the final book's publication. The same process map is displayed on two touch screens (Fig. 6) where users can view the book in detail and access further information. A master class tutorial can be accessed by touching various locations on the same map.

The Poetry in Print installation allows visitors to explore Yeats desire to be involved with the work related to the publishing of his book, including the illustrations, binding, type, and even the paper on which it was printed. The installation includes a display of Yeats' book art alongside two touch-screens which illustrate the process behind the design and provides insight into the work of the designers involved.

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[2] Designed and developed by the British Library and Armadillo Systems http://www.turningthepages.com/

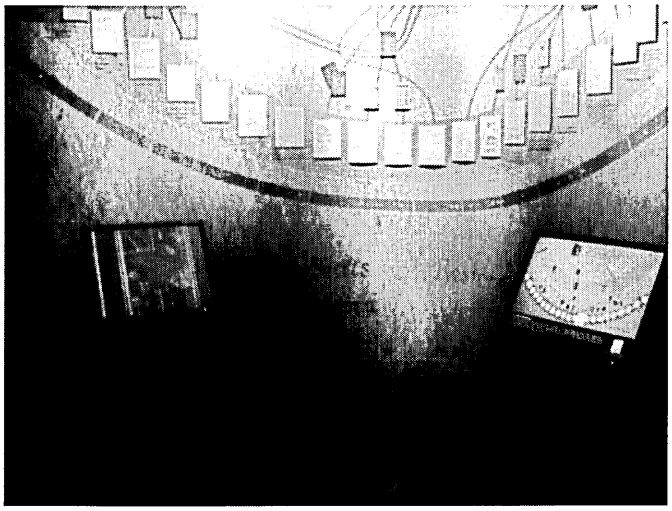

Figure 5. The Tower installation.

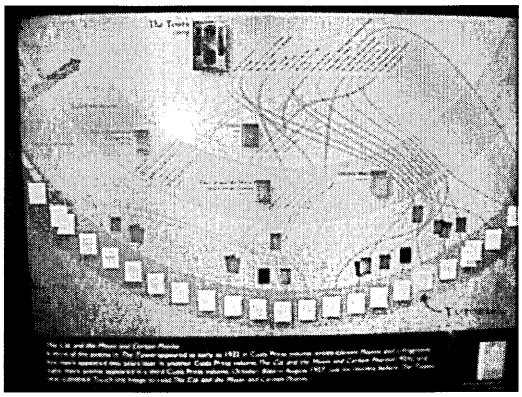

Figure 6. The touchscreen of The Tower.

2.6 Replicas

Digital images have been exploited to create simple and effective interaction objects. Few everyday objects have been recreated to render Yeats a more real person. His passport and the scrapbook of photographs of his family (Fig. 7) have been physically reproduces and let for the visitors to explore.
A questionnaire filled in by Yeats on creativity has been reproduced on a wallboard, enlarged enough to make his quite intricate writing as legible as possible. Though this is a more traditional way to communicate content in museum settings, it shows how digital images can be used to increase the impact of artefacts on visitors.

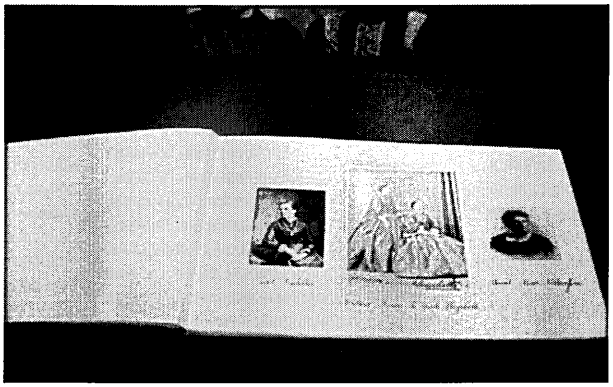

Figure 7. Yeats' photo album replicas.

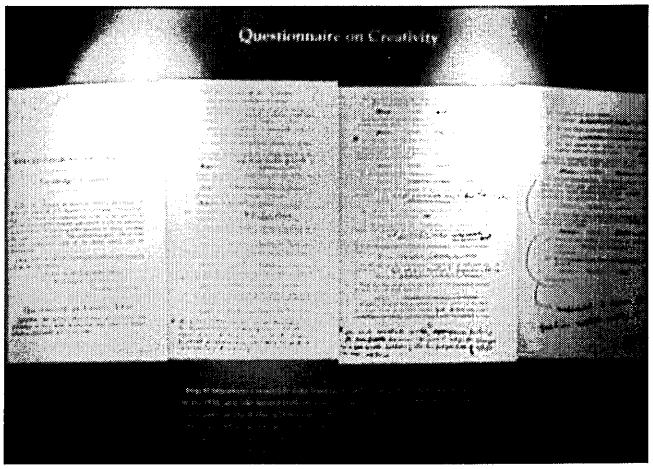

Figure 8. The questionnaire on Creativity.

3. The Study

As described in the previous section, The Life and Work of William Butler Yeats is an ambitious exhibition that uses a range of traditional (boards), interactive (replicas) and technological (touch screens) installations to affectively engage visitors with a collection of (mainly printed) material. A study was set up to investigate if the aims of the exhibition design team have been perceived and appreciated by visitors.
A multi-methods approach was used: a curator from the National Library of Ireland and two of the designers from Martello Media were interviewed to determine their individual perspective; a survey questionnaire filled by visitors while exiting the exhibition was used to understand the audience experience; finally a tour guide was interviewed to better understand the result of the survey. Interviews were transcribed and coded; surveys analysed statistically. Main results are summarized below, details can be found in (Reilly 2006).

3.1 Curator and Exhibition Designers Intents

Two semi-structured interview schemas were used with the curator and the designers. While the interview with the curator took place individually, the interview with the designers was done in pair. Interviewing the two together produced a richer set of data as they not only responded to the direct questions, but also raised questions of their own for the other to answer. A dialogue emerged between the two as they corroborated each others recollections and added to each other's responses.
A clear role division emerged between curator and designers: the curators of the exhibition decided the content, including the objects to be displayed, the signature images to be used, and the information content of the interactive installations. Much of the layout and all of the technical aspects were left up to Martello Media to design.

3.1.1 Aims and Layout. Curator's and designers' aims were obviously different but complementary. The curator wanted to expose the library treasures to the widest possible audience in a complete and coherent way in order make Yeats person and work unveiled and explained. Of particular interest was to present less known aspects of the poet's life, e.g. the interest for occultism and his political involvement. Designers were more concerned with exploring new ways of exploiting digital interaction while presenting the manuscripts in the Library at their best. Both curators and designers wanted to address a wider public than scholar.
The curator and the designers focused on different aspects of the exhibition layout: the curator on the organization of the content, the designers on the appearance. The curator discussed the autobiographical or chronological order that develops along a full circle around the room, "starting off with his early life and going right through to his epitaph".
The designers mainly discussed the sensorial and aesthetic aspects of the layout: a dark space with text displayed on screens in reverse (while on black background) to avoid white bright squares that would clash with the signature image nearby; the touch-screens suspended on poles that become an element to design the space; the use of warm and cold colours to underline Yeats' lunar cycles.

3.1.2 Content Selection. Discussions seemed to have occurred while the content was selected, although the curators were the ones who decided as they were both experts and knew the content of the collection. Novelty seems to have been the driving force in the content selection for the curator: 'material that the family would have donated', 'things that people haven't seen before that are considered important', 'manuscripts [...] never seen before because it's never been put on display'.
Designers pointed out that initially curators planned to exhibit only manuscripts (as previously done in the Joyce's exhibition), but where suggested including 'life cases' and 'stuff about the people', implemented in the exhibition by showing Yeats' passport or the filled questionnaire. Designers requested images that 'could

be treated thematically similarly' but the actual selection was done by the curators as 'they know which image is important and how they link to each other'.

3.1.3 Digitisation. As digital surrogates were at the bases of the exhibition, a section of the interview investigated the work done to digitize original material and the perceived value. Martello Media was mainly responsible for the digitization: different devices (scanner, camera, photographic table) were used depending on the material in hand and the expected use of the digitized image (e.g. the 2 meters high signature images). The digitization process was done iteratively as new material was selected for display.
The digitization is perceived by the curator as an outreach more than a preservation tool: '[of] a book you can only display the front or the back of a page whereas with a touch-screen you can show ...you can see the cover and flick through inside' 'turning the page technologies [..] really does give people an idea of the book'. The composition of a DVD of the exhibition was mentioned as an important result of the digitization.
Digitization for preservation was mentioned instead by the designers. They also highlighted the possibility to show every detail of every single page of the most delicate manuscript to everyone: 'It's like a democratic access to objects that you couldn't show otherwise'. Interestingly they pointed out how the digitized images can be overlapped with other material: 'you've got the manuscript there in front of you untouched but then you can layer information over it, highlight the various areas because the manuscript can be hard to interpret, the handwriting isn't always easy to understand, so you can highlight things, do the transcripts and all that and then you can wipe it all away again.'

3.1.4 Interactive Installations. Both the curator and the designers highlighted the fact that the interactive installations allowed to offer many more objects that what was physically possible: 'There are 400 objects on display and a further 2500 represented through the touch screens'. Displayed objects become starting points for navigation in a wider information space.
Another common comment was the possibility the interactive installation offer to explore complex in-depth concepts, the process of writing, the changes and the stages. The curator mentions the gaining of a deeper understanding, a more enjoyable experience and the stimulation of a more exploratory attitude as advantages of the interactive installations. The designers mentioned the possibility of providing multilingual captioning and the advantage of not overloading the wallboards with text (aesthetic) while 'having a real expert over the shoulder telling you into you ear exactly how it is'.

3.2 Visitors' View and Tour Guide Opinion

A questionnaire aiming at investigating visitors experience was distributed over a period of a week and had 148 respondents. The questionnaire consisted of fourteen closed and open-ended questions about: personal and group profile; their visiting experience (expectations, use of interactive installations, favourite exhibit); and their learning experience (general as well as particular).
The lack of control over the sampling process might have had an impact on the data collected: since it was entirely up to the visitor whether to respond or not, those who either had a very positive experience or a very negative experience may have been more motivated to fill out the questionnaires. In order to balance the questionnaire result, the tour guide was interviewed about her observations of visitors' interaction with exhibits.

3.2.1 Visitor Survey Result. The age of respondents was quite varied: 9% were children under 12; 7% teenagers; 16% between 18 and 30 years old; 37% between 31 and 55 and 30% above. Considering the topic of the exhibition (a poet) and the time (out of school time) these percentages with a majority of adult people should be expected. Visitors came with: a group 9%; the family 7%; friends 37% and alone 30%. The

percentage of respondents who visited alone is very high; this could be due to the fact that the exhibition is in the Library, a place where it is likely to go alone[3].

The global feedback was extremely positive with the majority of respondents (59%) that stated the exhibition exceeded their expectation; 30% who liked it and only 6% who said it did not meet expectation or 3% did not like it.

Two questions asked which was the most and least favourite exhibit. Tables 1 and 2 below show the answers (in numbers of respondents and percentage). As the question was open for respondent to write their opinion not all respondents filled in this field and the answers are quite varied. 93% of respondents decided to write their favourite exhibit, while only 34% wrote their least liked one.

Verse and Vision and the Evocations were the most favourite (if the instances related to evocation listed by visitors are added – Abbey, Study, Occult, Women, Georgie, Esoteric – the percentage rises at 24%). Next favourite was the touchscreen preferred by 10% then there is a spread of other preferred items. Interestingly, The Tower, surely the most complex and challenging of the installations, was the favourite of one visitor.

Physical aspects of the exhibition feature prominently as a least favourite aspect: sound (9%), darkness (4%), too much (4%) etc. The wide range of media used in the small space of the exhibition caused a conflict in audio presentations while darkness was necessary for the conservation of the artefacts on display. The audio was perceived as a problem wherever it was used, i.e. Verse and Vision, Evocations, and the tutorials on the touchscreens. To avoid this inconvenience and keep the social dimension of a shared experience directional audio devices should be used.

Verse and Vision and Evocations seem to be controversial items as they are the most disliked exhibits mentioned. The majority of respondents who disliked Verse and Vision were children that instead listed the replicas as their favourite. Both results are not surprising as listening to poetry is a passive and reflective experience, while children are likely to prefer a hands-on approach.

[3] No question investigated if the visit was planned or happened because the person was already in the Library.

Most Preferred Exhibit		
Verse & Vision	43	29%
Evocations	20	14%
Touchscreen	15	10%
All	12	8%
Replicas	7	5%
Artefacts	7	5%
Abbey	6	4%
Manuscripts	6	4%
Occult	5	3%
Wall Displays	2	1%
Women	2	1%
Study	2	1%
Objects	2	1%
Tour	2	1%
Tower	1	1%
Information	1	1%
Esoteric	1	1%
Georgie	1	1%
Influences	1	1%
Family tree	1	1%

Table 1. Answers to 'What's your favourite part of the exhibition'.

Least Preferred Exhibit		
Sound	13	9%
Evocations	7	5%
Verse & Vision	7	5%
Darkness	6	4%
Too much in exhibit	5	3%
Exhibition cases	3	2%
Manuscripts	3	2%
Wall displays	3	2%
Too many people	1	1%
Too much in small space	1	1%
Not enough seating	1	1%
Not enough poetry	1	1%

Table 2. Answer to 'What's your least favourite par of the exhibition'.

Respondents who disliked the evocations primarily dislike their content, in particular the evocation relating to the occult. This may be because of the new and controversial nature of this aspect of Yeats' life.

A set of questions specifically investigated the experience with the touchscreens. Of all those who responded, 85% interacted with the touchscreens while 10% did not. The reason for not using it were: not enough time (2%), no interest (2%), do not know how to use it (2%), do not like it (1%), too loud (1%), too crowded (1%). Of those who have used the touchscreen 93% said it was easy; the 7% who had difficulties stated that it did not work, the content was not interesting or too cluttered, that was too loud. The fact that 6 people said the touchscreens did not work does not mean necessarily that the technology is not robust: the short time of the survey and the fact that it was early in the opening[4] may have produced data unrepresentative on the long run. When questioned, 86% of respondents agreed that interacting with the touchscreens added something to the experience and 63% stated they have learnt some by interacting that they would have not found elsewhere in the exhibition (7% disagreed and 30% did not answer).
The last two questions aimed at understanding if the exhibition had been successful in terms of new knowledge acquired: 70% said they have learnt something new, while 5% did not (25% did not answer). The topics that was new to the most respondents was Yeats's interest for the occult (14%); this was expected as it is an aspect of Yeats' file that only recently came to the attention of scholars.

[4] Problems are likely to emerge soon when installation are in place, later set and solved.

What has been learnt		
Occult	16	16%
Yeat's Personal Life	14	14%
His Work	11	11%
Affairs	9	9%
Family	8	8%
Women	7	7%
Relationships	6	6%
Political life	5	5%
Everything	5	5%
Influences	4	4%
Abbey Theatre	4	4%
Work Process	4	4%
Georgie	3	3%
Political situation	1	1%
	97	

Table 3. Answers to the question: 'describe one new thing you have learnt'

Facts on his private life was a novelty for 14% of visitors, that could be extended to include answers like: affairs (9%), women (7%), relationship (6%), political life (5%). Considering Yeats is known as a poet, it is somehow surprising that 11% stated as they have learnt something new about his work: this indicate the exhibition has been successful in making Yeats' poetry better known and appreciated. Another interesting answer is the 4% of people who listed the work process as new learning; this is likely to refer to The Tower installation showing that even very complex content can be appreciated, even by just a minority.

3.2.2 Visitors as Observed by the Tour Guide. The role of the guide during the half hour long tour of the exhibition involved leading groups through the biographical path of the exhibition, providing an overview of each thematic area, drawing visitors' attention to particular exhibits and displays, and providing a demonstration on how to use the interactive touchscreens.

Visitors' feedback as perceived by the guide was generally very positive and many said it was necessary to comer back to take in all the information. Complaints were limited to the poor lighting, but the situation was easily accepted when conservation reasons were explained and the function of the touchcreens to see the objects in more detail proposed.

The guide suggested that older people did not interact with the technology very much while children loved it. A Chi square test of the correlation between age and use of the touchscreens showed that age does not have any bearing on the dislike of technology. This may be because of a preconception, similar to that disproved in the Petrelli and Not (2005) study, or it may be that the tour guide were asked by older visitors to show them how to use the screens, giving then the guide the impression that older people were unsure on how to interact while at the same time giving these visitors the encouragement and know-how to use it.

4 A Hybrid Approach Is the Key to Affective Communication

The aim of the exhibition as derived from the interviews was, not only to showcase the collection, but to reach out to as many people as possible and illuminate previously overlooked areas of Yeats' life. The range of content, the broad spectrum of respondents to the questionnaires, and the answer on what was learnt show that all of objectives were achieved.

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[4] Problems are likely to emerge soon when installation are in place, later set and solved.

The wide range of favourite aspects show the array of preferences exhibition designers have to cater for and emphasises the importance of using several methods for a successful engagement with the audience. The combination of items and concepts exposed should be as varied as possible. Although the initial plan was to use only manuscripts, the inclusion of everyday objects and personal items (e.g. the questionnaire) made the Yeats' exhibition more lively, approachable and enjoyable than the only exhibit of his work. The first challenge for exhibition designers is to identify a variety of content that can appeal different people.

The variety of content was matched in Yeats' exhibition by the variety of media used: more passive presentations (listening to poetry or watching videos) where interleaved with electronic interactive points (touchscreens and turn-the-pages installations) and more traditional touch-and-feel objects (replica of the passport and the family album). As not all visitors are excited by, or interested in, technology, this variety allowed each individual to engage with the modality they felt more comfortable with. Moreover the position of the interactive cases and the use of audio instead of text to convey content allowed passive visitors to acquire information by watching while someone else interacted. The second challenge is then to plan for different attitudes and abilities and design the digital interaction to support a 'social access' to the information.
To ensure that different media are seamlessly integrated effectively in the ambience is a further challenge: the content, the media and the environment have to be designed together to create a holistic experience. Particular attention should be paid to invasive media like audio: quite visitors may feel inhibited in the interaction if they perceive the narrative may annoy other visitors.

The presence of artefacts as mean in the learning experience was brought into question by the lack of respondents who mentioned the artefacts as their favourite part of the exhibition. This could be due to the excellent use of the digital images that recreated the sensation of interacting with the original both with a physical replica and its electronic reproductions. Indeed digital surrogates were used all across the exhibition in both high-tech (interactive displays) and more traditional (the wallboard questionnaire (Fig. 8)) forms. By mean of digital images the Library was successful in driving attention to Yeats' literary work and, ultimately, to fulfil its role.

The exhibition demonstrates the value of digital multimedia in creating engaging and stimulating environments. Through digital interaction it was possible to expose more artefacts and more information than what the space allowed (the exhibition has 400 items exposed and 2500 electronically available). The use of the digital medium allows to provide visitors with a choice and layers of information and supports personal attitude as each individual can investigate more or less of each issue. The role of an exhibition designer in than that of proposing to the public multiple paths of visits and leave each visitor free to select the mode and the level of engagement.

In summary, as for science museums (Davison et al. 1994), a mixture of more traditional presentations (cases with artefacts, reconstructions, graphic panels) supported by multimedia (audio and video, touchscreens) and hands-on sensory components (touch replicas) demonstrated to be the key for success even when the focus of the exhibition is composed by difficult objects like manuscripts.

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AutoTopography: What Can Physical Mementos Tell us about Digital Memories?

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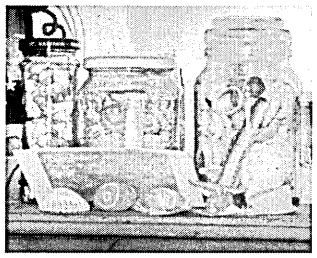
ABSTRACT
Current technology makes it possible to capture huge amounts of information related to everyday experiences. Despite this, we know little about the processes by which people identify and manage *mementos* - objects which are directly meaningful to their memories. Among the millions of objects people encounter in a lifetime, few become such reminders of people, places or events. We report fieldwork where participants gave us a tour of their homes describing how and why particular objects become mementos. Our findings extend the existing digital memory literature; first our participants didn't view their activities as experiential 'capture', nor were mementos limited to pictorial representations of people and events; instead they included everyday objects. Furthermore, mementos were not only displayed and shared, but also integrated into everyday activities. Finally there were complex relations between house location and memento type. We discuss the theoretical and technical implications of our work.

Author Keywords
Fieldwork, autobiographical memory, digital mementos.

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
Memories are crucial to self-identity and everyday functioning, yet memory is known to be fragile. Much research is currently being done into 'lifelogging'. Examples include recording every conversation, computer interaction and piece of encountered information [1], audiovisual logging of personal experiences [19, 22]. This approach is motivated by the view that memory is an *archive*, with a consequent emphasis on capture. By emphasizing capture, however, it fails to address people's motivations for remembering past experiences and what they value as mnemonic representations of their lives. While other research [7, 12, 10, 17, 23] has begun to document how different memory technologies are used by people, the dominant approach still emphasizes capture.

Instead of focusing on the technology involved in complete capture of one's entire life, this paper therefore reports a fieldwork study to understand the principles behind *mementos*. A memento is an object given or deliberately kept as a reminder of a person, place or event.



"the shells are quite important because they are memories of our family holidays"

Figure 1

A better understanding of what makes a memento, as well as how, when, and why mementos are chosen should help the design of technology for recording, storing and accessing digital memory. We are interested in documenting how people use such objects to construct a sense of themselves by cultivating their physical environment – behaviors referred to as *autotopography* [14]. An autotopography is an arrangement of those objects that constitute "a physical map of memory, history and belief." Our research therefore shifts the focus away from capture technology to ask how people choose significant memory objects and how they arrange and use those objects in their living space. We address the following questions:

- What *types* of objects are mementos? Are mementos predominantly photos and artwork, or do other types of object serve this function?
- *How* and *why* do certain objects serve as mementos? Do they represent an event in the owner's life, do they signal social relations with others, or are there other reasons?

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- *When* in a person's life are mementos drawn from? Do they relate to the distant past, or throughout the lifespan?
- *Where* are mementos kept, and does location relate to their type? For example, are personal mementos kept in private spaces and social mementos in public locations?
- *Invocation:* How do people interact with mementos? Are they used as talking points with others, or are they placed in personal spaces to facilitate more private reflection?

The study involves parents of young children touring their house and discussing objects related to their own past. We identify key principles that underlie objects becoming mementos. We discuss the implications of our findings, concluding with new design principles and concepts for digital memory technologies.

RELATED WORK

Our research intersects autobiographical memories, personal and family interaction, material culture and technology. So far, prior research has focused on each of the above separately and from a specific point of view.

Research on memory has been carried out mainly in psychology. Recent work challenges the traditional view of memory as a knowledge base [6], instead proposing a core role for recollection and social dynamics [4, 10, 21, 27].

Sociological studies of personal and family interaction have focused on the role of objects [8] or photographs [5]. When technology is included the focus is on family communication [9, 16] or photo sharing [7, 12].

Philosophers have theorized about the relation between the self and the home as lived experience of the space [2] and on the act of remembering as a constant shifting between the abstract mind and the physical world [3].

Some anthropological studies have examined material culture and the life of individuals. The process of commoditization changes the perceived value of objects depending on the culture [20]. Everyday objects can become biographical [15] or evocative [25] by virtue of the meaning imputed to them by the owner, e.g. as significant personal possession [15], or symbols of experiences [25].

HCI research has addressed helping people remember factual information (e.g. [17, 18, 23]), with rather fewer studies of the role of memories in people's emotional life and the implications for technology design. The Memory Box [11] used a jewelry box metaphor to associate a recorded narrative with a souvenir. It appealed more to women and children: children used it as a personal journal, while adults perceived the value of attaching narratives to objects only if they were given/received as gifts – but not for personal use. The work identified a clear need for a self-contained, simple technology for recording and playback.

The Living Memory Box [13] supported the collection, archiving and annotation of family memories. An ethnographic study investigated the "who, what, where, when and why of [parents] saving memories of their child's life". Parents collected some mementos for children but never recorded stories related to those objects. The resulting system allowed users to place a physical object in the Living Memory Box, record its appearance, an audio narrative and metadata to support later retrieval. The concept was tested with scrap-bookers. The results show that personal archival systems must be designed differently from PCs, supporting natural interaction (e.g. touch, voice).

Souvenirs, personal memory, and recollection were investigated in [26]. Participants discussed souvenirs they had brought to a focus group meeting. Analysis of discussions suggested that souvenirs are esoteric: they carry meaning for their owner but this is obscure to others. Furthermore, the telling of the story behind the object changed depending on the relation between owner and audience. A questionnaire on the perceived value of souvenirs and their function in people's lives revealed: souvenirs relate to memories of a personal experience (holiday, honeymoon) or a specific person (heirloom, gift), and are "used" (watched, talked about). Informed by these studies the author designed a system that used RFID-tagged physical objects to retrieve a set of images previously associated with the object. A hand-held device (a tablet PC) allowed users to view images, share a subset on a TV, manage collections, or send selected ones via email or print.

METHODOLOGY

Our fieldwork study aimed to understand the principles of how and why an object becomes a memento. The home was chosen as the place to study, as it is a space created and cultivated as a "container" of the owners' intimate self, beliefs and aspirations. The family home in particular contains personal and shared objects, the most valued often being related to memories [8]. The family home is a richer place to study than other inhabited public spaces, e.g. work places, as participants have more control over how that space is constituted and configured. We focused on families with young children as being active collectors of mementos. Parents have memories of their own lives before meeting their spouse; shared memories as a couple; and are generally highly active as curators of their children's 'future' memories.

We recruited a middle class sample on the basis of [8]'s finding that they are oriented to memories and relationships in contrast to other social groups that focus more on possessions. Participants were recruited by acquaintance and covered a range of professions (doctor, museum conservationist, high-level managers, architect, training consultant, publisher, marketing manager), a housewife (with a degree in psychology) and a few academics.

In contrast to much previous research that used interviews or focus groups for data collection, our participants had a highly active role. We gave them this orienting information: *'We would like you to take us on a tour of your house. We want to see rooms that you consider public, family rooms,*

and your own. In each room we would like you to pick 3 objects related to your life and tell us why each object is special, when and how you got it, why it is in this room and if you ever reflect on it or talk about it.'

For each participant, we collected at least 9 objects and their associated explanations and stories. By contrasting three different room types we wanted to probe the relations between the public/private nature of the space and the type and intimacy of the mementos in that space, e.g. a public room used for entertaining, might display an artwork received as gift, while the study might hold personally significant pieces, e.g. photographs of holidays.

This "memory tour" allowed us to collect both autobiographical narratives as well as observations about object location and any accompanying emotions displayed by the informant, e.g. the way an object was caressed or held. While there were specific topics we intended participants to discuss, e.g. what memory the object evoked and why it was important, we let participants talk freely and prompted only those topics that were not spontaneously mentioned. The overall tone was informal and friendly, and a small gift was given as token of gratitude for participation. Questions about the participant's attitude towards keeping objects concluded this memento tour. As we shall see, only one participant made reference to *digital* mementos during the tour, so we later explicitly probed attitudes to digital mementos. Participants were also asked to draw/sketch their autobiography. For reasons of space, we constrain our main analysis to the initial house tour and the objects people selected in it.

DATA COLLECTION AND ANALYSIS

In total, 16 people (from 12 families) participated in the study, 6 men and 10 women; 5 were living in a country different from the one they were born in. When both adult family members participated, the tour was done individually. Each session lasted 90-120 mins. and was tape recorded. Pictures captured the memento and its context. In total, 159 objects and their related stories were collected.

We were concerned that the affordance of the rooms and the request to select 3 objects might bias interviewees. However, participants often discussed more than the nine stipulated objects if more important ones came to mind at a later stage. Moreover some participants in the first room of the tour foreshadowed important mementos they would discuss in later rooms, showing they have a clear idea of which memories and mementos are important. Follow-up questions and comments also supported the view that we were able to collect stories about people's most critical autobiographical memories.

We transcribed all the interview tours, and systematically classified relevant portions of text. The topics of interest were used to start a broad classification, e.g. type of object, location, value, time (in the person's life), while other dimensions and refinements emerged from analysis of the narratives, e.g. reference to specific periods in the owner's life or emotional involvement. We first generated a wide set of terms that were later aggregated and distilled into a smaller set. The final set of dimensions of analysis were:

- *Type of object.*
- *Where* the object was located, and *how* it was displayed.
- *When* in the owner's life the object referred to.
- *Why* the object was precious, and the *nature* of the memory it represented.
- *How* it served as a memento, and
- In *what way* did it trigger memories?

The next section reports the results following this structure.

Some participants claimed not to distinguish between public and family rooms, while others clearly did, e.g. "*we use this room for proper visitors because friends would go in the kitchen and the dining room, whereas people like the financial advisor comes here*". By observing the properties of rooms classified by most participants as public, family and personal, we were able to extend the classification to all participants: *public* - formal rooms (sitting room, lounge), *family* - informal places (family room, kitchen, dining-room) and *personal* - rooms like bedroom or study.

FINDINGS

Types of Mementos

One striking observation was that *only one* participant chose a *digital* object during the tour: "*maps. I make my own maps because I do a lot of cycling and journeys. These maps then become the memory of the occasion and it's quite vivid for me*". This was not because the other 15 people did not have any digital mementos: indeed when we later specifically asked them to describe their digital artifacts, they referred to videos, digital pictures, emails and recordings. It was also clear these digital objects engendered strong feelings: "*[video] is a wonderful way of seeing someone alive, and when you're far away I think it has even more significance*", "*lots of emails, the history of what we were doing [...] feels like a record I would like to keep*". Nevertheless, despite this rich potential and their visibility in the toured rooms in the form of tapes or DVDs, only one digital memento was spontaneously chosen and talked about.

Much prior sociological and technology work on memory has studied photographs and how these are used for personal reflection and sharing [7, 12]. Consistent with those studies, we found some instances of photographs as significant mementos, especially if these were old, unique or irreplaceable in nature: "*this is my father, who died quite young, it's one of the few photographs I've got of him.*"

However photos were only one of a much larger set of objects that served as mementos. Strikingly, photos accounted for only 16% of mementos, and six people did not refer to photos at all. This does not mean that their houses did not have any photographs on display, but rather

that participants consciously selected other type of objects as the mementos they most relate to.

Artwork was another frequent choice, accounting for 28% of mementos discussed. It could take the form of *professionally* produced paintings or photographs, prints or drawings (17% mementos). An example is given by a scientist originally from France, who describes two paired paintings on display in the front room (A. is her husband, K. a close friend): "*I never thought that I would ever buy artworks, but meeting K. opened my eyes, and this is done by a French artist. A. picked it, and he knew I would love it, he just borrowed it from K.'s gallery and brought it home and said 'What do you think of that?' He was able to pick something that I totally loved ... It is amazing that you could understand someone like that, and for me, it gives me peace, it's a kind of giant monk, framed, and I'm never tired of looking at it, and it's the sort of first step in discovering that art is accessible to everyone, really*"

The quote shows that the function of the painting goes well beyond the simple aesthetic. Instead it is an embodiment of the strong bond with A, who has an 'amazing understanding' of her, and K who pushed her, a scientist, to discover her artistic side. Less evident, but significant, is the connection to her roots - as the artist, like her, is French.

Another important class of artwork was *amateur* efforts produced by family or friends (accounting for 11% mementos), in particular young children's art and craftwork projects (9%). One such example was a framed print produced by the son (F) and described by the father in this way (J is his wife) (Fig. 2):

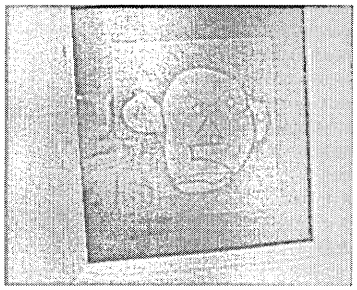

Figure 2 "*It is a print that F did... he did it very quickly at a fair... I do printing... I'm kind of interested... this is art and is really fantastic... it is also funny because when he did it he said very clearly it was uncle R... a crazy beast or a monkey is actually J's brother...we like it because he made, is very beautiful and funny but it is also a secret.*"

This object is important not only because it was made by his son, but also for the special bond between father and son via the printing activity, and the shared secret depiction of another family member.

As both examples show, these artworks were valued not only for aesthetic but for other reasons, i.e. bonds with family and friends, symbols of significant aspects of their lives, and humor.

Somewhat to our surprise, mass-produced objects often served as important mementos, and account for 28%. Mundane *everyday objects* such as a cup, clock, coffee machine, golf tee, pots, cookery book, teapot, children toys, ladder, calendar, bed, stove, candle holder and books were all chosen and talked about. What make them special is the time and energy invested in using them, as from the following examples.

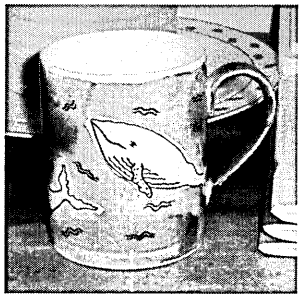

Figure 3: "*Object number one is this mug ... which is actually broken ... I've kept it because I really really like it ... I will never use it again but I can't quite bear to throw it away I feel very emotionally attached to it for some reason. [...] I bought it in London, when I was working in London. It cost a lot of money ... it felt like an indulgence but I felt like I could. I think [it's the memory of] working in publishing, living in London and going through a sort of fulfilling patch in my career ... Also I associate it with buying my first house, having it there in the kitchen in my first house...So its also an object of continuity because I think I must have had it for ... Ooh ... let me think I've probably had it for nearly 20 years!*"

In some cases, the value of a mundane object goes beyond its use, like in the following example where another French woman talks about a French cookery book: "*This cookery book is by Joanne Harris who wrote 'Chocolat' I often use it when cooking with my girls on special occasions like Christmas day. ... she's British, but she's got a French mother [...] When I first read 'Chocolat' I was thinking: 'This has to be the island [where I spent all my holidays as a child], it has to be'. And then I found this cookery book, and there's plenty of photos of the island!*"

The book symbolizes intimacies with her daughters but is also a connection to her native country and her roots via the island where she spent childhood summer holidays and where she still has a family home.

Everyday objects become mementos by virtue of what the owner has invested in them, be it time or emotion. Thus, it is not usually the physical characteristic of the objects that make them biographical, but the meaning imputed to them as significant personal possessions. This makes everyday objects substantially different from iconic and representational objects like photos and artworks. Everyday objects gain value by progressive appropriation: it does not matter if they become worn or cracked as this reflects the time passed for them and the owner alike.

Yet other participants chose what seemed to be unintuitive objects which we called *memorabilia* - accounting for 20% of mementos. These were objects with a specific function, but unlike the everyday objects they were not in habitual use. Examples here included a stereoscope, rocking horse, measuring glasses, and a set of illustrated cards.

A final class of mementos, accounting for 8% of the objects, was highly *idiosyncratic* – falling outside the above categories. They included a shell collection; pregnancy cast; a jar containing a father's ashes; child's first nose bogey; hand made lead bullet; a framed 1997 coffee shop receipt; 30 years of diaries; "objets trouvé" (e.g. a dog collar tag without a dog - *"maybe one day I'll phone this number, and find out a bit more about Barney the dog or his owner"*).

Idiosyncratic objects are important for deeply personal reasons. The medieval scholar who selected his baby son's first bogies provides this motivation: *"[laughing] some people keep their child's hair, why not a bogey?[then seriously] in the middle age they believed that this things were important... bits of body were used for invoking magical powers... keeping his bogies was in line with that tradition"*. Apart the humorous intention, the connection between early memories of his son and his professional interest is evident.

Idiosyncratic mementos are often intentionally created: *"the cast of my tummy when I was five months with R, I got the idea from some beautiful casts made in my friend's art gallery. My pregnancy with R was the last one and I wanted to have some memento of it, and it was quite fun to do it."*

Other idiosyncratic objects become mementos by chance because of what they symbolized: *"a receipt, from a café, in Buenos Aires for two 'submarinos', a kind of Argentinean version of hot chocolate. You cannot really see because it's faded but the date was Christmas Day, Christmas Day 1997. There's a story about that. Years ago, every Saturday Guardian[1] had a competition [...] we won a pair of Air France tickets to go anywhere they flew! So we went to Buenos Aires for Christmas and spent New Year in Paris. So it's a sort of celebratory thing, it reminds us of our lucky win but what we didn't know at that time is that J was pregnant, so we probably wouldn't have gone if we knew. I guess that's a memory of the trip and the gift of our family."* The receipt was later rediscovered in a guidebook and framed.

In sum, we found a large variety of different objects served as mementos, although only one was digital in format. Photos, often considered as the prototypical memory trigger, were only the fourth most frequent type of object. As expected, artwork was popular, but to our surprise we found an equal number of everyday objects being invested with mnemonic significance, as well as much more unusual memorabilia and idiosyncratic objects. What makes those other objects substantially different from photographs and artworks is that the relation to the original memory is often highly indirect. They do not directly represent significant events or people, nor are they conventionally visually attractive. As will become more evident later, their selection seems to be motivated by the fact that the owner has invested emotions in them, building meanings, and spending time cultivating them.

Where in the House were Mementos Located?

The reason for asking participants to select objects from public, family and personal rooms was to explore the relation between object type and location, e.g. were photos more likely to be in family/private than public spaces? Do people put objects that connote different meanings in different locations, e.g. social relationships in public?

	Artworks	Photo	Everyday	Memorabilia	Idiosyncratic
Public	44% (P=39, A=5)	17%	25%	11%	3%
Family	38% (P=16, A=22)	18%	33%	9%	2%
Personal	15% (P=10, A= 5)	15%	27%	29%	14%

Table 1. Types of Objects and their Locations (P is Professional, A is Amateur).

Differences were found among rooms (Table 1). Public locations often display professional artwork, primarily because of their aesthetic quality. In contrast, family spaces contain more amateur artwork (e.g. by children) to reinforce relationships in areas where families spend more time. Although memorabilia are generally kept to personal zones, they can at times be on display in public rooms as objects of curiosity or conversation, like granny's fruit plate or the framed receipt described above.

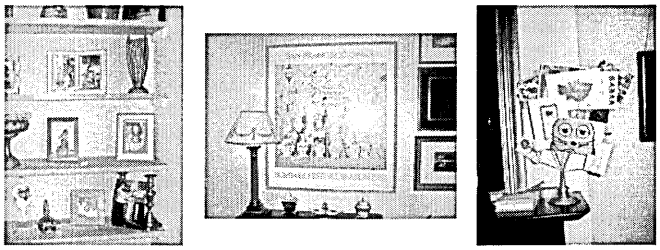

Figure 4. Photos, artwork and memorabilia in public spaces.

Finally personal spaces tended to have more objects related to the self (40%) or to long past events (20%). Here we also saw more symbols of professional achievement or personal interest, as well as more memorabilia and idiosyncratic objects. The reason for this dichotomy (memorabilia and idiosyncratic objects in personal spaces vs. artwork and photos in shared spaces), is clear in the words of an informant describing her grandmother's perpetual calendar that she keeps in her study (Fig. 5):

[1] The Guardian is a popular British newspaper.

Figure 5: *"That's something I remember playing with a lot as a child [..] sometimes these things are ... erm... untranslatable or "uncommunicable". I mean, [my husband] would say: "Oh, why do you keep* ***that?*** *" "*

In addition we looked at *where* in the room the objects were positioned. Our expectation was that objects would occupy prominent spots to serve as constant reminders of people's pasts, or to spark conversation with friends and relatives. This was true for artworks, photos, everyday objects and some memorabilia in public spaces. *"I like to have [the pots] out ... people would say "Oh that's a nice pot." and I say "My dad made it, actually." So there is a sort of conversation point, too."*

Strikingly, 25% of selected objects were not on display but put away in cupboards and drawers. In some cases the fragile nature of the object (china, glass) is the reason for storing. Often however (47% of time) the concealed objects were related to the person's distant past and rediscovering them is a special event, as discussed below.

In summary, there is a clear autotopography of rooms. There are clear differences in the *type* of mementos people use to populate their social, family and personal spaces and in the *position* they choose for those objects. Photos are distributed throughout the house, professional artworks are more likely to be found in public rooms while amateur (mainly children's) artwork is in the family room. Memorabilia and idiosyncratic objects are generally restricted to personal spaces. These differences seem to reflect different levels of intimacy with the spaces, providing good evidence for autotopographies.

What Time Period do Mementos Refer to?

We also looked at *when* in the person's life the mementos referred to. Previous research has described mementos that are typically objects from the distant past [6]. We did find some instances of objects invoking distant childhood (19%, of which 12% were early years, 7% teen-age) and youth (9%). However, the highest percentage (46%) of mementos relate to the *recent past* (the last 10 years) - connecting to current relationships and family. Another 22% of mementos refer to adulthood before marriage, as in the example of the whale mug. Finally 4% related to the interviewee's roots.

The time in the person's life that the memory refers to affects the memento's location (Table 2).

