iHCI 2014: Proceedings of the 8th Irish Human-Computer Interaction Conference

"Shaping our digital lives"

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Dublin City University

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iHCI 2014: A Preface

The Irish Human Computer Interaction (iHCI) conference is regarded as a key event that brings together a broad range of well-established academics (professors, lecturers, researchers, post-docs, research students) as well as industry and practitioners in the HCI domains in Ireland. iHCI was initiated in order to support networking in the Irish HCI community, with two primary goals: to establish fruitful collaborations; and strengthen the awareness of Irish research as world leading in the area of HCI. iHCI has been running for 7 years and organised in different locations within Ireland each year. iHCI organisers are constantly adapting the focus and structure to keep up with the ever-evolutional scope of HCI.

This year, in iHCI 2014, we have chosen “Shaping our Digital Lives” as a key theme that reflects how technology influences our personal and professional life, and the challenges associated in designing and deploying innovative and collaborative technologies that ultimately shape our lives. We believe that the organisation of iHCI around this theme which fits into the Personal Sensing strand of Insight, will allow people interested in human computer interaction in Ireland to engage in discussions around the modern industrial and market trends in this domain.

In order to push the Irish HCI community research and practice, two initiatives will be introduced in iHCI 2014. The first is a set of masterclasses for students that will allow active newcomers to interact with experienced researchers and industry partners and second is the invitation of keynote speakers who are well known in the HCI domain to bring exposure to the Irish HCI community.

This year, we are particularly excited about the presence of industry partners and excellent national and international keynote speakers. And we would like to thank Chris Dancy, Dr. Mark Hughes, Dr. David Monaghan, Dr. Graham Healey, Dr. Mark Magennis, and John Wood for their participation in making iHCI 2014 successful.

iHCI 2014 received in total 26 submissions; with a full paper acceptance rate of 60% (9 accepted papers out of 15 submissions), and short paper acceptance rate of 73%. A total of 61 people attended the event over the 2 days.

Gender diversity was also important throughout the organising committee. This consists of 2 iHCI chairs (1 male Rami Albatal and 1 female Niamh Caprani), external PC chair (female Julie Doyle), local chair (female Yang Yang), and PC (12 male, 8 female).

Finally we would like to take this opportunity to thank all of the authors as well as the hard-working programme committee members and reviewers as well as the session chairs and others who provided their time. Without their effort, iHCI 2014 could not have achieved such a strong programme. We would also like to thank Science Foundation Ireland and Insight Centre for Data Analytics for their generous support of the event.

We hope you enjoy the conference!
Rami Albatal, Julie Doyle, Yang Yang
Alan Smeaton & Niamh Caprani

Acknowledgements

iHCI is a collaborative effort designed to bring the Irish HCI community together. iHCI could not exist without the input and hard work of many people, especially those who take the time to review the submissions we receive. As a result, we would like to acknowledge the efforts and the contributions of the reviewers, the various committee members and session chairs, and of course the sponsors who make this conference possible.

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Full Papers

Fluctuations in Frustration Levels of Gamers Versus Non-Gamers

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ABSTRACT

This paper presents the results of a test conducted to determine the fluctuation in frustration levels of gamers versus non-gamers when playing computer games. The initial hypothesis states that gamers experience more pronounced fluctuations in mood while playing computer games. The test software was designed as a 3D first person shooter game that has a changing game environment. The test aims to intentionally disrupt widely accepted gameplay conventions to calculate the resultant mood changes of the participant.

Categories and Subject Descriptors

The Vizard Virtual Reality Toolkit provided the 3D models and environment for building the game to test the hypothesis. The project code was written in the Python programming language. The Vizard 4.0 documentation library was used as a code resource to implement the functionality of the game used for the test.

Keywords

IADT (Institute of Art, Design & Technology),
WASD (QWERTY keyboard controls)

1. INTRODUCTION

Many computer games contain violent, aggressive themes and objectives, which can inadvertently elicit negative emotional responses such as anger and frustration. While investigating the validity of this statement a paper entitled: *Video Games and Real-Life Aggression: Review of the Literature,* proved to be a vital resource to support this hypothesis. This paper by Bensley and Van Eenwyk [1] acknowledges that violent games can cause societal aggression and antisocial behaviour. Their research was conducted on primary, secondary and college students, and comprised a variety of test conditions and thorough pre and post-test screening exercises. The sample conducted on university students proved to be the most relevant for our purposes, and it showed a fluctuation in a participant's mood was evident as a result of playing both violent and nonviolent games.

Bensley and Van Eenwyk [1] state that, 'those individuals who reported having played video games when tense most often reported that game play made them slightly less tense, and those who reported playing when calm or relaxed most often reported that gameplay made them slightly less calm or relaxed.' This insight into mood fluctuations while people play computer games provided the basis for the hypothesis herein. Gamers play games as they are, 'primarily motivating to the extent that players experience autonomy, competence and relatedness while playing [2].

This reference from *A Motivational Model of Video Game Engagement,* investigates gamer's motivations to play and improve their gaming ability, which is seminal to another one of our primary sources; one that attempted to classify gamer's on a scale from novice to expert. The findings from this study proved that frequency of play is a factor in classifying a gamer, but so are game controls that are congruent with accepted 'rules'.

In most games there is an established set of mechanics that gamers intuitively understand due to their familiarity with various types of games. Whether it is a first person shooter or third person role playing games, basic controls and objectives usually remain consistent, which allows an experienced gamer to instantly adapt to a game they have never played before. Any deviation from this known formula could have a negative affect on the gamer's mood, 'need satisfaction predicted motivation to play, whereas need frustration was seen to predict a lack of persistence in play [3].

Our hypothesis will add that the lack of consistency that non-gamer's experienced playing our test game will be less pronounced in gamers due to their increased familiarity with the gaming medium.
This paper proposes that gamer's may perhaps experience a more dramatic change in frustration levels because of their frequency of play and exposure to the gaming medium.

It was believed that if an experiment comparing gamers and non-gamer participants could be developed to test this hypothesis then the results could provide a valuable resource for professionals in search of a greater understanding into the behavioral pyschology of gamers.

2. METHODS & MATERIALS

2.1 Identifying participants

A sample of 16 participants was taken from students at IADT whose study areas included, Multimedia Programming, Business and Visual Communication Design. These participants were divided into two categories: eight gamers (7 male, 1 female) and eight non-gamers (4 male, 4 female). The mean age of participants was 20. The two categories were determined by a questionnaire taken before and after the test.

2.2 Test Settings

The experiment took place in a classroom environment where participants were allocated a test machine with pre installed 3D emulation software as shown in Figure 1. The game was built using the Vizard VR environment and programmed using Python. The software emulated a typical first person shooter video game containing four different levels. Players navigate the 3D environment seeking out the correct targets and eliminating them within the time limit. The game screen has two interface components that are important to note.