	Roots	Childhood	Youth	Adulthood	Recent past
Total	4%	19%	9%	22%	46%
Public	1%	3%	1%	4%	13%
Family	2%	3%	2%	5%	17%
Personal	1%	13%	6%	13%	16%

Table 2. Time of memory by location.

While mementos from the recent past are equally distributed in the different locations, childhood mementos are rarely found in public spaces. Those in personal areas are more likely to be related to the distant past than in other areas of the house (41% refer to youth or childhood). The high overall percentage of mementos from the recent past may represent 'memory in progress' - objects for which the owner is currently building the meaning as time passes. The example of the shells above is one such case, or as revealed in *"[the children's books] for me it's sort of transmitting the love of reading"*.

Why did People choose these Objects?

The next questions we addressed were *how* and *why* these objects served as mementos.

Previous research has documented three main functions for mementos: referring to events, relationships, and the self [8]. Our findings confirm, but expand, those results. As we expected, 13% mementos represented an *important event* such as a wedding or birth, a significant period in a person's life, such as attending university, or long-term hobbies like bicycling.

	Events	Relationship	Reminiscing
Total	13%	59%	28%
Public	4%	16%	2%
Family	2%	20%	7%
Personal	7%	23%	19%

Table 3. Motivations for mementos with respect to places.

59% of objects signified a *relationship with others*. As expected, some of these objects were direct depictions of others (e.g. photos) or gifts received from others. However relationships often went beyond these simple links, e.g. they might represent *activities* done together, e.g. sculptures done in an art class taken by both partners, children's artwork from weekly visits to the library for children's story time, or the French cookery book discussed above.

A more individual function is *personal reminiscence* – where a person privately interacts with the memento to relive previous life experiences. 28% of objects were of this type. However *personal reminiscence* turned out to have multiple aspects. It could refer to *identity* – memories that contribute to the person being who they are - such as photos of ancestors, or childhood memorabilia. But it might also relate to the self in more complicated ways, such as objects that reflect interests, e.g. tools used for a favorite hobby. Alternatively they could refer to *achievements* the person was particularly proud of, such as awards, authored books, or a medal for completing the London marathon.

Object function also relates to its location, with social rooms (public and family) dominated by relationships, and personal spaces having more reminiscing (Table 3). The position of the object in the room also depends on its function (Table 4). As expected, mementos of relationships

are prominent or on display; mementos of reminiscing are prominent if they are self-referential, or concealed if they are nostalgic objects.

In contrast to previous research, in 30% of cases we discovered multiple motivations for choosing an object. E.g. personal, social and life events are all mentioned in the following excerpt where L reveals how a shell collection (Fig. 1) relates to family holidays (events), her childhood (personal), and her children's education (social): "*the shells are quite important because they are memories of our holidays, and we each year build up our collection. I had a collection of shells when I was a child displayed in boxes labelled with their names. ... This is the past six years and each time we add more. [Collecting shells] helps to entertain the kids for a long time on the beach, and [gives a purpose]. I find that if you do an activity and then you don't do anything to it, it's a bit negative, it's like you're wasting you're time.*"

		Events	Relationship	Reminiscing
Prominent	45%	6%	27%	11%
Display	31%	6%	22%	3%
Concealed	24%	3%	10%	11%

Table 4. Position of mementos with respect to motivations.

The reasons *why* an object is valued include *family bonds* (44%), *nostalgia* (20%), *aesthetic* (16%), and *moral values* (15%). The importance of mementos as conveyers of moral values was unexpected but evident, sometimes made explicit as in the excerpt above, but other times more implicit: "*my grandmother was sort of very liberal quite a modern sort of person. She was very accepting and welcoming*" (when discussing her grandmother's china).

Many participants exhibited quite strong feelings "*it's amazing that you could understand someone like that*", or in the way they held and caressed objects. As expected, happy memories were more frequent: 30% were described as 'very happy' and 42% 'happy'. But somewhat curiously, 20% of mementos did not seem to stimulate particular emotions.

Contrary to other work on photos [5], 80% of participants mentioned at least one object related to sad events, such as death or divorce. But often people talked about sad memories in a positive way, e.g. remembering positive aspects of the personality of a dead parent, or talking about the difficult times as "*having moved on*" and "*realizing how happy I am now*".

Personal spaces tended to contain more instances of objects that invoked very happy or very sad memories: 59% of very happy memories are in personal spaces, compared with 25% in family and 16% in public ones. Sad mementos are never on display in public rooms, but are located in personal (67%) or family (33%) spaces.

Summarizing, there are often multiple reasons why objects are selected. Mementos that represent relationships can be found in any room while objects related to personal reminiscing are generally confined to personal spaces. Moreover objects symbolizing relationships are mostly on display and in prominent positions. Objects for reminiscing occupy personal spaces, but are often concealed and reserved for special occasions.

How Are Mementos Invoked?

Our initial expectation was that mementos would be prominent and visible, to support functions of *personal-reminiscence* and *sharing*. We discovered *sharing* memories goes beyond the simple showing of photos of events or relations to family and friends documented in prior work [10, 5]. Such sharing can cement parent-child relationships as when a mother explored her childhood memory box with her daughter K. (Fig. 6):

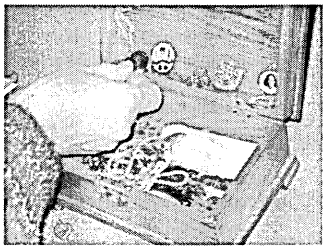

Figure 6: "*this was given to me by my grandmother when I was ten, and this was given to me by my mother when I was six, and this is my Brownie Badge... I showed [the box] to K. the other day and she was absolutely over the moon, she said 'I want a locket as well, with pictures of my mum and dad in it!'* [...] *You know, they've all got enormous meaning to me, but only to me now.* [...] *The only people I would think about sharing, would be the children. There is nothing inherently important. It's only important because it makes a link across the generations.*"

Spending time with children to explain one's own story, or those of parents, grandparents or extended family was a recurring theme. Parents and children alike enjoy it.

Boxes and containers of memorabilia as in the example are not unusual: thirteen (80%) of our participants showed or mentioned at least one such collection. Generally collections contain mementos of distant periods of the person's life, e.g. childhood, university life, and are created opportunistically with what has survived years of sorting and clearing. Other times they are created for a purpose, e.g. wedding memorabilia chest, or a family treasures box: "*My mother picked up all sorts of lovely little family treasures: pictures of my great grandparents, my great grandmother's sewing things, my great uncles wooden carvings and all sorts of old family things. It's like a little corner of part of my life.*"

These boxes of memories are often not easily accessible (stored in an attic, or deep in a wardrobe) and rarely opened. However when rediscovered they act as 'time

capsules', a whole past world is opened and the owner is thrown back in time - deeply immersed in reminiscing: "*that's one of [my son's] first pairs of socks can you remember when they were this tiny look look look ... oh I haven't looked in here for years funnily enough ... little bootie ... oh I can't even remember those were his first pair of little booties.*" Having these objects in constant view would habituate people; so concealing them makes more salient the contrast between that past world and the current one, triggering a world of nostalgia when brought to light.

At the opposite end of the spectrum are mundane objects that are often directly integrated into everyday activity: "*That was my father's step ladder, you see, and actually we have many objects of my father's around this house, even his car keys, the kids use his car keys as part of their toys ... I really like that because they're quite disappointed that they never knew him.*"

Incorporating memories into everyday life was a recurring topic: two people passed their teddy bears to their children, a girl played with her mother's jewelry, a son with his father's bow, an old stove found a new place in the lounge, and a grandmother's teapot was used everyday. People seemed to derive comfort from the integration of past and future, knowing that an important aspect of their past was somehow evoked every time they made a cup of tea, or lit the stove. Embedding mementos into a familiar space changes their nature: "*these photos are in the grain of the room, they're not just there because they can be. Sticking [a photo] on [the wall] is consuming it ... I often point one out to people ... that is so and so*". From this perspective, *using* mementos is more important than *preserving* them: "*objects on display are to be used, and not to be a museum piece. From time to time something does get broken ... the other day when I was mowing the lawn I mashed up my father's car keys because the kids had left them out there [...] I'd rather mash them up, knowing that the kids enjoyed playing with them for a few years rather than just have them in a cupboard.*"

Participants often mentioned the periodic sorting and clearing of personal belongings, distilling out what is still worth keeping: "*that drawer is all that survived from that bit of my childhood, really. It's been weeded down year after year. And every time you go through the drawer 'Oh God! look at all this rubbish, it's gotta go.' I wouldn't want to get rid of them altogether. I very much like having them here, in my house now*". Distillation is crucial: the process of going through a small collection of memorabilia is emotionally powerful, but large boxes put people off: "*loads of cardboard boxes with loads of stuff, in general junk really. I should chuck all out but I feel I should go through it and decide what I want to keep and it will take ages so I never do ... so the boxes sit in there*". As a result the content of these large boxes has little value, as it is never accessed. Thus having a compact collection is important in sustaining interaction throughout a lifetime.

In sum, different mementos are located in different places, affording different types of invocation. Apart from being displayed, memories are integrated in everyday life through mundane objects in everyday use - signaling continuity between past and present. Of particular emotional significance are small collections of objects concealed and opened only rarely. Accessing important collections, revisiting and sorting them is an enjoyable activity, reserved for smaller collections, while bigger ones tend to be ignored as the effort needed is perceived as too great.

Other Observations

There were other recurrent observations that fell outside the above analytic scheme.

Distinct gender differences emerged. For example, women seemed to determine what objects were placed in public spaces. As a result, men did not always find it possible to select 3 of their own objects in public or family spaces, and often resorted to talking about their wife's objects - making only weak connections with them. In contrast, they were much more forthcoming in their own space, such as their study, talking about more than 3 objects in this setting.

Consistent with other work [8], there were also large differences between men and women in terms of the objects that they chose. Men tended to choose objects that referenced themselves and promoted personal reminiscence, e.g. things that signified their interests or achievements. In contrast, women's objects tend to highlight relationships with family and friends.

The role of parents (and grandparents) as curators of children's memory was also evident. Every family saved children's artworks. Keeping, however, is not only done for the children, but for the parents to remind themselves of their offspring's achievements. Grandparents have an active role in connecting generations: most memorabilia boxes had been recently passed on from the grandparents to parents to be shared with the children.

DESIGNING DIGITAL MEMENTOS

We now discuss the design implications of our findings. In particular we are interested in bridging the divide between physical and digital memories. As we noted, only one participant selected a digital object as a memento, despite the fact that we later established that all our participants had large collections of digital memorabilia. Can we integrate these currently different worlds, combining some of the mnemonic affordances of physical objects into currently underexploited digital resources, or designing physical objects with enhanced digital mnemonic properties?

Active Selection Not Capture

Few participants viewed their activities as 'capture' in the way that current technology projects describe lifelogging. Capturing a large collection of mementos and later accessing these when needed is done only with photos. Instead participants talked about sifting through and

revisiting small collections of objects, choosing highly specific items for the associations that they triggered. The size of the collection matters and large collections tended to be ignored. This may be the fate of lifelog data, stored somewhere and ignored, if the owner is not given tools for sorting, clearing and distilling what is of value. It may therefore be that the processes involved in the creation of highly meaningful memory objects are very different from the rhetoric of total capture of one's entire life. Meaning construction rather than easy search should therefore be the goal of memory technology and time spent managing digital mementos should be perceived as creative and enjoyable, a substantially different experience from standard PC use. In practical terms, we need to build tools that facilitate sifting and selecting, rather than tools to retrieve *any* event from one's past.

Augmenting Objects with Digital Memories

The *types* of mementos people value is varied. Much current work on digital memory technology has focused on *representational* objects, especially photos. However photos (and pictorial artwork) accounted for less than half of the objects people chose. One obvious implication here is that we need to extend the set of digital technologies beyond the pictorial. While some work has begun to develop technologies that allow users to interact with other types of significant objects [13, 26], we need to broaden our designs to encompass everyday objects, memorabilia and other idiosyncratic objects that we saw being talked about here. We need ubiquitous technologies that allow users to interact with and manipulate external objects, rather than focusing on the 'capture' of images of events or people. The key principles designers should keep in mind are that digital mementos have to be tangible as well as long lasting, self-contained and straightforward to access.

Non-pictorial technologies usually bear an indirect, symbolic relationship to the original memory, and it is the informant's narrative that invests them with the relevant mnemonic meaning. In contrast to a wedding or vacation photo, one cannot look at nose bogey, a café bill or teapot and infer why these might be highly significant to their owner. But if we broaden the class of memory objects beyond the pictorial, we need new technologies that allow users to annotate and provide narrative explanations for the objects they value. Our participants showed great pleasure in manipulating their mementos indicating the value of embedding recording and playing functions in the object itself [13, 26], rather than a specialized device designed for memory capture.

A Memento for Every Mood

Mementos can be invoked in different ways. They can be *displayed* in prominent places, to be seen, reflected upon and *shared* via conversations; or they can be *integrated* into everyday life through everyday objects. Finally they can be *revealed* – so that when they are uncovered they regenerate forgotten experiences relating to concealed collections of objects. However current work on digital mementos has focused largely on the first types of usage, namely *display* and *sharing*, as represented by the use of large displays such as tabletops, TVs, or dedicated photoframes. Rather less attention has been paid to *integration* or *concealment*. How might we support these types of invocation? *Integration* might be achieved through the use of augmented reality techniques whereby everyday objects such as cups, teapots or even stepladders may source memories directly, e.g. placing a RFID tagged cup in a given location triggers sounds or images from the memory period relevant to that object. Investigations of these concepts has just begun: tagged souvenirs can retrieve related photos for display on a tablet PC [26] and an augmented shelf play narratives associated with the mementos that are placed on it [11]. Although some work addresses *revealing* [13], this may be more complex to support. How can we provide dedicated containers for small classes of physical or digital objects that allow users to 'enter that past world'? A special digital container could allow depositing digital (and physical) mementos by just dropping them into it. It might be a box that could be flattened when open providing a wider surface for interaction; it should be self contained, portable and not need additional software to show its content. As an augmented object (e.g. via RFID) is deposited, additional information can be automatically collected by the container and stored locally. When, 20 years later, the owner opens the container, she will find not only the objects she put in it but additional information that was automatically added - pictures of her friends at that time, her university timetable, maps of her travels in Peru, the music and news she was listening to, and clips of her then favorite TV programs.

Memories to Fit Living Spaces

We discovered a clear relation between object types and their locations. As expected, we found different classes of objects, with different emotional character in public, family and personal settings. Again we might want to think about different design characteristics for these different spaces, or augmented environments, with the emphasis being on *display* techniques in public areas, *integration* of everyday objects in family areas, and *revealing/reflection* in personal locations. An alternative is that a single object might have different properties in each location. Thus grandma's teapot might retrieve old family photographs when placed on the family interactive table for social sharing with the cousin's family visiting; when taken upstairs to the bedroom and placed next to grandma's portrait the teapot will play the stories she was used to tell the cousins at bedtime when they were young girls spending their holidays in her house.

CONCLUSIONS

We conducted a field study to understand the principles underlying the relations between people, their memories and their mementos. People relate to a small number of objects that are carefully selected and invested with meaning. Personal reminiscing and sharing of pictorial

representations are not the only ways of relating to personal memories. Mementos are ubiquitous, but their nature and functions can be very different. Artworks in public spaces support social display and conversation, children's drawings and mundane objects in the kitchen comfort the family in everyday life, while long forgotten private memorabilia kept in a drawer unlock emotions. Mementos in inhabited spaces thus create a memory landscape of autobiographical objects, an autotopography. "an addition, a trace, and a replacement for the intangible aspects of desire, identification, and social relations" [12]. The design of technology for personal memories must carefully consider these findings to avoid creating devices that do not reflect these processes. Tangible digital mementos, everyday objects augmented with digital memories and ambient technology show more promise than the lifelogging perspective. We need to move away from a philosophy of exhaustive 'capture' towards technologies that support active remembering with multiple types of objects that can be appropriated in highly flexible ways.

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ORIGINAL ARTICLE

Family memories in the home: contrasting physical and digital mementos

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Abstract We carried out fieldwork to characterise and compare physical and digital mementos in the home. Physical mementos are highly valued, heterogeneous and support different types of recollection. Contrary to expectations, we found physical mementos are not purely representational, and can involve appropriating common objects and more idiosyncratic forms. In contrast, digital mementos were initially perceived as less valuable, although participants later reconsidered this. Digital mementos were somewhat limited in function and expression, largely involving representational photos and videos, and infrequently accessed. We explain these digital limitations and conclude with design guidelines for digital mementos, including better techniques for accessing and integrating these into everyday life, allowing them to acquire the symbolic associations and lasting value that characterise their physical counterparts.

Keywords Autobiographical memory · Home technology · Mementos · Field study

1 Introduction

In their study of family homes, Csikszentmihalyi and Rochberg-Halton criticise home technology, arguing *"meaning, not possessions, is the ultimate goal of [people's] lives, and the fruits of technology [...] cannot alone provide this. People still need to know [...] that they are remembered and loved, and that their individual self is part of some greater design beyond the fleeting span of mortal years."* [11], p. 145). Despite this observation, this perspective has not been evident in early attempts to prototype smart homes. Evaluations show we need to better understand the environment where people live, and the meaning they attach to it, rather than simply realising new technological possibilities [42].

Consistent with this values-oriented perspective, we investigate the family home as a *place of memories*, with the goal of designing new technology for supporting and preserving those memories. While homes are primarily a space for practical and social activities, they are also where individual and collective memories accumulate. Indeed, as we shall see, homes are *designed* by their inhabitants to express and reinforce those memories. And although there are different ways to analyse the home and its contents (e.g. [3]), many of the most highly valued home objects relate to memories [11], making memories crucial to understanding home and family technology.

We use the term memory broadly here, not referring to the recall of purely factual information (e.g. remembering to attend a parent–teacher evening). Instead we focus on affective tokens, or *mementos*: objects given or deliberately kept as reminders of a person, place or event. Our research goals are to understand the nature of household mementos and the potential impact of new technologies on selecting and invoking these. In particular we want to understand the relations between physical and digital worlds. We address how *physical* mementos are selected, displayed and shared, and examine how these practices differ for *digital* mementos.

More specifically we examine:

What *types* of objects are mementos? Are mementos predominantly photos and artwork, or do other types of object serve this function?

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How and *why* do certain objects serve as mementos? Do they represent key events in the owner's life? Do they signal social relationships, or are there other different motivations?
Where are mementos kept, and does location relate to their type? For example, are personal mementos kept in private spaces and social mementos in public locations?
Invocation How do people interact with mementos? Are they used as talking points with others, or placed in personal spaces to facilitate more private reflection?
Preservation and management How are mementos organized and managed over long periods? How do people decide what to preserve or discard?
Physical versus digital How different are physical and digital mementos? How are mnemonic practices influenced by their being physical or digital?

To answer these questions we conducted a field study to investigate the home as a family memory landscape, contrasting physical and digital mementos. An overview of related research follows in Sect. 2. The study and data analysis are discussed in Sects. 3 and 4, respectively. Results are reported in Sect. 5. We then use these observations to explore implications for the design of new technology for family memories.

2 Related work

This is a multidisciplinary area. Our research intersects autobiographical memories, home studies, material culture, family and technology. Prior research has often focused on each of the above separately and from a specific point of view. We provide an overview that attempts to unify those different perspectives.

2.1 Autobiographical memory

Much psychology research has investigated cognitive aspects of memory. Early work examined memory through the lifespan, to determine which periods of our lives gave rise to the strongest memories, finding that early adulthood gives rise to the richest recollection of events [8]. Images also seem to be central to autobiographical memory [4, 5]. Furthermore, the nature of these images changes with the age of the memory: older events tend to be viewed from an observer rather than a participant perspective [4, 5].

Other work has focused on the processes by which autobiographical memories are retrieved, looking at how different types of cue serve to trigger memory. People best remember specific aspects of autobiographical events, including who was involved and what happened, whereas when or where events occurred is less well recalled [29, 46]. Underlying conceptions of autobiographical memory have also shifted from traditional views of a knowledge base [8], to instead proposing core roles for reconstruction and social dynamics [9, 15, 33, 30]. For example, Cohen [7] describes how sharing autobiographical memories serves as a mechanism for self-disclosure, developing or deepening social bonds. And Tversky [43] documents how people's narratives of their lives often contain distortions that are made to support the goals of telling the story. Tversky also shows how memories are changed by retellings of experiences: so that deliberate omissions or elaborations of the original event become confused with the original memory after repeated retellings.

2.2 The home and the self

As the space where people cultivate identity and mutual affection, the family home is a rich, varied composition of personal and family objects. Csikszentmihalyi and Rochberg-Halton [11] examined the home and found generational differences, with younger groups favouring active, self-defining objects whereas older people singled out contemplative, past-related objects. Mementos are often on display in family (e.g. kitchen) and social spaces (e.g. the sitting room). Often their 'true' (private to the family) meaning is not disclosed to visitors, who may be unaware they are sitting on furniture that has been in the family for generations, or looking at a sculpture made by a family member. Individuals exhibit strong connections with personal mementos: they express feelings of loss if these suddenly disappear and have a strong desire to pass them onto succeeding generations.

Our homes express various aspects of our pasts. The home is also where people keep a spatial and physical representation of their individual story, an *autotopography* [21]: *"just as a written autobiography is a series of narrated events, fantasies, and identification, so too an autotopography forms a spatial representation of important relations, emotional ties, and past events"* [21]. This organisation can exist in many forms: *"a careful, visual arrangement of mementos and heirlooms, on the one hand, and a jumbled, hidden assembly of dusty and unkempt objects, on the other, can both constitute a material memory landscape"* [21]. Recollecting our lives makes use of both physical and narrative aspects: mementos mark events, while the narrative plot organises these scattered points.

2.3 Personal collections

Personal collections have been extensively studied, but mainly from the perspective of work-related files and tasks. In work settings, people still accumulate huge collections of *paper* documents for both functional and emotional

reasons [47]. They also archive large numbers of emails [48, 50], and other information such as Webpages relevant to their work, and sometimes social life [1, 23]. One common observation from this research is that people are generally dissatisfied with the organisation of their collections, feeling their personal information is disorganised and hard to access. They also tend to be very conservative in their habits, building up large collections of materials 'just in case', they find it hard to delete materials and defer decisions about keeping information until they see how and when that information will be used [47, 50].

More recent work has looked at more personal information, such as the value and organisation of digital and analogue photo collections, documenting the importance of social sharing. With analogue collections, lightweight strategies are used to organise and share photos. Older valued analogue pictures might be gathered in an album or even a shoebox—to be accessed and shared occasionally. Once developed, newer rolls of pictures are discussed and shared in social settings before being added to the long term collection [18]. Recent work on digital photography has shown that despite the greater ease of taking and storing pictures, these older practices persist. Users capture pictures, sharing and discussing them soon after they are taken, using very lightweight strategies for their organisation [27, 39]. These lightweight organisational strategies may not be effective in supporting long term retrieval however. Whittaker et al. [49] found that people were unable to retrieve around 40% of personal photos that were more than a year old.

The number of digital and analogue belongings in our lives is rapidly increasing [2, 31]. As well as older analogue artifacts, family archives may now include digital recordings (images or videos), digital communications (emails, SMS, voice messages), and self-created digital artifacts (school assignments, blogs and Websites). Preserving these new belongings requires the owner to become a digital curator. Archivists acknowledge a need to personally preserve today's electronic culture [2], but this seems highly unrealistic. Particularly in the digital domain, most consumers lack the expertise and time to manage complex personal repositories and one consequence may be the loss of highly valued artefacts [31].

2.4 Technology for the family

Only a few studies have looked at homes as inhabited information spaces. Petersen and Gronbaek's [35] ethnographic study revealed that physical information is often distributed, being accessible to everyone and positioned in places where it is most relevant (letters to post in the entrance hall). This contrasts with digital information, which seems to be locked in the computer and generally available on an individual basis only.

Taylor et al. [42] studied the house as a place for activities and exchange, identifying key points (e.g. the fridge) that are public, privileged, frequently visited surfaces that might be used as information displays. However, their design approach was not simply to add a screen to the fridge, instead to augment existing practices using technology.

Roles are also important for mementos. The relations between parents and children, although sharing aspects with strong-tie relations (e.g. partners in life), are asymmetric with parents taking responsibility, providing security and care [12]. A similar dynamic is true of memories, with children focused on the self, and parents feeling a duty to preserve mementos from their children's everyday lives [41]. The variety of objects kept is huge: artefacts and artworks, clothes, photographs, videos. The intention is to pass on these collections, especially when adult children have children themselves [41].

2.5 Technology for personal recollection

HCI research has addressed helping people remember factual information (e.g. [24, 26]), with rather fewer studies of the role of memories in people's emotional life. The memory box [19] used a jewellery box metaphor to associate a recorded narrative with a souvenir. The living memory box [41] supported the collection, archiving and annotation of family memories. An ethnographic study investigated the "who, what, where, when and why of [parents] saving memories of their child's life". The resulting system allowed users to place a physical object in the living memory box, record its appearance, recording an audio narrative and metadata to support later retrieval. Parents collected some mementos for children, but never recorded stories related to those objects [41].

Souvenirs and recollection were also investigated by van den Hoven [44]. Analysis of focus group discussions suggested that souvenirs are esoteric: carrying meaning for owners that is obscure to others. Furthermore, the telling of the story behind the object changed depending on the relation between owner and audience. Souvenirs relate to memories of a personal experience (holiday, honeymoon) or a specific person (heirloom, gift), and are "used" (watched, talked about). A resulting system used RFID-tagged physical objects to retrieve images previously associated with the object, which could be managed or emailed using a tablet PC or TV [44].

3 The study

We focussed our research on families with young children—as they are active collectors of mementos [36, 41]. Furthermore, such families may have multiple different

types of memory; parents have memories of their own lives before meeting their partner; shared memories as a couple; and then as active curators of their children's 'future' memories. Csikszentmihalyi and Rochberg-Halton [11] found that the middle classes are oriented to memories and relationships. In contrast, other social groups focus more on possessions. Therefore, we focused on a specific group of middle class families with children, chosen because of their strong motivations to collect mementos of different types. Participants were recruited by acquaintance, covering a range of professions (doctor, museum conservationist, high-level managers, architect, training consultant, publisher, housewife and a few academics). All had at least one child aged 7–15, and used computers regularly for their work. Although we recognise that different social groups may have different foci, we expect other groups to behave in similar ways, but the degree of generalisability of our results needs to be explored in future fieldwork.

The study followed the methods of ethnography and took place in participants' homes. There were three parts to the study: a tour of various rooms explaining the value, role and function of mementos; an interview about digital mementos; and a drawing/sketching exercise for participants to map their lives visually. The overall tone was informal and friendly, and a small gift was given for participation. We limit our discussion to the memory tour and the interview, as here we are interested in comparing how the physical and digital support and express memories.

3.1 The home memory tour

In contrast to much previous research that used interviews or focus groups, our participants had a highly active role. We gave them this orienting information: '*We would like you to take us on a tour of your house. We want to see rooms that you consider public, family rooms, and your own. In each room we would like you to pick 3 objects related to your life and tell us why each object is special, when and how you got it, why it is in this room and if you ever reflect on it or talk about it.*'

For each participant, we collected at least nine objects and their associated explanations and stories. By contrasting three different room types, we could explore the relations between the public/private nature of the space and the type and intimacy of the mementos it contained, e.g. a public room used for entertaining might display artwork received as a gift, while a study might hold personally significant pieces, e.g. holiday photographs.

This "memory tour" allowed us to collect autobiographical narratives, observations about object location and other accompanying emotions displayed by informants, e.g. how an object was caressed or held. While there were specific topics we intended participants to discuss, e.g. what memory the object evoked and why it was important, we let participants talk freely, prompting only those topics not spontaneously mentioned. We concluded with questions about the participant's attitude towards keeping objects.

3.2 Discussing digital mementos

The second part of the study was an interview about *digital* mementos (outlined in "Appendix"). We started by questioning participants about their digital mementos (if they had any) and where these were located. We used the recently completed memory tour as prompt: "*You have shown us several mementos: do you have any 'special things' that are in electronic form?*" We were interested in exploring the whole landscape of digital memories, so we asked about emails and music as well as more traditional memory objects like photos and videos. We asked *where* digital mementos were kept (PC, laptop, external hard drive, CDs, mobile phone, etc.), *how* and *when* they were accessed and used. We also asked about plans for preserving digital mementos and how respondents felt about displaying them. This final question gave us the chance to probe participants' attitudes to future technological solutions.

4 Data collection and analysis

Seventeen people (from 13 families) participated, 6 men and 11 women; 5 were living in a country different from where they were born. When both adult family members participated, the tour was done individually, while the interview was joint to engender a richer discussion. Each session lasted 90–120 min and was recorded. Pictures captured each memento and its context. In total, we collected 169 objects and related stories.

In the memory tour, we were concerned that the affordances of the rooms and the request to select three objects might bias interviewees. However, participants often discussed more than the nine stipulated objects if more important ones later came to mind. Moreover, some participants in the first room of the tour foreshadowed important mementos they would discuss in later rooms, revealing a clear idea of which memories and mementos are important. Follow-up questions and comments also supported the view that we had collected stories about people's critical autobiographical memories.

Some participants claimed not to distinguish public and family rooms, while others clearly did. By observing the properties of rooms most participants classified as public,

family and personal, we applied the following classification to all participants: *public*, formal rooms (sitting room, lounge) where acquaintances and strangers were entertained; *family*, informal places (family room, kitchen, dining-room) reserved for family, relatives and friends; and *personal*, bedrooms or studies, accessed by all family members, but of particular significance to the interviewees.

Comments made during the tour and the interview were transcribed and systematically classified. Our initial topics of interest were used to start a broad classification, e.g. type of object, location, value, while other dimensions and refinements emerged from analysis of the narratives, e.g. management and preservation.

5 Results

We now compare what was found in the memory tour with the interview on digital mementos. As our focus is on the comparison, only part of the results of the memory tour is reported. Interested readers can find the complete analysis of physical mementos in Petrelli et al. [36].

5.1 Types of physical and digital mementos

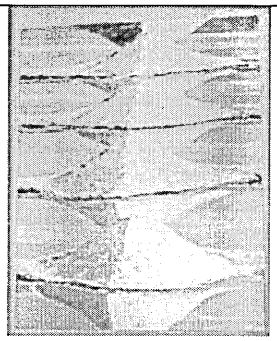
5.1.1 Physical

Photographs are generally considered *the* prototypical memento for personal reflection and sharing [10, 18]. Therefore, it was quite surprising to discover that six people selected *no* photos during the memory tour, despite having many on display in their house. When photos were selected, however, they had specific characteristics, being unique or irreplaceable: "*this is my father, who died quite young, it's one of the few photographs I've got of him*". Sometimes they symbolise a special event: "*a fantastic family holiday that we had a couple of years ago when we went to Canada*". The photos selected by our participants in the memory tour were highly emotionally significant. Their meaning was directly related to personal memories and identity, as opposed to a simple representation of people or events.

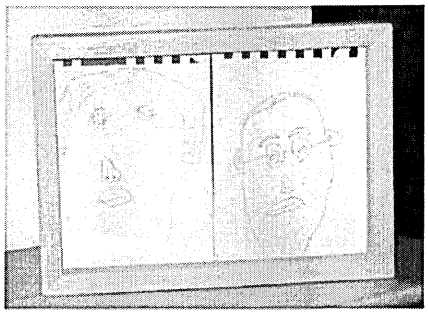
Only 16% of objects selected in the tour were photos. Artwork was a much more frequent choice, accounting for 28% of mementos discussed (Fig. 1). These could be *professional* paintings or photographs, prints or drawings (17%), or *amateur* efforts produced by family or friends (11%) in particular young children's art and craftwork (9%).

Just as the value of photos was not purely representational, in a similar way, the value of artworks is not purely aesthetic. The examples in Fig. 1 show artworks being symbolic of special relationships (personal identity, left, or parent–son, right), emphasising both origins and intimacy.

Somewhat to our surprise, mass-produced objects often served as important mementos, accounting for 28% overall. Mundane *everyday objects* such as a cup, clock, coffee machine, golf tee, cookery book, teapot, children's toys, ladder, calendar, bed, stove, and candle holders were

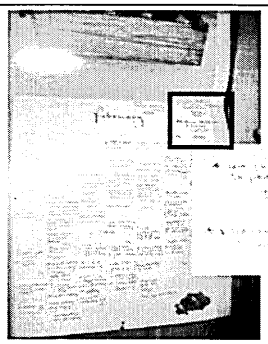


I absolutely love it, because it is the [French] island where I've been on holiday since I was a baby, my father had a house there. They had salt marshes. [...] The salt is collected in these little heaps [...] with the evening sun it's purple and pink. I thought this painter had really captured that, the evening shades. [...] I don't feel I have much attachment to France any more, much more to Scotland, but I do to this island. So [this painting] means a lot, because that is really my roots. We've always spent all of the summer there, every year. I still go. I share that house with my brothers.



This drawing is quite precious to me because [my son]- just without us even knowing - sat down and did those [portraits] when he was about three or four. I mean he was really little, you know, when they do it voluntarily. He did J. and me ... look at J. with his freckles.[...] I can only just remember him doing it.

Fig. 1 Two artworks and their associated stories, professional (*left*) and amateur (*right*)



"This calendar. I write everythingin here so that [the children] know what they were doing at various times: they'll know when they lost their teeth (see inset) and when they started speaking, what their first words were, when they first walked and how many steps they walked and things like that [...] everything is documented."

"The reason why this china is emotionally significant is because it was painted by my grandmother. She started painting as a hobby and was very arty crafty. [...] She taught me how to paint when I was about 14 or 15 [...] she lived to a great old age so she is a very significant person in the family."

Fig. 2 Everyday objects selected as mementos

chosen. What makes these special is the time and energy invested in using them, or because they belonged to someone special. Everyday objects are thus substantially different from iconic and representational ones like photos and artworks. Everyday objects become mementos by virtue of what owners have invested in them, be it time or emotion (Fig. 2).

Other mundane objects had specific functions, but unlike everyday objects were not habitually used. These were classified as *memorabilia,* accounting for 20% of mementos, including a stereoscope, a rocking horse, measuring glasses, and a set of illustrated cards.

A final class of mementos, accounting for 8% of objects, was highly *idiosyncratic*, falling outside any of the above categories. They are important for deeply personal reasons, often unintelligible to anybody but the owner. They included a shell collection; a pregnancy cast; a jar containing a father's ashes; a child's first nose bogey; a handmade bullet; a framed 1997 coffee shop receipt; 30 years of diaries; "objetstrouvés" (e.g. "*a dog collar tag without a dog: maybe one day I'll phone this number, and find out a bit more about Barney the dog*").

5.1.2 Digital

To our surprise, during the memory tour, only one participant chose a *digital* memento: "*maps. I make my own maps because I do a lot of cycling and journeys. These maps then become the memory of the occasion and it's quite vivid for me*". As we will see, this was not because the other 16 people did not have any digital mementos. In what follows we discuss reasons for their failure to choose the digital.

When explicitly questioned if they had digital as well as physical mementos, there was generally an initial denial. The exception was digital *photos* which were mentioned by everyone. However, as the follow-up interview progressed, an interesting variety of digital mementos emerged. *Videos*, stored on tapes or DVD, were the most mentioned after photographs, by 8 participants (47%) while 7 (41%) explicitly regretted not having a camcorder to capture special events. Those with a camcorder reported having hours of videos, mainly of children and family events. Those without camcorders all had short camera or camera-phone videoclips.

While no one had any digital artwork, consistent with the tour, digital *artifacts* were popular. Often they were created by children: stories, poems, drawings, PowerPoint presentations, animations and photomontages. Some were done for fun, others for school projects or for special occasions (mother's day, grandparents' wedding anniversary).

Again consistent with the tour, participants mentioned a few *idiosyncratic* digital objects: a recording of a person's participation in a TV programme; playful video clips on the mobile phone recorded by the children; answering machine messages; phone texts exchanged with a partner. We classified these objects as idiosyncratic because they are individual, although still being representational and understandable: *"the messages we got on the answerphone [...] on my birthday. I was not there, and I got most of my family singing 'Happy Birthday', and I loved it, and I kept it. I've got [...] six messages on this machine here, which I can't delete [...] one it's just me and the children phoning from France to J., telling their stories because he was not there, talking to their father."*

One category of digital mementos without immediate parallels in the physical world was *stored communications.* Only one person in the tour selected physical letters, and two others said they kept correspondence with important people. In contrast, most participants deliberately

Table 1 Motivations for mementos with respect to places

	Events (%)	Relationship (%)	Reminiscing (%)
Total	13	59	28
Public	4	16	2
Family	2	20	7
Personal	7	23	19

preserved emails. All participants used email for work, but six (35%) said some email messages were important on a personal basis; and five kept and filed correspondence with friends. While three felt they would never revisit these, another said: "*it is a record of what we and the kids were doing and [my friends] were doing – it is a sort of history and it is nice to read it from time to time [...] It is a bit like keeping a diary*".

Another major difference in the digital domain was that there were not many instances of *everyday digital objects* that paralleled how people incorporated physical objects of mnemonic significance into their life. The only exception was the background image on the PC mentioned by several as having this daily recollection function.

5.1.3 Summary

We were surprised in various ways by the physical mementos chosen. There were fewer photos than expected, and those chosen had strong symbolic meaning that prevailed over immediate representational meaning. We did not anticipate the observed widespread use of everyday objects or memorabilia. Both results seem to support Csikszentmihalyi and Rochberg-Halton's [11] finding of 'an enormous flexibility with which people can attach meanings to objects... Almost anything can be made to represent a set of meanings' [p87].

One potential reason for the small numbers of photos chosen is that our instructions focused people in selecting physically interesting objects. However, this seems unlikely to be the case. Almost all mementos were chosen because of their emotional expressiveness and the reason for overlooking many pictures was that they did not seem to be emotionally significant.

One essential similarity between digital and physical mementos was their variety: in both the digital and physical worlds participants collected many different types of mementos. While there was some overlap in the types across the two worlds, there were strong differences too. Pictures and artifacts were common to both physical and digital. However, there were not many instances of digital mementos being directly incorporated into people's everyday lives, nor did we see instances of digital memorabilia. In contrast, a common form of digital memento was *saved communications* which seemed less prevalent in the physical world.

5.2 Function and value of mementos

We identified each memento's function and value from the interview: the motivations for the object to be considered a memento were used to identify its function; the reasons for selecting one particular object instead of another were used to determine its value.

5.2.1 Physical

There were multiple reasons for a physical memento to be regarded as important (Table 1). Some mementos were reminders of an *important event* (wedding or birth), or a significant period in a person's life (attending university). Others signified a *relationship*: photos were direct depictions of others, but gifts also fall into this category, where the gift expresses a relation to the giver. However relationships often went beyond these simple links; mementos might represent joint *activities*, e.g. sculptures done in an art class taken by both partners, or the French cookery book used by a mother and her daughters when cooking together. The third category is *personal reminiscence*, where a person privately interacts with the memento to relive previous life experiences. This concept is broad: it can refer to *identity*, memories that contribute to the person being who they are, e.g. photos of ancestors, or childhood memorabilia; it could also relate to the self in more complicated ways, such as objects that reflect interests, e.g. tools used for a favourite hobby; or *personal achievements*, such as awards, authored books, or a medal for completing the London marathon.

In contrast to previous research, in 30% of cases we discovered *multiple motivations* for choosing an object. For example, personal, social and life events are all mentioned in the following excerpt where L. reveals how a shell collection (Fig. 3) relates to family holidays (events), her

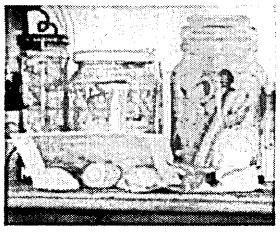


Fig. 3 An example of multiple functions of a memento

"the shells are quite important because they are memories of our holidays, and each year we build up our collection. I had a collection of shells when I was a child - displayed in boxes labelled with their names. ... This is the past six years and each time we add more. [Collecting shells] helps to entertain the kids for a long time on the beach, and [gives us a purpose]. I find that if you do an activity and then you don't do anything to it, it's a bit negative, it's like you're wasting your time."

childhood (reminiscence), and her children's education (relationships).

The reasons mentioned by participants about *why* an object was valued include *family bonds* (44%), *nostalgia* (20%), *aesthetic* (16%), and *moral values* (15%). The importance of mementos as conveyers of moral values was unexpected but evident, sometimes made explicit as in the excerpt above, but other times more implicit: "*my grandmother was sort of very liberal - quite a modern sort of person. She was very accepting and welcoming*" (when discussing her grandmother's china, Fig. 2). Moral-related comments were generally associated with relationships to parents and grandparents or aims for their children, showing the evolution of bonds in a family.

5.2.2 Digital

As they began to discuss values and functions in relation to their digital collections, participants went from being initially dismissive of their digital collections to gradually discover they actually had digital mementos and how important those mementos were: "*I've changed my mind, I think I do, yeah, I think I can have a sentimental attachment to stuff in [the computer], yeah*","*They are special but I don't think about them, I'd completely forgotten we'd had them*".

Sometimes people went to great lengths to produce or capture digital memories (Fig. 4).

Despite these efforts and the strength of the underlying memory, these digital objects did not immediately spring to mind as valuable mementos when we first talked to participants. Only later did participants begin to see them this way.When they finally acknowledged their significance, respondents showed strong attachments to their digital belongings: "*[video] is a wonderful way of seeing someone alive, and when you're far away I think it has even more significance*", "*lots of emails, the history of what we were doing [...] feels like a record I would like to keep*".

One reason for this generally low perceived importance may be because digital objects are stored away and people are not reminded about them on a daily basis. Unlike everyday physical objects, photos or artworks, digital objects are not in places where people persistently encounter them. However, this cannot be a complete explanation as some highly significant physical mementos were deliberately hidden from sight at the back of wardrobes or in drawers. A second reason may be digital objects' perceived instability and transience: "*[email] is quick and spontaneous, for me that doesn't warrant preserving*", "*digital feels sort of unstable it feels like it's not always going to work, sorry*", "*it's ephemeral I do not think we will be able to keep things that are on a computer anyway*".Technology is also viewed as inexpressive, incapable of fully representing individual and personal aspects of memories: "*email is impersonal [...]handwriting is something you can't beat, I mean the someone's handwriting is so personal*", "*looking at images [on the computer] doesn't feel as intimate [as flicking through prints]*".

Even though participants began to acknowledge that their digital collections engendered memories of relationships and events, we found few instances of digital mementos that supported personal reminiscence. In the physical world these mementos tended to be specific objects (medals, books, calendars) often located in private or family spaces and there were few equivalents of these in the digital domain.

5.2.3 Summary

Although they were not recognized as such initially, on reflection people came to see their digital mementos as valuable and worth preserving. However, digital belongings are perceived as problematic: being unstable and ephemeral compared with physical ones, and too impersonal to fully express the richness of memories. Their *functions* also seem different. Physical mementos are multifaceted in their value: as well as their representational values, objects often become abstract, esoteric symbols that are not understood by others without an explanation. Digital mementos seem much simpler; essentially representations of events or simple social relations, valued as simple triggers for past events or people. One reason for the difference could be the still primitive nature of digital technology and its recent status in people's lives. None of the participants mentioned passing digital mementos across generations, while several physical objects were talked about in this way. This lack of relationship to their personal

Creating digital memories	Capturing digital memories
"[our son] made a Powerpoint for mother's day. It was a quite creative piece and he spent ages doing it – he worked hours and hours on the animations – and the result was hilarious. He showed it after lunch at my mum's, it was like a show, very funny."	*"There was a children's radio program [...] and they have phone-in, you know, quizzes and competitions and [our daughter] would sometimes get on and speak to the nation. And whenever she was on, I recorded it and it's all on the computer. So we did go to a lot of effort in fact."*

Fig. 4 Two examples of effort expended on digital mementos

Table 2 Position of mementos with respect to motivations

		Events (%)	Relationship (%)	Reminiscing (%)
Prominent	45%	6	27	11
Display	31%	6	22	3
Concealed	24%	3	10	11

lives may be why people initially rejected the idea they had any digital mementos apart from pictures and videos.

5.3 Location and access

5.3.1 Physical

The value of a memento and its location in the house were related: social rooms (public and family) contain more objects that symbolise relationships, while personal spaces have more objects of reminiscing (Table 1). The position *within* the room seems to depend on function also (Table 2): mementos of relationships are prominent or on display; mementos of reminiscing are prominent if they are self-referential, but concealed if they are nostalgic objects.

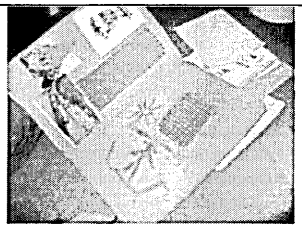
Mundane objects are often directly integrated into everyday activity: "*That was my father's step ladder, you see, and actually we have many objects of my father's around this house, even his car keys, the kids use his car keys as part of their games [...] I really like that because they're quite disappointed that they never knew him.*"

Incorporating memories into everyday life was a recurring topic: three people passed teddy bears onto their children, a son inherited his father's bow, an old family stove found a new place in the lounge, and a grandmother's teapot was used everyday. People derived comfort from integrating past and future, knowing that an important aspect of their past was evoked every time they made tea, or lit the stove. Embedding mementos into a familiar space changes their nature: "*these photos are in the grain of the room, they're not just there because they can be. Sticking [a photo] on [the wall] is consuming it ... I often point one out to people... that is so and so*". From this perspective, *using* mementos is more important than *preserving* them: "*objects on display are to be used, and not to be a museum piece. From time to time something does get broken ... the other day when I was mowing the lawn I mashed up my father's car keys because the kids had left them out there [...] I'd rather mash them up, knowing that the kids enjoyed playing with them for a few years rather than just have them in a cupboard.*" However, we also found evidence of the opposite behaviour, i.e. mementos that are rarely accessed and sometimes purposely concealed.

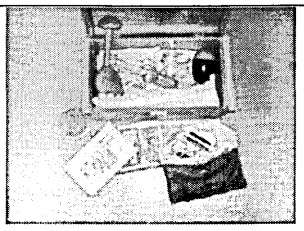
Boxes and containers of memorabilia were a popular way of organizing mementos: 13 (80%) of our participants mentioned at least one such collection. Some collections are organised by time, containing mementos of distant periods of the person's life, e.g. childhood, university life, and are created opportunistically with what has survived years of sorting and clearing (Fig. 5, left). Other times they are deliberately created around a topic, e.g. a wedding memorabilia chest, or a family treasures box (Fig. 5, right).

These boxes of memories are often not easily accessible (stored in an attic, or deep in a wardrobe) and rarely opened. However when rediscovered they act as 'time capsules', a whole past world is revealed and the owner is thrown back in time - deeply immersed in reminiscing: "*that's one of [my son's] first pairs of socks can you remember when they were this tiny look look look ... oh I haven't looked in here for years funnily enough ... little bootie ... oh I can't even remember - those were his first pair of little booties.*" Having these objects in constant view would habituate people to them, but concealing them makes more salient the contrast between past and present, triggering a world of nostalgia when they are brought to light.

However, most discussed mementos were deliberately placed where the person can easily glance at them: "*[the study] is not a place where I would put my memories*



"*There's a memory drawer in here of mine. Old scrapbooks, I mean, this is really old memories which is going back an awful long time to these programmes from school plays, school things. And I don't have an awful lot of those things any longer.*"



"*This was given to me by my mother, last Christmas. She picked up all sorts of lovely little family treasures: pictures of my great grandparents, my great grandmother's sewing things, my great uncles wooden carvings and all sorts of old family things. It's like a little corner of part of my life.*"

Fig. 5 Two examples of memorabilia collections: organized by time (*left*) or topic (*right*)

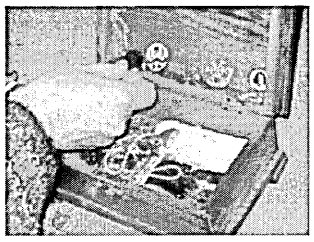


Fig. 6 Sharing a personal collection of childhood memorabilia with a child

"this was given to me by my grandmother when I was ten, and this was given to me by my mother when I was six, and this is my Brownie Badge... I showed [the box] to K. the other day and she was absolutely over the moon, she said 'I want a locket as well, with pictures of my mum and dad in it!' [...] *You know, they've all got enormous meaning to me, but only to me now.* [...] *The only people I would think about sharing with, would be the children. There is nothing inherently important. It's only important because it makes a link across the generations."*

because I rarely come in here and when I do it is because I need to work". Even when the container is rarely opened, having it in sight seems to offer comfort: "*things like the bowl or the painting that you can see are sort of public, but other things like this [the family box in Fig. 5 right] are sort of private. I mean I hardly ever show these to anybody. But they sit there [on a shelf in the family room next to the bowl and painting], and the fact that it's there and you know what it is, it's just a sort of rather nice thing to have around you.*" This suggests a passive role for certain mementos as constant, but rarely conscious, reminders. They are, indeed, rarely opened or purposely looked at: "*well I don't stand and look at them, but I don't need to stand to think about them, I mean, many times I'm sure, if I look at them and notice them properly, then it invokes the memory*". Together these examples indicate two types of reminding function: an active remembering connected to narrative or explanation and a passive mode supporting awareness and relationship building. The space is synonymous of persistence: "*there's something about the quality of having things overlaid on each other physically, you put them there, it's just there.*"

Active remembering is, most of the time, done in a social context, it is *sharing* memories. We discovered that sharing goes beyond the simple showing of photos of events or people to family and friends documented in prior work [6, 10, 16]. Such sharing can cement parent–child relationships, as when a mother explored her childhood memory box with her daughter K. (Fig. 6).

5.3.2 Digital

Digital mementos are accessed in very different ways from their physical counterparts. Whereas a minority of physical objects in collections may be deliberately concealed, most physical mementos are freely accessible, being on display or integrated into everyday life. Digital objects in contrast reside on the computer or a recording device (answering machine/phone) and consequently access is a deliberate and often major effort.

Both digital photos and videos are used to talk about what happened in the family: laptop or family video watching is generally associated with relatively rare special social occasions like grandparents visiting, or the children flicking through old photos at Christmas. In consequence, access tends to be rather infrequent. This engenders a sense of guilt, as if participants were not fully exploiting their digital mementos. Similar sentiments are expressed about the fact that they do not print photos any more.

More prosaic barriers to video access are that it is hard, and the results not very satisfying: "*it takes time to set up all the connections [...] you forget how it is done, I should write it down – it is all very frustrating*", "*it's a special cartridge you have to plug it into the TV, so it's not especially easy to watch.*"

Accessing digital photos is also perceived as difficult, the main issue being how they are organized [49], resulting from the division of labour that creates that organisation. Downloading, editing and organising photos seem to be a man's job done on their work computer, rarely on the home PC. Women complain as a result that they do not know where the files are, or they can't access them: "*I haven't got a compatible driver so I can't actually look at the disc that we've got with all the kids photos on so I have to look at them on his computer because I need to upgrade mine*";"*I do not know how to use it so I need him or one of the children to set it up for me*".

Feeling unable to freely access digital photos is a clear source of frustration: "*I suppose that ties to me saying that I'm not being able to get at themand it's frustrating and that's why it's nice to have an album of prints.*" The barriers to access are often compared with the democracy of physical prints that can be straightforwardly picked up and flicked through: "*I can just kind of flick through and I do that in a way I wouldn't just sit and look at stuff on the computer*".

The immediacy of physical access is contrasted with the effort demanded by technology: "*There's something about the quality of having things physically, you put them there, it's just there [...] compared to the act of scanning something, where it disappears into a black hole and you've got to organise, that's part of the issue. Being able to organise is good. Having to organise is a pressure.*" And time spent organizing on the PC is considered a housekeeping duty—not creative and rewarding ("*[if I have time] I prefer to work in the allotment*[1]"). It is too much like work, and there is the persistent worry that it

[1] An allotment is arable land rented from the local council.

may be a waste of time "*I think of digital as things that will not last*".

Despite our participants having large digital archives and being digitally literate, we saw few examples of participants using plug and play devices such as phones, iPods or laptops to access or share their digital mementos. Accessing the digital seemed to be intrinsically onerous and people had to make deliberate attempts to access them. Unlike physical objects, digital ones are still not easily integrated into our everyday environment.

We already noted that a major difference between the physical and digital is that physical objects are well incorporated into people's everyday lives. We wanted to probe respondents' views concerning various new technologies (e.g. digital picture frames) that make it possible to better incorporate digital mementos into everyday life. With few exceptions, the idea of having digital photos and video on constant display was unappealing.[2] Some found the idea of changing images irritating, others felt a digital display would intrude and change the fabric of the room: "*the problem is that you end up with something like a TV that has a particular [privileged] status, whereas the objects in the room are more in the grain of the space*". As it has been designed so far, digital technology does not seem to smoothly integrate into the homes that people have built around themselves.

5.3.3 Summary

In the home, different physical mementos are located in different places, affording different types of invocation. Apart from being actively displayed and shared, memories are integrated in everyday life through mundane, but significant, objects in everyday use—signalling continuity between past and present. Of particular emotional significance are small collections of objects concealed and opened only rarely. The use of space also offers the possibility of reminding, e.g. a memento that is usually in view can be easily converted into a more active experience, i.e. talking about the object at any time and in a very natural way.

Digital mementos in the home do not have the same property of being integrated in everyday life or being encountered by accident: they require an explicit act and a lengthy process to be accessed. Although it is occasionally possible to opportunistically re-encounter digital mementos, e.g. rediscovering significant text messages or photos when killing time fiddling with one's mobile phone, nevertheless the home is still predominantly physical. Accessing the digital seems to be a deliberate, often effortful, act. There were a few examples of families setting up digital photo shows for visiting relatives and some comments were made about serendipitous re-encounters with digital mementos, e.g. looking for a specific photo but spending an enjoyable hour browsing unrelated photos. However such digital experiences are an exception and do not show any integration of physical and digital. This lack of integration may prevent owners from building a daily relationship with digital objects that seems to be a frequent component of certain types of autobiographical memories. Furthermore, participants tended to be rather negative about new display technologies to show and share their digital images/videos. Physical objects are also more democratic. They may be of particular significance to just one person, but are accessible to everyone. Files on the computer in contrast, require people to know where they are stored. Often they are on personal laptops and unavailable to everybody.

Finally, these access problems may contribute to the initial lack of perceived value of digital collections. Digital mementos are stored in the computer, out of sight and out of mind. This prevents easy contact between the owner and the object, contact that may be essential in some cases, for the building of meaning, to turn the object into a valuable memento. This may explain why the digital objects spontaneously cited or first remembered were photos and videos that tend to be sporadically accessed, as there are specific social practices associated with revisiting key events. Photos and videos record events and are revisited when people purposefully recall those events. In contrast, idiosyncratic digital objects are unique and are more likely to be forgotten after the initial event is passed.

5.4 Management and long-term preservation

5.4.1 Physical

The management and preservation of physical mementos does not seem to generate major anxiety. All participants reported having boxes where they collected children's artwork and crafts, some also kept clothes or other special objects. All also mentioned periodic sorting and clearing, distilling what is still worth keeping, with minor guilt associated with such clearing out. This activity extends to personal possessions: "*that drawer is all that survived from that bit of my childhood, really. It's been weeded down year after year. And every time you go through the drawer: 'Oh God! look at all this rubbish, it's got to go.' I wouldn't want to get rid of them altogether. I very much like having*

[2] None of the interviewees possessed a digital photo frame. The three participants who were more positive to the idea of digital memories on constant display had heard of this technology and were somewhat open to the possibility.

them here, in my house now" (talking about the childhood memorabilia in Fig. 5 left). Distillation is crucial: sifting through a small collection of memorabilia is emotionally evocative, but large boxes put people off: "*loads of cardboard boxes with loads of stuff, in general junk really. I should chuck all out but I feel I should go through it and decide what I want to keep and it will take ages so I never do ... so the boxes sit in there*". The content of these large boxes has little value, as it is never accessed. Thus having a *compact* collection is important in sustaining interaction throughout a lifetime: "*when moving house I looked [into my suitcase of old stuff], I opened it, ah! I go:'look at this!' and then I close it again. I don't want to throw it away. [...] How many times have I looked in that box of mine? About once every ten years?*"

5.4.2 Digital

The persistence and the sense of security associated with physical mementos clearly contrasts with the perceived fragility of the digital. Most respondents backup their digital belongings onto CDs or DVDs. Some devise complex strategies to preserve these:"*before we go on holiday we always make sure we've copied all the photos on the computer onto an external hard drive and we hide it somewhere in the house so if someone came and nicked the computer we wouldn't lose all the photographs*".

Interviewees had clear strategies for digital preservation, but this does not prevent them from worrying about the viability of today's technology: "*I never feel confident that I've made the right choice about which kind of technology to back, so I'd prefer something which is tangible I think*", "*I think of digital [objects] as things that will not last*", "*I don't have a trust in [digital media], there is less physicality in the computer hard drive than having something on paper, which might fade, but you will still have an image*".

Three respondents, all men, mentioned scanning papers to preserve a digital copy. Of these, only one was motivated by the experience of loss: "*[my son] had fabulous drawings that he's done since he was two, and he took it into school to show the teacher, and he put it down at some point, forgot it. And so we've lost all the images he produced when he was a child. [...] so it's kind of desperate really, all wiped out, so if we had digital copies...*" There is a generic sense of physical objects as destined to last and in no real need of maintenance; the owner can forget about them for the next 30 years, to be rediscovered one day.

Section 5.3 mentioned conflicts in accessing common digital mementos stored on personal laptops. From the point of view of *managing* digital mementos the situation is even more complex. The same person may have "*an old laptop, which has got a whole load of emails on it* [...] *I'd like to kind of take that off because that feels like a record I would like to keep. And then obviously on my more recent computer I have my work files and all my working email and I've sort of got personal stuff as well.*" There are often work and family computers, several phones with images, clips and text, and possibly external storage media (DVDs, CDs). This makes up a multitude of devices that contain digital mementos and the owners do not have a clear map of what is located on each device [31].

Second, the organization of digital mementos is done around specific media: photos on external hard drives, videos on DVDs, emails zipped away, digital artifacts in several folders. This organization contrasts with that seen with physical objects which often follows the logic of time (objects of the same era) or topic (objects about the same event or person) tend to be co-located.

Organising digital information is also onerous. For example, people now take huge numbers of digital pictures relating to events (many more than their analogue equivalents). Then there is the time-consuming activity of deleting bad or undesirable pictures, occasionally cropping or editing them and organizing them into a scheme that will make retrieval possible. This is more work, which is less pleasurable than sorting through a small set of analogue pictures to add to an album [49].

Finally, digital content tends to multiply as a consequence of the owner's activity: "*I originally said 'Let's just recycle the video tapes', but I actually find it very hard to do, because erasing the images somehow just seems, not right. [...] it's almost as if the image carries a little bit of the person with it, which of course it doesn't really, on one level, but on another level it does, so I hate binning an image of my kids, even though I've got twenty copies of the same one spread through different computers.*" Keeping track of the many copies, the different resolutions and edits becomes a hard task, particularly as digital software is felt to be inadequate for organizational purposes [49].

5.4.3 Summary

Accessing important physical mementos, revisiting and sorting them is an enjoyable activity, reserved for smaller collections, while bigger ones tend to be ignored as the effort needed is perceived as too great. Selecting and reducing the number of kept objects is essential to a sustainable collection: but with the digital it is easy to overgenerate material: disregarding the future problem of management and access.

Preservation is also substantially different in physical and digital realms. Preserving physical tokens of children's memories requires an effort in terms of selection but does not require becoming a large scale curator. In 30 years time, that physical collage might have lost a bit of colour, but its essence will be preserved. The same cannot be said

of digital mementos. They demand more organisational effort, and attention has to be paid to move digital objects from old unused computers and migrate old files to new formats. Thus, while preservation from technical breakdown is anticipated, long-term preservation is viewed with trepidation.

6 Designing new technology for digital memories in the home

Our study identified many problems with digital mementos. Current digital artefacts were seen as invisible, hard to access and inexpressive compared with their analogue equivalents. Unlike their analogue counterparts, participants felt that digital artefacts were onerous to organise and maintain, as well as being more ephemeral and unstable. In order to provide digital mementos with the properties of physical mementos it is necessary to create technology that seamlessly integrates with people lives: the design has to start from human activities and should consider the whole user experience with digital mementos, from capturing, to organizing and managing, to accessing and sharing. In this section we look at how the current problems with digital could be overcome sketching out some possible design solutions.

6.1 Broadening the set of digitally captured objects

Our results indicate that, although there are many types of digital mementos, the set of captured objects could be broader and richer. One reason that our participants overlooked their digital memorabilia is that their digital collections did not encompass mundane physical objects that are critical for reminding as they are persistently reencountered. New technologies might address this in two ways. One possibility is to develop new tools that allow scanning of critical objects. For example, Kirk et al. [28] describe a tabletop application that allows people to straightforwardly scan images of significant objects and to organise them in a 3D software archive. Another (in our view more promising) approach is to explore ways to integrate the physical and the digital. Our participants were highly oriented to the tangible properties of many mementos and the fact that they could organise these spatially throughout the house. One way to retain this physicality, but to explore synergies with the digital, would be to create embodied objects where physical mementos are augmented with digital information. These types of experiments have already been carried out with some success by van den Hoven [44] and van den Hoven and Eggen [45] who explored augmented methods for interaction with physical souvenirs.

With this approach, critical tangible, situated properties of physical mementos could be retained, allowing their owners to better incorporate these into their everyday activities. In addition, such digitally augmented objects afford new properties, e.g. the ability to record and associate rich stories or narratives with the objects themselves [17]. Moreover, using sensors, it is also possible to capture the history of people's interactions with the object. In this way, an entire family's physical or verbal interactions with that object could be saved, stored and played back for future reminiscing.

The concept of mixed reality mementos that combine physical and digital has potential in other ways. Physical archiving practices such as making albums or scrapbooks or revisiting collections engender positive emotions; whereas digital archiving does not. One challenge for new digital archiving tools is to try and support new practices similar to making albums or scrapbooking that will lead participants to enjoy the process of sifting through their digital archives, selecting and composing. Again augmented reality might offer a way to replicate enjoyable physical practices, while simultaneously generating potentially useful digital metadata or narratives that might assist in the organisational process. An interactive table could become the working desk for cutting, pasting, decorating and composing digital mementos.

In some ways, digital memorabilia are different in kind from their physical counterparts, and there may be opportunities to exploit this. We noted that participants stored more digital conversations (e.g. emails, texts and voicemail messages) than physical ones. There may be opportunities to develop this advantage for the digital by designing tools that allow people to aggregate and organise such collections of conversations. One possibility might be to exploit tools that have been developed to visualise complex email or internet based group conversations (e.g. [13, 40]). Just as albums provide attractive ways to access and share physical photos, these visualisations may provide interesting ways for people to browse personal conversational histories.

Other work suggests that these new media might be treated in fundamentally different ways from their physical counterparts. In a recent study of sound memorabilia, we found that recording practices were very different from more traditional types of mementos [14]. Participants were not content to use sound to passively record events, instead they constructed and manipulated the situation to represent key events in a special way, e.g. to record 'radio plays' or interviews about key holiday events. It may be that developing new tools for capture and playback of conversational or sound mementos will lead to very different experiences and practices than those used for more visual or object-centric memorabilia.

6.2 Reducing the burdens of management and maintenance

Our study has shown that digital mementos are seen as onerous to organise and maintain. People had little enthusiasm for organising their digital collections with obvious implications for later access and retrieval [49]. However, new digital devices can record multiple types of metadata associated with each potential digital memento, e.g. location, time or time-stamped interaction history. This metadata might be exploited by machine learning tools to help organisation by clustering digital or augmented objects with similar profiles, e.g. those accessed at the same time or by the same people or in similar locations. However, despite very many explorations of automatic methods of analysing and clustering digital photos [22, 25, 32, 38], none are in widespread use in commercial products. One possible explanation is that these automatic methods do not mesh well with the ways that people think about, organise and access their mementos. For example, we know that with autobiographical memories, people most frequently think about these in terms of participants, social relations and key events [29, 46], whereas most content analysis software for photos focuses on low-level visual features, e.g. clustering outdoor vs. indoor pictures. Despite these difficulties some innovation is beginning to emerge: the new Apple's iPhoto '09[3]provides automatic person tagging using face recognition and exploits GPS information to position photos on a map. Crucial questions arise from a user and technical standpoint: are participants willing to tag enough people to allow face recognition to succeed, and what kinds of error rates will people tolerate?

Although it is likely we will see more of these features being included in software for managing digital photos, automatic clustering is nota general solution to users' organisational needs. Digital mementos are often dispersed across different folders and accessed via distinct applications; and sometimes they are stored on different devices or different computers. Our participants did not sort their physical belongings by type, but by meaning: grouping them by life period, event, or relationship. New computer infrastructures are needed to rationalize, collect and smoothly integrate these different fragments of our digital life. Docking a mobile phone for charging could automatically download undeleted messages and photos; these could be time-aligned with other photos and videos and with emails sent by the same people appearing in the pictures and in the messages. Our lives may be quite predictable: the group of people that pervade our life may be small enough to attempt automatic detection, e.g. using the names in the phone contact list it might be possible to identify emails from the same person. The same principle of displaying photos by time, place and people could then be applied across any personal digital media providing a more organic view on our digital life.

Finally our participants expressed strong concerns that digital data were ephemeral and hard to preserve. When they finally focused on their digital collections, participants saw them as artefacts they cared a great deal about and they worried they might lose. At the same time they did not wish to be concerned with low level maintenance activities, such as migrations across file formats/applications as these changes. As for the daily management discussed above, these low-level curation tasks are not things that interest or excite the average person. Companies, e.g. British Telecom, have started offering online storage or Digital Vaults. While this preserves the material from digital catastrophes, e.g. hard disk break down, a stolen PC, fire, there is no guarantee the software to read it will be still available in 20 years time. Without such a service, it is easy to imagine the dismay of a person who has received hundred of thousands of unreadable files that contain the life of a deceased beloved person. There may be no way to discriminate what is worth preserving and what is not as the content is not easily accessible. For this, we have hope that manufacturers will recognize the need for backward compatibility and provide solutions to allow our grandchildren to have a glimpse at our lives.

6.3 Enhanced access to mementos

The central weakness of current digital mementos is that they are inaccessible and not well integrated into everyday life. As a result they are forgotten, even by people who have invested countless hours in creating, collecting and organising them. Their inaccessibility leads to unfortunate consequences. Unlike physical mementos, they cannot be distributed to different locations around the house to express and elicit different styles of remembering. Instead of being seen and discussed by guests in public spaces, reinforcing family memories in the kitchen, or supporting personal reminiscence in an office or study, they are locked in the computer. Certain other things follow from this lack of integration. Digital mementos are not encountered on a daily basis. As a result they are not organised or sifted according to their value. The fact that they are locked away in the computer also restricts appropriation: they cannot express symbolic meanings through new uses, instead they are constrained to simple representations of events and people.

An augmented reality approach would overcome some of these current limitations. Augmented objects have many of the same affordances as physical ones, so there is no

[3] iPhotos already organizes pictures by time into 'events'; it also supports simple sharing on social websites like Flickr and Facebook.

software interface needed for accessing them: users simply treat augmented objects like physical ones finessing the problems of invisibility of digital archives. Small, self-contained augmented objects could be accessed, invoked and organised in familiar physical ways and more easily integrated into everyday practices in the home.

Ubiquitous computing in the home for the purpose of digital memories implies many CPUs and many display devices, likely of different size, portable and standing, all networked and interconnected. Handling mixed reality mementos might then provide valuable data for generating new types of enhanced digital experiences that are context sensitive. Frequently accessed objects might behave in ways that are different from less frequently handled ones, or objects that are handled in predominantly social settings might again have different properties from those that are private. For example, a tablet PC that looks like a book and sits on a shelf could display family photos when picked up in the lounge but could display personal communications when taken to the study for more intimate use. Emails could make use of fonts created with personal handwriting strokes depicting the email as a hand-written letter, and saved in piles linked with a ribbon. This contextualised combination of the physical and digital in a simple, dedicated information appliance [34] could reduce the feeling of the digital being ephemeral and inaccessible. Digital conversations, e.g. emails, text messages, and voicemails, are valued but rarely extracted from the device they were received on. Here, there is room for designing new techniques for integrating these conversations with more traditional types of artefacts. Narrative is core to bring memories back to life [33], but it is rarely captured [14, 37]: ambient technology or augmented objects could be used for this purpose but lightweight techniques to capture and integrate digital narratives are needed [16, 17].

Our analysis of physical mementos also revealed different types of access experience. Some mementos are highly visible—placed in social locations to engender conversation. Others are mundane objects incorporated into everyday activities that often have a secret story that is not available to those outside the family. Yet others are stored in hidden places at the back of drawers or in attics where access is an immersive experience with a secret collection.

We can reflect on how we might replicate these experiences in the digital domain. For purely digital objects, the immersive experience should be the easiest to achieve, as we can capitalise on the fact that digital collections are currently seen as being hidden or invisible. One way to enhance this experience might be to embody digital collections in attractive physical forms, like the Memory boxes that people stash away in the backs of drawers or wardrobes [19, 36]. New innovative design could take advantage of network technology to create a much more engaging memory box: when mementos (digital as well as physical) are dropped into it, additional information could be automatically collected by the box and stored locally; when, 20 years later, the owner opens the active memory box, she will find the objects she put into it, along with additional automatically collected information, such as pictures of her friends at that time, her university timetable, the map of her travels in South America, the music she was listening to, plus the news and clips of her favourite TV programs.

Other types of access such as public sharing of strategically placed mementos should also become easier as different types of screens and display devices become readily available in the home. Rather than sharing digital mementos passing a laptop between people or gathering around a PC, it will soon be possible to straightforwardly send digital mementos to a chosen convenient display device, e.g. a television [20, 44]. It should be easier to 'dock' different digital devices that contain mementos and to share these with others via whatever display we choose.

Another intriguing possibility is the prospect of making digital mementos more mobile, i.e. taking them outside the home. People now routinely use mp3s and iPod to carry their personal music with them wherever they are, allowing them to immerse themselves in their own sound world when they travel. The same might be possible for digital mementos. Carrying digital memorabilia on a mobile device like an iPod or phone allows, for example, personalising an anonymous hotel room when travelling by displaying personal digital mementos. They might also be using mobile devices to share mementos with others in multiple mobile situations.

A final extension might be to use interaction data as a way to recreate the concealment and rediscovery of mementos we observed in the memory tour. Active use can be a good implicit indicator of memento importance, i.e. printing, sending as email attachment, or editing a photo are all examples of associated value. By observing user's actions a few important mementos could emerge from the wider collection, while the rest disappear into the store of seldom-accessed memories. This distinction between implicit favourite and the rest of the collection could promote new and engaging ways of revisiting, for example a photo album of 'never seen before' or the random display of rarely seen photos could occur when the user logs on or off their computer.

7 Summary

We characterised and compared physical and digital mementos in the home. Physical mementos are highly valued, heterogeneous and support different types of recollection. Contrary to expectations, they are not purely

representational, and can involve appropriating common objects and more idiosyncratic forms. In contrast, digital mementos were initially perceived as less valuable, although participants later reconsidered this. Overall digital mementos were more limited in function and expression than their physical counterparts, largely involving representational photos and videos. Designing new methods for capturing organising and accessing digital memorabilia presents clear challenges, but our results suggest numerous interesting avenues for possible exploration, addressing some of the current limitations of digital mementos. We explain these digital limitations and conclude with design guidelines for digital mementos, including better techniques for accessing and integrating these into everyday life, allowing them to acquire the symbolic associations and lasting value that characterise their physical counterparts.

Appendix: Digital memento interview schema

Do you have any "special things" that are in digital format? (if the respondent seems perplexed prompt with: email or voice messages, photo, video clips, artifacts they/they-children have made, music. Be sure all the media are covered: text, speech, image, video clips, music, artifacts).

Where is each one kept? (Interviewer—be sure to mention all: home PC, work PC, laptop, PDA, mobile phone, camera, camcorder, iPod, CDROM, cassette, disks) Do you mind showing it to me?

How often do you access it? In which context? (Interviewer—responses could be: while travelling, by chance, to show someone, ... —be sure all possibilities have been considered by the respondent).

Have you shared (sent or shown) this with someone? If not, is there anyone in particular you would like to share this "digital memento" with?

What are you going to do with this "digital memento" when you change laptop/phone/PC?

How would you feel about having this digital thing displayed in a room? Which room would you put it in?

If the respondent is not interested in digital memories:

- why is that so?
- would a different way of interacting with personal digital memories change this attitude?

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Making History: Intentional Capture of Future Memories

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ABSTRACT

'Lifelogging' technology makes it possible to amass digital data about every aspect of our everyday lives. Instead of focusing on such technical possibilities, here we investigate the way people compose long-term mnemonic representations of their lives. We asked 10 families to create a *time capsule*, a collection of objects used to trigger remembering in the distant future. Our results show that contrary to the lifelogging view, people are less interested in exhaustively digitally recording their past than in reconstructing it from carefully selected cues that are often physical objects. Time capsules were highly expressive and personal, many objects were made explicitly for inclusion, however with little object annotation. We use these findings to propose principles for designing technology that supports the active reconstruction of our future past.

Author Keywords

Autobiographical memory, cultural probes, fieldwork, lifelogs.

ACM Classification Keywords

H.5.2. User Interfaces and H.5.m Miscellaneous.

INTRODUCTION

Storing and accessing information relating to personal memories is a widely recognized computational challenge (e.g. DARPA's LifeLog and EPSRC's Memories for Life initiatives). Various new technologies allow people to capture an enormous mass of personal data using 'lifelogging' tools. The lifelogging vision is to capture 'everything': every event we experience, conversation we participate in, and any piece of digital data we ever touch [1, 17, 19]. According to this vision, these accurate digital records can then be accessed to re-live past events. However, with few exceptions (e.g. [14, 27]), most lifelogging work has focused on *technology*, rather than on *understanding the nature* of long-term remembering.

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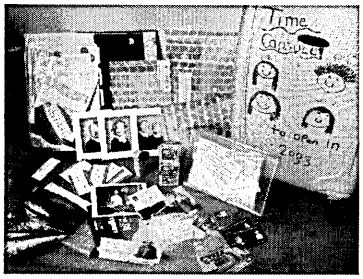
Instead of focusing on tools for capturing the minutiae of one's entire life, this paper looks at the human side. Our aim is to better understand what people would like to remember of their past and why. We explore the motivations behind intentional experiential capture, examining what people consider being valuable long-term mnemonic representations of their lives. To do this we asked 10 families to create a *time capsule* (Fig. 1): a collection of items to represent themselves and their lives - to be viewed 25 years in the future.



"I would have never done it, but there was a reason and it was just fab. I enjoyed it greatly!"

Figure 1. A time capsule, its contents, a co-creator's comment.

In particular we wanted to address the following questions:

- *What* do people want to remember in the long-term? Are they more interested in people or experiences? Do they emphasise important events or more mundane aspects of everyday life?
- What *types of objects* are chosen as long-term memory cues? Are these representational objects, e.g. photographs, theatre tickets, or are they more symbolic, e.g. a child's first tooth or pair of socks?
- *Why* do people want to remember? Do they want to recall facts about their past, to reminisce or to preserve significant objects from their lives?
- *How* is remembering going to happen? Is the time-capsule intended to support *veridical recall* of events as lifelogging suggests? Or will it function as a set of more fragmentary *cues* for the *re-construction* of meaning in the recall context, as work on autobiographical and collective memory claims?

Understanding these issues is fundamental for the effective design of digital systems that support long-term remembering.

RELATED WORK

This topic is interdisciplinary, relating to work in psychology, sociology, material culture, computer science and technology. Each area takes a different perspective.

Work on autobiographical memory within psychology documents its neurological basis [11], development [21], consolidation [4] and decline [23]. Recent theories emphasize *narrative* - claiming memories are not fixed but continuously reconstructed within a social context [31].

Theory in sociology claims the context of recollection changes the reconstruction of memories [13], arguing rituals are fundamental for the transmission of collective memories in the form of tradition [3].

Material culture examines the spaces people inhabit as autobiographical representations [12], the meaning of objects in people's lives [6], how mundane objects become evocative of life events offering comfort during important life changes [2,30], and how heirlooms provide a fine-grained understanding even of a distant past [18].

In HCI, in addition to lifelogging, studies of personal digital memories focus mainly on photos. Of particular relevance here is social story telling as a way to contextualize photos and construct families' self representations [5, 7, 28]. Some technology research looks at the role of memories in people's lives. [8] finds that souvenirs enriched by audio narratives are valued by adults only if given/received as presents. [29] shows that parents actively collect children's mementos, but fail to capture narratives related to those objects. [32] explores the potential of physical-digital tools for mixed reality and mixed media scrapbooking. In [15] digitally augmented RFID-tagged physical objects were used to retrieve a set of previously associated images.

Recent work has looked at the value of visual [14, 27], or sonic content [16, 22] for personal recollection. [25] shows mundane objects or artwork are more representative of autobiographical memories than photos or digital content.

THE CONCEPT AND METHOD OF THE TIME CAPSULE

A *time-capsule* is a way of leaving traces of our life for ourselves or others to discover in the future. It is an intriguing idea that captured the imagination of many, including artist Andy Warhol who assembled 370 such boxes in 13 years. It has been used in educational settings, community and art projects. In this study, the process of deliberately composing future-oriented mnemonic representations in a time capsule was a playful way to engage our participants in reflecting on their daily lives and memories in the distant future.

Participants

We invited families with young children to create their own time capsules to be opened in 25 years time by their (yet unborn) grandchildren. Selecting these families allowed us to contextualise the study in a familiar setting, that of the children becoming parents. Parents of young children also see themselves as active curators of their children's 'future memories' [29]. We recruited a middle class sample on the basis of [6]'s finding that they are oriented towards memories and relationships - in contrast to other social groups who focus more on possessions. In total, ten families, 20 adults and 19 children (9 boys, 10 girls), participated in the study. The families were recruited by acquaintance and the adults covered a range of professions (teachers, museum conservationist, high-level managers, architects, writers, nurse, doctor, Anglican priest and 5 academics). All families were regular users of digital technology, e.g. digital cameras and computers. The average age of parents was 45 (38 to 54) and for the children 9 (5 to 14). All families but 1 had 2 children.

Reflection and Creation Stages

The study consisted of: (a) an initial reflection phase, to decide what was important to capture, (b) a creation phase when the time capsule and its contents were created.

Reflection started with an introductory explanation and the handing over of a set of cultural probes [9]. The probes (see Fig. 2) were intended to inspire participants when composing their time capsules [10]. They were designed specifically to provoke reflection about participants' *past* - what they might like to remember from 25 years ago – as well as the *future* - what they might want their grandchildren to know 25 years from now.

Figure 2. Probe sets (left) and individual probes (right).

The probes included: a 2-week diary, '25 year' notepads (to reflect on what they might want to recall from 25 years ago), a local map with stickers, cue cards with "who, what, when, where, how" to remember, shaped post-its for 'messages to the future', scrapbooking materials, and a questionnaire.

By keeping a 2-week diary and recording their movements on the map, we oriented participants to the notion of careful information capture and the procedures and goals of lifelogging. By asking older participants to reflect on their distant past, we intended to make them familiar with the process of recalling very old information and the cues that would be needed to do this. The reflection phase ended after about 10 days with an informal interview on the probes and plans for the creation phase. This phase required families to create their own time capsules and contents. No

restrictions were given except that each family member should contribute. It was made clear that sensitive content could be included in a sealed form and would not be inspected, but an idea of the content should be provided. We explicitly invited participants to include digital objects in any form.

When the family felt ready, after about a month, they presented the time capsule and its contents to us. During the final videotaped meeting, which lasted 1 to 2 hours, family members described each object, explaining what it was and why they included it. Questions about the overall experience concluded the creation phase. As a token of our appreciation we gave each family a photo printer.

Data Analysis

Space limitations prevent us from discussing the used cultural probes, despite their effectiveness. Instead our analysis focuses on the contents of the time capsules which were photographed and catalogued before being returned to their families for final storage. Video interviews were transcribed, systematically analysed and classified. Interview coding was rooted in participants' descriptions of objects. Key phrases were labelled and clustered by affinity, i.e. topics that reoccurred in interviews became categories. Indexing and counting were used to highlight phenomena.

We categorised the *types of objects* stored in the time capsule, i.e. whether they were photos, significant objects, ephemera, craftwork, essays, videos, or publications. We also determined *what those objects referred to*, i.e. people, places, events or things. Nearly all objects had a single major referent; the few objects with multiple meanings were classified with respect to what was considered the dominant one. For example a photo of the children sitting on a tree described as "*this is a place where the children like to paddle. It's S's favourite place, Padley Gorge*" was classified as 'place' instead of 'people'. We also classified the *type of memory* each object engendered i.e. what memory function was being served, such as recall, reminiscence, or simple preservation.

To further understand the mnemonic functions of the collected objects, the 369 items were classified with respect to Peirce's [24] typology of signs associated with objects: icon, index, and symbol. An *icon* shares qualities with its corresponding object, i.e. by resembling or imitating it. A photograph of the family house acts as its icon; newspapers, technology samples, holiday photos, maps are all examples of icons. 'My favourites' and diaries were classified as icons as participants described them as related directly to themselves and their experiences. An *index* relates to an object via a physical or causal connection. Swimsuits and sailing maps are indexes of a family's passion for water-sports; recipes, scout badges, children's craftwork, school reports, awards and medals are all examples of indexes. Shopping bills were included in this category because their purpose is not purely representing the cost of commodities, but to indirectly represent what the family bought. A *symbol* denotes its object solely for those who are able to interpret it. "*Ballet socks, actually not a pair nor pristine. They tell a lot about how we are: we do things but we are not hugely organized and we do not mind too much about certain things.*" A knife and fork, flower-shaped hanger, and a letter to the future are all examples of symbols.