1. The Timer that counts down to 0 (e.g. starting time is 90 secs)
2. The Targets remaining label that shows the current amount of targets remaining.

Each game level begin with 5 targets (except Level 4) that must be found and eliminated within the time limit. There are two types of target: a male and a female human character, but only one is the correct target. Identifying the correct target to shoot is found by analysing whether the UI component showing the targets remaining has decreased after a target has been shot. Participants are briefed on the basic gameplay mechanics prior to the test, and are put through a practice level to familiarize with the game.

The starting conditions for each level is as follows:

1. 90 second time limit. Targets remaining is 5.Find the 5 human male targets and shoot within the time limit.

2. 90 second time limit. Targets remaining is 5. Find the 5 human female targets and shoot within the time limit. Movement controls are inverted.

3. 60 second time limit. Targets remaining is 5. Find the 5 human male targets and shoot within the time limit. Targets run away when approached.

4. 90 second time limit. Targets remaining is 27, but shooting a target increases score. Every 10 second score decreases by 8. Targets run away when approached.

2.3 Test Controls

The game environment is navigated using the WASD keys of a conventional QWERTY keyboard to move forwards, backwards, left and right respectively. The mouse is used to control head position (i.e. turning around). The shoot mechanism is triggered with the left mouse click.

2.4 Measured Variables

The aim of the experiment was to collect data that would prove that gamers experience higher frustration levels when compared to non-gamers. As the sample data was small, it was expected that the experiment would only develop the hypothesis rather than prove it outright.

2.4.1 Score variable

Each level has an indicator to show the number of targets remaining. The number of targets eliminated was accumulated for each participant throughout the levels to denote the participants overall game performance.

Figure 1 - 3D Game environment

A sample of this scorecard is shown in Figure 2. This variable was chosen as it was a reliable indication of the test participants aptitude and performance in the game.

2.4.2 Questionnaire:

Testing with a small sample size directly affected the 'response rate' [7] of a questionnaire that was designed for the test. To improve accuracy, it was decided not to use an anonymous questionnaire and instead the choice was made to interview each participant in person. Three studies reported by Lelkes et al. [8] demonstrate that allowing college student

	Participant 01		**Participant 02**		**Participant 03**		**Participant 04**	
	Time Remaining	Targets Remaining	Time Remaining	Targets Remaining	Time Remaining	Targets Remaining	Time Remaining	Targets Remaining
Level 1	0	2	24	0	0	3	0	1
Level 2	0	3	0	5	0	1	46	0
Level 3	0	4	1	0	0	3	0	2
Level 4	0	9	0	38	7	6	9	0
Avg.	0	3	8.33	1.66	0	7.33	15.33	1

Figure 2 - Test scores sample

participants to answer questions completely anonymously sometimes increased reports of socially undesirable attributes, while consistently reducing report accuracy.

The questionnaire was given to the participants after completion of the test. Prior to the test, participants were asked how frustrated they were on a scale of 1-10 (1 being very happy, and 10 being ready to commit a violent action against another person). The question was reiterated at the end of the test. Additional questions were also asked to reliably discern whether the test participant was indeed a gamer or not. Some participants said they were not gamers, but it turned out they had in fact been a gamer at one stage in their lives, which - due to familiarity - places them in the category of gamer. The results of the questionnaire for non-gamers is shown in Figure 3.

The questions were used as an additional way of measuring a participant's experience of playing the game and assessing their frustration levels. Data from the questionnaire was compared for two conditions, whether participant's felt more frustrated or less. Additionally as an academic exercise, participants were asked to explain if/how the game environment and objectives changed throughout the test and whether they noticed the changes or not.

2.4.3 Temperament variable

Physiological responses could not be measured in this experiment; so instead a second 'temperament' variable was used to measure a participant's frustration. The variable was extracted from the questionnaire, where each participant was asked to rate their mood before and after the game.

To further ground the temperament variable, participants responses were closely monitored during the experiment. Kawaluch [6] believes, 'participant observation can be used as a way to increase the validity of the study, as observations may help the researcher have a better understanding of the context and phenomenon under study'. Any words, phrases and gestures were recorded to recognize common themes/patterns that could be categorised into variables/elements to further support the theory.

2.4.4 What to observe:

1. Verbalisations showing evidence of confusion/surprise about an aspect of the controls/interface.
2. Verbalisations showing evidence of frustration.
3. Changes in body language/position.
4. Spontaneous verbalisations

This observational method helped to refine the analysis of the participants answers whilst evaluating their frustration rating.

3. STATISTICAL ANALYSIS

3.1 Experiment 1: Measure Temperament

A paired t-test was conducted to detect if each participant had changed their temperament as a result of playing the game. This statistical analysis is a two-tailed t-test as there in no prior information concerning a person's frustration before and after playing a game.

Test participants were asked to rate their temperament on a scale of 1-10, 1 being very happy and 10 being very frustrated. Participants then played the game and upon completion were asked to rate their temperament once again. The same questions were put to gamers and non-gamers. The temperament variable for non-gamers is displayed in the questionnaire results Figure 3.

Question	1	2	3	4	5	6	7	8
Age/Gender	20F	22M	19M	19M	21F	22M	22F	21F
Pre-Test								
On a scale of 1-10 how do you feel right now?	3	3	3	6	5	4	4	2
Post-Test								
On a scale of 1-10 how do you feel right now?	5	5	3	4	6	4	7	2
How many hours per week do you play games?	0	0	0	0	1	1	0	0
Do you play more console or PC games?	Console	Console	Console	Console	Console	Console	-	Console
Thoughts on the Game								
What did you think of the game?	Fun	Annoying	Fun	Fun	Fun	Confusing	Fun	Fun
Did you find it frustrating or enjoyable?	Frustrating	Frustrating	Enjoyable	Enjoyable	Enjoyable	Frustrating	Enjoyable	Enjoyable
Did you find the virtual environment easy or difficult to adapt to?	Easy	Hard	Easy	Easy	Easy	Easy	Difficult	Easy
Did you find the game controls easy to use?	Yes	Yes	Sometimes	No	Yes	Yes	No	Yes

Figure 3 - Questionnaire Results (Non-Gamer)

The hypothesis is u1 – u2 =0 or u1 = u2. The alternative hypothesis is u1 ≠ u2. The test statistic for a paired t-test is calculated in Figure 4.

$$t = \frac{\overline{d} - 0}{s_d \sqrt{n}}$$

Figure 4 - Experiment 1: Test Statistic

Using this formula, t is calculated as follows: d = 0.875, Sd = 1.7464, t = 1.413.