Homogeneous sets of objects were classified in groups, e.g. photos, VHS cassettes, children drawings, unless their individual value was made explicit, e.g. videos of a house and a birthday party counted as two instances.

FINDINGS

Participants greatly enjoyed the process of constructing time capsules and were highly animated when describing them. They took the construction process seriously as evidenced by the fact that, despite them being extremely busy, many objects (craftwork, photo collages, messages to the future) were *deliberately constructed* for the exclusive purpose of including them in the time capsule: "*It was an enjoyable activity. Although we have been very busy and we didn't have much time, we could have gone on for months*", "*It has been very interesting, we have done a lot of things and caught a lot of things for this that we would have probably have let slip by.*"

In the next two sections we first describe what the contents of the time capsules were and what they looked like, then we discuss in detail the meaning behind: the types of memories, reasons for storing and what this tells us about how people want to remember

What *objects* serve as memory cues?

Deliberately Constructed: In line with [8, 25, 29] we expected the time capsules to contain small collections of precious objects participants selected from existing long-term belongings. But *belongings* accounted for only 37%: and of these, very few were older possessions (4%), instead the majority were from the last 4 years.

To our surprise, participants put a lot of effort in assembling *new content*: 37% of objects were created for the sole purpose of being included in the time capsule, a further 26% were deliberately collected for this reason. This is an important result not only because it challenges the lifelogging notion of passive event capture, but also because it shows the level of commitment and interest that the overall project engendered in our participants.

Objects made for the time capsule included photos, scrapbooks and writing, but also photocopies or scan-and-print copies of unique items like a home address book or photos of great-grand-parents. The selection process depends on the *type of memory* participants want to capture. If the function of the object is symbolic, e.g. the photo of the 2nd of May 1997 discussed below, the selection is very careful and precise. If instead it is representational, capturing everyday life, a random sample suffices: "*[music brochures/leaflets] are fairly random because they are not more important than others we could have chosen, they just*

happen to be there." However random, the sample must be detailed: "*We wanted something that is a sample of life, it has to be a fairly random thing but described in quite some details. The detail then becomes important because you do not know what it is going to be.*" It is important they are 'a samples', not an exhaustive record: "*the last supermarket shop receipt. You do not want to keep much of this sort of stuff, but it brings back all flavour of the time. You could be quite surprised about what you were doing 20 years ago.*"

All 369 objects were initially classified with respect to their physical properties, see Table 1 below.

	photo (98)	thing (80)	craft-work (60)	ephe-mera (49)	essay (38)	publi-cation (33)	video (11)
F1 (42)	12%	17%	21%	24%	12%	14%	0
F8 (31)	23%	16%	10%	23%	10%	19%	0
F2 (48)	12%	60%	0	4%	0	24%	0
F4 (63)	12%	14%	33%	14%	14%	3%	9%
F3 (27)	25%	36%	11%	14%	11%	4%	0
F6 (30)	26%	19%	26%	3%	10%	6%	10%
F7 (21)	32%	16%	16%	5%	26%	5%	0
F5 (42)	37%	7%	16%	21%	14%	5%	0
F9 (40)	56%	15%	10%	12%	5%	2%	0
F10 (19)	60%	10%	10%	5%	10%	0	5%

Table 1. Fx represents a family, (x) the number of objects included and x% the types of objects each family favoured.

<u>*Photos*</u> were the most popular type of object accounting for 27%, showing the dominant belief that visual cues can trigger memories ("*there is nothing as good as a visual trigger to help you remember lots of other things, even keeping a diary would not necessarily be as thorough as a visual stimulus*"). Photos were mainly used to remember *people*: 13% depicted oneself, 6% family, 21% others (teachers, friends, relatives), and 5% ancestors. Photos showing *places* were popular (26%), just as experiences of events or everyday life (24%). A small minority of photos showed *today's world* (3%): e.g. photos of contemporary technology such as TVs, computers, cars and streets.

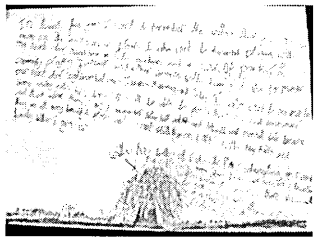
The majority of photos (54%) were deliberately taken for the time capsule to capture what was not commonly recorded and which might have been easily forgotten. The most commonly depicted people are not family but friends, distant relatives or acquaintances: "*childminder and after school club... these are all pictures I would not have taken of the people who look after the girls and they would have just disappeared.*"

<u>*Things*</u> is the second most popular type of time capsule object, 22%. It includes objects that were *once in use*, e.g. last year's family calendar, film cameras, mobile phones, tamagotchis; *personal belongings*, e.g. necklaces, first shoes, piano books; *awards and certificates*, e.g. spelling awards, medals and trophies. Participants also included a number of objects they thought iconic of the current time, "*plastic cards [library card, credit card]: plastic is very much like 'now'*", or objects that could disappear, "*This is a book, made of paper, you know. Will books in this form still be around in 25 years?*"

<u>*Craftwork*</u> accounts for 16%: drawings, paintings, models, webpages, scrapbooks done at home or school. 72% of craftwork was done by children, 28% by parents; 58% were *purposefully created* for the time capsule and 42% selected from an already owned collection. The selection criteria also differed across families, as from these quotes all commenting children's drawings: "*these are mushroom houses. My grandma did that one, I did that one [....] I wanted to remember what I did with grandma when I am 32*"; a painting of a panda on Chinese paper "*it is the best painting that M [aged 7] has done so far*"; 4 little paper note drawings "*the sort of things that in 25 years time will have a completely different significance just found in there. I don't have anything like that from when I was 7.*"

<u>*Ephemera*</u> (13%), items – generally printed – of short-term use or popularity that are not expected to last: "*bits and bobs, sort of things that otherwise will be thrown away*", e.g. theatre, cinema and train tickets; postcards; shopping bills; brochures; bank statements and school reports. Many are included in anticipation of their disappearance in 25 years time, "*a Visitors' Parking Permit that may or may not be useful in 25 years time. Maybe not because probably there will be less cars around I guess*", "*bank statements won't be around in 25 years time. They are beginning to fade right now as all saving can be looked at online*".

<u>*Essays*</u>: Writing of different sorts was classified as essays, 10%. Examples are: "*a couple of short stories I've been writing [...] It was the deep of winter when, you know, you are looking for something constructive to do. It was a big thing during the year*"; "*I [aged 14] printed off computer screenshots of MSN [chats]. Just thought it's gonna be nice [to see] what I talked about to my friends*". Schoolbooks and various children's writings were included in this category. Sometimes the writing was purposefully done to capture today's memories and feelings (see Fig. 3).



"*This is something I wrote about the willow tree that got pulled out of its roots in the flood in the park last year [2007]. Mum and I really really liked it. Now that side of the river looks really plain without it.*"

Figure 3. Example of an essay, 'what I want to remember'.

<u>*Publications*</u> (7%) are public documents including newspapers (national and local); magazines; periodicals; bulletins; 'official' websites; books. Again a copy of a recent newspaper captures today: the local newspaper "*represents where we live, the sort of things people think about*" and "*gives you all sort of information, you know, how much cars cost, jobs, supermarket adverts [for food*

prices]"; a national one for "*the world's facts.*" A publication could also be a symbolic representation of one's self, interest or beliefs: "*a copy of the Friend because I am a Quaker and that is a big part of my life*", "*Private Eye*[1] *it will be a period piece for what was going on at that time*", "*Two books. Stuff I am very fond of now. It would be interesting to see if in the future I still like it*". It might also provide the context for autobiographical events: "*my brother bought [this newspaper] for me on the morning my mother died. Newspapers are a very interesting cross-section of what is going on in the world as well as a background to your own personal life.*"

Videos, 3%, have a category of their own as participants commented on video's unique value: "*I did a walk around the house as it was without tidying up. I think this would give a better impression of how the house was really like*", "*F and grandma playing a duet at the piano because we thought it would be fabulous for her to watch*".

What are time capsules *like*?

Expressive: The capsules were highly expressive. Looking at them one could infer hobbies, interests, attitudes and in some cases significant events that had happened to the family. The number of objects per family varied greatly with a maximum of 63 objects and a minimum of 19. It is obvious from Table 1 that time capsules were highly personalised, differing in important ways across families. Some families were highly object-focused (F2 and F3). Others were centred on photographs (F9, F10 and F5). These differences represent different meanings that families chose to express. Two main typologies emerged: 4 time capsules were centred on the nuclear family with few references to friends and relatives (F3, F7, F9, F10); the other 6 had a broader focus and captured aspects of today's world and society.

The choice of container was also idiosyncratic, with some families favouring the practical, "*a plastic container to prevent damp*", the symbolic "*all of this will go in an organ pipe*" (the priest's family), or current icons "*5 years ago nobody had wheely suitcase now everybody has*" (see Fig. 1), or complex jokes involving time travel "*we wanted to use a TARDIS*[2] *but could not find one big enough*".

Undigital: We found very few digital objects, despite our explicit request to include them. Of the 369 items in the 10 time capsules only 7% was digital. Another 17% were originally digital but were represented physically: digital photos, scans, IM communications, Bebo pages[3]. This small number (7%) is explained by the fact that 4 families did not choose to include *any* digital content: "*sorry, we are just not digital*", "*you can still see Victorian pictures but if we will be able to see digital photos in 25 years I am not sure*". Since all participating families used digital technology on a daily basis, failing to include anything digital in their time capsules reveals a deliberate stance on the significance and fragility of such technology.

Three other families took the pragmatic approach of including devices, a laptop, a CD player and an iPod, to be able to access digital data in the future. The 3 families who included digital storage (1 CD, 1 USB memory stick, 1 digital tape) expected the technology to persist or they relied on experts to migrate their digital material into future formats: "*maybe USB will still be readable on old computers or maybe not.*" The reason for relying on experts was, in one case, rooted in experiences of being unable to access one's old computer: "*my first computer, my Amstrad, I still have it and it might still work as far as I know but I do not remember how to use it, apart switching it on.*"

Personal: Although certain high level patterns can be found within families, different family members chose objects to reflect their own personality: "*interestingly that reflects how the various members of the family live their lives, because L sort of put in a summary of where she is now in life, you know, there's no rubbish at all; all the ephemera - or what some people describe as waste – is mine. I suppose that reflects my visual dominance and my background.*"

Between families, the same objective, e.g. to record details of everyday life is realised in very different ways: a calendar, a detailed diary for a month, a 2 week summary, or a 1-day photo diary were used. Even when *exactly the same object* was included, the meaning differed from family to family. A bottle of wine in 3 time capsules expressed three very different motives: to represent the family "*We both enjoy wine. It is not that we expect it to taste great in 25 years time, it is just representative*", a focus on change "*good wine is supposed to improve with age. A 35 year old bottle of wine is rather a treasure and it is quite enticing to see what it turns into*", and to celebrate the capsule's opening "*We could turn it into some sort of family event I imagine. Have a time capsule party. I think it will be celebrated.*"

From this perspective, the lifelogging digital one-size-fits-all approach does not seem to apply. We need technologies that respect the highly personal nature of people's collections, and that can incorporate idiosyncratic physical objects.

What *types* of memories do people want to recall?

We wanted to understand *what* people would like to remember about their lives. We expected participants' to show a desire to record people, places and events, but much less their attempts to grasp the essence of the world and society as they are today. And we did not anticipate intimate communications they sent into the future.

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[1] A British satirical magazine dealing largely with politics.

[2] The police box used as a time machine by Doctor Who, a popular UK TV character.

[3] www.bebo.com is a social media network.

People: Unsurprisingly, this is the single most important memory topic accounting for 43% of the objects. This is split into self (22%); nuclear family (10%); others with close ties - like extended family, friends or acquaintances (9%); and ancestors (3%). For remembering non-nuclear others (e.g. scout/brownies leaders, colleagues, teachers) it is usually a matter of *capturing their appearance* (via photos). For the self and nuclear family it is via symbolic and evocative objects. So there are *self-related symbolic* objects that say:

- who I am: "*[the story of my institution] I wrote 6 months ago which contains 2 or 3 pages of what my role is quite apart from being my view of the whole thing*";
- what I do: "*my 'quarrel buster[4]' photo and this is the hat I use when I am on duty*";
- what I like: "*the TV programs that I watch and the channels they are on*";
- what I've done: "*an article that T. wrote about one of the climbs he'd done*".

Similarly *symbolic family objects* represent the identity of the family: "*these are some music things [brochures, leaflets]. Music is very important in our family*", "*food and recipes: we all like cooking and eating together*". Some such objects represent deep beliefs and values, "*a [charity institution] bulletin to symbolise we do not live only for ourselves*", or very close relatives: "*grandma gave me this dream catcher. It is for when I have bad dreams I put it next to my bed*".

Even when a family photo is included, its meaning does not seem to be representational: "*this is an official portrait [of the family] – it is the day we went to court and adopted M*". The participants' stated meanings of family photos that seemed to transcend the obvious and become more symbolic: "*this picture of F when she was one, it was taken the 2nd of May 1997 the day after Labour won the 1997 elections after 18 years or whatever of Tories rule. We were all very happy, we took the day off and we were up all night. For S and me it encapsulates all the happy times ahead.*" The process of selecting that particular highly meaningful family photo from among thousands is fundamental. It contrasts with lifelogging technology that records peoples' lives, but lacks in supporting selection and meaning construction.

Ancestors and family histories were captured in family trees or as (visual or written) clues. The intention seems to be to prompt storytelling: "*a photo of my grandmother's father - she told me stories about him, stories that only I know because only I asked so I feel I have to remember*". In another case clues are written: "*Story of Chris Junie captured by Indians. The rocking chair from the Revolutionary War. Aunt Ella's horseshoe.*" Again these are fragmentary and symbolic, probably impossible to decipher unless the story is already known.

Experiences: Undoubtedly a big part of life is what we do. Capturing experiences accounted for 26%, with 14% being events and 12% everyday life. Participants concentrated on capturing the mundane: "*the sort of flavour of this particular time, what we did day by day, the things that tend to get missed, forgotten*", "*just what we do today, a snapshot of our kind of life today.*" With one exception, the types of events captured are minor ones: cousins visiting for a few days; going to the cinema; receiving spelling awards or performing in a concert. Even a 7th birthday is seen in perspective: "*Photos of the presents A received and a transcription of her saying what they are and who they were from.* [...] *In 25 years time you wouldn't have a clue of what your child have got. It could seem quite banal now but I think it will be an interesting cross section because by that time they will be having very different things [...] It is a sample of the everyday but it is actually an annual everyday, if that it's not a contradiction.*"

The way of capturing daily life (12%) varies from family to family: from a 1-day photo diary, to a one week summary "*C and her boyfriend, T, T and his wife, J, came for dinner to celebrate A's birthday. We had salmon and a chocolate birthday cake*", to a detailed diary for a month "*M. left for America at 4:30am. Howard came to take him to the airport as he always does when it is a drastically early or late flight*", to a 2007 family calendar "*so we can see what everyone was doing, when and with whom*". Other objects represent fragments of everyday life, e.g. a veterinary business card, spelling practice sheet, or school class photo.

Places: Places were also important to participants. Similar to experiences, important places are *familiar*, not exceptional: "*Places where we go a lot. [why?] The places that you know so well become ordinary and we don't have actually any record of it because it is so very familiar.*" As a result, the most recorded places are: the home and garden, the local park, the favourite walk, grandparents' place and school. Interestingly, just seeing a little corner of a familiar place provokes endless stories.

Representing today: We expected participants to capture people, experiences and places, but some also attempted to record today's world and society, accounting for 15%. Newspapers and magazines, bills and credit cards, parking permits and train tickets were all collected to capture the present and to feed future reflection: "*I wanted to look back and see what food bills were like and how much it took to fill up my car with petrol*", "*A copy of the Oxford Handbook of Clinical Specialties from 1995. It starts to show signs of dating in the advice it gives so it would be interesting to see in 25 years time how medicine has changed*". These instances are motivated by the expectation that these things will change, allowing one to compare past and present.

[4] A 'Quarrel Buster' is a pupil who is in charge of resolving conflicts rising in the school yard at playtime (recess).

Sometimes participants commented on how their personal life interlinks with the world they live in: "*[this CD] is one of my favourites and the BBC has used many pieces of this album for adverts so there is the associated memory [of popular culture of this time]*".

Communicating with the Future: In the same vein as capturing our current world, 6 participants sealed their thoughts, worries, and hopes to be sent into the future. Thoughts for the future were only 3% of all items but represent a deep emotional involvement. The reasons were different, and included the wish to explain ones' life: "*Perhaps trying to justify our parenting and the way we live and I hope [the children] will have a kind of appreciation for the way we live, more than what they have now.*" The desire to capture the children's characters: "*what type of people they are now [...] because it would be interesting to know if they have got those personality traits or if life has altered them in some way.*" the wish to record one's deepest hopes: "*what I hope now, personally, for the whole family and for the world too.*" the expectations about the future: "*a list of things that I would like to do from now [aged 12] until I open it. I want to see how many of these has happened.*" Only 1 young child included something for the future, Fig.4: presents for her children.

"*I have put in presents for when I'm 32 for my children, if I have children. And for my husband.*"

[the label read: *'to won of my childrn – love from C'* - misspellings in the original]

Figure 4. Message to the future.

To conclude, as we expected people referred to themselves, their family and to events, but somewhat surprisingly they wanted to record social history as well as to send messages into the future.

Reasons to Store

Lifelogging assumes people's main reason for capturing their life is to *relive* it. Although recording was a predominant reason, we also found other motives: people want to compare today and the future, preserve their past and add a bit of humour. Table 2 shows a summary.

Records, 46%, were simple attempts to capture literal aspects of life: schoolbooks and children's drawings; representing activities like going to school or Brownies, school trips, or climbing.

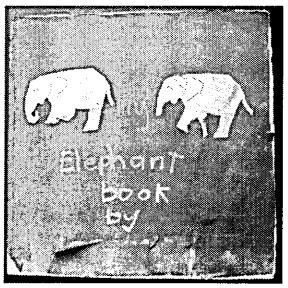
Reminisce: 30% of objects were included to foster rethinking, sometimes with a nostalgic nuance. This includes essays that reflect today, but also predicting the future emotional value of specific objects like father's day cards "*there is a sort of innocence to both the cards that in 25 years time won't be there, probably won't be there in 5 years time*". Objects that foster reminiscing are rarely representative and immediate, tending to be evocative and symbolic "*knife and fork – they represent eating together as a cultural statement* [...] *and a lot of our arguing time 'use your knife and fork' that sort of stuff*".

	Record (46%)	Reminisce (30%)	Compare (12%)	Preserve (8%)	Fun (4%)
Photo	63%	21%	5%	9%	2%
Essay	55%	26%	5%	11%	3%
Craftwork	84%	8%	0	8%	0
Ephemera	59%	16%	16%	4%	4%
Things	33%	29%	21%	2%	15%
Video	64%	27%	9%	0	0
Publications	67%	9%	18%	6%	0

Table 2. Types of objects and reasons chosen.

Compare: recording is often done to compare today with tomorrow (12%). Technology is an obvious candidate for such anticipated changes: "*'Miraculous technology': mobile phone, iPod, remote control. We don't know how they will look 25 years from now or if they will still exist*", "*an - already quite old - piece of technology: a mobile phone. We are interested in where technology is going to be in 25 years time. We'll probably think this is extremely old fashioned, but it doesn't feel it.*" Items of comparison have a value not only for the people who selected them, but more generally for today's generation and maybe future ones: "*[the time capsule] is very personal but at the same time it is very much of our era and our time so for anybody in the future whether they have never seen 2008 or whether they remember 2008 it's going to be exciting [to open it]*".

Preserve: The idea of the time capsule engenders the need to preserve: 8% of items were put in purely for preservation. Elements in this class are often unique and the intent is to pass something on from past to future generations. There is a sort of fear that objects could otherwise be lost and preservation is often directed to future generations, see Fig. 5 for one such a case.



"*A little book that I made when I was 5 or 6 about elephants which I thought might be quite nice to share with any other little children... C's children that she is so sure she is going to have...* [see Figure 4] *An old fashioned book made by an old person.*"

Fig 5: An example of preserving an object for the future.

Fun: Somewhat to our surprise, a small group of items was put in for fun (4%). Having a laugh when the time capsule is opened seemed the only motivation: "*this [flower-shaped hanger] fell off L's door 3 times. It will remind me of DIY*[5]

[5] DIY or Do It Yourself is the activity of creating or repairing something without the help of a professional.

failures. It will make me laugh in 25 years time", "*a toilet roll as a symbol of time passing and the fact that we are 'nappy free' now.*" The fun is in putting the object in now - as the joke is unlikely to hold 25 years.

How is remembering going to happen?

The implicit assumption in lifelogging is to support *veridical recall*, i.e. the person reliving their life while going through an exhaustive log. However this has been recently called into question by the failure of participants to relate such logs to their lives [28] and their attempts to re-interpret log evidence [14]. Our results echo these criticisms - showing veridical recall is only one of many aspects of autobiographical memories.

As stated before, all objects were classified according to whether they were iconic, symbolic or indexical. Table 3 shows the relation between *type* and *the reason* for the object to be included in the time capsule. A dichotomy emerges. Icons (i.e. objects that directly depict what's signified) are most associated with *recording* today - for looking back - and *comparison*. In contrast, symbols (where the relation between object and signified is indirect or esoteric) connect with *reminisce*, *fun* or *preservation*.

	Icon (48%)	Index (33%)	Symbol (19%)
Record	**63%**	35%	2%
Compare	**56%**	38%	5%
Reminisce	11%	32%	**67%**
Fun	12%	29%	**59%**
Preserve	33%	17%	**50%**

Table 3. Relation between typologies and object functions.

Lifelogging is an unmediated recording activity. By capturing without intervention, lifelogging works at an iconic level. However when interpretation comes into play human intervention is needed. The meaning of indexes could probably be reconstructed by the opener of the time capsule - at least for familiar people or activities represented by the object, e.g. swim suits as reminder of many childhood summers. The symbolic level, in contrast, requires a high degree of human involvement in meaning building (during capture) or interpretation (when accessing). Inferring that a pair of unpaired ballet socks represents the philosophy of the family cannot be directly 'captured' or inferred.

Deep, cryptic meanings that characterise symbols can be communicated only via added narrative or descriptions. We were therefore surprised to find that these were minimal: 7 capsules contained no annotations, 2 had minimal labelling, e.g. "*M is car mad*", and only 1 had exhaustive descriptions, e.g. "*P's favourite things are cups of tea – You don't give Mum any problem until after her first cup of tea in the morning.*" The lack of annotations was surely not the result of casual attitudes to the project, as hours were spent in creating and collecting new material. Neither was it due to the lack of forethought as the probes pushed parents to reflect what they had done 25 years before, thus exposing them to the problems of retrieving from their distant pasts. As with for photo collections [7, 26], participants seemed to believe that because they can remember now, they will be able to do so in the distant future: "*I would like to think that it would be still obvious why we have done it*". When explicitly questioned about fully understanding what is in the capsule in 25 years time, their first reaction was to suggest they add a list. But on reflection, participants were less troubled, and instead amused by the interpretive challenge: "*part of the fun of opening it would be to try to work it out why or what it was about. So to give some sort of freedom to that instead of saying 'this is in because', instead of giving just one reason.*"

Clearly the time capsule is clearly seen not a veridical, exhaustive record, but rather a *set of cues* whose meaning has to be actively reconstructed. Participants did not want a complete record of their past, instead they wanted fine-grained details about a 'typical' day: "*a sample of life, fairly random but described in quite some detail, the detail becomes important.*" Consistent with [31 and 13], our results argue that remembering is an active process based on reconstruction from often fragmentary cues. This suggests new possibilities for the design of digital technology, more oriented towards supporting the creative reconstruction of autobiographical memories, rather than focusing on exhaustive recording, i.e. as in lifelogging.

PRINCIPLES FOR AUTOBIOGRAPHICAL TECHNOLOGY

Active meaning building not passive capture

Two striking properties of the time capsules were an absence of detailed annotations and a focus on highly personal, often specifically constructed, objects. Together these meant that objects were seen as cues for active reconstruction of memories. This has strong implications for the general design of autobiographical tools which therefore need to support active user appropriation, a creative step far beyond the initial passive capture. Thus, instead of recording vast amounts of low-level personal data, we need new applications that allow people to reflect on, and sort through objects related to their pasts. Indeed participants dedicated time and effort in *creating* objects for their time capsule, in the same way that people now make a physical photo album or a CD to celebrate a specific event. Their focus is not on capture but in analysing, reflecting on, and selecting among different materials relating to the past.

New technology should aim to support *active selection*, *creativity* and *meaning building*. These activities could also potentially exploit automatically captured data to enrich recollection [14, 27]. But tools to support the processes of collation, reflection and sorting, have to be *fun*, and we must identify ways to engage people with their digital collections whether these are generated by future lifelogs or current technologies such as digital cameras or videos. The time capsule engendered a high level of engagement around physical objects: e.g. printing from the computer, cutting, as well as gluing, decorating, drawing and writing. Tangible

interaction might therefore be a promising method to motivate people to analyse their digital memorabilia and construct new things. One manifestation might be a "digital bricoleur interactive table" where people can collaboratively manipulate physical and virtual objects. Objects could be created and placed on the surface to retrieve digital content, e.g. a snorkel mask would retrieve photos and video clips from a holiday, along with a travel map and the website of the campsite. Placing scissors, glue and coloured pencils on the table would activate their familiar functions and supports the social creation of the "Summer 2008 – Sailing holiday" augmented scrapbook. Personal comments might be another important creative component: handwriting should not be automatically corrected as small children's spelling mistakes (as in Fig. 4) are an integral and charming part of remembering "life as it was." Finally the table might record the ongoing talk at creation time as this is likely to contain explanations, a critical element in remembering the meaning of symbolic objects. Playback, however, should not be automatic but on request to allow for speculation and reconstruction.

Detect and abstract our habits (then hide them)

We initially expected the time capsules to contain a few emotionally important objects preserved for the future. Instead they often contained mundane elements of everyday life: ephemera that are generally thrown away, as well as recordings of familiar places and activities. But although our participants greatly enjoyed the project, it required considerable commitment: "*I have always wanted to do something like this but never managed to. I am glad you forced me.*" Lifelogging tools might reduce the effort needed to record the mundane by automatically creating *sample summaries* of the everyday. They should abstract data into high-level representations. What people want is not a mass of low level data, but high-level information about familiar habits, places and activities. Next generation lifelogging tools should detect habitual patterns – identifying familiar places and activities, automatically creating maps to be enriched with photos and personal comments. Similarly online booking of theatre shows, grocery shopping, online news or other forms of mundane activities might be automatically *sampled* to grasp the flavour of today's life. The data could be used to pre-populate a digital week's diary, or left lingering on the hard drive to be rediscovered, or automatically redisplayed, years later. This would create a 'digital memory box' allowing casual rediscovery of memorabilia, resembling the emotionally powerful experience of finding long forgotten ephemera in the back of a drawer [8, 29, 25]. However this scenario leaves us with the problem of technology fragility [20]: hardware and software is not expected to last - leading our participants to be emphatically undigital. Without an effort to create self contained and long lasting technology one worry is that the destiny of current digital mementos is to be printed or otherwise to disappear.

Logging the context of life

A second, possibly more important, role for lifelogs might be to provide *contextual information* for the interpretation of more symbolic cues. Few participants provided annotations or explanations as to why certain objects were chosen, in part we argue because they were not focused on the context of retrieval. Lifelogging could provide *context*, e.g. about users' past interactions with an object, allowing them to more easily reconstruct the memories associated with it. Thus instead of lifelogs being *the* critical type of data we record about our pasts, we see them as being important metadata, to allow the interpretation of other more prominent objects. By using sticker-like tags users could collect and organise objects in the same natural way they currently organise photos in albums [15]. The objects could then be returned to their original locations and continue being used. By tracking them we could generate an enhanced time capsule, which not only included the set of objects but also (suitably filtered) relevant contextual information. This additional information could support the users in solving the interpretation 'puzzle'.

And similar principles might be extended to existing digital photo software. Instead of passively storing digital photos, new applications might add history to pictures by tracking which pictures were accessed when and by whom, in what context, and which were edited by which people [7]. Such data, suitably filtered, might serve to animate and contextualise digital photo collections, and make them somewhat more compelling.

CONCLUSIONS

The time capsule was successful in exploring the deliberate capture of mnemonic representations. All participants expended considerable time and effort in construction and believed that they had created collections of significant value. These results suggest important ways to overcome limits in the lifelogging vision. People do not want complete daily records, but rather samples of their everyday habits. They also do not annotate their object collections. A critical role for lifelogging might be to provide metadata for those objects, or sampled abstractions from detailed daily recordings. Our findings also emphasise the importance of active (re)construction rather than passive memory capture. Future technologies need to support active selection and appropriation to allow people to "make their own history".

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Sonic Souvenirs: Exploring the Paradoxes of Recorded Sound for Family Remembering

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ABSTRACT
Many studies have explored social processes and technologies associated with sharing photos. In contrast, we explore the role of *sound* as a medium for social reminiscing. We involved 10 families in recording '*sonic souvenirs*' of their holidays. They shared and discussed their collections on their return. We compared these sounds with their photo taking activities and reminiscences. Both sounds and pictures triggered active collaborative reminiscing, and attempts to capture iconic representations of events. However sounds differed from photos in that they were more varied, familial and creative. Further, they often expressed the negative or mundane in order to be 'true to life', and were harder to interpret than photos. Finally we saw little use of pure explanatory narrative. We reflect on the relations between sound and family memory and propose new designs on the basis of our findings, to better support the sharing and manipulation of social sounds.

Author Keywords
Collaborative remembering, collective memory, sounds, photos, families, fieldwork.

ACM Classification Keywords
H.5.2. User Interfaces H.5.3 Group and Organizational Interfaces - CSCW

INTRODUCTION
Memory is an integral facet of our social and individual identity. Much recent interest in the technology of memory has been fuelled by technical developments in networking, storage, retrieval and new sensors. This in turn has led to the development of many new tools intended to help our fragile memories [1,5,14]. So far, with a few exceptions [13,27] rather less research has examined how such technologies might be deployed in actual social contexts.

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However one area where there has been extensive human-centric research activity is in the technology and practices associated with photos and remembering. Multiple CSCW studies emphasize the social processes involved in photo sharing. These studies reveal that photos tend to be of familiar people (friends, family) portrayed in a largely positive light and at landmark events (holidays, parties) [2,8]. Narrative, known as phototalk, is also crucial [4,9]: people collaborate interactively to produce stories about their photos that are shaped in subtle ways by the participants and their relation to the recorded event. Frohlich [8] argues that there is a connection between the positive quality of most photos and the process of sharing them. When people take photos they are aware that the result will be shared with others, which leads them to edit out potentially negative or embarrassing subjects.

While that prior research has focused on *images*, talk and memory, rather less work has looked at the relation between *sounds*, talk and memory. In the current study, we extend earlier work on photos and family remembering, explicitly looking at the relation between sounds and memory in a quintessential mnemonic setting - where participants are creating mementos from a family holiday.

There are various reasons why sound is a promising technology to explore in the social context of memory. Studies of phototalk highlight the crucial role of conversation around the sharing of photos [4,9] and sound seems a natural way to record such narratives. Other work suggests that sounds can be highly evocative whether in isolation [21,22], or when accompanying existing photos [9]. To focus directly on the affordances of sound, we asked participants to create and share with us *sound-only* mementos of a family holiday. We called these *sonic souvenirs,* and compared them with regular holiday photos. We address the following questions:

- How do sonic souvenirs differ from photos? We know that photos tend to have predictable content (people, places, events) with a generally positive tone. But do sound mementos have different properties?

- Given the opportunity to record sounds, what kind of practices emerge, and what types of sounds do people

collect? What are the affordances of sound? How are sonic souvenirs composed and consumed? Like photos, do they capture ideal 'Kodak' moments, or are they accurate representations of what actually went on? Are they always easy to interpret?

- How do people share their sounds with others? As with photos, do they engage in collaborative reminiscence?

- What is the role of narrative? Sound seems like a natural narrative technology, but how do people tell stories with sounds? Do people exploit audio to record narratives of events, or do they use audio for different purposes?

RELATED WORK

Although there has been a large amount of work into family communication through awareness [16,18,19,23,25], media spaces [14,16] and technologies for annotating and managing photos [31], rather less work has looked at the relation between technology and family reminiscence.

The Memory Box [10] used a jewelry box metaphor to associate a recorded narrative with a souvenir, considered of value only if given/received as a gift, but not for personal use. The work identified a clear need for a self-contained, simple technology for recording and play back.

Oleksik et al. [20,21] investigated the soundscape of the home: participants valued the mundane aspect of domestic sound and the authors explored some design ideas for 'simple to use' technology to capture and replay sound in, so called, 'sonic gems'.

More general research on audio in HCI has explored 'sonification', i.e. mapping data into sound to reveal characteristics of data in support of exploration, often for visually impaired users [28] or on mobile devices [32]. It has also looked at using sounds to increase audience engagement in public spaces [24] and in interactive environments [7].

Frohlich [8,9,10] studied the process of photosharing and proposed using sound to enrich digital photography. Early studies examined sound recorded at the time of photo capture, later he also analysed phototalk.

Studies exploring records of family life are also rare. Stevens et al. [27] studied family archival practice, observing that parents felt a duty to preserve mementos of their children's everyday lives, while children focused on the present and the self, with little reference to the future.

Petrelli et al. [22] asked families with children to create time capsules of both material and digital objects to be opened in the distant future. Families used a huge variety of objects to represent themselves, as well as to reference society at large. Digital mementos seemed problematic for capture, playback and preservation.

The future of personal digital belongings is another under-researched area. People are rapidly acquiring huge personal collections of images, videos, emails, and self-created digital artifacts (school assignments, blogs, Websites) [17]. However most consumers lack the expertise and time to manage and share such complex repositories [18,31].

THE STUDY

To examine the affordances of sound for family mementos, we designed a study that combines participant-led sonic experiments and interviews. In the summer of 2008, we gave 10 middle-class, UK families Olympus Dictaphone DS 30 digital voice recorders and asked them to actively record and select sounds that would make up a representative collection of at least part of their holiday.

We recruited our participants through poster adverts in the local community. Each family had to be going on holiday for a minimum of one week, with at least one child aged 7-15. The children generally took a highly active part in the recording activities. Once we had recruited our families, we met them at their homes to give orienting instructions and a hands-on tutorial on how to use the digital recorder. To allow for comparative analysis, we selected families who were also users of digital cameras.

To have participants focus on sounds, we asked them to refrain from using recording devices other than the sound recorder, for 3 days of their choice. We called these *sound only* days. We hoped this constrained situation would encourage them to engage in the practice of recording sounds, and reflect on their relation to memory. Further we hoped it might allow us to gain insight into the suitability of sound as a mode for story telling, especially when unaccompanied by photos or videos.

We asked them to record a minimum of 30 sounds throughout their holiday. They were completely free as to the *kinds* of sounds they wished to record. For the remainder of their holiday, participants were free to use any device or medium, such as picture and video cameras, or if they chose, the sound recorders we provided.

Within 3 weeks of their return, we interviewed the families in their homes. We reviewed their sounds and pictures, and heard what they had to say about them. Interviews lasted 2-4 hours, and we visited one family twice. Most family members were present at the interview and took an active part in the discussion. Participants laughed and recounted stories about their holidays while sharing sounds as well as holiday pictures. As we listened to the collected sounds, we asked participants to name and label them for reference.

Interviews and the sounds themselves were analysed to identify recurring topics which were transcribed and clustered by affinity. We identified similar kinds of sounds, as well as similar participant reactions expressed during the interviews. Themes emerging across multiple families were used as dimensions for analysis. Discrepancies between families or individuals were also noted, providing a diverse and exhaustive analysis of the nature of sound related practices and reminscences.

FINDINGS

Overall Characteristics and Interpretation of Sounds

All participants seemed to enjoy our sonic exercise and appropriated the activity as their own, recording sounds before, during and after their holidays. In total 654 sounds were recorded. The number of sounds varied from family to family and ranged from the lowest recording rate of only 9 samples to an impressive 197. Although 4 families had recorded over 80 sounds, 3 families recorded fewer than the 30 requested. The number, however, does not seem to be affected by the length of the holidays, e.g. a family that stayed away for 20 days recorded only 9 sounds, another way for 7 more than 50. The clip lengths varied between 30s-12min. Recording style was highly individual, with different approaches being taken even within the same family.

All participants enjoyed reviewing the sounds together as a family and reminiscing. As with phototalk [4,9], relistening was a highly interactive, collaborative process, as the following example shows.

A family recorded the sound of tea being poured at an outdoor cafe. As they listened to the clip, it triggered many associative memories: it made them think of the wasps that buzzed around their outdoor table, what they had to drink, as well as the location and other salient landmarks. Notice, too, how different contributions build upon each other, and the entire family takes part in constructing the evolving narrative, as a collaborative recollection [29].

{The sound of liquid being poured}

Dad: *"Oh yes. We had the cream tea at Ford Abbey. Yes."*

Children and Mum: *"Oh yes."*

Mum: *"You hear the tea being poured there."*

Dad: *"Yes. You hear the tea being poured."*

Child2: *"That was awful. There were wasps everywhere."*

Dad: *"Well we were sitting outside."*

Mum: *"Then we got wasps inside."*

Child1: *"Yeah."*

Dad: *"That was an interesting place. It had this huge fountain."*

Child1: *"The tallest powered fountain in the UK."*

Dad: *"I think we tried to record that didn't we?"*

The importance of these collaborative connections and associations cannot be overstated. Listening to a simple sound led to the recounting of an entire story about the holiday. This triggered talk about another place, another sound and another story. Such 'collective remembering' is not only due to having shared the same experience, but also to belonging to the same group with shared values [11]. Indeed, relistenings triggered family dynamics and episodes of familial intimacy. We saw laughter, internal jokes and intimate teasing (when the rest of the family mocked the father for not remembering a sound he was not involved in recording), as an essential component of the re-listening.

However, unlike photos, and more like other types of mementos [3,22], sounds were considered to be specific to the family. In contrast to their photos, none of the families had shared their sounds with extended family and friends. Indeed, some participants recorded inside jokes that only their immediate family could understand. It seemed as though the sound recordings were considered more personal, a part of the family's history, like a secret memento that is kept for the future (and perhaps only occasionally brought out for 'consumption').

Sounds were also personal in another way: individual family members were more eager to listen to the specific sounds they personally remembered recording, than those recorded by others.

Furthermore, and as seen by the above example, sounds often had the effect of triggering other memories, and participants sought to contextualize them, particularly in terms of their location. During the interviews, when labelling their sounds, participants often referred to the names of the places they had been (some even pulling out paper and digital maps) to situate their sonic collections by connecting and contextualizing them spatially.

What did families record?

Families engaged in many forms of creative practices with their recorders. Some used the recorders to create a *narrative* about their holiday. For example, one family composed a short introduction to their entire trip and complemented their commentary with the sound of the car pulling out of the drive:

"This is the 2nd of August. We are just leaving for holiday. Here is the car coming down the drive. Go!"

{The sound of the engine and of the brakes squeaking}

"Wait for me!"

Perhaps the most striking characteristic of the sounds was their *variety.* The kinds of sounds participants recorded ranged from mock interviews of other passengers in a train, family conversations, giggles, pseudo radio shows, commentary about the day's activities, to the ambient sounds of insects heard while on a walk. A few participants recorded verbal diaries or more abstract reflections about their trip, speaking into the recorder about their favourite parts of the holiday, and what they were looking forward to on their way back home. Many recordings involved the combination of different types of sounds, i.e. diary-like observations followed by dialogue or ambient sounds. In their reactions to these composite recordings, memories were triggered even when they weren't directly 'captured' in a recording. For example, in the following clip, the narrator introduced the sounds of footsteps of a walk in the

woods during a visit to a reptile zoo, where direct audio recordings would have been unsuccessful (iguanas behind glass don't make much noise). A recorded log-like commentary, combined with the sounds of their footsteps, evoked the quiet slithery creatures the family had visited.

{Sound of footsteps, with recorded voice-over}

Child1: *"These are the sounds at a reptiliary in the New Forest"*

During the interview this drew the following comments:

Dad: *"We went to meet a friend of ours [...] at this place called the reptiliary, which had reptiles and some amphibians [...] They were in enclosures so they don't make any noise [...] That was interesting, we saw adders, and grass snakes and lizards [...]"*

Child2: "and natterjack toads"

Dad: "yes and natterjack toads - which are quite rare."

Participants themselves were surprised on relistening by the richness and diversity of what they produced. When reflecting on their sounds with us, participants shared feelings of voyeurism, affection and surprise that contradicted what they had initially thought they would do with their recordings: *"I was surprised – interested by how we chose to use [the recorder] – which is about people and about private things. My expectations were that we'd actually go for single distinctive sounds: 'say, look how unusual that creaking door sounds, or that bird song, or air conditioning fan or something.' So it's interesting to hear, you know, people's voices and interviews – so that surprised me."*

This participant points to a number of recurrent themes we will now explore, including the private nature of sounds, records of natural conversations, and semi-scripted interviews. We elaborate on our findings through a series of apparent *paradoxes* to do with sound:

- the *temporality* of listening that seems to both *expand* the remembering, as well as *constrain* the listener to the pace of the sound;
- the desire to capture *real* and *natural* moments, as well as *constructed* and *performative* events;
- the *evocativeness* of certain sounds and their *symbolism* that may require focused listening and decoding.

We seek to draw attention to these distinct and somewhat paradoxical qualities brought to the fore by participants and their recordings.

IMAGINATIVE FREEDOM OR CONSTRAINING PACE?

According to our participants, sound is often more faithful of duration and details. One person, comparing sound with snapshots said: *"[it] gives you quite a sense of passing time. [...] subtle nuances of people's voices, and phrasing, and language"*. This participant's son added that sound results in a more memorable experience: *"I think I remember it more [with sound] because it's longer. Whereas photos just capture one moment, a sound captures a number of moments"*. The view that listening has a stronger reminiscing power emerged in other interviews too: *"I'm enjoying it... It does bring back the memories of the holiday and it helps fix them. Because you have the experience and sometimes it goes so quickly. And you don't have the opportunity to review it – you just forget about things. But this brings it back."*

Yet sound is more demanding than photographs when both recording and listening: *"Another thing that's both good and bad is that it requires more of an investment in time, both in terms of making the recording and also in terms of re-experiencing it. And in some ways again that could be because sometimes the more you invest in it, the more you get out of it. But unlike visual images where you get a lot with a brief investment of time, in a couple of seconds, a glimpse, and you've got lots of information."* With sound, the participant explains, *"you're less in control of the information"* - the flow in and out of the device. But this lack of control over what is captured and played back can be seen as positive. It may offer more flexibility for collaborative imagination and interpretation than pictures, as explained by another family, while listening to a recording of playing volleyball at a family camp.

Mum: "*So when you see a picture of it though it's a frozen moment. Here you're hearing a sort of–*"

Dad: "*- And the focus, if you saw a picture the focus would be the ball. And here the focus is much more on the people taking part.*"

Child1: "*In a video it would be the ball.*"

Mum: "*Although I'm thinking, when I'm listening to it, I'm thinking the green grass.*"

Dad: "*Yeah*"

Mum: "*I'm thinking about being out of doors. It's quite a different quality with the sound.*"

Child1: "*I can see Richard being a leaping salmon.*"

Child2: "*I can see Richard being a leaping salmon too.*"

Mum: "*Is that what he called himself?*"

{The family laughs}

This excerpt highlights two aspects of reminiscing through sound. First we see collaborative, highly evocative and pleasurable elements. Second the triggering of collaborative reminiscing is inspired, but not constrained, by what has been captured: the mother remembers the grass, not the ball. For many participants, as for the mother above and the child below, sound seemed to unleash imagination in a richer, more dynamic way than pictures.

Child1: "*I think [sound] can bring back more memories than photos.*"

Mum: "*Well it's just a different kind of memory though.*"

Child2: "*It gave me a memory!*"

Child1: "*With a photo, in my head I just picture the photo itself. But when there's a sound I picture everyone doing everything –*"

Mum: "*- the whole thing.*"

Child1: "*- and I can see everyone, and imagine them actually doing it, not just frozen.*"

Mum: "*Yeah.*"

However other participants perceived the underspecified and temporal nature of sound as a problem: *"Visually, if you look at a photograph, you can focus on this or this or this."*. With sound, the listener is less in control of where they focus. *"[Sound is] intermittent. If you're looking at a photograph you've got a constant flow of information whereas you've got a recording and your focus is the human voice or something, then it starts and it stops and you've got to wait for it to pick up again; so it makes it a very different experience. I suppose sometimes it could add to the drama of events, or other times the experience could be frustrating."*

In summary, the temporality intrinsic to the sound medium is an interesting feature that creates possibilities in terms of creative composition as well as intimate and collaborative reminiscing. Occasionally, however, the demands on the listener's time, and lack of intentional focus are perceived more as a constraint than a positive feature.

NATURAL AND/OR PERFORMATIVE?

Naturalness

Chalfen and Frohlich [2,8] suggest that picture-taking allows one to present oneself in a 'good light,' often because the aim is to share events with others afterwards. And indeed we found that most families' holiday photos were positive portraits of people and events intended to be shared. We expected to find a similar positive tone in the types of sounds participants recorded, but were surprised to find that many sounds seemed less flattering.

Although there were several instances of positive sounds such as children playing and laughing, we also found other sounds that evoked family life in unexpected and less obviously positive ways. Not only did these participants not strive to 'smile for the recorder,' several families recorded sounds of disputes they had while on holiday: siblings arguing, parents sternly quieting them, etc. Participants were given the choice to vet their collections before discussion. A few families preferred not to record or preserve arguments, and even deleted sounds that included voices that were not part of the planned recording. Most however, chose to keep sounds of themselves as a chaotic family, whining and quarrelling with each other. Some didn't always know they were being recorded at the time by one of the family members, yet chose to keep them. Others knowingly left the recorder on during a heated discussion.

Here, two sisters recorded themselves spending time together in a tent. One of them turned off the music and they tried hard to agree on what to play next:

{Music is playing and then stops}

Child1: "*What do you want on then Suzy?*"

Child2: *"You're Beautiful"*

Child1: "*No, because we've already had that today.*"

Child2: *"So?"*

Child1: *"We always have that Suzy."*

Child2: *"No we don't! We never have James Blunt."*

Child1: *"We do! We had it in the car today – over and over. We played it over and over!"*

Child2: *"We hardly ever have it."*

Child1: *"No we don't. We have it all the time in the car."*

[...]

Child2: *"No - what's wrong with it? Can you answer that question for me?"*

Child1: *"Because we've already had it Suzy. We want a different variety."*

Child2: *"No nononono..."*

Child1: *"You're so naughty!"*

Child2: *"You're so naughty." {Mimicking her older sister}*

Child1: *"Don't mock me!"*

[...]

Child2: *"Ok. You slapped me in the car."*

Child1: *"No Suzy! I'm not talking about before, and you did that first to me anyway. I'm talking about now. You're still saying that I'm being mean. What have I done now?"*

Child2: *{Sigh} "You won't let me have that song."*

Child1: *"Yeah but Suzy, what about what I want? It always has to be your way!"*

Listening to this particular recording of the children negotiating and chiding each other evoked a great deal of pleasure in their parents. They considered it a very 'typical' recording and were highly amused when hearing it.

"It's brilliant, it's just great! [...] as a kind of show of siblings".

The parents laughed almost to tears and coughs. They were genuinely moved by the interaction between their children.

"I haven't heard that before [...] It's very nice to hear that. Children behave differently when you're not there and

because you're not there you don't know what it's like, so a recording of what they were doing while we weren't there is – it's lovely [...] it's fantastic though isn't it! I think it's wonderful to listen to [...] you can hear them trying to find their way to settle things."

Less posed than a picture, audio gave the impression of being much more real and intimate, because of the recorder's unobtrusiveness, leading to the possibility of eventually forgetting about the presence of the device. Commenting on another recording of a family argument, a participant said: *"It's less posed in a way. I think with a camera it'd have been more staged like: 'Alright now we're going to do our performance in front of the camera'. The audio's somehow captured a bit more reality."*

People generated other surprising types of sounds, relating to the veridical qualities of recorded media. These included sounds of boredom. No families took *pictures* of themselves loitering, nor did they photograph themselves waiting for something interesting to happen; yet many recorded sounds of themselves in uneventful situations. Here is a record of the rain, and the boredom:

Mum: *"It's raining and we're stuck in the tent. And we're a bit bored, but we keep finding things to do. But there's not a lot to do when it rains in a campsite. And lots of people are going home because it's too wet. And we're not, because we are booked until Saturday. And we are hoping it's not too wet to pull the tent down because that won't be very good."*

{A child murmurs in the background, the mother hands him the recorder}

Child1: *"I am totally bored! I don't know what to do. I've done everything I can think of. Drawn loads of pictures, read my book."*

{The voice of another child is audible in the background}

Child1: *"Oh no! It's Jack, panic."* {laughs} *"What have you been doing?"* {to mother}

Mum: *"Me?"*

Child1: *"Yeah."*

Mum: *"Reading the paper. Just stuff."*

During the interview, the family explicitly contrasted this realism, with photos that they had taken: *"With a camera, you wouldn't necessarily get how bored we were because it rained so much".*

This recording of 'empty time' was not unique; one family recorded the sounds of conversations they were having while waiting for a ferry: *"I thought this was interesting from the point of view of the kind of mundane parts of travelling [...] being on holiday, you know like sitting in a queue waiting for something to happen."* Recording mundane situations was another theme that would make a very unusual subject for a photo: *"- something you wouldn't normally take photographs of, for example."*

The 'naturalness' of sound was, at times, unintentional. Participants commented that unlike a camera, the sound recorder is unselective, and unfocused in its recording. It doesn't discriminate which sounds to pick up. Some participants complained about the recorder's tendency to pick up background noise. But others were pleased at how they had unintentionally recorded several concurrent conversations. *"I don't really remember it all"*, a family said expressing a kind of amazement at the number of conversations the recorder picked up. But they were happy with the way the recorded conversations could be heard weaving in and out of each other: *"That's what it's like there. That's a very very typical conversation with so many adults and kids [...] all talking at once."* In this case, the recording again points to a *typical family experience* – if not the actual distinct conversations. Here the intermingled sounds act as a referent for something larger: the nature of family experiences and conversations.

Performances

Other sounds were the direct opposite of the natural private recordings. They can be thought of as experimental and performative. Participants created radio shows, put on airline pilot voices and sang songs into the device.

Here is an example – while exploring a bay, a son and father make up a radio show, dubbed Radio Tom delivered in mock documentary style:

Dad: "*We are now coming to the bay – over to Tom*"

Tom: "*Thank you dad. Oh yes, I am here at the bay today and it's a very nice day I'll tell all you viewers out there! Yes – um – <u>listeners</u> out there. There are hundreds upon thousands upon twenties of boats in the bay and it's of <u>lowish</u> tide really. There's quite a lot of dry sand just at the top. Not enough room for playing any really good games. Several rocks in sight. Well, thank you for that all you listeners out there and back to dad in the studio.*"

Dad: "*Well thank you for that Tom. Tom? Tom? Can you still hear me there?"*

Tom: "*Yes, I'm still here dad. What is it?"*

Dad: "*Great Tom. I've just heard somebody say there are some funny stone structures down by the beach. Could you perhaps tell us a little bit about those?"*

Tom: "*Yeah. Well I can see just – well I won't show you because obviously you can't see but I can see just over there there's a sort of tower, several bricks missing [...]"*

{A woman's voice is audible in the background}

Tom: "*I'm now getting information telling me they are windows.*"

Dad: "*What do you think that was used for?"*

{Another child's voice is audible as well}

Tom: "*I reckon it might have been used for a bunker – perhaps protecting the docks.*"

Dad: "*I can't see any docks. All I can see is [...] grass [...]*"

{giggles}

Others used the Dictaphone to playfully interview fellow travellers. On their way to London Heathrow en route to California, the youngest girl in the family interviews another (adult) passenger on the train:

Child: *"Are you going to America?"*

Passenger: *"Yes, I am. On the 5th of August."*

Child: *"Where are you going in America?"*

Passenger: *"New York."*

Child: *"Very nice. We are going to L.A."*

Passenger: *"Oh – You're going to L.A. I'm not going to L.A. I'm going to New York only."*

Child: *"Have you been to America before?"*

Passenger: *"Yeah. I've been to L.A. as well."*

Child: *"Is it nice there?"*

Passenger: *"Oh it's lovely. You'll love it, especially the beaches."*

These practices of carefully staging what is to be recorded seem to fit more closely with those of posing for the camera, although the energy and creativity evidenced in the sounds seem to outdo most of their posed holiday pictures in terms of originality. As with the more intimate recordings, re-listening to these sonic performances after their holiday spurred huge amounts of laughter in the participants.

In summary, participants captured plenty of natural sounds as well as aspects of normal life, from arguments to boredom and empty times. At the same time they constructed 'artificial' situations and recorded the associated performance producing quite the opposite effect. This apparent paradox brings to the fore the flexibility of the sound medium. Photos, although having the same potential, do not seem to stimulate such a range of creativity and engagement.

SOUND AS SYMBOL OR MEMORY TRIGGER?

People's attitude to recording was very different from family to family. Some families didn't record many conversations, claiming that these 'just didn't sound natural,' because people tend to perform for the recorder. For them, the act of recording was intentional and they avoided recording candid sounds of people, claiming that to do so might be viewed as deceitful. Acknowledging this, and deliberately not recording intimate moments, they preferred to focus on their environment by recording ambient sounds and at times accompanied these by explanatory log-like narratives: '*We recorded the sound of this song because it's what we were listening to during that week*', the song symbolising summer 2008. Thus sound recordings, like photographs of the cottage where one family spent their holiday, served as an iconic marker, encapsulating where and when the holiday took place.

One family carefully planned the recording of certain sounds that typified highlights of their holiday. Often these required several attempts to get the desired noise, like that of a steam train whistle. There is clear intentionality in these recordings - an attempt to capture the essence of a place, a specific experience, or the entire holiday. Some ambient sounds seemed to evoke a place in a way a picture can't: "*this is the silence of the desert*".

Sounds also became evocative and intentional symbols. Cicadas recorded in the summer were recorded to warm up and colour a cold, grey British winter: *"remember how those were very loud... playing cicadas would be nice when it's a winter evening here, because they do make you feel you're in the south when you hear them"*. The act of recording (and re-listening) takes reminiscing a step further from 'feeling the south', to a more intimate level of recollection: *"In many ways the sounds are more evocative. You know because – the cicadas things, yeah ok, you could just download a sound of a cicada, but if it's those cicadas that you actually heard somehow it just brings it back very effectively"*. It is not just the sound, but also the experience of being there and making the recording that sustains the remembering and reinforces the evocativeness of an ambient sound. Here one participant talked about a recording of moths: *"this was the moths bashing against the light [...] it was so evocative of the holiday and where we were. [...] And it's very distinctive. But if you didn't know it was that, I don't know if you would [...] go ahh! That's the moths."*

As well as being representative of the place and time, such ambient sounds also triggered unanticipated memories. A family went to a summer camp with other families where they stayed close to a river. Here they reconstruct a family walk. Again, note how every family member contributes and builds upon others' thoughts, as well as the obvious pleasure they take in collectively remembering.

{listening to a recorded sound of muffled voices and footsteps}

Child1 calls out (as if playing charades): "*Walking*"

Child2: "*Was it the really wet walk*?"

Child1: "*Yeah*"

Mum: "*Ah- Do you remember that walk was so wet! Is that the one? Is that the rain?*"

Child3: "*We went across the river.*"

Child2: "*It sounds like wet footsteps.*"

Child3: "*It could be walking through* – "

Dad interrupts: "*I think it was the wet walk and it was our artistic attempt to record nature.*"

{Everyone laughs}

Mum: "*Nature with all* this *crowd*!"

Dad: "*With about 30 other people.*"

{Everyone laughs again}

Ambient sounds also offered a positive 'true to life' quality. In the context of another family interview, children were excited to hear sounds their mother had recorded of them playing in the pool: *"They were sounds we often heard while we were staying there – these two playing. They just seemed to be having fun. It was a nice noise."* The sounds of the water and the children laughing brought back a string of memories related to the particular layout of the country cottage in which they stayed, and to the toys they played with in the water. This then evoked the recollection of the activities they had done before and after swimming.

Participation seems crucial: if one wasn't actively engaged (or focused) in the act of recording, its value as a memory cue seems to diminish, especially with respect to ambient sounds. Temporarily absent family members couldn't recognize certain sounds if they were not present during the recordings. It isn't a question of the sound per se, but of the family member's investment in capturing the sound.

{The sound of a crowd of people in a room plays for about a minute. The family listens and looks at each other inquisitively.}

Child1 - "It's a murder mystery."

Child2 - "Oh- This is what I recorded."

{The family chuckles and recalls the event. Child2 had deliberately left the recorder on the table.}

The ambiguous quality of sound that made it at times poetic and evocative also made it somewhat cryptic. Participants had to, in a sense, 'get into the sound' in order to recall and reminisce. As such, sound seemed to require a more sustained engagement and contemplation than did photographs. Pictures were fragments, snapshots, yet often easier to decipher. No participants had to guess what their pictures represented. In contrast, there was sometimes a delay in recall that occurred with sound, a kind of moment in between the sound hitting one's ear and the '*ahh! Yes, that's the sound of...*' spark of recognition.

To recapitulate, symbolic sounds were often recorded as a way of pinpointing something special and particularly evocative of the holiday. At capture time, participants predicted the effect the sound would provoke when re-listening. However, when listening, those sounds needed decoding. It seems that the act of recording was actually what encoded the special meaning of the sound.

DISCUSSION

We conducted a relatively short-term intervention and longer-term explorations are needed to better understand relations between sound and memory. Nevertheless our study adds to the rich existing CSCW literature documenting social processes and technologies for family photo sharing. Consistent with that work, we observed processes of interactive social reconstruction around shared mementos, and the use of symbols to trigger memories of key events or people. However there are significant differences between sounds and photos. This gives rise to various novel technological suggestions that are very different from photo sharing tools.

Sounds versus Pictures

There were obvious overlaps between sounds and pictures as family holiday mementos. People take 'iconic' pictures of their holiday cottage or a view of a bay where the aim is to represent key events or experiences [2,8]. Participants used non-narrative ambient sounds in the same way. Train whistles, children playing or cicadas were used to capture the essence of moods and places. And collaborative reminiscence around sounds was an interactive family experience with many of the same collaborative aspects that have been documented in phototalk studies [4,9].

However there were other major differences between sounds and pictures. Sound as a medium seems to leave participants much more open to exploration compared with picture taking. Perhaps this is because, unlike family photo albums or preformatted baby's first-year books, there doesn't seem to be a pre-existing 'cultural' norm for how to record and collect sounds. Without prior conventional formats, our participants seem to have explored a wide range of sonic recordings.

This led to unexpected uses, one of which was to record the *natural*, even in less flattering ways. We heard many clips that captured real-life events – whether this was the boredom of sitting in a tent in the rain, or the reality of a family argument about what music to listen to. Here there was no airbrushed posing for the camera, and negative feelings were captured. They were valued precisely because they expressed the reality of family life, or holidays as they 'really were'. At the opposite extreme we saw highly *constructed* content in the form of radio shows, journals and interviews – which were clearly pre-planned and carefully composed.

Other ways in which sounds differed from pictures were in their *interpretation*. Unlike viewing photographs, listening to sounds demanded attention and focus. Families collectively engaged in a kind of deciphering game, recognising the sound, and recalling where and when it was captured, sometimes listening several times before naming it. Even veridical sounds tended to be harder to interpret than pictures, although once successful, interpretation was highly evocative and the collective process highly enjoyable.

Finally unlike pictures, no one envisaged sharing their sounds outside the immediate family. This may in part be due to the practical details of editing and manipulating sounds, or it may result from the lack of pre-existing social practices associated with sharing sounds. This in turn may be why participants were happy to capture family bickering,

because the records were not being shared outside the immediate family.

We expected sound capturing devices to be ideal for recording the *explanatory narratives* that are known to be central to phototalk (e.g. 'here we are at the beach'). Our participants did indeed record some talk, but this mainly seemed to include the naturalistic (arguments, crosstalk) and the performed (radio shows, interviews), with only a few detailed descriptions of 'what happened when' in people's daily logs. As others have observed [12], it may be that the value of explanatory narratives only occurs in the social context of explaining mementos to others, i.e. when interactively sharing.

Design Implications

When we talked to participants, although they hugely enjoyed relistening and reminiscing with us they couldn't clearly imagine what they might *do* with their sounds. Again this might relate to the absence of existing practices associated with recording and sharing sounds, but their obvious enjoyment indicates there is enormous potential for new technologies. It is also clear that current technologies don't facilitate the manipulation and playback of sounds. Ironically, this is still the case when the advent of mobile digital music, i.e. iPods or MP3 players, has made the management of personal music collections very easy and their use pervasive. One strategy is therefore to look at current users' activities where sound is involved and devise ways to embed personal sounds in those contexts. Expanding on the iPod concept then, one can imagine directly downloading recorded souvenirs (maybe captured via mobile phones) and playing them 'shuffled' or intermingled among music tracks. Similarly, a 'serendipitous rediscovery' could be planned by playing a random clip from a family's collection every time the PC is switched on, instead of the standard anonymous 'booting' music clip. This would act like the sonic equivalent to the common practice of using a personal photo as screen saver.

However, another strategy might be to create completely new sound technology. Sonic souvenirs could be associated with relevant material souvenirs via RFID tags. Playback could occur when the object is moved next to some playing device. This design would support explicit reminiscing, e.g. playing the cicadas sound when turning on the central heating on a cold winter day to be reminded of summer.

A more radical design is 'sonically augmented creative technologies'. We were encouraged in this direction by the evident creativity and enthusiasm for constructing sonic souvenirs, as well as the obvious pleasure that people took in reminiscing about them.

One such device might be a family scrapbook in which one could incorporate collected sounds. Families often make visual sketchbooks of pictures and drawings to preserve their memories for the long term, and engage in creative collective tasks in the present. Short sonic snippets could become an integral part of an autobiographical sonic family album. An early experiment with a mixed media scrapbook [30] required using a PC for playing back. Instead, the technology we envisage for playback is hidden in the book spine. Playback would occur when an action is detected on the page containing the sonic tag (e.g. turning the page, detected via a light sensor; hand touch, detected via a heat sensor; or RFID activation via a pen).

For those more artistically inclined, the sketchbook could be a 'sketchwall', or projected surface on which one could draw, as well as drag and drop sounds [6]. The sketch would be augmented with snippets from the family sound library. Family members would update their sound library by remotely sending their audio snippets from their mobile devices while engaging in their other daily activities at home or outside. The sonic sketch wall could visually capture the associative quality of memories, and the collaborative character of family life.

When reviewing their sounds, most families expressed an interest in having a sound-editing tool, to shorten their longer sound snippets. This would be an appropriate feature for our sketch wall, allowing people to manipulate sounds as well as add and delete them.

Another approach might be to focus on the everyday, whether this is capturing passing traffic, arguments, boredom or crosstalk. While we would shy away from approaches that suggest recording large parts of our lives for posterity [1,14,26], collecting *fragments* of these are evocative, as well as fun to interpret. Other work with passive recording technologies suggests how such veridical examples can serve as evocative proxies for everyday activities [13].

CONCLUSIONS

We add to studies of technologically mediated reminiscence by exploring the role of sound as a medium for social memory and recollection. We extend and elaborate concepts of memory, mementos and narrative. As with phototalk, reminiscing was a highly interactive and social process. And as in previous work [22], in generating mementos, families went beyond passive capture via simple recording. Instead they engaged in highly constructive and creative practices. The resulting mementos, the 'sonic souvenirs', were often intimate and somewhat hard for non-participants to share and comprehend. And consistent with prior work we saw that a huge range of different sounds can serve as mementos, and the reason for constructing a given memento is private and highly symbolic. Although sounds are rich and evocative, our results indicate that technologies for accessing and sharing sounds need to be very different from current photosharing tools.

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FM Radio: Family Interplay with Sonic Mementos

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ABSTRACT

Digital mementos are increasingly problematic, as people acquire large amounts of digital belongings that are hard to access and often forgotten. Based on fieldwork with 10 families, we designed a new type of *embodied digital memento*, the FM Radio. It allows families to access and play sonic mementos of their previous holidays. We describe our underlying design motivation where recordings are presented as a series of channels on an old fashioned radio. User feedback suggests that the device met our design goals: being playful and intriguing, easy to use and social. It facilitated family interaction, and allowed ready access to mementos, thus sharing many of the properties of physical mementos that we intended to trigger.

Author Keywords

Memories, mementos, narrative, audio, tangible interaction.

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

Today's technology makes it possible to accumulate extensive personal digital collections. Developments in digital cameras, networking, and storage now mean that many people have gigabytes of digital belongings. But digital collections are not viewed or acted upon in the same way as their physical counterparts. Prior work reveals that digital collections tend to be perceived as *invisible* and *inaccessible* [16]. People are far less likely to choose digital than physical memorabilia when asked to select important mementos in their home [15]. They also have difficulties in retrieving important items from their digital collections, e.g. they are often unsuccessful at finding older digital photos [24]. Part of the reason is that owners of digital collections seem to acquire more stuff, but expend little time in organizing or accessing it, leaving it to accumulate on their hard drive [1]. There is a vicious circle operating here: poor organization means that digital mementos are hard to access; as a result, collections are seldom accessed, so that poor organisation is undiscovered. In contrast, physical mementos are sifted and organised into photo albums, memory boxes or household mementos making them straightforward and fun to access [5, 9, 16].

We address these problems with digital mementos by exploring a new design approach. Rather than leaving digital mementos 'imprisoned' in a computer, we explore ways that digital collections can be made more accessible, interesting and better integrated into people's everyday lives. Our new designs also need to fit seamlessly into the home by appropriating familiar objects and metaphors. We explore the concept of *embodied digital mementos* of 'sonic souvenirs', family recordings taken during summer holidays. Our design allows these to be accessed through a familiar domestic object: a radio (Fig. 1). We shed light on the motivation, design and evaluation of devices for personal digital mementos, by studying how digital sound can engender and enhance collective family reminiscing.

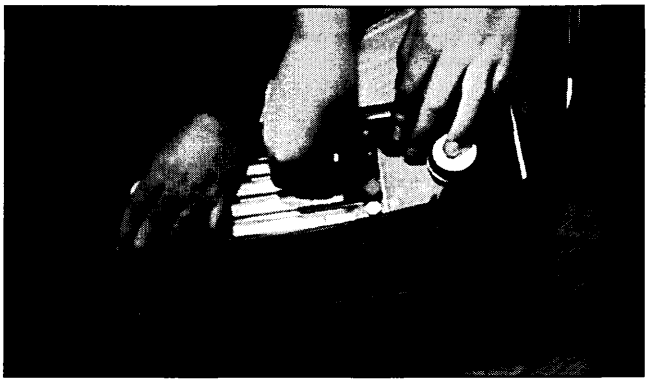

Fig. 1 Three siblings interacting with the Family Memory Radio.

The Family Memory Radio (FM Radio, Fig. 1) is a digitally enhanced object designed to reflect insights from a field study: 10 families recorded 'sonic souvenirs' (audio mementos) of their holiday in summer 2008. Our design was intended to easily fit in the home being embodied as a familiar object. By using a radio we maintained the evocativeness and ambiguity of sound, at the same time allowing for easy exploration of the sonic collection. Each family's sounds were uploaded to the FM Radio and given

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back to the family in Summer 2009, for reminiscing about the previous year's holiday.

We first summarise initial fieldwork that explores sonic memorabilia and family reminiscing. We then describe our design motivations for FM Radio, followed by the families' impressions and feedback. Observations of how the family listened and interacted with their collection stimulated reflection on the effectiveness of our design decisions. We also derive general principles for designing technology for affective interaction with personal digital mementos.

RELATED WORK

Technology for reminiscing about personal photos has been the focus of much HCI research. There are many proposals for the home, e.g., using augmented objects and the TV [9, 12], multiple interactive digital frames [11, 20], or a tabletop [18]. However little work has been done to explore the role of sound and how people interact with it. This could be due to the difficulties in navigating and accessing audio [25]. An exception is a recent study on domestic sound has shown its value [13, 14].

To overcome the problem of accessing sounds, designs that explore audio for personal recollection have embedded it in tangible objects, old mementos [6, 19] or newly created squeezable devices [14]. More traditional storage (on a PC) but using a radically new pictorial interface has been explored in StoryBank [7].

Some research on family photos has explored combinations of images and recorded sound, involving special devices that play back the sound linked to the photo [5]. Other research has explored sound in different contexts: e.g. for visually impaired users [21], on mobile devices [23], for increasing the engagement with audiences in public spaces [17] and in interactive environments [4].

There is also research into the general nature of reminiscence. Autobiographical memories very often have a social dimension. Talk about the past is shaped by who is present and the social relations between participants [2, 5]. Studies in sociology have explicitly looked at collective remembering as a way to tighten social bonds [8]. Shared experiences and shared narratives are at the core of collective memories. Some authors claim that individual, autobiographical memory only exists as a narrative to others, as social narrative [22].

Taken together, the literature both from HCI and sociology poses interesting but unanswered questions about the nature and place of audio in the fabric of a family home.

CAPTURING AND LISTENING TO SONIC MEMENTOS

In summer 2008, we invited families to capture "sonic souvenirs" of their holiday. Instead of the usual practice of collecting visual images (i.e. photos) as holiday mementos, we asked them to actively record and select *sounds* that would make up a representative collection of their holiday. Using sound also allowed us to investigate the role of narrative in reminiscing. The study is discussed in more detail in [3]. Here we summarise the methodology and report only results relevant for the design of the FM Radio.

Methodology

Participating families had to have at least a child aged 7-15 and to go on holiday for a minimum of 7 days. In 3 days of their choice they had to capture memorable aspects of their holidays using sound only, i.e. no pictures could be taken on those "sound only days". We hoped this constraint would encourage participants to develop practices around recording sounds, and reflect on the relation between sound and memory. We hoped it might also allow us to gain insight into the suitability of sound as a medium for memory related story telling, especially when unaccompanied by photos or videos. For the remainder of their holiday, participants were free to use any device or medium, such as picture and video cameras, or if they chose, the sound recorders we provided. We asked them to record a minimum of 30 sounds throughout their holiday. They were completely free as to the *kinds* of sounds they wished to record.

Ten families were recruited and given Olympus Dictaphone DS 30 digital voice recorders to use during the study. Before the families left for their holiday, a researcher met them at their homes to give orienting instructions and a hands-on tutorial on how to use the digital recorder. Within 3 weeks of their return, the same researcher visited the families to collect their impressions conducting a follow-up interview and to collect the sounds they had recorded. Most family members were present and took an active part in that second discussion. They laughed and recounted their holidays while sharing sounds as well as holiday pictures. We also asked them as a family to select 10 favourite sounds and compare their choices with the well-known practice of taking and talking about pictures.

Results

Every family recorded a different number of sounds, from only 9 to an impressive 197, and the clip lengths varied between 30s-12min. The variety of sounds recorded was broad: mock interviews, family conversations, giggles, pseudo radio shows, commentary about what they were doing (waiting in an airport, having breakfast), family arguments, ambient sounds both natural (animals, water) and human (volleyball match, murder mystery game), created sounds (bubbles blown with a straw in water, the creak of a door). A few participants recorded verbal diaries or more abstract reflections about their trip, e.g. their favourite parts of the holiday.

Each family and each individual within the family seemed to have a personal style in recording: some introduced the sound with a comment, others did not; some participants favoured recordings of ambient sounds, while others took an active role making sound or performing. During recollection, participants were sometimes listening for the first time to the sounds recorded by other family members. This happened regularly for children's performances (e.g. radio shows, singing) that parents were unaware had been

recorded. Listening was very much a social activity, with the author of the recording explaining what it was and the other members joining in. It was clear that any device for family recollection needs to reinforce this social aspect of *collective engagement.*

Sounds were very *evocative* and seemed to engender deeper and more specific sensations than a picture could convey. Commenting on the recording of a volleyball match one family said:

Mum: "*So when you see a picture of it though it's a frozen moment. Here you're hearing a sort of –*"

Dad: "- *And the focus, if you saw a picture the focus would be the ball. And here the focus is much more on the people taking part.*"

Mum: "*Although I'm thinking, when I'm listening to it, I'm thinking the green grass. I'm thinking about being out of doors. It's quite a different quality with the sound.*"

This perceived contrast between the evocativeness of sound and pictures was echoed by other participants: "*With a photo, in my head, I just picture the photo itself. But when there's a sound [...] I can see everyone, and imagine them actually doing it, not just frozen*", and "*With a camera, you wouldn't necessarily get how bored we were because it rained so much.*" In our FM Radio design we wanted to preserve the evocativeness of sound. We wanted to evoke these personal interpretations - allowing sounds to mean different things to different people.

We also wanted to preserve the *engagement* people experienced when attempting to interpret a sound. Only a few participants recorded explicit comments about what each sound was, instead the majority recorded stand-alone sounds. As a result, when listening, participants had to pay attention and sometimes re-listen to what they heard. Animated discussions about what the recording was and where it took place were not unusual:

Mum: "*Is it water or rain? It's going very fast. Is this [Dad's] nature sound?*"

Dad: "*I don't know, let's listen.*"

Child: "*I know what it is. It's when [the dog] was crossing the river. There was a waterfall.*"

Dad: "*I don't know, I did not record that.*"

[the sound ends]

Mum: "*So was it water or rain?*"

[they re-listen turning the volume up]

Dad: "*Whatever it was, it was quite nice.*"

Dad then (re)constructed a story inferring that the recording was associated with a walk along a river. Questioned about providing a commentary for the sound while recording for easier interpretation after, Dad said: "*to have recorded what it was would have made it obvious*", Mum: "*it wouldn't have made your memory work so hard.*" Participants seemed to enjoy this ambiguity and not mind too much whether they could precisely locate the event. Participants sometimes had to listen carefully before they could recognize the sound. Compared with images, audio has an aura of 'mystery': revealing its full meaning only after extended listening. The FM Radio design should emphasise this suspense and preserve the sense of magic as listeners wait for the audio to reveal itself.

Previous research indicated the need for technology to be immediate, and ready to use. There is also a degree of reluctance to adopt standard digital technology in the home space as it affects the style of a room [16]. After reminiscing about their sonic souvenirs, we prompted our participants about what would be an acceptable form of memento technology for the home. Examples mentioned included: a sketching board to associate sound and images, objects to squeeze to produce sound or that play when a person moves closer. There was a clear generation gap with younger participants preferring a techie look, "*it would be cool*". Parents rejected automatic solutions, "*something that plays when you walk in would be really irritating*", or intrusive displays, "*the idea of sketching and attaching sounds does not appeal to me.*" A tangible solution suggested playfulness: "*I like the idea of having something with the sounds on, then you shake it or do something. That would be quite fun.*"

Implications for Design

The open ended task of collecting Sonic Souvenirs generated strong evidence for the benefits of audio as an affective memory medium. It also informed the design possibilities and challenges to making sound more accessible. At the same time, by participating in the initial study, families created a collection of mementos of personal value. Having such a collection was a prerequisite for evaluating personal technology.

Sound is a special kind of digital memento. It does not exist in any other form, i.e. printing isn't possible. It is also very different from images as it unfolds in time as opposed to being instantaneous. As a result, it seems to engender more personal memories and feelings than images: "*photographs are very objective, you see what it is, while with sound people would think different things.*" We wanted our design to maintain this evocativeness. Unlike other work [5], we therefore excluded the association of sounds with images even though this makes it easier to discriminate between sounds. Making sound easy to navigate while keeping it mysterious and evocative was a design challenge, but we considered this critical to induce engagement.

Listening to sonic souvenirs was highly engaging for the whole family. They laughed and talked while playing the sounds. With this in mind, we aimed at a design that preserves collaborative social engagement (i.e. instantaneous exchange of device control). We wanted to

make access to audio files straightforward in order to sustain an uninterrupted flow.

Another defining quality of sound is that listening is not 'attention exclusive'. Listening can be done at the same time as other activities. Based on prior work [20], we aimed at designing around people's lives more than realizing technological possibilities. It was therefore fundamental to support a context of use that is integrated into everyday life - that does not require looking at a computer. Thus you should be able to listen to sonic memorabilia while cooking.

Naming and organizing files is tedious, and using a computer to play audio was perceived as intruding between the family and their sonic mementos. Thus, another design constraint was that the device be playful, and different from normal PC interaction; it had to be surprising and fun. As a final constraint, we wanted an object that could easily fit the home, which would not look like a digital gadget. As with physical mementos we wanted this object to trigger social conversation. In developing design concepts we considered the aesthetic and the materiality as important as the technology.

NEW TECHNOLOGY IN AN OLD-FASHIONED SHELL

Design Rationale

The starting point for our design was a classic transistor radio. Our intention in designing a novel device that borrows heavily from the design language of an old radio was twofold: firstly, we felt that the classic aesthetic of the object would attract and encourage families to adopt this new technology into their home; and, secondly, we hoped that, by modelling the interface around existing concepts of radio controls, we could exploit familiarity with the purpose and operation of this novel device. The radio would also serve to make the sounds visible and accessible, acting as a tangible reminder to the family of what it holds. By embodying users' sonic souvenirs in a familiar, easily controllable physical object we also hoped to avoid the problems associated with other digital memorabilia, namely that these are invisible and inaccessible [16].

The radio form-factor was also representative of the way we believe families might best engage with their sonic mementos. A radio is clearly not a personal audio-playback device like an iPod, and it encourages a shared listening experience. It is relatively small, light, and - aside from power – does not require external infrastructure to operate. As with a traditional radio, the interface was intended to require minimal visual attention and only occasional input, emphasizing instead the interactive aural experience. This requirement stemmed from our understanding of how and when the sonic collection might be replayed: not only collectively but also in a relatively passive and peripheral manner, perhaps while multi-tasking or attending to other activities that demand visual focus.

The requirements that resulted from our design rationale did not readily map to any existing audio-playback device. We therefore needed to create a bespoke appliance that we could give families to evaluate their reactions to a working prototype. The rest of this section details the design decisions and implementation strategy involved in the realization of the Family Memory Radio.

Content Organization: Radio Channels

Personal content is essential for personal technology. However, as the recent literature on retrieving digital photos shows [24], navigating to, and finding items can be challenging and frustrating. To make navigation easier, we decided to organize the collection around the concept of *channels*. A channel is a subset of sonic files of the same type that a user can "tune to" to play back the sounds it contains. A user is able to explicitly browse a channel by moving backwards and forwards through the sequence of sounds. When a particular sound is over, playback is automatically advanced to the next sound in the channel list, looping back to the beginning when all sounds have been played. Grouping homogeneous sounds into themed channels makes the navigation through the sound collection easier. The design also supports continuous and passive listening (initiated by tuning into a channel), or active and explicit interaction with the content (by changing channel, or navigating within a channel).

To decide which channel classification was best we listened to all the recordings. As mentioned above collections were extremely heterogeneous. We considered several options, including a personalized classification for each family. However four channels found general consensus:

Time Travel: contains all the sounds played in order by the day and time they were recorded;

Ambient: contains the natural sounds, such as water or animals, as well as 'human produced' sounds, such as the sound of walking in the woods or blowing bubbles with a straw; here the playing order is chronological;

Voices: contains all human sounds including intentional speech, such as performances or interviews, background conversations, or human activities, such as playing games or praying; the playing order is chronological;

Favourites: contains the sounds selected by the family as favourites in chronological order. This channel is updated every time the user presses the 'favourite' button during playback (see Interface (re)Design section and Figure 2 bottom): the sound currently playing is added to the end of favourite channel.

The number of channels we should support was a matter of much deliberation. Having more channels results in more specific categories, each containing a smaller subset of sounds. This would make it easier to navigate through a channel to find and replay a particular sound. However, fewer channels would necessitate that users be more active in their interaction with the radio: they would have to frequently change these fewer channels to avoid repetitive playback of a single set of sounds. We decided to organize

the sounds into relatively broad categories as described above and discuss alternatives with the families during the feedback visit.

Interface (Re)Design

The basis for our FM Radio prototype is a Roberts R707 radio, first manufactured in the early 1970's, which we found and purchased on eBay. We chose this model because of its clean, simple and elegant design. The original control panel of the R707 (Fig 2, top) includes a number and variety of mechanical controls that we hoped to reuse and map to the digital functionality of our interface: four rotary knobs, one toggle push-button, and four radio-buttons. Many different mappings and control layouts were considered. The final design (Figure 2, bottom) maintains a similar style to the original, along with some necessary cosmetic and functional changes.

In the original radio, the left knob was used to control the volume and power state of the radio (moving it beyond the minimum volume level powered the radio off). In the FM Radio this knob maintains a similar functionality. Turning it clockwise will first turn the FM Radio on and starts playback of the selected channel at the desired volume.

The bank of radio buttons and single push-button was maintained in our redesign, but their functionality re-interpreted. Originally, these buttons allowed the user to select the tuning frequency of the radio (Short Wave, Medium Wave, Long Wave, VHF); in our design, the four buttons are placed adjacent to a set of dynamic labels that display the name of the four channels (Fig. 2 middle: Time Travel, Ambient, Voices, Favourites). Pressing a radio button causes its associated channel to be selected, and all other channels to be deselected – through the original mechanical design of the radio buttons, any deselected channel pops up automatically, providing unambiguous, consistent visual and tactile feedback about its state. The fifth button, which is mechanically independent of the radio button bank, is associated with the static label "Mark as Favourite." Pressing this button during playback adds the currently selected track to the Favourites channel.