The decided risk factor before conducting the experiment was 5%. When the standard deviation is unknown, the distribution of the sample mean is t with n-1 degrees of freedom. The n-1 degrees of freedom here are 9. The critical value is 2.365 using the t-distribution table. Since the test statistic falls under the critical region, the hypothesis cannot be rejected as the frustration levels are the same. This proves that the experiment is random, meaning that a person's frustration levels are not influenced by playing a game.

It must be noted that the experiment was based on a very small sample size (16 participants in total) so the test's ability to detect slight, but signficant differences in participants frustration levels is low, and the likelihood of a type 2 error (false negative) is high.

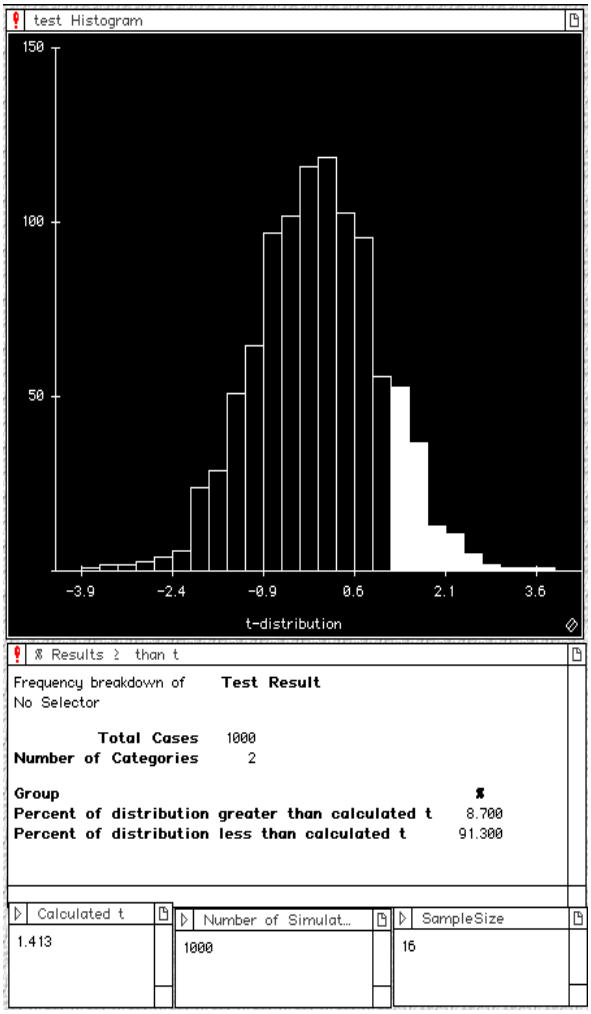

Figure 5 - Paired t-test (measuring frustration)

The paired t-test has also been simulated to provide further insight. This is shown in Figure 5. In the lower panel the calculated t value has been entered, along with the sample size. The graphic displays visual representation of the distribution of the test statistic after it has been simulated 1,000 times, assuming that both the frustration levels before and after the game remain the same. This table displays the percentage of tests that are greater than the calculated t-test - in this case 8.7% (illustrated in white). This is not within the critical region for rejecting the hypothesis (i.e. less than 2.5 %). Therefore this result is consistent with the results obtained directly from the t-tables.

3.2 Experiment 2: Measure gaming ability

Measure participants gaming ability. A two tailed unpaired t-test was conducted to measure gaming ability. It is two tailed as there is no prior statistical information available for this test to predict gamers score results. Two groups of testers were asked to complete 4 levels in a custom first person shooter game. The test demographic was 8 experienced gamers and 8 non-gamers. The average scores were then calculated for each participant based on the results gathered from the questionnaire for both gamers and non-gamers.

The hypothesis is u1 = u2. The alternative hypothesis is u1 ≠ u2.

A two-sample t-test was conducted to determine if there were any significant differences between the two test subjects. The test statistic for an unpaired t-test is calculated in Figure 6.

$$t = \frac{[(\overline{x_1} - \overline{x_2})] - 0}{s\sqrt{(1/n_1 + 1/n_2)}}$$

$$n_1 = 8$$

$$S_1 2 = 6.27 \quad S_2 2 = 5.55$$

$$\overline{x_1} = 11.6 \quad \overline{x_2} = 8$$

Figure 6 - Experiment 2: Test Statistic

Using these values, t is calculated as 1.186. The decided risk factor before conducting the experiment was 5%. When the standard deviation is unknown, the distribution of the sample mean is t with n-1 degrees of freedom. The critical region here is 2.365 using the t-distribution table. As the calculated t is outside the critical region we do not reject the hypothesis as the mean scores are the same.

Again, the experiment was based on a very small sample size (16 participants in total) so the power of the test to detect any difference is low, and the likelihood of a type 2 error (false negative) is high.

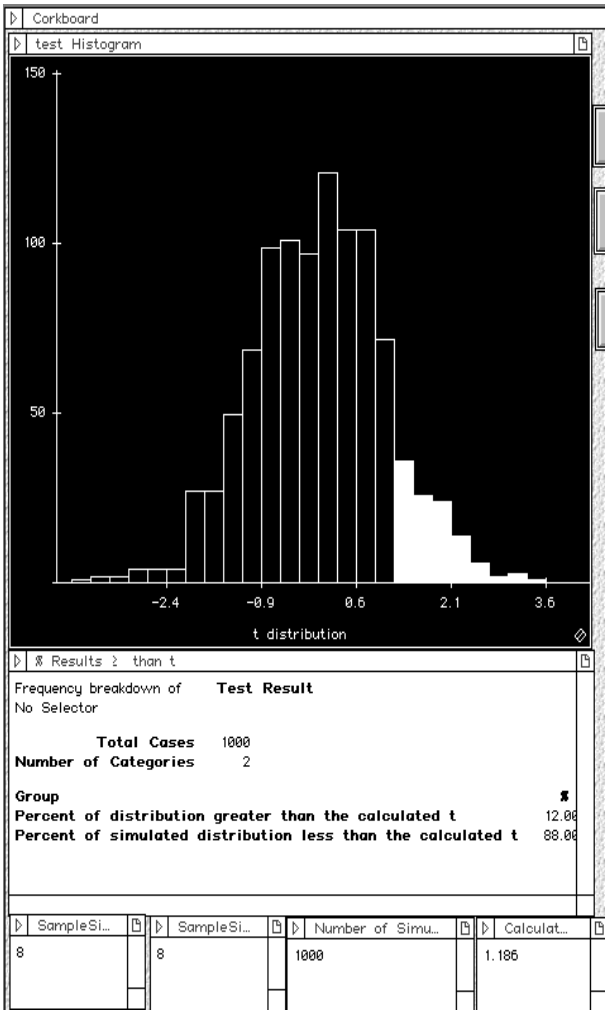

Figure 7 - Unpaired t-test (gaming ability)

The result of the unpaired t-test has been visualized in Figure 7. The sample size for both groups has been inputted, as well as the calculated t value: 1.186 to simulate the distribution of t – assuming both means and variances are the same. After generating 1,000 simulations, the results prove that the chances of obtaining a t-value of 1.186 are approx. 12% (illustrated in white). This is well over the 2.5% critical region and therefore concludes there is no sufficient evidence to reject the null hypothesis that gamers and non-gamers have the same scores.