The right "Tuning" knob allows the user to navigate within a selected channel. Turning it a small distance anticlockwise causes playback to skip back a few seconds. A clockwise has the opposite effect. Together these allow users to find and replay a particular segment of a sound. A quick turn of the knob will to skip to the next or previous sound in the channel. This dual functionality of fine-and-coarse navigation is analogous to the way Fast-forward and Rewind buttons operate in many examples of digital music equipment. We felt it was appropriate to replicate this to support navigation, even though this diverged from the strict radio analogy.

There are some further subtleties in the design of the FM Radio interface that are worth mentioning. Once playback starts, a channel plays continuously, one sound after another, looping back to the first sound on reaching the last sound in the channel. When the FM Radio is turned off, or the channel is changed, playback of the current channel stops: when the radio is turned back on or the channel is re-selected, the play resumes from its previous position.

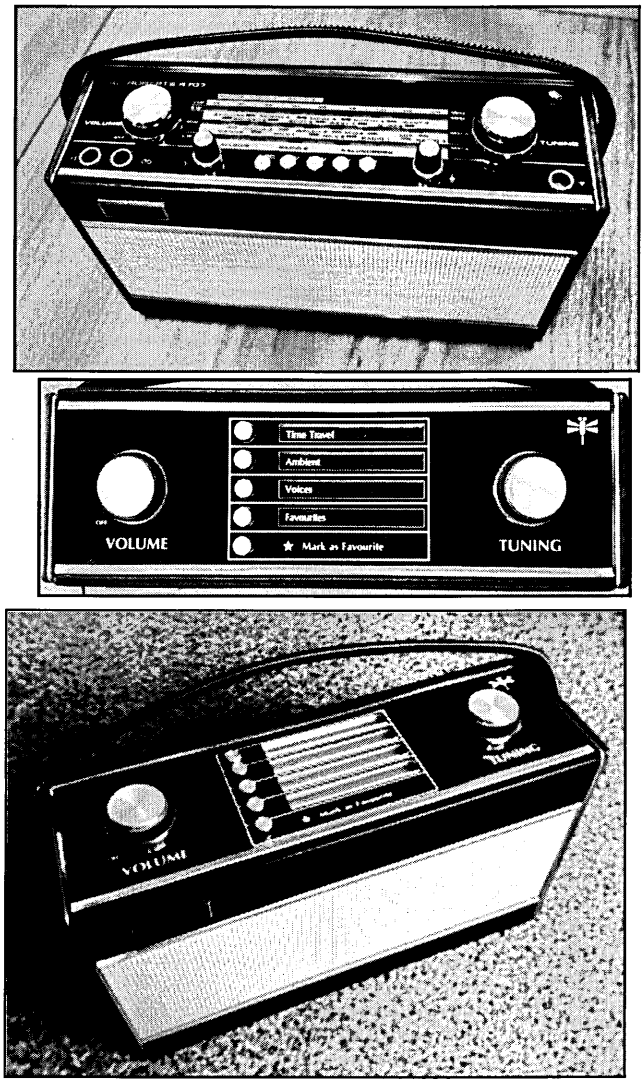

Figure 2. The original Roberts R707 (top); the redesigned FM Radio (bottom) and its interface (middle).

The dynamic labels associated with each channel make it easy to change the name associated with each sound set (see Implementation, below). We strongly considered the idea of using these dynamic labels to also display the name of the currently-playing sound. The main motivation for this would be to allow users to browse and recall sounds by their name. However, as mentioned previously, the process of naming individual sounds was cumbersome and tedious, and we felt that, in practice, users would not go through the process of exhaustively naming their sounds. Furthermore, in some cases, the names that were assigned to a sound were sometimes guesswork, and might prove to be misleading when re-listening at a later date.

The radio does not support 'sound management': sorting, naming and organizing sounds was considered a task to be done on a PC where a display, mouse and keyboard are available; user-defined folders could then easily be uploaded back on the radio. Only the 'Mark as Favourite' option was designed to support organization during playback. This requires minimal interaction: users can select individual sounds for simple recall at a later point. In balancing these concerns, we opted for a design where sound identification happens exclusively through its aural dimension and chronological ordering within a channel.

In general, we steered away from design choices that entailed unnecessarily frequent interaction with the radio controls. We wanted to balance the need to provide controls for users to navigate and find content, with support for passive browsing, unobtrusive background listening and immersive reminiscing.

Implementation

We considered a number of implementation strategies. In essence, the device is a digital sound player, so we considered the possibility of making use of an off-the-shelf personal music player, such as an Apple iPod, to provide the core playback functionality. However, the difficulty of remotely controlling such a device, interfacing it with the mechanical controls of the radio, synchronizing with its internal state or implementing our concept of channels made the idea infeasible. Another alternative we considered was to use a laptop or tablet PC, but the size constraints of the Roberts R707 radio case severely limited our choice of suitable devices. In addition, this option implied the overhead of having to implement our appliance on top of an operating system, which implied long start-up times and the possibility of non-deterministic behaviour.

We chose instead to develop the FM Radio using an experimental modular hardware platform, Dragonfly. The platform is based on a small but powerful embedded processing unit to which a number of electronic modules can be easily connected. Modules provide additional capabilities for input, output, communications, power, display, sensing and actuation. Modules can be easily connected and disconnected using a standardized interconnection mechanism, making the hardware very flexible and reusable. The hardware can be programmed in a high-level, object-oriented language and live-debugged from within a development environment that provides sophisticated debugging tools.

In large part, the FM Radio was implemented using the standard hardware modules pictured in Figure 3: the *Mainboard* provides core processing functionalities; the *TFT Display* module is used to enable the dynamic channel labels; the *Knob* is used for the Tuning control; the *Programming* module doubles power supply for the system; the *USB* module allows a memory-stick (containing the sound files, encoded in MP3 format) to be connected, and the *Audio* module decodes and reproduces the MP3 files.

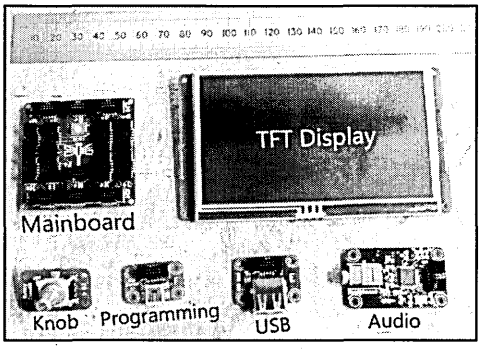

Figure 3. The enabling modular hardware components

In addition to these modules, two of the original radio controls were adapted as bespoke modules, allowing them to connect directly to the system (see Figure 4, top). The rotary potentiometer and switch which served as the original Volume/Power control was connected to an Analog-To-Digital converter on the Mainboard, allowing it to decode its position, and used to digitally control the volume level of the Audio module. The original radio-buttons were connected in such a way as to serve as digital input controls. The original control faceplate was replaced by a similar reproduction, which included the new and adapted controls in a new layout (Figure 4, middle). In the completed faceplate, the TFT display is only visible through slits that act as the dynamic labels for the channel-selection buttons.

The assembled system, including a pair of stereo speakers and amplifier (which is powered from the main circuit) fits easily within the radio case, from which the original electronics have been carefully removed (Figure 4, bottom). The USB module is mounted on the back panel for easy access, allowing a memory-stick to be quickly changed. When the system is powered on, its program checks the contents of the memory-stick. The names of the first four directories found on the root of the drive form the basis of the channel names, which are then displayed on the dynamic labels. The contents of each of these directories are used to generate playlists corresponding to each of the four channels. This mechanism allows users who are comfortable with file management to remove the memory-stick and connect it to a PC in order to change the name and contents of each channel.

LISTENING TO AND INTERACTING WITH FM RADIO

Set-up and Data Collection

The design of FM Radio as an embodied playful device for collective reminiscing was evaluated with the families who participated in the initial Sonic Souvenirs study. One year after making their recordings, we invited them to use the Radio for revisiting the sounds they collected in summer 2008. We contacted only families who had recorded more than 50 sounds. We imposed this threshold to sustain sound exploration over time, as fewer sounds would have led to repetitive playing. Six families accepted our invitation with enthusiasm; 23 people took part. The families were

unaware of what we had designed: we mentioned they would be asked to try out "a device" and provide some feedback. This intentional "secrecy" allowed us to capture initial impressions about the Radio and how participants first related to it.

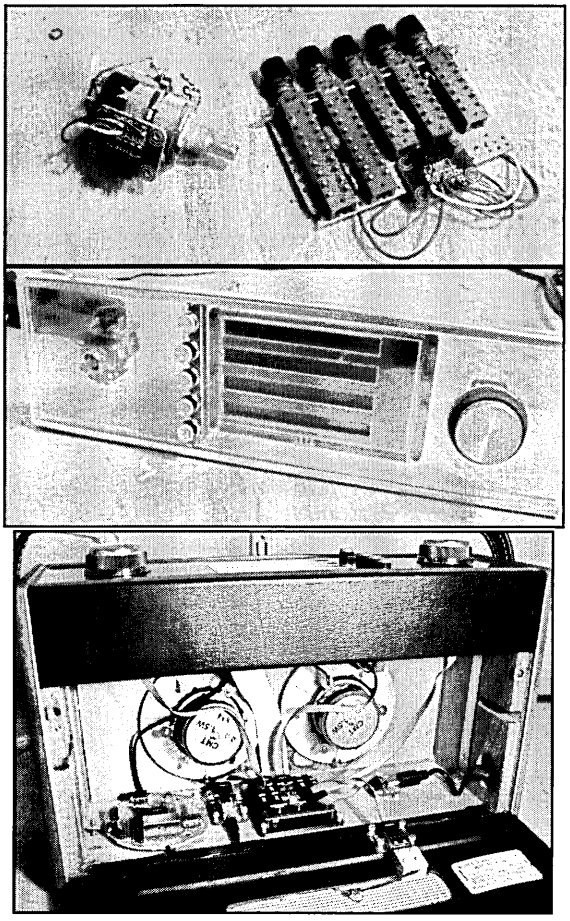

Figure 4. The digitally-enhanced original radio controls (top), the replacement control panel assembly (middle), and the assembled FM Radio (bottom)

The visit lasted 60 to 90 minutes. It was video recorded for further analysis, and was organized into three phases. We first asked families if they had used the Dictaphone since summer 2008 and probed whether they had re-listened to their recordings we had stored on their PC. The radio was then taken out of a box and positioned where every member of the family could reach it. They were invited to try it out by themselves and figure out how it worked. No instructions on how to operate the radio were given - as we wanted to probe how much our design afforded a natural interaction. Every member of the family was encouraged to experiment with the radio hands-on to explore the sounds.

When the radio was on the table, the researcher retreated into the background, acting as a quiet observer of the family dynamic as they were interacting, listening, reminiscing and playing their sounds. After about 30 minutes of self-discovery, ten open questions were posed to investigate: their feelings on re-listening to their sounds, their perception of the interaction, the aesthetic of the radio and its projected use in family life. Observed behaviours and comments made during the interaction were used to stimulate discussion and further elicit participants' views.

The videos were analysed and comments transcribed whenever appropriate; the behaviour of the family members while listening and interacting with the radio was noted. Comments and actions were grouped by similarity.

User Feedback

Recording and Re-listening with Dictaphone and PC

To our surprise, all families had used their Dictaphone in the past year. In 2 instances the mother used it for professional purposes, but in all others the motivation was consistent with our topic of study, i.e. personal recording for social recollection. Motivations were different: a teenager loaded her music on it and recorded friends and parties; a mother recorded (unaware) children in their bedroom playing and other snippets of family life; a father recorded his father's 80th birthday party and the speeches made; a father and child recorded a special family event. This shows an appropriation of the mode of recording sounds and participants perception of the value of sound. However there were clear limitations in the current technology: everyone complained about the difficulty in retrieving sounds from the device. Only the 80th birthday speech was downloaded from and sent to the grandparents as a memento. The other families rarely listened to what they had captured - making "disposable" use of their Dictaphone sounds by deleting old files when the device was full.

As part of the initial study we transferred people's sonic souvenirs to their PC. Consistent with prior research [16], re-listening to sounds on the PC was rare and happened by chance. When the sounds were on parents' laptop, several happened to re-discover the directory while looking for something else. They all reported being puzzled at first by what that directory contained, as they had forgotten they had it. They then played a few snippets, describing the experience as evocative and enjoyable.

To summarize, we found clear barriers to accessing and recording sonic mementos. Our next question was whether FM Radio could overcome these.

Evocativeness and Reminiscing

When the radio was put on the table there was a general sense of surprise. The expectation seemed to be that families would see a shiny new piece of digital technology. With the parents there was immediate recognition, followed by jokes about remembering similar radios. In contrast, the children did not seem to have a clue about the device as today's audio technology (e.g. MP3 players) looks very different. Hands-on exploration was done by the whole family collectively, with the parents often suggesting the right action, e.g. press a button to select another channel, most likely because of their familiarity with knobs and buttons, from previous experience with older technology.

Listening to sounds on the FM Radio engendered extensive laughter and family jokes very much in the same way as in the initial study. What was radically different was the *social interaction* focused on the device: e.g. when a sound recorded by a child (e.g. funny or mocking noises) was played s/he immediately wanted to interrupt it, whereas siblings wanted to play it repeatedly. This conflict over the controls (Figure 1) was an expression of sibling rivalry observed in many families which usually ended up in shared laughter. Clearly the Radio afforded a level of collective interaction that neither the Dictaphone nor the PC allowed. Participants commented on how much better their experience was with the radio: "*with [the Dictaphone] you have to pass it around and lean on it*". It is also a more democratic way of accessing common memories than a PC: "*the files are on my laptop and [the kids] don't have easy access to it*". The radio therefore seemed to overcome perceived barriers with current ways of accessing digital memorabilia.

In addition to these moments of direct interaction, families became deeply involved in listening and reminiscing. They discussed when a certain sound was recorded and talked about different aspects of the holiday that were often unrelated to the clip. They explored the different channels exhaustively to listen to their entire collections. All families commented on the excellent quality of the audio and how vivid the event was: "*it's incredible! It seems like having him in this room!*" Again they explained how the radio made listening to their sounds a much better experience compared to a Dictaphone or PC, thus supporting our design goals.

Style and Function

Adults and children both liked the old fashioned style, although one adult would have preferred a smaller size, and another was not concerned with any style. Its distinctive look made it an intrinsically interesting object. Just as with physical mementos [15], people saw it is being a *prompt* for conversation: "*I can see visitors asking about it. It would make a good conversation point*". Only one person, a child, saw it as a private device to keep in their bedroom. This is a clear indication that our decision to use an old fashioned object as a shell for digital technology is appropriate and should make the radio a provocative talking point.

The size of the radio and embodied character was noted as being good for reminding. Unlike the Dictaphone or mementos on the PC, where digital collections are often forgotten, participants thought that the physical presence of the radio would *remind* them about their sounds and promote playing – addressing the invisibility problem with many digital collections. Participants were confident that the device would not end up forgotten and unused in a drawer "*like so many digital gadgets we have*". Such reminding could prompt more recordings of sound as personal mementos: "*[while listening to the sounds] I regret I did not record more this year. I suppose it is a matter of remembering that we can.*"

When questioned *where* they would place it, all families indicated a common room, e.g. the lounge, the dining room or the kitchen. This choice was consistent with our design goal of having an object that could be accessed, talked about and shared by the entire family (in contrast to both Dictaphone and PC). The exact location chosen depended on the audience people foresaw: some could only contemplate listening to it with immediate-family members, whereas others saw it as being a resource for friends and more extended family. Of course the mobility of the device, and the fact that it fits aesthetically into multiple locations makes it easy to relocate the radio, allowing these multiple functions to be satisfied. Although families tended to say that they would find a specific place for it and leave it there, there was some discussion on the varied uses different members of the family could foresee. The same person suggested both personal and social uses: "*I can easily imagine listening to it doing odd jobs, like washing up*" and "*while having a barbeque with the friends we were with in Paris – that would make a nice background*". This combined personal and collective use, occurred in others' comments. Suggestions of individual use were varied: "*while doing the homework*", "*potting in the cellar*", "*cooking*", "*while on the computer*". Envisaged social uses varied as well: "*at family meals – when we are all together and talk*", "*when we relax*", "*grandma would like this*", "*with friends*". The comments clearly show how the range of possible uses envisaged by participants is broader than we had imagined, while remaining consistent with our aim to support both individual and social use. The comments underline how the unlike the Dictaphone or PC, the radio exploits sound's affordances: sounds can play in the background but could suddenly become the focus if anything triggers attention.

There was minor concern about boring sounds might be for those who did not participate in the original event. People also mentioned ethical issues about recording people and replaying their sounds to others. And some recordings, e.g. private comments or jokes, were felt to be ill-adapted for sharing at large. A recurring suggestion was for sounds to serve as background to photo sharing. Some people wanted sounds and images synchronized so that sounds captured at the same place and time would be triggered together (like in [5]). However, when we discussed the effort of manually tagging/linking photos and sound, most were happy with much looser association between these.

Feelings and Appropriation

Everyone liked the organization of sounds in time and favourites. But there was less consensus about the other channels, as individuals in the same family wanted their own channel. Parents liked the idea of a children's channel where their changing voices would be recorded year after year: "*that would be a very sentimental channel - them as babbling babies, then their first words and now their jokes*"; children instead preferred recordings of activities or

events for playing them to a specific group of friends: "*[my channels would be] 'good', 'bad' and 'boring'* ".

Random (shuffle) was considered a desirable feature. People imagined using the radio in family games involving who could identify the sound first. People also wanted to mix sounds with music. They wanted their personal digital music on a dedicated Radio channel and to randomly mix personal sounds with that music. This suggests users should be supported in organizing their sounds in their own way on a PC, but allowed to scroll and select a channel, among many, at the time of listening.

Participants were willing to create and organize their own folders and all but one agreed that a PC would be the best tool for this. The one person who wanted to organize files on the radio motivated it by saying that the context would trigger him into action and he would never organize anything if he were forced to sit at a PC to do this dull job. The 'Favourites' was appreciated as it allows real-time organization with minimal effort. However it was pointed out that different people within the family may have different favourites.

Affordances and Usability

Figuring out what the "Tuning" knob did took a little time, provoking much discussion and fun. In one family the children repeatedly turned the knob back, re-playing the same snipped over and over: "*That's cool! It's a rap!*" When the forward/rewind functionality was discovered, the analogy with the fast-forward control of many devices (e.g., DVD or MP3 players) was immediately mentioned showing a successful metaphor mapping. The tangible interaction was much appreciated by parents and children alike: "*there is a physical satisfaction in pressing a mechanical button or turning a knob*", "*it's cool, I want to show it to my friends*". There seems to be a sense of durability and rewarding tangibility connected with the mechanical clicking.

Two easily addressable usability issues emerged. When powered on, the radio displays the channel names giving the impression it is ready to play. Participants started pressing the buttons expecting the sound to start. They then quickly spotted the 'off' label on the 'Volume' knob and turned to starting playing. Lighting the screen only when the knob is turned on would easily fix this. The second issue was the lack of prominent feedback on the display when the 'Tuning' knob is turned: while trying to discover what that knob was for, participants turned it slowly, but a slow turn produces a limited skip forward in the playing. The change in the audio was thus difficult to perceive leaving the impression that nothing had happened. This led to much discussion on the lack of feedback about where one was in the channel, e.g. the beginning, middle or end. Indeed if any visual feedback were provided on the channel display there would have been no question about whether the knob was working. In addition two families tried to find a specific sound they remembered recording. In both cases they had to spend considerable time browsing through different channels, and when they found it there was no way to know where it was located. Marking it as favourite would be a first step but this would not entirely solve their problem as they would still have to scroll through the "Favourites" channel to retrieve it. The most common suggestion to improve feedback was to have a slide-bar with a tag showing the current position. We discussed this at the design stage as it fitted the radio metaphor, but rejected it as taking up too much space. We therefore discussed other options with the families, i.e. to provide the number of the current snippet so that it would be possible to retrieve it quite easily by scrolling to the right position. However this proposal did not induce much enthusiasm even when it was observed that re-finding would be much more efficient: "*I don't mind to have to listen to few sounds to find it when I roughly know where it is. It is not like work when you have to be efficient, is it?*" All families wanted to retrieve specific sounds particularly if the number of sounds in channels is high or they wanted to play something specific to a visitor. Proposals included some form of editing, and more sophisticated (iPod like) browsing functions.

CONCLUSION

The design of the FM Radio was motivated by a field study that provided direct evidence of the potential of sound for capturing and reminiscing for families. However our fieldwork left room for exploring several design possibilities. Our main decision was radical, to diverge from current digital audio technology, reverting to the basic properties of sound and the core interactions with it. Nevertheless when confronted our design, families reacted very positively to experiencing personal audio using a bespoke appliance. The evaluation showed FM Radio met our design requirements as it (1) supports browsing in a non task-oriented way, (2) encourages playfulness, exploration, reminiscing (3) allows the mnemonic experience to be inclusive, and shared by many at the same time (4) embodiment increased accessibility, serving to remind people about their mementos.

Some clear lessons emerge for designing innovative devices for personal digital mementos. Our fieldwork was rigorous enough to provide guidance for taking design decisions, but open enough to inspire creativity. That investigation with potential final users was also essential for collecting personal data to be used later in the evaluation. Obviously reactions would have been very different to someone else's recordings. Secondly the design should not stem from what technology is available but from the intended effect and use. We were therefore committed to a social device that was directly focused on the sound experience.

Design has to find an effective compromise between affordances, constraints and intended functionality. In implementing the FM Radio, we strove to remain sensitive to the original design of the Roberts R707. Within the freedom of the design space, we were guided by the original aesthetics, and whenever possible tried to make use

of existing controls and operational affordances. The families greatly appreciated the result that would not be achievable in any other way thus exemplifying how digital technology can be inspired by past non-digital products.

The challenge of implementing the FM Radio as a robust and fully-functional bespoke appliance was made considerably simpler by the use of our experimental modular platform – equally in terms of supplying the enabling electronics, programming the functionality and interaction, and physically integrating the components into an existing case design. The process of development made us consider the wider implications and future possibilities of using and reusing existing artefacts as shells for new information appliances and embedded interactive devices. The enthusiasm the FM Radio received during the evaluation clearly supports this reflection, and indicates that injecting obsolete and vintage objects with new technology, updating their functionality and prolonging their relevance in daily use is an interesting alternative for the development of digital technology intended for the home.

In conclusion, participant reactions demonstrated our design represents a promising approach to designing digital memorabilia, overcoming prior barriers of invisibility and inaccessibility. Embodying sound in the radio promoted evocative collective reminiscing, sharing many of the properties of physical mementos that we intended to trigger.

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Remembering today tomorrow: Exploring the human-centred design of digital mementos

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Abstract

This paper describes two-part research exploring the context for and human-centred design of 'digital mementos', as an example of technology for reflection on personal experience (in this case, autobiographical memories). Field studies into families' use of physical and digital objects for remembering provided a rich understanding of associated user needs and human values, and suggested properties for 'digital mementos' such as being 'not like work', discoverable and fun. In a subsequent design study, artefacts were devised to express these features and develop the understanding of needs and values further via discussion with groups of potential 'users'. 'Critical artefacts' (the products of Critical Design) were used to enable participants to envisage broader possibilities for social practices and applications of technology in the context of personal remembering, and thus to engage in the design of novel devices and systems relevant to their lives. Reflection was a common theme in the work, being what the digital mementos were designed to afford and the mechanism by which the design activity progressed. Ideas for digital mementos formed the output of this research and expressed the designer's and researcher's understanding of participants' practices and needs, and the human values that underlie them and, in doing so, suggest devices and systems that go beyond usability to support a broader conception of human activity.

Keywords: Personal memory; Participatory design; Critical design; Innovation; Human-centred design; Design methods

1. Introduction

> "*meaning, not possessions, is the ultimate goal of [people's] lives, and the fruits of technology [...] cannot alone provide this. People still need to know [...] that they are remembered and loved, and that their individual self is part of some greater design beyond the fleeting span of mortal years.*" (Csikszentmihalyi and Rochberg-Halton, 1981, p. 145).

Designing for the personal sphere requires a change of perspective: from technology-focussed (efficiency and effectiveness at work) to human-focussed (aspirations and desires at home). Technological advancements and improved capabilities are undoubtedly exciting, but a blind adoption might lead to design in the wrong direction. Evaluations of implemented smart home technology, for example, showed there is still the need to better understand the environment where people live, and the meaning they attach to it, rather than simply realising new technological possibilities (Taylor et al., 2007).

In a similar vein, life-logging now allows recording of every conversation, computer interaction and piece of information encountered, as well as audiovisual logging of personal experiences (Bell and Gemmell, 2007; Kern et al., 2007; Mann, 2004). This approach fails to understand people's motivations for remembering past experiences and what they value as mnemonic representations of their lives. Some work has looked critically at life-logging (e.g., Sellen et al., 2007; Harper et al., 2008), but the starting point is still life-log data already collected. Our approach in developing technology that supports personal memories started at the opposite end and focused on motivations and values. Instead of looking at what use people may have for life-logging we looked at what they considered worth

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remembering and how technology could be designed to support this highly personal activity.

This paper describes our collaborative work as researcher (Daniela) and designer (Simon) to understand the potential for the digital equivalent of mementos, as objects that prompt personal reflection on past experiences. Such *digital mementos* (as we conceptualised them) might be digital devices to aid remembering or traces of people's digital lives that become mementos (such as the emails they send or receive, the photographs they take, the websites they visit), or a combination of both. Daniela's field studies of families' practices and objects for remembering provided insights that were developed by producing ideas for digital memento devices and software in discussion with those who might use them. Simon led this design activity applying a methodology where provocative 'critical artefacts' were used to stimulate ideation. Fig. 1 illustrates the sequence of activities and our roles in each.

Both field studies and design activity were human-centred, a term we use instead of user-centred recognising: the need to firstly understand meanings and values and the way they can affect the use of technology (Strain, 2003; Frohlich and Kraut, 2003); the need to consider the numerous stakeholders affected by a product or system as well as its users; that design should advance human dignity rather than unquestioningly produce usable, marketable or desirable products and systems (Buchanan, 2001); and that over-reliance on a single conceptualisation such as 'the user' (or 'the stakeholder', etc.) can stifle creativity (Wright et al., 2006).

In this work, reflection is not only the final products' function (ideas for digital mementos), but also the means by which the enquiry progressed. Reflection was core to the field studies, discussed in Section 3, that encouraged participants to think about their own life and what was of value to them, and what was worth preserving for the future. Reflection prompted by 'critical artefacts' was a central principle of the design methodology, discussed in Section 4, which explored possibilities for digital mementos with groups of stakeholders in an open and exploratory manner.

2. Related work

2.1. Personal memories and digital technology

While much research in HCI has looked at personal reminiscence with photos (Crabtree et al., 2004; Frohlich et al., 2002; Rodden and Wood, 2003), only a few studies explored how digital technology could support affective personal memories.

Narrative and sound has been considered very evocative in personal recollection and a few studies investigated this concept. The *Memory Box* (Frohlich and Murphy, 2000) works as a jewellery box: recorded narrative is attached to a souvenir that then plays when the object is removed from the box. Children used it as a personal journal, while adults perceived its value only if the narrative-enriched objects were given/received as gifts – but not for personal use. The work identified a clear need for a self-contained, simple technology for recording and playback. *Sonic Gems* (Oleslik and Brown, 2008) provide a tangible interaction with sounds: an audio device is embedded in a ball-like case (a gem) and is triggered when the gem is taken out of a bowl. The design derives from a field study conducted in the home investigating the evocativeness of domestic sounds, and confirms that audio has potential for capturing sentimental memories, although much research is needed to explore effective human interaction with digital sound. The *FM Radio (Family Memory Radio)* (Petrelli et al., 2010) is a first step in this direction: technology for uploading and playing back self-registered sonic souvenirs was imbedded in an old fashion radio and evaluated with families that listened to sounds recorded in their previous year's holidays (Dib et al., 2010). The results show that a new and innovative design, departing from the tradition of technology-centred appliances, is more appealing in the home context and could afford a natural interaction with digital belongings.

Two design studies have investigated the interaction possibilities offered by enriching objects and memorabilia with sensors for the purpose of personal recollection. The *Living Memory Box* (Stevens et al., 2003) is intended to support the collection, archiving and annotation of family memories. In the design concept proposed, the *Living*

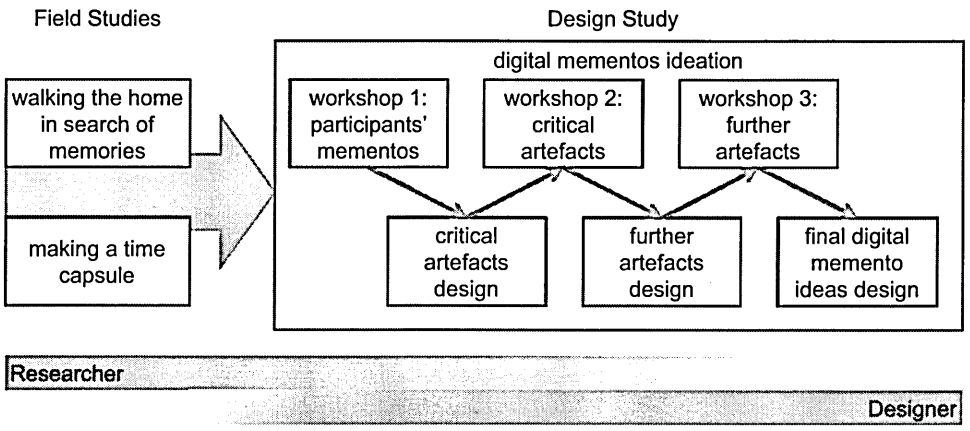


Fig. 1. Overview of field studies and design study.

Memory Box records the appearance of physical objects placed into it together with audio narratives and metadata to support later retrieval. The concept was evaluated with scrap-bookers showing that personal archival systems must be designed differently from PCs, supporting natural interaction (e.g. touch, voice). Frohlich and Fennell (2007) have explored design concepts related to objects in the home. Besides devices for visualising photographs, they discuss the *Memory Shelf* and the *Anniversary Plinth*: the former records objects' stories and triggers their playback when the object is placed on the shelf; the latter prints a long strip of paper with important facts associated with an object on important dates.

Souvenirs, personal memory, and recollection were investigated in Hoven and Eggen (2003). Souvenirs are reminders of personal experience (holiday, honeymoon) or a specific person (heirloom, gift), and are 'used' (watched, talked about); souvenirs are often idiosyncratic and carry meaning for their owner only, while their true meaning is obscure to others. With the intention of materializing digital photos, RFID-tagged objects were used to retrieve a set of images; a tablet computer supported an individual view of the image that could be sent for sharing on a television screen. A similar approach was proposed more recently by Nunes et al. (2009): the TV screen becomes the focus of the social viewing of photos associated with active memorabilia used to physically select a photo collection by sweeping the object at the TV screen.

2.2. Participatory design, innovation and critical design

Participatory design (PD) (Greenbaum and Kyng, 1991; Schuler and Namioka, 1993) ensures that the users of technological artefacts are involved in their design as informants or co-designers. This stems from an ethos that users have a democratic right to be included in design and will benefit as a result, and that doing so results in better (more efficient, usable, profitable, etc.) products and systems. Ehn (1993) refers to this as the political and technical features of participatory design. So, participatory design gives value to both human and operational improvement; it aims to produce 'happier' (empowered, enabled, valued, fulfilled) users and better products/productivity.

In PD, professional designers work together with users to explore a 'space of possibilities' for technological artefacts based on their combined knowledge and experiences. Such approaches generate products that reflect participants' current practices and expectations as 'users' but are often less useful at generating novel products which they can appropriate for new practices and roles for technology relevant to their lives. A quote, often attributed to pioneering car manufacturer Henry Ford, characterises the challenge:

> *"If I'd asked people what they wanted, they would have asked for a better horse."*

Ford's customers did not know the potential of motorised road transport, so could not say what they wanted from it. The motorcar was outside their space of possibilities. To develop innovative ideas using PD, designers and other participants need to be able to envisage a broader space of possibilities, from which to agree relevant solutions. In the methods described below, provocative conceptual designs are used to facilitate this broadening (Gaver and Martin, 2000). These artefacts relate to the products of Critical Design and similar practices.

Dunne (1999), Dunne and Raby (2001) propose Critical Design as an alternative to mainstream "affirmative design". The products of critical design are not explicitly intended for manufacture and sale, rather they provoke reflection in their audiences (and are frequently encountered in galleries, e.g. (García-Antòn et al., 2007; Blauvelt, 2003)). They express alternative social practices, values and technological possibilities that critique the assumed roles and functions for electronic products (such as Dunne's devices that draw attention to the physical phenomena of electromagnetic waves). In Dunne's words:

> *"Critical Design uses speculative design proposals to challenge narrow assumptions, preconceptions and givens about the role products play in everyday life."* (Z33, 2007)

Such 'design for debate' is not new, Italian new wave designers such as Archizoom and Superstudio were critiquing contemporary architecture and design from the late 1960s (Branzi, 1984). However the increasing prevalence of digital devices in everyday life has resulted in a number of challenges to their uncritical design, e.g. the social roles of mobile phones (Ideo, 2002). Whilst some of these designers explicitly link their work to Dunne's Critical Design, others produce artefacts for similar ends, e.g. the "fictional products" of Human Beans (2008) and Naylor and Ball's (2005) "design poetics" of mature products such as office chairs. Each of these 'Critical Design Practices' (as we term them) shares an intention to prompt their audience's reflection on their assumptions (further discussion and examples in Bowen, 2007; Bowen, 2009).

'Critical artefacts' (as we term the products of Critical Design) prompt their audience to reflect on their assumed possibilities for design, its products, and their associated and afforded practices. In reflecting on the alternative possibilities (for design, products, and practices) expressed by critical artefacts, their audience recognises the restricted possibilities that they had assumed and can therefore envisage new possibilities. These artefacts-as-critiques have a similar role to critical theories (Geuss, 1981; Calhoun, 1995; Dant, 2003) in that they seek to transform as well as express understanding (discussed further in Bowen, 2009).

In Critical Design Practices, the designer's involvement generally ends with the production of critical artefacts. Others have discussed using reflection within the research and design process to address the limitations imposed by researchers' and designers' conceptualisations of their practices and contexts (Agre, 1997; Sengers et al., 2005). We have employed the reflection prompted by critical artefacts to further inform the design activity. Returning

to our discussion of PD, participants' assumptions limit the 'space of possibilities' for design. The reflection prompted by critical artefacts is used to broaden the space of possibilities for participants to explore. We applied such a 'critical artefact methodology' (Bowen, 2009) in devising innovative proposals for digital mementos as described in Section 4.

3. Field studies: current practices for remembering

3.1. Understanding human values via reflective tasks

Despite their innovative perspectives on technology for autobiographical recollection, most of the work in Section 2.1 used traditional approaches (e.g. workshops and focus groups) to understand reality and feed the design process. However, to design technology devoted to personal reflection, new research methods more focussed on human values are needed. This section summarises two studies that Daniela led to better understand the realm of autobiographical memories. The two approaches are very different to one another but share the core idea of putting the participant in charge and seeing their individual reality through their eyes.

Although this approach borrows from many field-research practices, it also differs in many ways. As with ethnography, we put the human and their world in the centre, but we gave participants a trace to follow, an idea to develop creatively for their own pleasure. Participants steered the activity and we were happy to be sidetracked 'down memory lane'. The data collected in the studies reported in Section 3.2 was rich in nuances, full of autobiographical stories, and needed a degree of interpretation to extract insights from affective accounts to feed the second part of the research, the design-led workshops discussed in Section 4.

3.2. Walking the home in search of autobiographical memories

Only some aspects of the study are reported here; more detailed discussions could be found in Petrelli et al. (2008) and Petrelli and Whittaker (2010).

3.2.1. The study

The first study looked at why and how a material object becomes a *memento*: among the millions of objects people encounter in a lifetime, only a few become affective reminders of people, places or events. The aim of the study was to find out the driving principles and gain inspiration for the design of digital technology for personal recollection.

The home was chosen as the place to study as a space created and cultivated as a 'container' of the owners' intimate self, beliefs and aspirations (Bachelard, 1964). We focused on families with young children: parents have memories of their own lives before meeting their partner; shared memories as a couple; and are generally highly active as curators of their children's 'future' memories.

The 16 participants were asked to take us on a 'memory tour' of their home, pick up three objects in three different spaces (public, family or personal), describe what the memento was and why it was important. This very loose task left much space for personal interpretation and indeed the variety of objects and spaces we saw was richer than we anticipated. Objects chosen ranged from highly idiosyncratic ones, e.g. a father's ashes, to mundane objects, e.g. a mug; spaces included predictable rooms like kitchen and study, but also unexpected corners like drawers and a pantry door.

The tour provided a very rich canvas for contrasting digital mementos discussed in a semi-structured interview: "*You have shown us several mementos: do you have 'special things' that are in electronic form?*" With informants we explored the whole landscape of digital memories, from emails and music to more traditional media like photos and videos. To compare with the material world we asked *where* digital mementos were kept (desktop or laptop computer, external hard drive, CDs, mobile phone, etc.), *how* and *when* they were accessed and used.

3.2.2. The results

The first reaction when questioned about digital mementos was denial. Then, participants seemed to discover that they actually had digital mementos and how important they were: "*I've changed my mind, I think I do, yeah, I think I can have a sentimental attachment to stuff in [the computer], yeah*", "*They are special but I don't think about them, I'd completely forgotten we'd had them*".

The central weakness of current digital technology for personal memories is inaccessibility and lack of integration into everyday life. Consequently they are forgotten, even by people who have invested hours in collecting and organising them, being seldom invoked except on special occasions. Digital objects cannot be distributed around the house to express and elicit different styles of remembering (e.g. a photo of grandparents on display all year around can suddenly spark stories of their lives when a daughter asks her mother about it) or left in a drawer to be rediscovered by accident. Indeed rediscovery is loaded with emotions, a world of nostalgia when brought to light (Fig. 2).

This closed, metal vase lays on the mantelpiece in the lounge. Inside is a collection of the son's first things.

"That's one of [my son's] first pairs of socks, can you remember when they were this tiny?.. look look look ... oh I haven't looked in here for years funnily enough ... little bootie ... oh I can't even remember those were his first pair of little booties."

Fig. 2. One of the mementos chosen in the memory tour, a container of memorabilia, and the participant's comment when opening it.

In general digital mementos require an explicit intention and a lengthy process to be accessed: "I haven't got a compatible driver so I can't actually look at the disc that we've got with all the kids photos on so I have to look at them on his computer because I need to upgrade mine". Physical objects are more democratic. They may be of particular significance to just one person, but are accessible to everyone. The barriers to access digital objects are often compared with the straightforward pick up of physical prints: "I can just kind of flick through and I do that in a way I wouldn't just sit and look at stuff on the computer."

A clear distinction between digital and material is that the current experience with digital is shaped by work and as such carries feelings that do not apply to the personal sphere. Adjectives used by our participants to describe digital are "*dull*", "*impersonal*", and current technology is considered "*too much like work*". They also expressed concerns on the fact that "*digital does not last*" and "*it is ephemeral*" leaving a sense of uncertainty and diminished value.

In summary the study pointed out the limitations of current digital technology and the properties digital mementos should have: being easily accessible and immediate; being in the space and easy to be rediscovered; being self-contained and lasting without any need for attention (e.g. migration to new hardware); they should be fun and personal, appealing and intimate "*like handwriting.*"

3.3. Building tomorrow's memories today: making a time capsule

3.3.1. The study

The purpose of the second study was to understand the nature of long term remembering: what, of their current life, people would like to remember in the far future; to identify which elements of their digital lives would be worth preserving and how technology should support it. We asked 10 families with young children to make a *time capsule*[1] to be opened in 25 years' time. This process of deliberately composing future-oriented mnemonic representations in a time capsule was a playful way to engage our participants in reflecting on their daily lives and memories in the distant future.

Before constructing the capsule and its content, we asked participants to reflect on what they remember or wished to have kept from 25 years ago, and what they might want their grandchildren to know 25 years from now. We left material to keep a 2-week diary, and a local map with stickers to introduce participants to the notion of careful information capture and the procedures and goals of life-logging. No restrictions were given except that each family member should contribute to the time capsule. We explicitly asked participants to include digital objects in any form. It was made clear that sensitive content could be included in a sealed form and would not be inspected, but an idea of the content should be provided.

[1]A time capsule is a collection of objects and/or information, often sealed and buried, intended to communicate to people in the future.

[Mother] *"Mainly family memories really. Just what we do today, a snapshot of our kind of life today."*

[Father] *"We'd like to see how things were now. You know, it would be interesting to see how we were as a family in trends and how the things around us were. This is why it came out like this: we and our friends and things around us like technology, the street outside."*

Fig. 3. One of the ten time capsules created for the study and participants' comments.

"I enjoyed it, well I could carry on it's a sort of semi-permanent thing for me ... it's a sort of archive"

Fig. 4. A very rich time capsule and its owner's comment.