4. RESULTS

4.0.1 Experiment 1

This did not show enough evidence to reject the hypothesis that temperament before and after playing video games are the same. Our test results support the research conducted by Bensley & Van Eenwyk that suggests college students experience mood fluctuations from playing computer games, but nothing we found proved that gamers were more inclined to frustration than their non-gaming counterparts. Therefore we have concluded that there are no consistent findings that frustration among gamers is more pronounced when playing computer games compared to non-gamers. However it has been noted that the sample size was very small and testing from a larger number of participants may have yielded a more significant result.

4.0.2 Experiment 2

Measuring participants gaming ability did not provide enough evidence to reject the hypothesis that gamers and non-gamers score the same. Therefore it was concluded that there were no significant findings that gamers score better in video games than non-gamers. Again sample size was very small and may have resulted in a false negative. To be thorough in any future experiments, a larger participant size will be adopted.

4.0.3 A Note On Experiment 1

Throughout the test each participant was monitored for any unusual behaviour that may indicate fluctuations in mood. It became obvious that gamers were visibly more frustrated than non-gamers, on account of their increased altering of body positions, use of expletive language, heavy sighing and general verbalised discontent with the game they were playing.

4.0.4 A Note On Experiment 2

Both sample groups were asked what changes they noticed as the game progressed and neither one noticed that the correct target that resulted in a postive score changed throughout the levels. It is interesting to note that once the timer started and the basic objective was thought to be understood that the participant carried on regardless of the feedback they received from the interface display.

5. DISCUSSION & CONCLUSION

This paper investigated the fluctuation in frustration levels of gamers versus non-gamers when playing computer games. According to the Journal of Experimental Social Psychology [4], violent video games increase aggression, if only in the short term. In order to carry out the experiment, the test participant was provoked by altering the input controls and interface display. The user expects something simple, but it turns out to be complex, resulting in frustration[5].

Two variables were used: score, and change in temperament; score being used to calculate participants gaming ability, and temperament to measure fluctuations in frustration. The latter variable was more difficult to determine, and so it was supported via the pre and post-test questionnaires, as well through observing participants verbalisations and gestures.

Although our experiment did not yield any conclusive statistical results to say that gamers experienced more dramatic fluctuations in frustration levels when compared to non-gamers, the notes taken from the experiments suggested otherwise. Both types of participant recorded similar frustration levels when we reviewed the questionnaire, however it was clear that gamers appeared to be visibly more frustrated after the test - according to our direct observation; the uncomfortable body language and use of expletives supported this evidence. Although we were unable to accurately measure this distinction for our statistical analysis, it could suggest that our measurement tools were inadequate. Asking participants to verbally communicate their feelings at the end of the test seemed to produce an incomplete picture of what the participant was actually feeling. Originally we had requested the use of physiological monitoring tools to gather more accurate results from partipants. Unfortunately we were unable to use any of these devices due to restrictions surrounding the ethical standards of the test. A future experiment could however incorporate these kind of monitoring tools to help calculate physiological indicators such as the heart rate, and brainwaves of the test participant. These metrics could prove more useful than the ones used for this study, and go further in proving our initial hypothesis.

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Our thanks to Dr. Tim McNichols of IADT for providing us with best practice research methologies, as well as his valuable critique that helped to improve the overall quality of this document. Additional thanks to IADT for provisioning the necessary technical resources and access to our user testing groups. Finally, we sincerely thank the iHCI 2014 Programme Committee for selecting our paper for inclusion within this years conference.

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Considering place and problem solving in the virtual world

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ABSTRACT

This paper examines the interplay between the person and their environment throughout the problem solving process.

Although there are endless opportunities to electronically access information and knowledge the concern is that, rather than strengthening, building upon and enhancing an individual's knowledge, these systems do not support and allow for further losses of previously acquired knowledge.

While there are a myriad of contributing factors that impact knowledge capture and transfer, this paper is concerned primarily with tacit knowledge and the role of the surrounding environment during the problem solving process.

Of core concern is the role of the location in tacit knowledge acquisition and retrieval and whether access to prior situations in a tacit form allows for a richer access to tacit knowledge.

Categories and Subject Descriptors
H. Information Systems, H.1.1. Information theory, H.1.2. Human factors, human information processing

General Terms
Documentation, Performance, Design, Human Factors

Keywords
Problem solving, place dependence, tacit knowledge, situated knowledge, 3D virtual worlds

1. INTRODUCTION

This project aims to examine the role of the surrounding environment in facilitating access to and the transfer of tacit and situated knowledge for the purposes of human problem solving, both individual and collaborative. This focus on the surrounding environment or *place* is relevant in an era where human communication is increasingly becoming a remote, distributed and dislocated activity. This research is concerned with the relationship between place and knowledge and how virtual systems may support this relationship.

It is the contention of this research that when collaborative activities are attempted via remote access there are negative implications for tacit and situated knowledge in particular. The research postulates the absence of a persistent place is an impediment to accessing tacit and situated knowledge, for both the individual as he/she tries to access his/her own tacit knowledge and for teams whose members attempt to communicate their own tactic knowledge and to gain access to their colleagues' tacit knowledge.

Knowledge and the capacity to access it is intertwined in the surrounding place. This research argues that the co-located place, in addition to being the ideal platform for the social process, is important for the externalisation of internal representations. It also acts as a storage buffer allowing access to previous meta-learning states.

The broader aims of the research are to examine the surrounding environment and its role in tacit knowledge transfer within the collaborative process. This paper focuses solely on the individual as he/she engages in the problem solving process, gains tacit knowledge and transfers it (or not) to subsequent processes. The main objective is to determine whether the surrounding environment plays a role in this process.

This paper discusses an experiment designed to test the acquisition of tacit knowledge and the relationship with the surrounding environment during the problem solving process. The value of capturing the actions carried out during the process (tacit entities) and the evolution of both the problem solving process and the surrounding environment will be examined.

2. TACIT KNOWLEDGE, SITUATED KNOWLEDGE AND THE EXTENDED MIND

Much of the context for this work is derived from research on the current understanding of tacit knowledge and how it defines professional knowledge and experience. Tacit knowledge encompasses the informal craft or skill demonstrated by an expert in addition to a cognitive dimension consisting of schemata, belief systems and mental models that are so embedded they are taken for granted [17]. This knowledge includes expertise, comprehension and professional insight formed as a result of experience [22] and domain immersion. Therefore tacit knowledge, unlike explicit knowledge, does not yield as readily to capture and distribution by electronic media. Experiences are unrepeatable in terms of detail and individuality.

Professional knowledge depends heavily on the reuse of ideas, experience and knowledge [15, 2, 8, 4]. Professional know-how is derived from history and the evolution [20] of improvements on and refinements of previous experiences.

"In important problems, we almost always need to bring old knowledge to bear upon the solution of new problems, and to relate new knowledge to old knowledge" [19].

This history and evolution effects and shapes present events. Problem solving approaches are subject to the situation, the context and the dynamic world in which they operate [12, 11]. Thought processes are in a state of flux. Each memory that is constructed is an addition to the experience, so that the experience is augmented by memories of it. The concept of *situatedness* is concerned with locating everything in a context so that the decisions taken are a function of both the situation and the way the situation is constructed or interpreted [12, 5]. The current state is of thought is derived from both historical and current processes [18]. *"The mind is a dynamic system changing over time as new experiences are accumulated. Therefore, our interpretation of the same external artefact will be different each time we look at it."* [16].

Problem solvers create external representations to communicate and express their internal thoughts. These representations are produced based on the projected meaning of the situation and allow for interpretation of situations. Knowledge is related to the place where it originates and to its application. Johnson claims that experiences derived within an inhabited place have a permanence that can be recalled more vividly as a result of being in that place. *"The permanence of a place in contrast to the changes daily life undergoes provides a means of accessing memories associated with the place"* [13].

Proponents of the situatedness perspective all give significant to the "where" of design in terms of context. Several consider the coupled system of agent and environment [3, 10], acknowledging the interactions between agent and environment. However the focus is on the human, who is viewed as the active participant in the situated process. Less research relates to the physical "where" and the surrounding environments role as a dynamic entity, in and off itself, in the situated problem solving process. The surrounding environment and the artefacts that reside in it also have their own history and evolve over time through interactions.

The Clark and Chalmers hypothesis of the *extended mind* argues that cognitive processes are not bounded by *"skin and skull"* but may be grounded in the individual's external physical environment. The Parity principal put forth by Clark and Chalmers states:

"If, as we confront some task, a part of the world functions as a process which, were it to go on in the head, we would have no hesitation in accepting as part of the cognitive process, then that part of the world is (for that time) part of the cognitive process" [6].

If, as is argued here, the surrounding environment facilitates better access to previous knowledge, on which all problem solving processes are ultimately dependent, then what are the effects on the problem solving process when individuals engage in a problem solving process remotely? What are the implications when we losing the physical surroundings and the "*indefinable tacitness of being there"* [9]?

3. PLACE AND PROBLEM SOLVING

Technology has provided the means to access expertise that is rare, unique and invaluable and to extend enterprises. Explicit knowledge is reducible to digital media and available ubiquitously. However tacit knowledge, due to its elusive nature, remains less readily captured and transferred. As it is this knowledge that makes expertise individual and unique, how best to support it is of concern. This paper suggests that the surrounding environment plays a role in an individual's ability to recall previous knowledge. If problem solving tasks are carried out remotely using technology (that is without a persistent physical surrounding environment) then what implications does this present? If those implications are significant then what can be done to overcome the deficiency of the physical surroundings in supporting tacit knowledge?

While current technological systems cannot directly interpret and derive meaning from the tacit knowledge and rationale that is part of a problem solving process, it is possible to better support access to this knowledge.

3D virtual worlds may be used as simulated real world representations. While they may not provide the same level of presence as real physical surroundings, they can support the experience of being in a place, allow for the creation of knowledge in that place and allow the place to evolve over time and build its own history. Additionally the transitions, meta-learning, and evolution that an environment undergoes as a problem solving process progresses and is revisited can be stored, tracked and measured in its native form. This is not as feasible in a physical environment and as a result processes tend to be documented as a means of capturing them. Documenting and recording decisions and experiences does not integrate well with the problem process and burdens problem solver with additional tasks. In cases where documentation is available it is still an explicit entity trying to explain a tacit one - ill formed and not readily accessible, it requires the patience and time to search through [2].

While virtual worlds originate from the computer gaming industry and many rely on game engine technology, their focus is different. *"Games are primarily designed to foster accumulating points or reaching new levels and the like"* [Schroeder 2008]. They do not involve following pre-defined narratives and aim to allow for individual autonomy within the world [1]. It is possible to build and incorporate the computer applications that are used in the virtual world so that the problem solver is one with the world and the knowledge that he/she generates and creates.

To examine how the surrounding environment, physical or virtual, impacts the ability to recall and reuse tacit knowledge an experiment that involves the acquisition of tacit knowledge is necessary. Once this knowledge has been acquired it is then necessary to test it in both physical and virtual surroundings.

For the purposes of this experiment a puzzle is used as the means of acquiring tacit knowledge. The puzzle is sufficiently intricate to ensure that the solution is not readily recalled when the problem solver makes subsequent attempts, having disassembled and assembled it once. The physical version of the assembled puzzle is shown in figure 1.

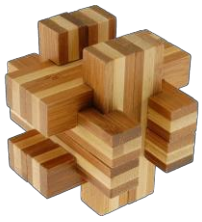

Figure 1: real puzzle assembled

Figure one shows a twelve piece puzzle which has eleven identical parts. The puzzle is solved through a series of movements involving the key piece. Disassembling the piece is easier than re-assembling it which involves moving parts back and forth or individual and collective parts so that these can interlock correctly. The task is a

tactic on as it involves acquiring a practical hands-on knowledge that is difficult to articulate.

This puzzle will be used in a physical setting whereby problem solvers will be asked to solve the problem. Individuals in this group will be informed that they will be asked to complete this task again at some point in the future. They will be encouraged to use the surrounding environment in any way they wish to assist them to re-solve the puzzle at a future date. They may make drawings, notes, place the pieces in a certain order or placement and so forth.

The 3D version of the assembled puzzle is shown in figure 2.

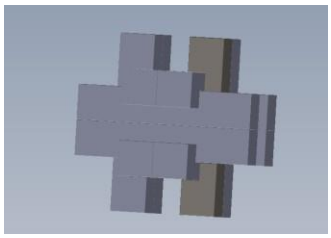

Figure 2: 3D puzzle assembled

The same puzzle has been developed as a 3D assembly with 12 separate parts within a 3D game engine. Individuals may solve the puzzle using the same steps as the physical puzzle by interacting with the individual pieces via the computer keyboard and mouse.