When the family felt ready, after about a month, they presented the time capsule and its contents to us. During the final videotaped one to two hours meeting, family members described each object, explaining what it was and why they included it. A short interview on the whole experience concluded the study.

The capsule and its content were catalogued and then returned to the family for their final storage.

3.3.2. The results

With 369 objects, the content of the ten capsules was very rich in terms of both types of objects and media (Fig. 3): here we report only the points related to this paper (further details in Petrelli et al., 2009).

Every time capsule captured a different 'family personality' (Figs. 3 and 4). Each family had a lot of discussion on what to include and spent a lot of time actively making or collecting objects that would describe their life in some detail: school books and awards, birthday presents, writing and artworks, pictures of the home, the garden, the favourite places. Some families tried to capture today via newspapers, shopping bills, samples of technology (e.g. film camera, mobile phones, Tamagotchi[2]). A few parents wrote to their children: the history of their family, their hopes for their future, reflections on their parenting.

Reflections around the time capsule were not always merry: "If I leave to open this 25 years later I will be 80. It is a pretty strange thought with my mother dying recently. It does focus your mind on the transience of things the fact that one day if you are still around you will be out and Anna will be in her 30s... sobering thoughts." This deep reflective

[2]A 'digital pet' interactive key fob.

stage was key to engage participants; it induced them to spend a considerable amount of time and energies in making and collecting objects for the time capsule (Fig. 4).

Digital is still seen as a problem. Only 20 items of the 369 across the 10 time capsules were digital, a further 40 were originally digital, but have been printed: digital photos, scans, instant messenger communications, Bebo pages.[3]

All the families had experience of the consequences of a fast changing technology and the inability to use old formats. To preserve the digital, three families took the pragmatic approach of including devices (a laptop, a CD player and an iPod) to be able to access digital data in the future. Three other families included digital storage (1 CD, 1 USB memory stick, 1 digital tape) expecting the technology to persist or to rely on experts to migrate their digital material into future formats: "*maybe USB will still be readable on old computers or maybe not.*"

In summary, families were interested in capturing a wide range of their everyday life as well as the most common aspects of today's society. Whilst this was an easy task with material objects, it became problematic when mediated by digital technology. All participants used the Web daily, but none captured the online experience of shopping or reading the news. There is no trust that digital will last: technology to last generations must then be self-contained.

4. Design study: new possibilities for remembering

Daniela's fieldwork results provided a deep understanding of the desired properties and motivations for effective digital mementos, but were largely interpretative and related to participants' *current* practices and needs. At this point we developed the idea of collaborating to design digital memento devices that would both embody this understanding and develop it further by exploring *new possibilities* for practices and roles for digital technology with those who might use such devices. To accomplish this, Simon led a series of discussion workshops following a critical artefact methodology, introduced in Section 2.2 and described further below.

4.1. A critical artefact methodology

Our design work employed a methodology intended to foster human-centred innovation. It suggests a method of generating ideas that is described in more detail in Bowen (2009) but, in brief, involves using provocative proposals for what '*could* be' to determine what '*should* be' as facilitated by designer's and participants' subjective interpretation of each other's understanding developed and expressed through artefacts and their engagement with them. Typically, this critical artefact methodology is applied via a series of workshops. Fig. 1 shows its application in the digital mementos ideation work.

As noted in Section 2.2, critical artefacts (the products of Critical Design) could be used to broaden the 'space of possibilities' explored via participatory design. They enable participants to recognise that the possibilities they assume (for design, its products and their afforded practices) are limited, and to envisage new possibilities. This operation relies on participants' reflection on the alternative possibilities that critical artefacts express. The design of critical artefacts and the form of participants' engagement with them is therefore key. In this methodology, participatory activities inform the design activity in a particular manner (participation is not co-creation).

The designer participates in group discussions centred on artefacts with the intention of developing their understanding of participants' current practices and needs, and potential new practices and roles for technology that could become part of participants' lives. However this understanding is tacit as, during the workshops, the designer's attention is on what they will design next rather than producing an explicit description of those practices, needs and roles (Polanyi's (1966) concept of "indwelling" offers a description of this process). Following this rationale, the process begins with participants' engagement with artefacts and ends with designed artefacts that are informed by this engagement.

Discussion of existing artefacts gives the designer insight into participants' current practices and needs which, in part, they can then challenge through the critical artefacts that they design. These critical artefacts then 'open up' the design exercise by broadening the 'space of possibilities'. In reflecting on the provocative (strange, alien or unusual) possibilities expressed in critical artefacts, participants can envisage new practices and roles for technology. Their ongoing engagement with the critical artefacts can also provide the designer with a tacit appreciation of participants' needs in respect of the newly envisaged possibilities. The designer can then 'close down' the design exercise by producing a further set of artefacts that suggest which new practices and roles could fit participants' lives and values. Participants' engagement with these further artefacts then enables the designer to refine and resolve their ideas into proposals for products that should be both innovative (affording new practices and roles for technology) and human-centred (having relevance to participants' lives and values).

This suggests a progression from critical artefacts for 'opening-up' to further artefacts for 'closing-down'. The earlier artefacts are therefore more provocative but progress towards being more 'prototypical' (suggestive of an end product or direction for the design activity) as the designer's tacit understanding of participants' practices and needs develops. Such a process relies upon cycles of subjective interpretation: designers develop and express their understanding through designing artefacts and workshop participants reflect upon and express their understanding via their engagement with these artefacts.

4.2. Designing and discussing digital mementos

4.2.1. The design study

A series of three, one-hour workshops were set up to explore the design of digital mementos. This study was used

[3]www.bebo.com is a social media network.

to refine Simon's design methods and his previous work (Bowen, 2008) had suggested that open-minded and imaginative participants attuned to the possibilities of novel situations (as might be afforded by the creation and use of digital mementos) would usefully inform the design activity. As such, two separate groups participated in the workshops: one filtered to have such characteristics and another group recruited from participants in Daniela's fieldwork (discussed in Section 3). The filtered group engaged with the artefacts in a more open and exploratory manner than the fieldwork group, which was more productive for ideation and consequently their workshops are discussed here as a more representative illustration of a critical artefact methodology in action. This group consisted of three men and three women in their 30s (one in their late 40s), unfamiliar with the previous fieldwork, and recruited as being open-minded/imaginative and potential users of digital mementos (using digital technology in their personal lives and at a life-stage where numerous personal memories were being made). The recruitment method, rationale for identifying 'suitable participants' and differences between the two groups is discussed further in Bowen (2009).

The workshops ran over four months and were held in our own homes during the evenings to promote an open, informal environment for discussions. Participants were told that the workshops would be a 'dialogue' between them, as potential users, and Simon as a designer. Daniela acted as observer. Workshops were video-recorded for later reference.

4.2.2. *The first workshop*

Participants were asked to bring two objects along to the first workshop that they might put into a (hypothetical) time capsule to be opened in 20 years' time. During the workshop, each person in turn shared their objects and reasons for choosing them, with the discussion then flowing freely as others made connections with their own experiences. Participants brought in a broad range of objects (from photos to a rock tour T-shirt), and discussed the events, places and people they represented and how they used them for remembering. The discussions illustrated how some objects are purchased specifically for future remembering (a pair of fridge magnets, an ethnic statuette) whilst others are obtained for practical purposes and later kept as mementos of an experience (a small bell worn to prevent startling bears whilst trekking in Canada), and how people use some objects to prompt frequent remembering (a souvenir tankard from a special holiday in everyday use) whilst others are for more infrequent and directed remembering (a newspaper from the participant's wedding day stored in a box of keepsakes).

Along with features suggested by Daniela's fieldwork such as making digital mementos easily accessible and self-contained, the first workshop discussions suggested aspects of physical mementos that we wanted to explore in digital mementos including: keeping a variety of digital artefacts as mementos, how forgotten records of people's 'digital lives' could become mementos, and how digital mementos could be discovered and discoverable. Simon designed a set of critical artefacts that proposed how these aspects could be realised and, rather than being explicitly intended as practical proposals, instead expressed alternative practices and applications of technology to challenge participants' expectations of what digital mementos could be.

4.2.3. *Critical artefacts and the second workshop*

At the beginning of the second workshop a series of PowerPoint slides were shown to 'set the scene' by illustrating the increasing application of digital devices in personal life, and reminding participants that once seemingly fantastic designs are now part of everyday life (such as the mobile phone's resemblance to the *Star Trek* communicator). Each critical artefact was then presented in turn, described as 'conversation starters' to 'continue the dialogue', and participants were asked to discuss and explore the situations that they suggested.

Participants were shown basic mock-ups of the critical artefacts along with specific usage scenarios via series of PowerPoint slides. Their use was described in relation to previous or imagined memorable events in Simon's marriage (first date, wedding, honeymoon, first child). The four critical artefacts – *Txt Globe*, *Aroma-mouse*, *Mem Eggs* and *Once Upon a Web* (Figs. 5–8) – explored aspects of digital mementos inspired by the previous activities.

4.2.4. *Second workshop discussions*

Our intention was to challenge participants' assumptions of what digital mementos *could be* during the second workshop. The critical artefacts were provocative in that they suggested alien applications of technology (a Bluetooth snow globe, a 'Wi-Fi drawer freshener', a device that determines if and when it can be used), unusual practices (devices to be deliberately lost or for rating 'happily ever after'), and alternative forms of memento (mouse-eye views and web forms). They also expressed technological possibilities such as making digital information visible, tangible and self-organising. We also hoped that discussing them would provide insights into which new practices and roles for technology might fit participants' lives and values. To illustrate this we refer to two artefacts' discussions below.

Following the presentation of *Aroma-mouse* the initial discussion centred on its practical implementation (would

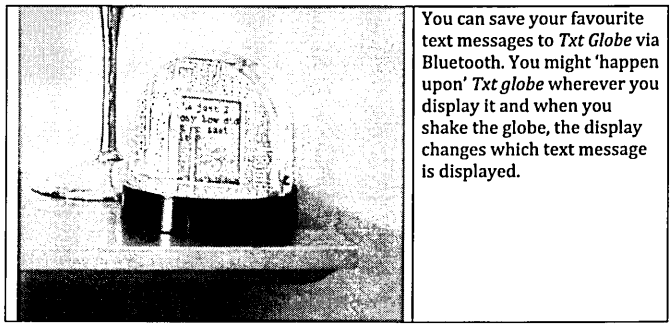
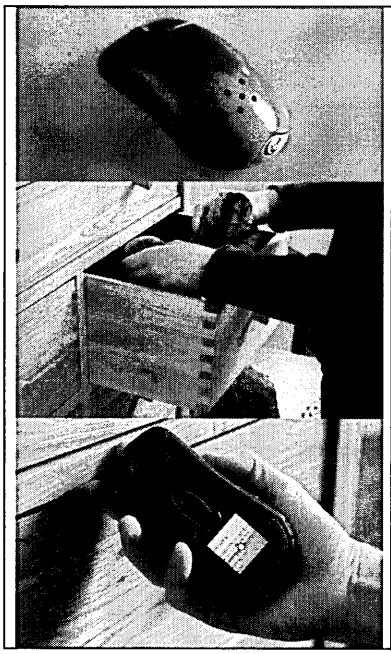
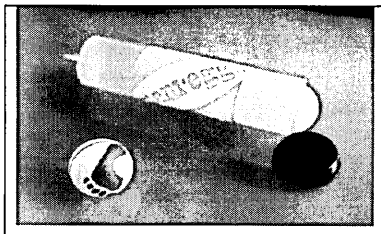


Fig. 5. *Txt Globe*: making text messages accessible and discoverable.



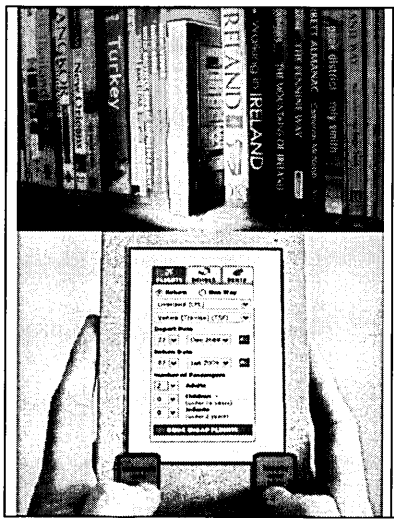
Aroma-mouse gives off a pleasant fragrance, you could put it in a drawer with your socks to keep them smelling fresh. Via a wireless connection it also stores 100 pixel square images of the web links you visit on your home computer. If discovered forgotten at the back of a drawer, clicking on *Aroma-mouse*'s buttons cycles through the stored 'mouse-eye views' on its small screen.

Fig. 6. *Aroma-mouse*: replaying 'mouse-eye views' of visited web pages.



Mem-eggs come in multi-packs. Once switched on, a *mem-egg* wirelessly sends a unique code to all compatible devices in range that is then used to 'label' all photos, videos or messages that are created whilst it is active. *Mem-eggs* can then be used to retrieve media (assuming it is stored centrally on the Internet), whichever device or whoever has created it, and can be written on or decorated to personalise them.

Fig. 7. *Mem-eggs*: labelling and sorting digital recordings automatically.



Once upon a web is a device that you might put amongst your travel guidebooks. It is also wirelessly connected to your home computer and stores copies of the website forms that you submit. Occasionally, at random, the device's spine glows indicating that it has turned on. At this point it shows web forms stored from one or more years previously. You can then choose to rate forms as 'happily ever after' or 'unhappily ever after' according to whether they should be kept as mementos (and shown again) or deleted (for boring tax returns, perhaps).

Fig. 8. *Once upon a web*: 'happily ever after' web forms?

the device record too many web pages, could web pages be chosen rather than automatically stored?), useful comments if we had intended to refine it into a finished product. However the aim was to provoke participants' reflection on what they considered possible. As the discussion continued, participants moved on from questioning the specifics of the proposed devices and started to explore how they could fit into their lives:

P1: "perhaps there're things when you click on at the time you don't think there's much significance but [...] I'm thinking when [we] booked our flights and accommodation when we went travelling [if] I could just have a little glimpse of some of the links to the different booking websites and so on, that would probably trigger the memory for me [...]"

P2: "with digital you are losing a hard record of what you've seen."

P1: "with booking significant things I've got all the emails, I've still got all those from things years gone by that I've just kept almost like as a digital memory I suppose [...]"

P2: "[Aroma-mouse] reminds me of going in [my Mum's] loft and you see all your old school books and things which maybe you wouldn't be able to do now.. if I was studying now I don't know if I'd have an exercise book."

With *Once upon a web*, although participants commented on elements that they did not like (the use of web forms), their discussion suggested other features that they did find desirable:

P3: "part of that is my favourite one so far because there's something quite magical about having a hardback book on a bookshelf that's slowly glowing.. [but] I would probably choose to transfer something other than forms onto it because I find forms a bit uninspiring."

Another participant made connections between the practices the device afforded and her own experiences:

P4: "I keep photographs all over the house and once in a while I walk past and think 'oh I haven't looked at those for a while' and I take them out and look at them, I love that. This would give me a chance to do that digitally."

Discussing this critical artefact also prompted further reflection on *Aroma-mouse*:

P4: "the more I think about the mouse the more I think actually, if I had one, I probably would use it [..] and it's just a nice little personal moment that you can think about your past.. but I do think it's quite pointless in one sense but then art doesn't always have to have a deeper meaning does it? It's just a moment for you to share with your history I suppose."

Whilst participants did not want to own or use the critical artefacts as presented, discussion of them appeared to broaden the 'space of possibilities' for digital mementos.

In discussing *Aroma-mouse*, P1 starts to appreciate that digital mementos might be more than just photographs, that snapshots of his online activity could act as mementos, and P1 and P2 begin to appreciate a need to capture elements of their 'digital lives' for later remembering. The discussions also suggested which aspects could be relevant to participants' practices and needs, such as *Once upon a web's* 'magical' quality and potential to prompt an act of remembering.

Participating in the discussions informed Simon's tacit understanding of the participants' values and the features digital mementos should offer as result. This included making digital data (as mementos) somehow tangible, digital mementos being discoverable serendipitously and affording intimate 'personal memory moments'. This understanding was developed and expressed in a further set of artefacts.

4.2.5. Further artefacts and the third workshop

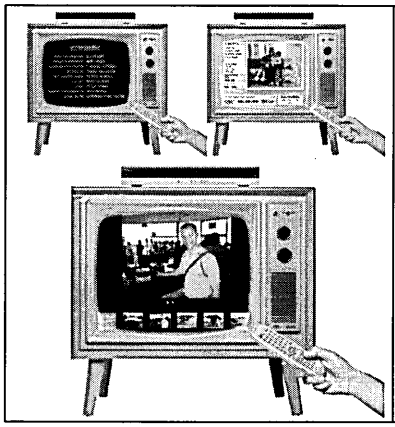
Rather than being critical artefacts to challenge assumptions, the artefacts presented in the third workshop were intended to resolve ideas for digital memento devices that would be both innovative and relevant to participants' lives and values. Simon designed these artefacts to 'close down' the design activity by expressing features the previous fieldwork and two workshop discussions (and his reflection on them via designing) had suggested were desirable and practical. Participants' discussion of these artefacts would then develop and verify this understanding. Again the workshop was presented as 'continuing the dialogue' with each artefact presentation followed by a discussion of 'what if (these devices existed)?'. Basic mock-ups, scenarios and PowerPoint were used as before.

Four artefacts were presented. *Txt-Bowl* and *Web Trails* derived from two of the critical artefacts and tested their desirable elements in a more practical form – a bowl for storing the contents of your pockets as well as displaying stored text messages and a 'magical' device for replaying graphical 'trails' of the websites you have visited. *Previously... Widget* re-examined the ideas expressed by *Aroma-mouse* by suggesting personal computer software to capture the names of files you edit for longer than 30 minutes and then randomly remind you of them one year in advance. More specifically, *Channel Pix* (Fig. 9) developed the ideas of mementos being discoverable by serendipity and affording 'personal memory moments' as informed by the discussions of *Once upon a web* and *Aroma-mouse*.

All the participants stated that they liked *Channel Pix* and discussed the beneficial experiences they recognised it could offer. E.g.:

> *P5: "I like the fact that it almost encourages you, saying you're wasting time, do something productive here's something important to look at."*

As the discussion continued, participants offered amendments to the device to tailor it to their needs, such as being triggered by moving around the electronic programme guide (EPG) in addition to 'channel surfing'.



Channel Pix is a device within your television (or its set top box) that monitors your viewing behaviour. If you begin changing TV channel several times without lingering on any in particular ('channel surfing'), *Channel Pix* detects that you might be bored and instead displays a random personal photograph. Pressing a particular button on the remote control then allows you to browse your photographs on your TV, or ignoring it means you can continue 'surfing'.

Fig. 9. *Channel Pix*: watching your memories.

4.2.6. The results

In the third workshop, participants discussed artefacts that expressed our understanding of their current practices and needs, and potential new practices relevant to their lives and values. To follow the methodology discussed in Section 4.1, the designer (Simon) then reflects upon these discussions and expresses their understanding by designing a final set of artefacts. So, Simon produced five ideas for digital memento devices and systems that embodied the understanding we had developed from the fieldwork, the three workshop discussions and the artefacts designed in response. This final set of designs, described in Section 4.3, then expresses our understanding at the end of the project of current and potential new practices relevant to participants' lives and the human values that underlie them. They effectively express our proposals for designing human-centred digital mementos (such as being "serendipitously discoverable" and "not like work"). As such, they reflect a broader range of human practices and technological possibilities as enabled by the participants' engagement with the critical artefacts.

4.3. Design ideas for digital mementos

4.3.1. Channel Pix

The *Channel Pix* artefact (Fig. 9) presented at the third workshop was taken forward as an output as participants unanimously liked it and we felt it adequately expressed our understanding at the end of the project.

4.3.2. Txt Box

Txt Box (Fig. 10) is a place to put all your personal 'clutter' when you enter your home – your keys, loose change, and mobile phone. However it does more than just keep your entrance hall clutter-free. *Txt Box* can communicate with your mobile phone via Bluetooth and download your forthcoming diary. When you lift the lid and take your phone, *Txt Box* detects your phone has been removed and may remind

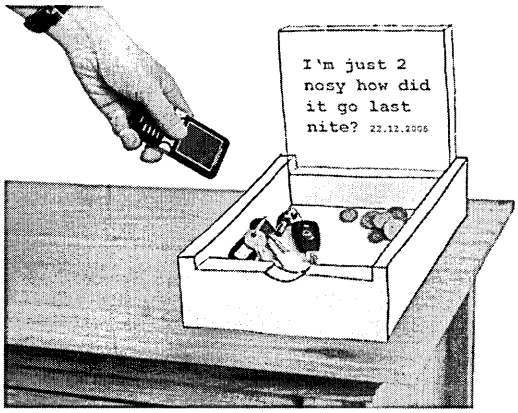


Fig. 10. *Txt Box*: memory moments as you leave home.

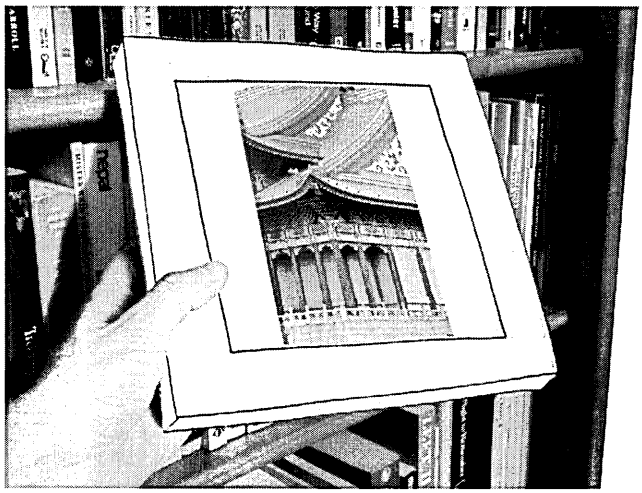


Fig. 11. *You WERE Here.*

you of any appointments. But it also copies any text messages (SMS) that you have saved on your phone for longer than six months. When the text messages are over one year old, it will occasionally display one and give you a reminder of a past memory before you leave the house. And because *Txt Box* recognises which phone has been removed, you will only see your own appointments and saved text messages.

Txt Box demonstrates making text messages tangible and easily accessible whilst also responding to participants' expressed need for a useful device.

4.3.3. You WERE Here

This device (Fig. 11) sits unobtrusively amongst your books (akin to *Once upon a web*, Fig. 8). It connects wirelessly to your home computer, the Internet and mobile phone networks (which know your phone's location according to the network transmitters you are nearest). *You WERE Here* keeps a record of when and where you've been outside your normal everyday journeys to work, etc.

Occasionally, on the anniversary of your travels, *You WERE Here*'s spine starts to glow, attracting your attention. If you pick up the device its temperature sensor turns on its display, and it shows photographs of your travels from one, two or more years ago. In this design proposal, it finds these photos from the global positioning system (GPS) location data your camera records with each image.

You WERE Here develops the idea of a 'magical' device that prompts moments of personal remembering, and attends to the need for digital information to be self-organising.

4.3.4. Previously... Widget 2

This second version of a third workshop artefact deals with participants' concern that it was too intrusive. *Previously... Widget 2* is software on your home computer. If you've been using the same application for longer than fifteen minutes (clicking on things with a mouse, typing), then the software starts 'remembering' what you were doing by saving a screenshot of the application. Of course, you might not want the software to remember what you were doing, in which case you can click on its icon and 'blindfold' it. Then, when you come to shut down your computer *Previously... Widget 2* (Fig. 12) will occasionally remind you of what you were doing with a screenshot.

Previously... Widget 2 demonstrates capturing aspects of people's 'digital lives' to act as prompts for remembering in the future. Some of the screenshots could then 'grow' into being mementos, although others may not if recalling less personally significant moments.

4.3.5. Mem Tabs

This idea assumes a 'digital utopia' where all data is stored and accessed directly on the Internet rather than on individual devices, e.g. a camera sends photographs wirelessly to central servers rather than saving them onto a memory card.

Mem Tabs (Fig. 13) are a product from this digital utopia – little tablet-shaped devices that you buy in packs. After turning one on by squeezing it, it transmits a signal to any *Mem Tab*-enabled digital device within a short range for one day or one week (depending on the type you bought). Each *Mem Tab* has a unique number and any devices in range will label any files they create with this number.

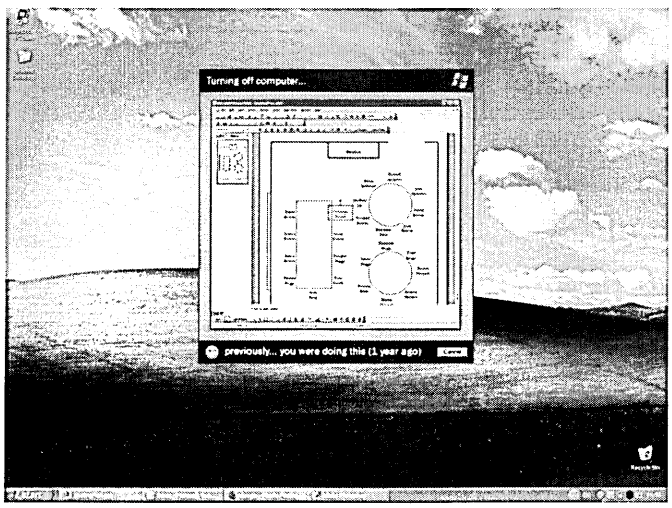


Fig. 12. *Previously... Widget 2*: something you did earlier.

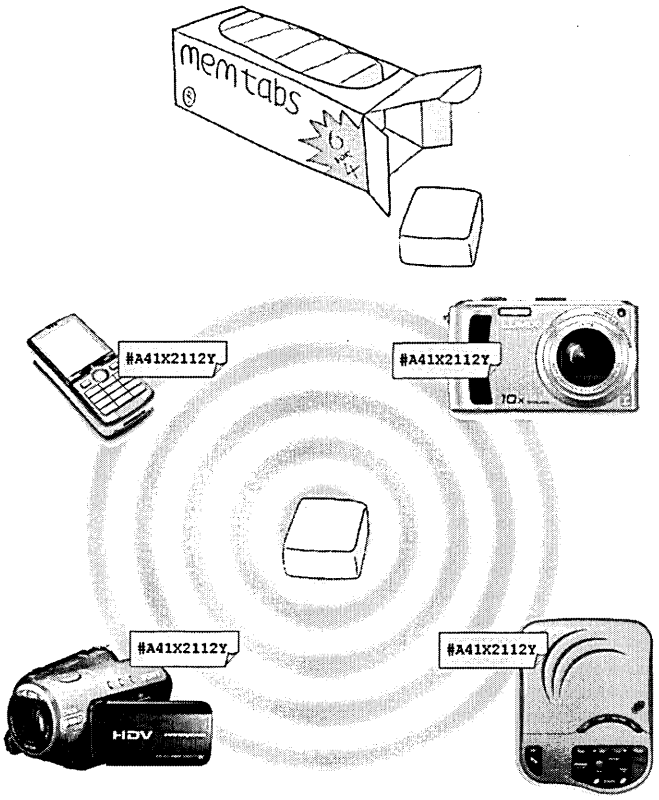


Fig. 13. *Mem Tabs*: labelling your digital media.

So for example, if a couple are at the hospital having their first child and activate a *Mem Tab*, all the digital files created in range will be labelled with its number: the text messages from their mobile phone, the photos from the new grandparents' camera, even the security camera recordings.

To re-play digital media from a particular event, just place the appropriate *Mem Tab* on a reader next to a playback device (such as a television), which will then display all digital files labelled with that *Mem Tab*'s number. Two *Mem Tabs* will display all the files with both labels, etc.

A refinement of the *Mem-Eggs* critical artefact, this demonstrates self-organising digital data and a product for easily accessing it that can be fun and personal.

5. Discussion: designing digital mementos for and with reflection

In this paper we have discussed how we explored possibilities for digital mementos by understanding their human context (through field studies – Section 3) and developing this understanding by designing (via artefact-centred discussions – Section 4). Our intention is that such digital devices and systems should support people's reflection on their past personal experiences (memories). We can then offer guidance on designing *for* reflection based on our experiences in this two-part research. And, as we will discuss in Section 5.3, our use of critical artefacts also demonstrates a method of designing *with* reflection.

5.1. Understanding user needs and human values

As discussed in Section 1, designing human-centred devices and systems means considering more than usability. In addition to people's current needs as 'users', we should understand the human values that drive their practices, which provide insights into new possible functions ('uses') supporting a broader conceptualisation of human activity.

The field studies looked beyond participants' practices and identified both their needs (e.g. "don't want to organise my digital stuff, let the computer do it") and underlying human values (e.g. un-sought for moments of remembering in daily life). This is necessary as considering people as 'users' alone could privilege utilitarian 'work-like' designs, whilst we recognise that a focus on values alone could leave technological problems unresolved.

This design shift from technology optimised for 'use' to supporting human values changes which features are important, e.g. efficiency is meaningless when revisiting memories happens once every 5–10 years. For the owner, the value is not the frequency of access but the emotional investment captured by old mementos rarely accessed:

> "In the attic I have a box full of things from [..] 30 years ago, but I never open it. I just move it around. When I move house, I look, I open it, ah! I go look at this and then I close it again. I don't wanna throw it away. How many times have I looked in that box of mine? About once every ten years."

A change of perspective from user to human calls for a change in approach to field studies. It is helpful to design the study in such a way that participants can appropriate the activity, exercise their creativity and describe and represent their own lives (as those best positioned to do so). Participants find such activities valuable, not in terms of given rewards (money or gifts), but in doing something that is precious and satisfying [commenting on the time capsule study] "*I would have never done it, but there was a reason and it was just fab. I enjoyed it greatly!*". Such studies also motivate continuing participation and consequently provide more insights: "*It has been very interesting, we have done a lot of things and caught a lot of things for this that we would have probably have let slip by.*"

The time capsule activity gained enthusiasm because participants kept the product: it was a work done for themselves, not just for the researchers. The memory tour produced a rich set of stories because of the attachment between the person and their memento. Material collected in this way may be more difficult to use as factual evidence to justify design decisions because some interpretation is required, a subjective interpretation by the researcher through the lens of their personal experience. However the needs and human values that are identified provide a useful basis for imagining and designing truly innovative technology.

5.2. Designing digital technology for reflection

Understanding human values is particularly important when designing devices for personal reflection, where other factors

may have more importance than usability such as ambiguity, playfulness and (as we found with *Once upon a web*) 'magicalness'. Therefore, in understanding the context for such design work, we should appreciate current practices and needs but also gain a deep understanding of the aspects of personal life we intend to affect (in our case autobiographical memories).

In our work, if we had designed artefacts to evaluate the social and technological functions suggested by the fieldwork directly ('prototyping') we may have only explored a restricted 'space of possibilities' (for social practices and applications of technology). Instead, we used critical artefacts that expressed alternative and provocative possibilities (informed by the fieldwork) to encourage participants to reflect on these alternatives, recognise their assumptions and envisage new possibilities. Critical artefacts 'opened up' a broader space of possibilities and further (less provocative) artefacts were used to 'close down' to design ideas relevant to participants' lives and values. We hoped that the final design ideas would be more human-centred as they were resolved within a broader conceptualisation of social practices and technology rather than (prior to engagement with critical artefacts) narrow assumptions of 'what technology is *for*'.

The field studies and discussion of participants' own objects suggested (amongst other things) that digital mementos should be accessible, (re)discoverable and reflect the broad range of objects people choose to keep as mementos. The critical artefacts encouraged participants to reflect on alternative possibilities for digital mementos. Although they did not see *Aroma-mouse* and *Once upon a web* as specifically relevant to their needs (which was not the point), participants began to appreciate the potential of more general possibilities that they might not have previously considered, such as using traces of their 'digital lives' (e.g. web activity) as mementos and having tangible devices to prompt remembering. The discussions also developed our appreciation of what was of value to participants in their practices, such as affording personal time and space for remembering.

In the subsequent design work and discussions we developed ideas for digital mementos that both embodied these broader possibilities and reflected our understanding of what was relevant to participants' lives and values. E.g. *Txt Box* prompts 'personal memory moments' with saved text messages but is also relevant to everyday life (somewhere to dump your pockets' contents when arriving home).

The final design ideas embody our understanding, as researcher and designer, of features that human-centred digital memento devices and systems should have: being 'not like work', serendipitously discoverable and self-organising, and capturing a broad variety of digital material that might become mementos in time. But do they work as mementos?

Clearly not all digital material makes an effective memento. E.g. the workshop participants felt that most of their web activity was routine and boring and did not adequately represent significant past life experiences. However the selection of objects that can (or will) prompt reflection is a highly personal activity, sometimes long after the object's original function has ended. The problem with 'digital objects' is that they are fleeting and ephemeral. Our final design ideas demonstrate ways of retaining and materialising traces of people's digital lives that might otherwise be lost, from which they can create their own mementos.

5.3. Designing digital mementos with reflection

The fieldwork and design methods discussed above rely on a continual process of subjective interpretation. In the fieldwork, the participants' interpretation of the researcher's brief (to give a tour, to make a time capsule) and the researcher's interpretation of the gathered material. The designer's interpretation of the fieldwork (from the researcher) and the researcher's understanding of the context (from the design proposals). And in the design-led workshops, designer and participants interpret each other's experiences and ideas through the design of and engagement with artefacts.

This fits with an alternative view of knowledge production that (Boehner et al., 2007) have discussed as applying to the Cultural Probes approach (Gaver et al., 1999, 2004). In this view, knowledge is produced as part of an ongoing dialogical process between designers and participants. There is no objective process of refining a 'correct' understanding of people's experiences, as to do so denies the agency of both participants and designers in interpreting *any* understanding – each have their own subjective interpretations of the others' experiences and expectations.

Reflection is a key element within this subjective interpretation so the methods discussed here also describe designing *with* reflection: reflection as a mechanism for understanding the context and progressing the design activity (being central to how the critical artefacts were designed and employed). Our earlier work suggested that critical artefacts could encourage people to consider novel design possibilities (Bowen, 2007) and that these artefacts should be used in a particular manner with certain types of participants in order to develop useful insights for designing (Bowen, 2008). Applying the resulting critical artefact methodology in this study has enabled us to design ideas that are grounded in participants' needs and values whilst also proposing innovative uses of technology. However, this reflects one designer's practice with one group of participants. The ideation process depends on the designer facilitating a reflective dialogue with participants via what they design and how they attend to its discussion, which was not straightforward in this study and consequently other designers may find difficult. Further, needs and values recognised by these participants may not be entirely applicable to others.

The ideas for digital mementos we propose above (Section 4.3) are an embodiment of our understanding of what human needs and values such devices could support *at this point* in our research. They suggest directions for further design work refining these ideas into human-centred products and systems that a large proportion of people would recognise as being

relevant to their lives. The design of these digital mementos illustrates our tactic of using critical artefacts to prompt a reflective dialogue, but further work is required to determine how such methods could be utilised by other designers.

Finally there is another level of reflective dialogue, particular to mementos: people's ongoing re-interpretation of their memories via the objects and artefacts that they keep. Further study with working prototypes could suggest whether the digital mementos we propose mediate and afford such dialogues, which we intended in e.g. *Previously... Widget 2*. Instead, at this point we offer another desirable feature for digital mementos: that they should allow digital material to be appropriated for remembering (or forgetting) over time.

6. Conclusion

We have presented the notion of digital mementos as technology that affords reflection on personal experience (memories), discussed our work exploring user needs and human values in the context of autobiographical recollection and the design of digital memento devices and systems to support them. Our research and design produced ideas for devices and systems to afford remembering that participants felt were relevant to their lives and values (i.e. were human-centred) but were also innovative in suggesting novel practices and technological applications. Such methods could then be useful in designing other forms of personal reflection.

Throughout this work, reflection was a central mechanism for researcher, designer and participants to develop their understanding of what digital mementos *could* and *should* be. And the resulting design proposals, in reflecting a broader range of possibilities for human activity and applications of technology, themselves prompt reflection. Our digital mementos propose how people could remember today tomorrow but also provide a critique of how we remember yesterday today.

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On the role of user-centred evaluation in the advancement of interactive information retrieval

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Abstract

This paper discusses the role of user-centred evaluations as an essential method for researching interactive information retrieval. It draws mainly on the work carried out during the Clarity Project where different user-centred evaluations were run during the lifecycle of a cross-language information retrieval system. The iterative testing was not only instrumental to the development of a usable system, but it enhanced our knowledge of the potential, impact, and actual use of cross-language information retrieval technology. Indeed the role of the user evaluation was dual: by testing a specific prototype it was possible to gain a micro-view and assess the effectiveness of each component of the complex system; by cumulating the result of all the evaluations (in total 43 people were involved) it was possible to build a macro-view of how cross-language retrieval would impact on users and their tasks. By showing the richness of results that can be acquired, this paper aims at stimulating researchers into considering user-centred evaluations as a flexible, adaptable and comprehensive technique for investigating non-traditional information access systems.

Keywords: Interaction design; Iterative user evaluation; Empirical studies; Cross-language information retrieval

1. Introduction

Very often user evaluations are done in IR at the end of the system development process. However, this approach is likely to have a limited impact on the system design since the main choices have been made and a lot of implementation effort has already been spent. This type of evaluation undertaken at the end of a design project is referred to as a *summative evaluation*, since it sums up the work done so far. However, user evaluations can be run at any time during the design process. These are *formative evaluations* and help in finding out critical points in the interaction and thus contribute to the transformation of the design in progress. The goal of these iterative evaluations is to verify if the interaction is as expected, find out where the problems are, understand what is wrong and how it may be addressed (Dumas & Redish, 1999): they are an essential element in system design as they keep the focus on the user (Preece, Rogers, & Sharp, 2002).

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In the area of Interactive Information Retrieval (IIR), the iteration of design and evaluation has been identified as key to achieve effective systems and the way to avoid the "user-centered design paradox" (Marchionini, 1995): "We cannot discover how users can best work with systems until the systems are built, yet we should build systems based on knowledge of users and how they work." "The solution [to the user-centered paradox] has been to design iteratively, conducting usability studies of prototypes and revising the system, over time." (Marchionini, 1995, p. 75).

Despite the recognized importance, there is a general lack of studies that show how design of IIR systems evolved and explain the rationale for the choices made. This could be because formative evaluations are not often considered a research instrument rather just a tool for practitioners, a way to produce an IR system that works in the real world (e.g., Schusteritsch, Rao, & Rodden, 2005). For research purposes other methods are preferred, e.g. qualitative experiments for information seeking and behaviour studies (e.g., Kelly & Belkin, 2004; Talja, 2002), quantitative studies of log records (e.g., Anick, 2003; Ozmutlu, Spink, & Ozmutlu, 2004) or comparative tests for user interface features (e.g., Hughes, Marchionini, Wildemuth, & Wilkins, 2003; Koenemann & Belkin, 1996). These methods allow one to study in depth a fraction of the user–system interaction, but fail in capturing much of the context (the system, the user, or the environment respectively) and do not provide a holistic understanding of the phenomenon under study. When studying new areas of interactive information retrieval (e.g. cross language, multimedia, or personal information retrieval), a tool that supports an explorative and inquisitive approach is more promising than one aiming at a definitive answer.

This paper discusses the role of user-centred evaluations as an essential method for researching interactive information retrieval (IIR). It draws mainly on the work carried out during the Clarity Project where different user-centred evaluations were used during the lifecycle of a cross-language information retrieval (CLIR) system. The iterative testing was not only instrumental to the development of a usable system, but more importantly, it enhanced our knowledge of the potential, impact and actual use of CLIR technology. By showing the richness of results that can be acquired, this paper aims at stimulating researchers into considering user-centred evaluations as a flexible, adaptable and comprehensive technique for investigating non-traditional information access systems. A set of related evaluations allows understanding of the evolution of a certain interaction design, i.e. to understand the *why* and not only the *what*. In the case reported here for example, the design choice for the interaction was explicitly done against user preferences. By understanding why users preferred one solution against another, it was possible to find a compromise that satisfied users and exploited the system capabilities.

2. Interactive IR evaluation

2.1. Ecological vs. controlled

The system-oriented laboratory-based IR evaluation framework has been challenged in the past, particularly with respect to the lack of user involvement and attention to interaction. Critiques include: lack of insight into the user–system interaction (Robertson & Hancock-Beaulieu, 1992), narrow focus on the system at the expense of the searcher and the context (Saracevic, 1995) and a disregard for iterative and exploratory retrieval (Draper & Dunlop, 1997). Ingwersen and Järvelin (2005, p. 7) go further and list ten objections to the laboratory-based evaluation framework including limitations of precision and recall in representing a successful interaction, and a leaning toward average results to the detriment of a deeper understanding.