The 3D environment will have two user test groups. For one of these groups a timeline application will exist within the environment which will capture the intermittent problem solving steps. This timeline will be available to each individual on his/her subsequent attempts which will allow the individual to revisit their own previous meta-learning processes to assist them with the current one.

The other users using the virtual environment will not have access to the timeline application or any information other than the puzzle itself. It will be conducted in a different location for each attempt, devoid of the same environmental cues.

The three groups will be analysed qualitatively through observational analysis and a post self-analysis survey. The productivity of each group will be measured quantitatively by carrying out a time study to calculate the basic and standard time of each individual. Time study is a work measurement technique for recording the times of performing a certain specific job or its elements carried out under specified conditions, and for analysing the data so as to obtain the time necessary for an individual to carry it out at a defined rate of performance.

The calculations will be compared at the individual level between initial subsequent processes and collectively so that productivity at individual and group level can be determined and analysed.

According to Wilson *et al*. an improvement in performance demonstrates tacit knowledge [21]. For the purposes of this test, demonstrating access to *"tacit knowledge"* constitutes an improvement in performance in subsequent attempts. Improved performance constitutes a speeder solution or an alternative (more efficient) approach in the subsequent attempt. This will demonstrate whether tacit knowledge has been gained and successfully transferred from attempt to attempt.

4. EXPECTED RESULTS

It is anticipated that this experiment will lend support to two of the hypotheses put forth by this research. These are:

1) Recreating the situation in which a problem solving process takes place enables the problem solver to access his or her own tacit knowledge in a way that is superior to referring to his or her documentation about the process.
2) Tacit knowledge is partially location dependent.

If the experiment yields results that are supportive of the hypotheses it will contribute towards a greater insight to the relationship between place and knowledge and how technological systems may support this relationship.

Furthermore it will examine the value of capturing the meta learning states in their tacit form as a means of assisting recall rather than relying on the final solution.

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Co-designing a Collaborative Platform with Cultural Heritage Professionals

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ABSTRACT
The paper describes our work undertaken as part of a EU-funded collaborative project involving twelve partners from six European countries, aiming to provide a platform for the creation of tangible smart exhibits to enable heritage professionals to design and assemble physical artefacts enriched by digital content in a DIY manner. Our approach is grounded on principles of co-design, the broad participation of designers, developers and stakeholders into the process, and on a Do-It-Yourself philosophy to making and experimentation. Hands-on design and prototyping workshops are employed throughout the project to inform and shape development. The paper focuses on these co-design activities, wherein cultural heritage professionals (CHPs), designers and technologists work together in local and consortium-wide workshops to co-create the DIY platform. It presents the results of an investigation into the design thinking, practices, and processes of a particular set of users - cultural heritage professionals – who are involved in the design and realisation of cultural heritage exhibitions involving digital interactive technologies.

Categories and Subject Descriptors
[Interaction design] *Interaction design process and methods*

General Terms
Design, Experimentation, Human Factors

Keywords
Co-design, cultural heritage, interactive exhibits

1. INTRODUCTION
The research project described in this paper has the goal of designing, developing and deploying tools for the creation of tangible interactive experiences that connect the physical experience of museums and exhibitions with relevant digital cross-media information in novel ways [9]. A wealth of digital cultural heritage content is currently available in on-line repositories and archives; however, this content is not widely utilized and the current delivery models are rather static. Our project proposes to bridge the gap between visitors' cultural heritage experience on-site and on-line by providing a platform for the creation of experiential smart exhibits, that will enable heritage professionals to compose and realise physical artifacts enriched by digital content without the need for specialised technical knowledge; the platform will include an authoring environment for the composition of physical/digital narratives to be mapped to interactive artefacts, and an embedded multi-sensor digital system platform for the construction of ad-hoc physical adaptive smart objects. The ultimate goal of the project is to support the creation of an open community of cultural heritage institutions driving and sharing a new generation of physical/digital museum interactive exhibits. In order to empower cultural heritage professionals to do so, it is first of all important to investigate the potential of their role in acting as designers of such interactive installations and in taking on control of technologies that can be customised or modified to suit the needs of an institution.

In the following sections of this paper we will present a discussion of existing research related to the topic of interactive exhibition design, design processes and the design of cultural heritage toolkits. We will then report on the process of co-design and present a review of the co-design activities undertaken throughout the first year of the project, followed by an analysis of the main findings that have emerged from it. We conclude the paper with a discussion of the key challenges in designing and deploying innovative and collaborative technologies such as the DIY platform and how the design of interactive exhibitions by cultural heritage professionals could be supported. By presenting some of the lessons learnt that could be of interest to other researchers when extending design practices to include participants not accustomed to this type of creative practice, this work intends to contribute to the larger research agenda of collaboration technologies and participatory design within the HCI field.

2. BACKGROUND
2.1 HCI and Interactive Exhibits in Cultural Heritage Settings
Within the HCI community, an established body of research examines the design, development and evaluation of technology-driven interactive exhibitions in various heritage settings. The "users" of such technologies have been almost always considered to be the visitors and research tended to focus on the visitor experience of interactive artefacts in cultural heritage exhibitions and on how this experience can be supported and enhanced [13]. While visitors are the ones who ultimately interact with these artefacts in exhibitions, the role of cultural heritage professionals

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in shaping and often maintaining such installations has not been given the same attention and there has been little research on the design thinking, processes and practices embraced by these professionals who are behind the creation of interactive exhibits. Cultural heritage professionals have often taken on the role of advisors in the majority of technology design endeavours in museum contexts, while in few cases, they were actively involved in the design [4, 14, 6, 7, 10]. However, it is more commonly the case where the main responsibility for the design of such exhibits falls ultimately with others including the likes of technology experts, design consultants, media consultants and researchers.

2.2 Approaches to the Design Process

The approaches to design and the design processes applied in creating interactive museum exhibits are diverse. For example, within a user-centred design frame, end-users (i.e. visitors) and other stakeholders are studied to assemble design requirements for the interactive exhibits, and evaluation is conducted by investigating visitor interactions and by gathering data on visitor opinions and reactions to the technology [4]. However, other examples of work exist where the approach to the design process is participatory, and various stakeholders are included within the team so as to incorporate the knowledge and expertise of relevant communities into the design decisions. Participatory design methods can be used to gather design ideas for interactive exhibitions from a target visitor base. Recent work explores the involvement of children in the design of interactive exhibitions in museums [3]. There are also, albeit fewer examples of a participatory design approach to the creation of interactive exhibits that see the inclusion of CHPs within the design team, providing expert advice on content, the curatorial goals of the institution and its educational mission [13]. Designerly approaches such as reflective practice and meta-design have also been adopted by some interaction design research projects on interactive exhibitions [5].

2.3 Cultural Heritage Toolkits and Cultural Heritage Professionals as End-users of an Interactive System

As previously mentioned, the overall motivation of our research is to develop a toolkit that would allow for cultural heritage professionals (CHPs) with little technical knowledge to create interactive exhibitions merging digital content with tangible objects. A limited body of research exists on the development of cultural heritage toolkits and on CHPs as end-users of an interactive system, however, to our knowledge, there are very few examples of HCI projects that focus specifically on the design of smart exhibits. For example, toolkits have been developed for the creation of virtual interactive exhibitions, such as ARCO [12], and of screen-based exhibitions, including 'Curator' [11] for tabletop exhibitions; and more recently, a toolkit for the creation of tablet-based guiding tools was built [1]. While these examples contribute to the growing interest in the theme of heritage professionals as designers of interactive exhibits, they do not offer comprehensive insights into their practice and experience of creating interactive exhibitions. To this end, we have identified a significant gap in relation to the knowledge and input of heritage professionals in the development of interactive exhibitions, and their design thinking and processes.

3. COLLABORATION AND EMPLOYING CO-DESIGN THROUGHOUT THE PROCESS

The collaborative relationships amongst the different partners as strengthened through the co-design activities is recognised as a powerful way to bridge the gaps between the different disciplines and to develop contextually appropriate solutions. The project's co-design approach provides the opportunity for technical partners, designers and CHPs in the consortium to build a shared understanding, work together and discuss issues and opportunities in developing the authoring tool. As a multi-site, multidisciplinary project, it explores the challenge of co-designing in a very complex and distributed setting: the consortium partners come from 12 different institutions and the expertise of project members ranges from museum curators and product designers, to computer scientists, electronic engineers and social scientists. Through the practice of co-design, the collaborative work allows for a deeper understanding of CHPs' practices, for instance, for the curators to clarify what they want to enhance in the museum and what kind of connections with digital content they envisage, the desired functionalities for the authoring tool, basic templates that could ease the start of authoring, and the design requirements for offering personalised cultural data to end-users. Importantly, the co-design activities also aim to empower CHPs, considering them as 'co-creators' rather than simply informants in the design process.

This co-design methodology is implemented within a learning-by-doing framework: the smart exhibit prototypes developed so far are not seen as demonstrators of achievements, but as a way to learn through the process of making. This is a well-known practice in design research that advances the project iteratively through design and evaluation phases. Iterations are functional to the project's progress toward its final goals.

3.1 Co-design Methodology and Activities

Over the course of the first year of the project, a variety of methods have been employed by the project team to deepen our understanding of cultural heritage institutions, the practices of visitors and CHPs and the particular requirements regarding technology management and authoring. Site observations, surveys and interviews with more than 20 CHPs have been used within the project in conjunction with hands-on co-design activities to explore their experiences and strategies in designing interactive exhibitions and to inform our research. Generating design concepts and developing prototypes is a means of research within the project. Through the creation of visitor storyboards and prototypes we have been able to elicit reactions from CHPs and cultural heritage audiences and to understand the flow of the creation process that needs to be facilitated by the DIY toolkit. The prototyping activities occurred over time and the process of developing scenarios and prototypes has not been linear. Multiple ideas were generated in every co-design activity and no selection process was put in place: good concepts emerged in a natural, organic way, as similar concepts were proposed and elaborated at different points in time and in different circumstances. The different concepts that somehow resonated with one another were merged, and at the same time knowledge and understanding gained outside design fed into the process, e.g. the study of curatorial practices [8, 2].

Figure 1. The sequence of events throughout the four main consortium project co-design workshops

All the activities were carried out in groups of mixed expertise, always including in the team CHPs, designers, and technical experts. A number of concepts were generated at each co-design meeting and several were developed into working prototypes. Figure 1 demonstrates the sequence of events throughout the four main consortium project co-design workshops and gives an idea of the scale and variety of the concepts generated and explored. These four consortium workshops were complemented by an array of local co-design activities with the partner museums, which were held in parallel throughout the year. Details of the local activities are discussed in section 4.3.

4. CO-DESIGN ACTIVITIES

During the first year of the project, many different co-design activities were carried out in the context of consortium-wide meetings, as well as several other local events run by specific partners. In the following section, we will outline a number of different approaches and techniques adopted as part of the co-design process. Although the final aim was the same, the examples of activities below are very different: some have technology as a starting point and then move toward deployment in specific cultural heritage contexts; some others start with cultural heritage contexts and move toward developing a technological solution; others instead bring out the same level of detail in discussing both themes simultaneously. The co-generation of concepts of possible interactive installations was the starting point: by understanding the type of interactive installations that heritage professionals want to offer to their visitors, we could begin to envision the type of tools that had to be used to create them. The focus on the cultural heritage professionals, their expertise and attitude to technology, and how they would approach the process of designing and realising an interactive exhibition in an independent way constitutes the core of the project.

4.1 Rapid Physical Prototyping Workshop

The first consortium co-design workshop 1 (as indicated in Figure 1) featured a hands-on workshop for rapid physical prototyping. The goal of this session was for the different partners to experience what could be created by non-technical users with recent DIY technology within a very limited amount of time. For this purpose the .NET Gadgeteer platform was employed as it offers a modular approach where no soldering is needed – sensors and actuators can be plugged into free slots on a mainboard – as well as an IDE (Integrated Development Environment) that abstracts from many low-level details and allows to easily create high level behaviour (Figure 2).

The entire rapid physical prototyping session took place at Sheffield Hallam University over the course of a morning and lasted approximately 4 hours in total. To initiate the session, a hands-on task of building a working prototype was undertaken in small groups to illustrate the functionality of the kit. Each group consisted of 4 – 5 various different members from the consortium partner organisations including CHPs, designers, technical experts

and researchers. Each group included at least one technical expert and one CHP. With a better understanding of what was achievable with the technology, the designers, CHPs and technologists within each group collaborated to devise a scenario for a digital interactive experience in a museum. Laptops with the coding platform were readily available, and three Gadgeteer experts from one of the partner institutions were available to support and help the teams. After the concepts were developed, the hardware composition and coding was supported by the technical experts; in approximately an hour, the groups were able to implement their ideas and have a functioning prototype.