The need for a distinct and broader evaluation framework for Interactive IR (IIR) was recognized through the many years of the interactive TREC track and a lot of effort was spent to move user evaluation from a system-orientated perspective to a more realistic user-orientated one. As observed by Over (2001), the need for a broad consensus among interactive TREC participants led to a generic framework focused on strictly controlled laboratory user evaluations. This centralized control of the experimental design was essential for result generalization but hampered a more operational and ecological approach. Studying the interaction in natural settings (e.g. offices, libraries) with real users each with a well-defined information need, is the ideal way to investigate reality. Indeed, the lack of realism in controlled user evaluation has been criticized and the need to perform more realistic tasks has been strongly advocated (Robertson & Hancock-Beaulieu, 1992; Su, 1992). Unfortunately an ecological approach fails to collect homogeneous data indispensable to

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address usability issues. To understand how serious a problem it really is, experimenters have to know how many people encountered specific difficulties. However, if users search different topics (as in the ecological setting) the outcomes are not comparable. When the focus is a quantitative study, conducting an experiment under controlled conditions is essential and a laboratory is the best place.

Controlled tests and ecological observations are the two extremes of the user evaluation spectrum, in between the two are many degrees of intermediate solutions. Evaluations run periodically during a project lifecycle allow for a progressive move from strictly controlled laboratory test to more relaxed conditions resembling naturalistic observations. In the early stages of system design it is far more important to understand why the system is not working properly, while when a stable prototype is available the goal of a broader investigation is to assess the impact of the designed system on the user in their natural context. Some forms of user-centred evaluation can also be used in the very early stage of the project when ideas are generated to more effectively identify user requirements. From this point of view periodical user evaluations are a kind of longitudinal study done on the same evolving system: they allow investigating if and how patterns of user behaviours change or stay when the interaction changes inside a given framework. As a research method longitudinal study allows for the exploration of alternatives but similar solutions, and supports a steadier accumulation of knowledge on how users would interact with a certain technology besides the specific implementation. This incremental and explorative approach is not widely adopted in the IIR community: the work of Nick Belkin and colleagues at Rutgers University is an exception and not the rule. In three years of Interactive TREC (2001–2003) they investigated several interface features to discover the effects on query length (Belkin et al., 2003; Belkin et al., 2002).

2.2. Operational vs. hypothesis-based

User evaluation of innovative IIR systems is often seen as a part of the software development process. The user test is run to measure how the system performs when put in use (as in Dumais et al., 2003). This operational evaluation is generally an approximation of real life conditions: a system retrieves documents in real time; a fully developed user interface is provided to the user to interact with; a task is given to the user to be carried out. The performance analysis can provide good insight into the effectiveness of the new technology as well as its impact on users and their satisfaction. However, its potential to advance the knowledge of interactive IR is rarely exploited and the result offered to the research community is often just the assessment of the developed system.

Another form of IIR user evaluation is the hypothesis-based: a proposition is formulated in advance and the evaluation is set up to confirm or refute the underlined theory. In the most of the cases two interface conditions are compared to test which one works best. There is no constraint to reality: the system can effectively retrieve (Sav, Jones, Lee, O'Connor, & Smeaton, 2006) or be just a simulation (Dumais, Cutrell, & Chen, 2001); the user interface can support the accomplishment of a task (McDonald & Tait, 2003) or just collect user's answers (e.g. relevance judgement) (Oard, Gonzalo, Sanderson, Lopez-Ostenero, & Wang, 2004). The research is quantitative and targeted to evaluate a single hypothesis. Result generalization is possible, but depends on the question and the statistical significance of the results. The utility of this type of evaluation is in the evidence they offer in terms of which feature works best: designers of interactive IR should use the outcome of these types of experiments when deciding on the composition of the interface and the dynamic of the interaction.

Though different in form, these two types of evaluations should not be considered antithetic; neither should the second be considered more research than the first one. Indeed from the point of view of the advancement of interactive IR research both have advantages: the first is more innovative (i.e. a new IIR system) and offers a broader view, the second is highly focussed and more reliable. A synergistic use of the two types of evaluation would allow a better investigation of innovative interactive IR: operational evaluation provides a generic understanding, hypothesis-based evaluation provides empirical evidence.

Evaluations are the core of the user-centred design approach where iteration of design and evaluation support the understanding of the context and quality of use as well as the testing of the system performance. The next section outline the user-centred approach for information access and discusses how the different evaluations (ecological or controlled, operational or hypothesis-based) fit in the general framework. Section

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4 reports on the series of user-centred evaluations (some operational oriented, others hypothesis-oriented) periodically carried out during the design and development of a cross-language retrieval system. The aim is to discuss how the different user-centred evaluations were used to direct the design and the rationale for the choices made. All evaluations served to increase the level of understanding of the human–CLIR interaction.

3. Roles of user-centred evaluation in IIR

Until recently, the three areas of IIR, systemic IR and information seeking have for the most part followed their own research agenda. Ingwersen and Järvelin (2005) have classified the objectives of information seeking research, interactive IR research and system IR research and observed how little overlap among the three disciplines has been accomplished so far. In their view, information seeking research has been successful so far in developing a theoretical understanding of the seeking process and in providing an empirical understanding of the underlying phenomena, but has fallen short in supporting information management and system design. The reason for this lies in the focus of research, which has generally excluded the system (Ingwersen & Järvelin, 2005).

In contrast, when the IR system is at the centre of the investigation and the interaction is the focus of the research, the users are involved, but the sample is generally opportunistic (e.g. students recruited in the institution) and the context is not real. This de-contextualization allows basic interaction factors to be measured (e.g. completion time, number of relevant document retrieved) but fails in capturing the quality of information with respect to its use or the process that triggered the search activity. The dichotomy is reflected in the opinion that each other's results are of limited use: IR research sees information seeking results as short of practical utility ("unusable academic exercise" in Ingwersen and Järvelin terms, p. 2); information seeking sees IR research as lacking in understanding and abstraction ("too narrowly bound with technology" in Ingwersen and Järvelin terms, p. 2).

To overcome this separation, Ingwersen and Jarvelin advocate a holistic perspective and propose a cognitive framework of nested contexts of information retrieval, information seeking and work/interest (Ingwersen & Järvelin, 2005, p. 322). They list a set of dimensions (e.g. natural work/search task, actor characteristics, etc.) and a number of variables for each of them, and discuss how both IR research and information seeking studies should enlarge their perspective to include those aspects of the context.

However complexity increases with the number of aspects and only simple cases can be fully investigated in a single evaluation. An iterative framework can support the creation of a holistic view by composing and cumulating the knowledge derived by each single evaluation. As in the case of Clarity discussed in Section 4, user-centred evaluation can function as a deductive or inductive tool depending on the set up and the time in the system design life it is performed, and supports the researcher in moving between the theory (deductive approach, to prove a theory or confirm a hypothesis) and the empirical data (inductive approach, observations and intuitions leading to concept formation) in an abductive way (Manson, 2002).

Fig. 1 shows the design–evaluation cycle that is the foundation of a user-centred approach. There is no prescribed starting point; what is core is that each phase impacts on the following. An iterative user-centred design as the one implemented in Clarity is articulated in four phases, each encompassing at least one cycle:

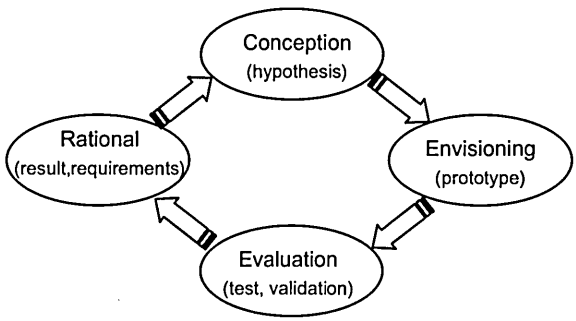

Fig. 1. The design–evaluation cycle.

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1. *First cycle: understanding users, tasks and environment*
   The first cycle should provide an understanding of the broad context of use (i.e. study the "work task", Ingwersen & Järvelin, 2005, p. 322): information behaviour research is likely to match this stage and should be used to inspire the design. Studies centred on the individual, their motivations and their environment fit this initial cycle and are instrumental to gain a generic understanding, can support the selection of realistic tasks and feed the system design phase (Whittaker, Terveen, & Nardi, 2000). The informal test of an existing CLIR system and the observational study done in Clarity (section X.1) are example of the inductive research appropriate to this stage. Indeed any implementation prototype created as a proof of concept (Hounde & Hill, 1997) can be used to start an iterative investigation and point out potential problems that could became the core of deeper investigations.
2. *Second cycle: testing ideas with low-fidelity prototyping*
   Several studies have shown that the data collected when low-fidelity prototypes (i.e. paper mock-ups) are used is as reliable as that collected with an actual prototype (Catani & Biers, 1998; Sefelin, Tscheligi, & Giller, 2003; Virzi, Karis, & Sokolov, 1996). Although rarely used in the design of IIR systems, paper mock-ups can be used at a very early stage to validate design ideas. In Clarity paper mock-ups were validated in participatory design sessions (section X.1).
3. *Third cycle: advancing system design with high-fidelity prototyping*
   As the design of the system progresses, evaluations are likely to include only part of the context of use and focus on the IIR and IR aspects, namely interaction and retrieval. Controlled evaluations that make use of real tasks and representative users are one example. Evaluations of this kind help the design progress by cumulating knowledge and understanding on how the system performs under realistic conditions and how users perceive it. More variables (in the sense of Ingwersen and Jarvelin above, i.e. different tasks, users, etc.) can be introduced and tested when previous questions have been answered and the prototype consolidated. Sections 4.2 and 4.3 describe two controlled evaluations (one hypothesis-based one more operational) that motivated the evolution of Clarity design. User evaluations done at this stage are the most important for the progress of the system design and should inspect the different software components as well as the different dimensions of the quality of use (this issue is further discussed in Section 5).
4. *Fourth cycle: overall validation*
   At this point in the project lifecycle the needed functionalities are in place (e.g. fast completion, appropriate number of translations) and the evaluation should move from a controlled setting into the real context of use and should address the quality of use of the designed system into a real work environment. Section 4.4 reports Clarity final evaluation that included ecological aspects (work context, final users and individual tasks). At the end of the iteration the user satisfaction can become the most important parameter (Su, 1992), possibly not the only one its value is strongly influenced by personality and attitude (i.e. computer anxiety) (Johnson, 2005).

The next section provides more details on how the five user evaluations performed in the Clarity project advanced out knowledge of user–CLIR system interaction as well as the system design.

4. User evaluation in action: a case for support

Clarity[1] was a EU-funded project aimed at creating an interactive cross-language information retrieval system (CLIR) for rare languages, namely Finnish, Swedish, Latvian and Lithuanian. The purpose of CLIR is to allow a user to search text documents written in a language (destination language) using a different language for the query (source language). For the retrieval to succeed, the query or the documents must be translated into the other language (or both into a third one). Translating the whole document collection from the destination language into the source language requires specific machine translation software; the translation of the query instead can be done using machine translation or a simpler bilingual dictionary (Oard, 1998). Which method can be applied might not be related to the effectiveness of the technique alone. The translation of the

[1] http://www.dcs.shef.ac.uk/nlp/clarity/.

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whole collection requires knowing in advance which languages the user could use to query; this could present problems of storage and updating.

Although machine translation is becoming more and more popular, it is still limited to the most widespread languages, for many others the only electronic resource available is a dictionary and the only option is the translation of the query. This was the case of the languages Clarity was dealing with. Therefore, in the following analysis all the evaluations refer to the mechanism of translating the query from the source language to the destination language and use the translated query to search.

From the user point of view, the process of cross-language interactive information retrieval is articulated into several steps: the user inputs a query in a source language; the system translates the query; the translated query could then be displayed to the user for validation before being used to search a collection of documents written in the target language (different from the source one); finally, the result could be translated into the user language before being displayed. Different user evaluations were run during the lifecycle of the project:

(1) to form an initial understanding of the user–CLIR interaction in order to foresee potential problems with the envisaged interface (informal evaluation of paper mock-ups and existing CLIR system during the requirement analysis);
(2) to base the interaction design on empirical evidence (two formative evaluations);
(3) to test the final design and investigate the potential of the developed technology with actual users (summative evaluation).

A detailed report about all three evaluations is beyond the scope of this paper and hence only contextually significant examples are presented. A more detailed analysis is in previously published papers (Petrelli, Beaulieu, Sanderson, & Hansen, 2002; Petrelli et al., 2004; Petrelli, Levin, Beaulieu, & Sanderson, 2006).

4.1. Testing ideas: paper mock-ups and informal evaluations

The early stages in the design of a new system are devoted to the definition of requirements, what the system will do and how. In a system-centred view, the requirements are the functionalities the system will provide. Formalism exists (e.g. UML) to precisely define use-cases that describe how the system will react to user's actions and, although the focus is on software engineering, attention is paid to the user and their social context (Goguen and Jirotka, 1994, van Lamsweerde, 2000).

As discussed in Section 3, a user-centred approach starts with a cycle of observing and understanding the user context in order to define an appropriate set of user requirements for an effective design (Hackos & Redish, 1998). Starting with the user point of view, the requirement analysis can suggest a different system than the one initially envisaged by the researchers and can therefore help in identifying and removing misconception before any final decision is taken.

Both system and user requirements are needed: system requirements provide what is technologically feasible, user requirements what is actually useful. The role of the interaction designer is to mediate between the two (often contrasting) points of view and come out with a compromise that exploits the technology in a way that users would find valuable. This mediation takes place during the conceptual design: an abstract picture of what information and functions are needed for the system to achieve its purpose is outlined together with a conceptualization of the envisaged solution and how that conceptualization will be communicated to people (Benyon, Turner, & Turner, 2005). The conceptual design feeds the physical design: interface and interaction details are fully specified and linked to internal functionalities (Benyon et al., 2005).

4.1.1. Goal and set-up

Clarity user requirements were the outcome of a field study (Petrelli & Beaulieu, 2002; Petrelli et al., 2002). Five complementary techniques were used to collect data and compose a picture as extended and realistic as possible[2]: contextual inquiries, interviews and questionnaires allowed users and tasks to be classified, while

[2] These are just a few of the many techniques that can be used to collect user requirements (Hackos & Redish, 1998).

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informal evaluations of an existing CLIR system and participatory design sessions were used to test Clarity preliminary ideas against potential users. Informal evaluations and participatory designs can be seen as kinds of user-centred evaluations and are therefore discussed further.

In line with the few interactive CLIR systems available at that time (Ogden et al., 1999, Ogden and Davis, 2000, Capstick et al., 2000), the Clarity interaction was split into two phases: query translation checked by the user followed by actual search. Key points of the interaction were captured in paper mock-ups. In the participatory design sessions, scenarios of use describing a user and his/her information needs were discussed with participants and used to explore the interaction with the system visualized by the mock-ups. The use of paper mock-ups instead of a working prototype to test initial ideas had the advantage of focussing the discussion on the functionalities instead of the layout; working with paper mock-ups users felt free to actively contribute by proposing (i.e. drawing) a different interface that better reflected their view and was not perceived as being dismissive of the work already done.

In the informal user evaluation, participants were observed trying out ARCTOS[3] (Ogden and Davis, 2000), a CLIR system which was available on-line at the time of study. Although it could be set up as a formal evaluation (i.e. with tasks to accomplish and measures taken), this test was left informal and user directed. The intent was to observe how users would naturally interact with a CLIR system that shared some design rational with ours. Participants were questioned during the interaction in order to gain a better understanding of what was in their mind.

4.1.2. Data analysis and results

Both studies were videotaped. The analysis was qualitative and based on observations of participant's behaviour; users' activities were decomposed using six dimensions: goals, tasks, acts, community, practices and procedures, opinions and suggestions. Affinity diagrams (Hackos & Redish, 1998) were created to cluster users' activities around few common and recognizable phenomena. Users were then classified respect to their ability, attitudes and expectations; requirements for each user class and the whole community were listed.

The two evaluation sessions pointed out potential problems with the anticipated user–CLARITY interaction. Users were not interested in controlling (or did not know how to control) the query translation step, nor were they interested in graphical visualisations of the global result. Instead, a simple mechanism of typing in the query and receiving back the list of relevant documents was expected.

A tension emerged between CLIR common practice (i.e. display the query translation for user validation) and user expectations (i.e. display the search result). Instead of choosing one of the two directions, a comparative user test was set up to investigate the two conditions in a more formal setting.

4.1.3. Lesson learnt: the value of informal user evaluation

Trying out our ideas with users at a very early stage in the project design was essential to raise our awareness of potential problems in adopting the user-supervised solution as the interaction mode. The use of paper mock-ups and scenarios supported the participants in getting a grip on what the system would do and the low-technology setting was ideal to allow them to actively contribute.

The informal evaluation with the ARCTOS system was equally informative: By observing participants struggling with the query translation and the result display we became aware of how unfamiliar users would be with basic concepts of cross-language retrieval.

4.2. Learning by doing: user evaluation as an exploration tool

4.2.1. Goal, set-up, and data

A comparative user evaluation was undertaken to empirically investigate the two approaches (Petrelli et al., 2004):

[3] Screenshots of the ARCTOS system are available at http://crl.nmsu.edu/~ogden/i-clir/cltr-interactive/arctos/pagel.html (accessed 23.3.2006).

- *Supervised:* derived from the CLIR/IR literature; this required the user to check the translation before the search was done;
- *Delegated:* derived from the requirements analysis; this required the user to only input the query, then the system would translate it and search without any user intervention.

The experimental design followed the CLEF[4] framework (Gonzalo and Oard, 2002): a collection of newspaper articles, four topics (+ 1 for training) with their corresponding relevance assessment were used. Six English native speakers with no knowledge of Finnish searched Finnish documents; in addition to a training task, they performed four tasks, two on each system. Users were given a simulated task (Borlund, 2000) derived from the CLEF 2002 topics and were asked to retrieve relevant documents; documents judged as relevant were saved in a ad hoc list. The total time of the experiment was 3 h. Queries and relevance judgements were logged and time-stamped; questionnaires on user profiles and satisfaction were collected; observations were made whenever possible.

The data was not consistent enough to statistically select one interaction as the best and another test (3.3) was run later for this purpose. However the data was analysed through a qualitative inspection of the user's actions. All the user's queries were compared to the query translation (if presented to the user), the result displayed and the follow-up query. This allowed patterns of behaviours to be identified, as discussed below. The relevant judgements were analysed to assess the effectiveness of the result display: the documents selected by the user as relevant were compared with the list provided by CLEF in order to identify correct selections; false positive (documents judged as relevant by the user but that were not relevant in CLEF assessment) and false negative (documents not selected as relevant but that were listed as relevant in the CLEF assessment) were considered as well. System weaknesses emerged in both user interface and system functionalities.

4.2.2. Results and changes

The user's perception was most affected by the speed of the system: every single user complained about the fact that the system sometimes needed minutes to return results. The system's architecture was redesigned and strategies were adopted to make the system more efficient (e.g. pre-translation of the titles). A response time of 5 s[5] was set as usability target in further tests.

The second weakness was the number of translations used for polysemic words. All the senses were included which made the search inefficient and the user confused as when, for example, the Finnish for "golf pitch" was proposed as the translation of "green". The number of translations was then reduced to the three most common. This also greatly simplified the result display as titles and keywords were translated using the same mechanism.

Seeing the query translation affected the whole interaction. The analysis of logs showed a tendency to change the query before the search if the translation included ambiguous terms. A user started with "green power" but ended searching with the non-ambiguous query "wind turbine", thus potentially missing relevant documents.

Proper names were widely used by participants but badly managed by the system. Some names where in the dictionary (e.g. Europe) thus were translated, others where not (e.g. Alzheimer), and others were wrongly translated (e.g. "Bobby Sands" a famous hunger striker was translated into the Finnish equivalent of "policeman beach"). Fuzzy name translation (Pirkola, Toivonen, Keskustalo, Visala, & Järvelin, 2003) would probably resolve the non-translation but not the misleading one. A new feature was introduced to allow the user to mark terms which must not be translated.

An overwhelming preference for the Delegated mode (70%) over the Supervised one (15%) emerged from the questionnaires thus reinforcing what found in the field study (15% were neutral).

[4] CLEF stands for Cross-Language Evaluation Forum and is the annual evaluation campaign for research on cross-language information retrieval for European-based languages (http://www.clef-campaign.org/ accessed 10.7.2006).

[5] Jacob Nielsen reports (pp. 44) 10 s as the limit for keeping the user's attention focussed on the interaction and 1 s as the limit for the user's flow of thought to remain uninterrupted (Nielsen, 2000). By setting the response time to 5 s we were confident the interaction would be fluid enough to be successful.

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4.2.3. Lesson learnt: the value of qualitative analysis

The high variability in the data prevented any statistical analysis. Variability was due to task feasibility, user's search skills and tiredness:

- *Tasks:* one task was unfeasible (i.e. no user retrieved any document) and for another there was a very low success rate. Although being in the worst condition stimulated users into trying new strategies (which was positive for qualitative studies), the amount of data collected was affected by a nearly 40% reduction. Moreover some users can experience high level of frustration.[6]
- *Users:* search attitude was measured by a self-rating questionnaire that indicated participants formed a homogeneous group, but the user's actual engagement with the search task (e.g. number of queries issued, number of different terms used) and the user's search effectiveness was disparate. A homogeneous group of users is needed to collect consistent data, essential in the early phases when the system is in evolution as its performance is the object of the study: variation in the performance can then be attributed to the different system design and not to the different users' capabilities. When a consolidated prototype is available, different classes of users can be involved to test the system under different conditions and detect previously uncovered problems (Caulton, 2001).
- *Tiredness:* the engagement with the search tasks dropped steeply in the last two tasks for two of the six users.[7]

These issues were taken into account when the next user evaluation was designed and effort was spent to mitigate the negative effects. By controlling task feasibility, user's ability, and evaluation duration more closely, we hoped to collect more reliable data that could be statistically analysed.

The data collected was very rich in terms of user behaviours: by analysing user's interactions we were able to detect pattern of behaviour that negatively impacted upon the system effectiveness, i.e. the focussing of the query after having seen the translation and before the search. Through the qualitative analysis technical limitations were also detected, e.g. the weak translation of proper names. Faults and weaknesses gave suggestions of what needed to be changed to make the interaction more successful. A statistical analysis would not provide such a rich set of inspiring examples of actual CLIR use that helped in re-focussing the design.

4.3. Directing design: controlled user evaluation

4.3.1. Goal, set-up, and data

The new clarity prototype took advantage of the changes made after the previous evaluation and was tested in a second formative evaluation (Levin & Petrelli, 2003). The same text collections and relevance assessments as in the previous evaluation were used but a different set-up was planned to reduce data variability. The experiment was shortened with only one task per system; the two chosen were those with the highest success rate in the previous test across all users. Participants were eight Finnish and eight Swedish native speakers (bilingual with English) who tested four language pairs (En → Fi; Fi → En; En → Sw; Sw → En); subjects were screened through a practical task to confirm their search skills (participants used Google to search for "jaguar" – the animal, not the car – we observed their skills in generating new terms and disambiguate the query). More sophisticated tests can be set up to investigate users' ability (Saracevic, Kantor, Chamis, & Trivison, 1988), however to recruit people with similar searching skills or, at least, to exclude the worst, this simple screening was considered enough.

The exhaustive data collection encompassed: (i) full log of the time-stamped interaction (e.g. queries, selection on the interface, documents opened, etc.); (ii) videos of user's actions and comments; (iii) questionnaires and interviews.

[6] Participants can show real discomfort if they feel they are performing badly independently from the reassurance of the experimenter. During the evaluation of an image retrieval system two participants out of eight asked how the others had performed and did not want to give up the task even if the time had elapsed.

[7] Other two were consistently effective and two were consistently unsuccessful during the whole test.

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4.3.2. Data analysis and results

The data collected was rich in both objective and subjective measures; *objective* measures pertain to facts (like the number of terms and queries issued by each participant or completion time) and were recorded in logs, while *subjective* measures pertain to users' opinions (if they liked or disliked something) and were collected in questionnaires and interviews. Data was analysed both quantitatively and qualitatively. *Quantitative analysis* used aggregated values of objective measures to determine system efficiency and effectiveness while subjective measures were used for user satisfaction. Observation and interviews were used in *qualitative analysis* to inspect each interaction and scrutinize behaviours.

The interaction was measured with respect to *efficiency, effectiveness* and *user satisfaction*. Efficiency was measured in time needed to get an answer from the system and effort spent. The threshold of 5 s was generally kept and no user complained about system speed. The effort spent was calculated in terms of number of user's actions. The mean of queries issued in the Delegated Mode (DM) was higher than in the Supervised one, but the difference was not statistically significant. However, the Supervised Mode (SM) offered the user the possibility of deselecting translated terms. Then the number of queries was used as measure of engagement with the DM interface, while for the SM the measure includes both the number of queries and the number of deselected terms. A paired-samples t-test was conducted: There was a statistically significant increase in the engagement from Delegated ($M = 6.23$, SD $= 3.44$) to Supervised ($M = 9.62$, SD $= 5.05$), $t(12) = -4.58$, $p < 0.001$. Indeed the possibility of deselecting terms was central as all the users deselected at least one sense (and up to 6) from those offered by the Supervised interface. The number of deselections depended upon the words used in the context of the search task. In summary, the users interacted more with the Supervised mode, but produced less queries.

To assess the overall effectiveness of each interaction mode in supporting query formulation, average precision and recall (P and R) measures were calculated. The measurement took place at display time, before the users bookmarked the relevant documents. In other words, as for the batch approach, the output of the search was used to calculate P and R. This was done to avoid biasing the objective measure of effectiveness with the variability inherent in a subjective relevance judgement (Mizzaro, 1997). In this way precision and recall measure the effectiveness of the query formulation step in isolation from the rest of the interaction. User relevance judgement was used to assess the effectiveness of the result display.

Although SM performed better ($P = 0.206$, $R = 0.473$) than DM ($P = 0.167$, $R = 0.418$), the differences were minimal and not statistically significant when a paired-samples t-test was applied. However, such small difference is still meaningful from a user point of view as it corresponds to at least one more relevant document being retrieved out of the 12–17 available in the collection, that is to say a 6–8% increase.

Users' relevance judgement was used to assess the effectiveness of the output display alone. The assumption was that a good presentation would allow the user to select a high percentage of the relevant documents retrieved and displayed. The portion of relevant documents correctly identified out of the set of the relevant documents retrieved was used. This can be seen as a sort of precision calculated on the basis of the retrieved set and not in relation to the whole document collection. The rationale behind this is that if relevant documents were not retrieved, the users had no chance to select them, therefore this distinguishes the effectiveness of the retrieval mechanism and effectiveness of the display. As the display was equal in both systems the result was cumulated giving a precision at display time of 0.57; this was not a high performance considering users were native or fluent in the target language and can be partially explained by the behaviour of judging relevance by the title, as discussed below in 4.3.3.

Users marginally preferred DM (Delegated = 50%, Supervised = 37.5%, Neutral = 12.5%) but the difference was small and decreased greatly from the previous test (Delegated = 70%, Supervised = 15%, Neutral = 15%). Interviews allowed the interpretation of the questionnaire results. Users' dislike for SM was related to a perceived slowness or the unnecessary obligatory step of checking the query translation and not to interaction complexity. Many users favourably commented on their increased control of the system and the inspiration for new terms which occurred in checking the translation.

Once again a contrast emerged from what the user preferred (Delegated) and what was more effective (Supervised). However in light of the insight offered by the interviews, the final interface is a compromise between Supervised and Delegated: the final interface automatically translates and searches (Delegated),

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and then the query translation is displayed on top of the result list (Supervised). In this way there is no interruption in reaching the result but the user can review the translation if the result is poor.

4.3.3. Lesson learnt: the importance of replication and the fallacy of measures

By keeping the same evaluation set-up (i.e. same document collection, same queries) we were able to compare if the interaction improved with the new design. The focussing of the query when seeing ambiguous translations recorded in the previous evaluation nearly disappeared. Thus the new layout did not stimulate a potentially negative behaviour and search effectiveness was not hampered.

The set of relevant documents selected by participants was analysed with respect to correct and incorrect relevance judgement. The number of non-relevant documents selected as relevant was surprisingly high as participants were fluent speakers in the target language. Only 50% of the documents "wrongly" selected as relevant by participants had been actually assessed; the other half was not in the CLEF pool and therefore had never been seen by any assessor.[8] The assumption that those documents were not relevant was then likely to be false.

The fact that documents which were rated as relevant by the assessors were not selected by the users was unexpected. Participants' behaviour was then analysed: they did not open (thus did not get the chance to read) the documents retrieved and judged the relevance from the title therefore discarding documents listed as relevant but that did not contained keywords in the title. This further confirms what was discussed by Mizzaro (1997) about the surrogate-based relevance judgement with the title surrogate performing worst. The use of relevance judgement as a way to measure the effectiveness of the whole system is therefore put into question.

4.4. Final system assessment: stepping out of the lab

4.4.1. Goal and set-up

The evaluation of the final prototype was a summative evaluation of the work done over the three years (details in Levin & Petrelli, 2004). In addition to the tasks and questionnaires previously used, participants were invited to bring a topic of their choice. The intent was to relax the controlled condition and move toward a more ecological setting, i.e. users with their individual task searching in their natural setting. Indeed the setting of this evaluation differed from the previous formative ones as: it was done at the user's premises and a single system was tested in all its aspects. Participants were eleven information professionals belonging to the user classes identified in the first user requirement study. They were business analysts, journalists, librarians and translators, people likely to use CLIR technology in the future. As the first showed (4.1 above) each class had different goals, expertise and attitude and we were interested in investigating how that variety of users experienced the Clarity system.

Users were assigned three tasks to test the different parts of the system (i.e. one-to-one cross-language retrieval, multilingual retrieval, concept hierarchy browsing) and were required to bring a topic of their choice to test cross-language retrieval from English to Latvian. The three tasks assigned were those used in the previous evaluations: knowing tasks and system performance in advance allowed us to outline expected users' behaviour and to question them if they did not conform.

Topics chosen by participants for the fourth task included: the Eurovision Song Contest, the restoration of Riga's Opera House, the status of Russians in Latvia, and Latvian foreign policy. None of the participants could understand Latvian, all thought the system had retrieved documents relevant to their query and felt the translated titles and translations of terms found in the documents were helpful enough to be able to judge whether a document was relevant or not.

4.4.2. Data and results

The data collected was both objective and subjective, though this time subjective measures (e.g. user's feeling and comfort) were considered more important than objective ones (e.g. completion time, documents

[8] The reliability of the relevance assessment with a pooling method depends on the number and variety of search engines involved: the more and diverse the engines the more reliable the judgement.

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retrieved). Results showed that the final system was robust, fast, accurate, easy and appealing to casual users. Comments were extremely positive and critiques were limited to very minor problems, e.g. keeping the translation selection from one turn to the next.

In the previous tests we discovered participants did not read the documents but judged the relevance from the title. This time we could ask the users' "why". Participants stated that "this is not real life! In real life I would read through even 200 documents if it matters" and "I have already got enough documents so I do not bother about others" and "I first collect what seems useful and read the material at a second stage". Each answer explains the behaviour of not reading the documents and judging the relevance from the surrogate, but it does not help in making relevance judgement a more reliable measure. The paradox discussed in Section 2.1 is emerging again: a more realistic evaluation with real task and use prevent comparison; an experimental set-up for comparison is not ecological. Researchers should consider this tension when deciding to use relevance judgement as primary measure of IIR.

4.4.3. Lesson learnt: user evaluation to explore the future

The "hybrid" evaluation adopted here, partially controlled and partially free, allowed monitoring the system improvement in respect to the previous prototype (the controlled condition) but also supported a shallow investigation on how the Clarity system could affect users' work. The fact that participants were required to formulate their own topic to search documents written in an unknown language prompted discussion on personal work (all the topics reflected their own work interest).

From the perspective of system development tasks variation becomes an issue when the major questions on design have been answered (Whittaker et al., 2000). Thus it is toward the end of the project that several tasks with different degrees of complexity are worth testing. Asking the user to use their own topic to search the collection of Latvian newspaper articles allowed us to test the system in a broader sense and gave us the chance of discussing the condition of searching unknown languages (none of the participants could understand Latvian).

5. User-centred evaluation as an inspection method

Controlled user evaluations were instrumental to make the Clarity design progress (Section 4.3). The setting adopted allowed to inspect both the software components (query formulation support, retrieval, and result visualization) and the user-interaction thus providing the Clarity team with a full understanding. The setting adopted is the topic of this section.

5.1. Separating and inspecting IIR components

The quality of retrieval is commonly measured at the end of the interaction. A single measure of the whole interaction (being that Precision and Recall or more user-centred ones, like in Su, 1992) cannot expose what is really going on beside the interface. Experimenters would gain no insight into what were the negative factors: Was it the query formulation step that failed? Was it the search technique that was not robust enough? Was it

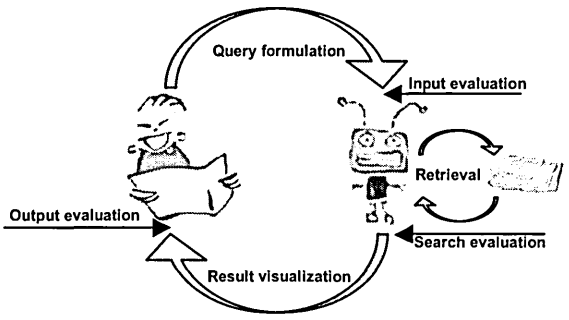

Fig. 2. Measurement points in the IIR cycle.

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the inappropriate display of the results? To gain full understanding, the different components of an IIR system has to be separated, measurements need to be taken during the whole interaction and related to the appropriate sub-task:

1. The user formulates a query in some form compatible with the modality required by the system input;
2. The system searches using internal algorithms;
3. The result of the search is presented to the user to evaluate.

Steps 1 and 3 pertain to the user interface, while step 2 is concerned with more technical issues (i.e. software architecture, searching algorithms). Inspecting each component separately allows locating where the problem is and why it occurs. This can be achieved by introducing intermediate measurement points. Fig. 2 exemplifies this concept; the evaluation should determine: (i) if the system adequately supports the user in expressing their needs; (ii) if the search mechanism is effective given the user query; and (iii) if the presentation of the results is good enough for the user to detect the relevant documents. Data should then be collected at each point.

The data collected should be both objective and subjective and should be analysed quantitatively and qualitatively. Indeed the aim of the evaluation is not just to assess the system performance, but to monitor the interaction and highlight cognitive aspects to be understood. The Clarity case showed that a rich set of data could be analysed in multiple ways; data collected included:

- *automatic log* (at each point): collect objective data (e.g. completion time, query terms, query number, clicks, document retrieved, documents seen) to be analysed quantitatively (to determine efficiency and effectiveness), as well as qualitatively (to find out problematic queries or unexpected behaviours);
- *observations of interaction:* collect information the log generally misses (e.g. user's attention, scrolling activity) to be analysed qualitatively;
- *interviews:* collect users' opinions and allow to ask questions about the observed behaviours (qualitative);
- *questionnaires:* collect users view on specific points and measure "how much" (e.g. system speed, reliability, layout) and therefore provide subjective data to be analysed in a quantitative way.

Quantitative analysis should measure effectiveness, efficiency and user satisfaction (as in the ISO definition of usability (Van Welie, van der Veer, & Eliens, 1999) as inconsistency between objective and subjective measures is not unusual when complex systems are evaluated (Sellen, 1995; Whittaker, Geelhoed, & Robinson, 1993; Frøkjæsr, Hertzum, & Hornbaek, 2000; He, Wang, Oard, & Nossal, 2002). In Clarity (4.3) the most satisfying system (subjective) was not the best performer (objective). The qualitative analysis of users' behaviour provided an explanation for the phenomena and supported the designers in taking an informed decision on the final layout and interaction. Qualitative inspection should not be limited to the user–system interaction: search failures and mistranslation of proper names were identified through an analytical study of the recorded log (4.2.2). Qualitative analysis can also produce new research questions (e.g. why users did not open relevant documents 4.3.3) that can be explored in following evaluations.

The Clarity project shows that both quantitative and qualitative analysis should be done as they provide different insight; the first addresses the *what* the second the *why*. They should be considered as a kind of triangulation inside the same evaluation that allows covering multiple aspects and supporting cross-checking of the results thus improving the robustness of the findings.

5.1.1. Query formulation

Query formulation often determines the success of the whole interaction. CLIR is the ideal setting to show its importance, as the query translation is part of the query formulation step. The failure to correctly translate proper names was identified at this point by inspecting the log and comparing the query as entered by the user and the one used to search. Similarly, another CLIR user-centred evaluation (Petrelli & Clough, 2005) revealed a numbers of improper translations of polysemous words that negatively affected the search.

However, query formulation is not just a matter of internal mechanism, the user interface also has a strong impact. Deciding which indicators are the most appropriate is crucial. Indeed, it could be more sensible to measure the success of the query formulation at the search evaluation point in terms of relevant documents

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retrieved: the higher the number of relevant documents retrieved the more effective the query session has been. Thus, precision can be used as a measure of effectiveness of the query formulation step.

To fully understand how much effort the user had to make to get a satisfactory outcome, efficiency needs to be addressed: the number of queries issued, the number of different terms used, and the average length of the queries can be considered as indicators of the level of user's effort (Belkin et al., 2003). The correct measure is then a balance between the effort spent in formulating a good query (efficiency) with its success (effectiveness). In Clarity (4.3.2) more effort was required by the supervised mode in terms of the number of actions, but the number of queries was less and the number of documents retrieved was higher.

5.1.2. Retrieval

The time the system spends in searching is a good indicator of efficiency, whereas the classical indices of precision and recall are both measures of effectiveness (Dunlop, 2000). However, the examination of the performance of the search module should not be limited to the quantitative level; a qualitative analysis can be much more powerful in showing how the system is performing with respect to the user's query. For example, in the first Clarity evaluation (4.2), the queries "gene DNA disease" and "DNA genetic disorder", although semantically equivalent, returned different relevant documents. Qualitative diagnostic analysis is instrumental in detecting weak points and can inform us about how to improve search functionality. In Clarity, for example, discovering the wrong translation of proper names suggested a mechanism to by-pass that step. Examples of critical queries extracted from log data can be collected to build a corpus of actual user queries. This can be later used as user-simulated input during system tests without directly involving users (as done by Zhang, Chai, & Jin, 2005).

5.1.3. Result visualization

An interface that fails to display results effectively may hamper the successful use of the whole IIR system. Relevant documents retrieved can be used only if the user is able to identify them. An effective layout is important in general but becomes crucial when new forms of information retrieval are under investigation, e.g. multimedia IR, ubiquitous and mobile IR.

The effectiveness of the display strategy can be measured by considering the portion of relevant documents correctly identified out of the set of the documents retrieved, a sort of precision calculated on the basis of the retrieved set and not in relation to the whole document collection. This measure can be complemented with the measure of the portion of relevant documents wrongly judged by the user as non-relevant, i.e. the fallouts (Tague-Sutcliffe, 1992).

Even though relevance judgements have been the core measure for a long time (Mizzaro, 1997), they can be a weak measure if it is not known which documents have been judged by the assessors or how the assessment was done (on title, surrogate or the whole document). This is likely to happen when a pooling system is used, as in TREC (Harman, 1995), as only a subset of the text collection is assessed. Thus it is possible that other relevant documents are in the collection but are considered non-relevant because no assessor has read them through (as we discovered in 4.3.3). Researchers should be aware of the potential problem and use this measure with caution, by for example introducing a further measure as an external judgement of the quality of the answer/solution given by the user (Hertzum & Frokjasr, 1996).

6. Conclusions

The importance of user evaluation of IIR systems is becoming more widely accepted and typically involves user testing at the end of a project. Although it is essential to assess the system as a whole, user-centred evaluation also allows exploration of new forms of information access when performed iteratively. Evaluations are set at specific times in the project lifecycle to elicit different information: preliminary ideas can be tested using paper mock-ups and/or already existing systems; early tests with partial prototypes allow the system's potentials and limits to be explored; empirical evidence for design choices can emerge by evaluating consolidated prototypes and finding out how the system would perform in real life.

The complex interaction between a user and an interactive information retrieval system should consider the search engine as separated from the input mechanism and the result visualization. Only by measuring each

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sub-task separately from the others is it possible to gain the micro-view needed to assess the effectiveness of each component.

The process of iterative evaluation, instead, provides the macro-view of IIR. Iterative evaluations can be done involving a limited number of participants, though the total number of people involved is comparable to a solid user-centred evaluation: in total 43 people participated in the Clarity studies. The strength of this approach lies more in the exploration of several solutions than on the definitive result of a single experiment. By iterative testing it was possible not only to state that the supervised mode for cross-language information retrieval was more effective but less preferred by users than the delegated one (as also He et al., 2002) but it allowed us to understand why and to reach a solution that was both better performing and most preferred. The user-centred evaluation then becomes a research tool that the experimenter can bend to the research needs; it is a form of longitudinal study applied to the IIR system.

User-centred evaluations are generally used to confirm or refute a hypothesis or to test a system. When used in formative evaluations as tool to explore innovative IR interactions, user-centred evaluation should aims at provide a complete picture; this can be achieved only if the range of data collected is rich in both objective (e.g. completion time, number of queries and terms) and subjective data (e.g. users' opinion), and if this range of data is analysed quantitatively as well as qualitatively. This makes possible a triangulation of data that better informs on the solution under study and does not stop at the "what" but reaches up for the "why".

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