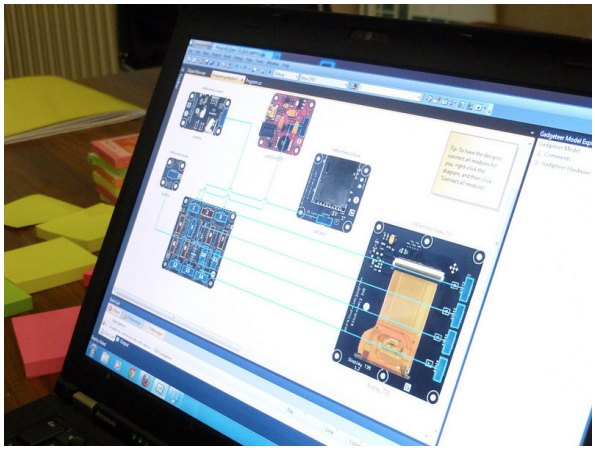

Figure 2. Working with the .NET Gadgeteer graphical user interface for physically connecting the mainboard with modules.

An example of the type of prototype created included an intelligent bag (Figure 3) to be used in the context of a treasure hunt around a museum. While walking around the museum, visitors would collect digitally augmented objects and then put them in the bag; the bag itself would recognise the object and deliver related content to the visitor. This was realised by adding an RFID reader and a small display to the opening of the bag and equipping the artefact replicas with RFID tags.

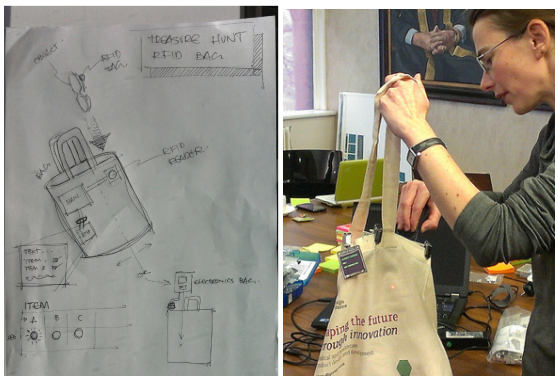

Figure 3. The intelligent bag for a museum treasure hunt from paper sketch (left) to hardware sketch (right).

4.2 Working with Physical Artefacts

The third consortium co-design workshop as indicated in Figure 1, took a technology free approach, whereby participants worked solely with analogue resources. It was aimed at exploring possible interactions and narratives connected to various existing museum artefacts. Working with real museum artefacts and visual and textual representations of artefacts, the challenge was to imagine and demonstrate simple interactions that could be constructed around physical museum objects, giving consideration to how different interactions could be experienced, what the capabilities and limitations of the objects were and how they related to the museum narratives.

The workshop, which took place over the course of a morning session (approximately 3 hours), was held at one of the consortium partner museums, Museo della Guerra (the War Museum) in Italy. The advantages of hosting the workshop at the museum were the direct access to museum artefacts and the inspirational setting provided by the museum environment, especially effective for those technical and design partners who would not normally work in such a setting. Working in small groups of 4- 5 people which featured a mix of CHPs, designers and facilitators, the participants were invited to reflect on questions such as 'What would I like the object to do?' and 'What story would I like the interactions to tell?' Each group included at least one CHP. Participants shared their ideas on what kind of interactions an object could afford and what sort of narrative they could portray (Figure 4). They then acted out the interactions through show-and-tell and role-playing techniques. By using these specific techniques, the physical dimensions and material capabilities of the objects are scrutinized. Role-playing with the objects also serves to highlight and break down the individual steps involved in the visitor interaction, which is crucial for the participants to understand if the interaction were to be designed for.

Figure 4. Working directly with museum artefacts to consider possible user interactions.

Working directly with the physical objects allowed the groups to discuss and identify different types of interactions that would make sense to the CHPs. Considering the sequence of interactions as performed by the visitor and the type of content needed to structure the exhibition narrative were also important aspects of the exercise for the CHPs. In addition, several of the CHPs participating, detailed the design process that they would undertake in designing such an exhibit. This information on the stages of exhibit design provided important input in terms of understanding at what stage they would use the DIY platform.

4.3 Local Co-Design Workshops

In order to address the specific needs of each museum partner, additional co-design activities where held in local settings with these partners. The main goal of these workshops was to understand their specific needs and motivations in using technology as part of their strategy and to make initial ideas on prototyping more specific. Before the co-design sessions, designers and technologists visited each museum and had discussions with the staff to get an understanding of the museum, its audience and its challenges in presenting its collections.

In the case of one partner museum, Museon, a science museum in Den Haag, the Netherlands, their main motivation for using technology in their exhibitions was to be aligned with state-of-the-art developments and to focus on the learning experience. One of the major issues that needed to be addressed, as recognized by the museum staff, was the problem of visitor navigation and how to help the visitor to make sense of all the information and materials on offer within the museum space. Based on the museum visits and internal discussions, sketching and prototyping, the designers explored a number of potential concepts and smart objects, which were introduced to the museums' CHPs including 'the compass' as an object that would guide the visitor through the exhibition (Figure 5). The participants were divided into groups with the goal of letting the curators explore and apply the concepts to their vision, museum, content and audience(s). The brief was: "What kind of experience do you want to create and translate this into a scenario using the concepts and referring to your 'questions'. "

Figure 5. Exploring the museums' collections using the compass prototype.

It was important to organize this type of activity within the actual museum environment, to have room and objects at hand and to be familiar with their routines. It also helped establish a common understanding between design and heritage professionals that can be referred to later on in the project. Important conceptual and practical considerations from the session included the fact that not every object has a story that can be easily made interactive and not all content is easily transferable into visitor friendly formats, as is the case with for example long academic texts,. In addition, the social aspect of interaction (i.e. how groups, as opposed to individuals, would interact and behave with the object) needs to be addressed.

An additional local co-design workshop with local partners brought together partners from the two Dutch consortium partner museums (the Allard Pierson Museum in Amsterdam and Museon in Den Haag) alongside a number of local CHPs from outside the consortium, to link content of their choice to the interaction possibilities of prototypes developed as part of the project, and to test and refine this combination. A number of the consortium's technology experts attended the day long co-design activity, bringing along some of the early project prototypes, while the CHPs brought ideas for exhibits and various types of content. The prototypes that were presented included two wayfinding devices: one wayfinding tool provided tactile feedback in the form of vibrations that could guide visitors to exhibits; and another that took the form of a magnifying glass, that could also be used to guide visitors and provide more information about exhibits. Another was an interactive plinth (Figure 6); the plinth contained distance sensors on each side and hence information presented about the exhibit could be dynamically updated, depending on the distance between the visitor and the plinth. Another prototype that was presented at the workshop was a wristband; the concept of the wristband was to enable personalised experiences for visitors around the museum. The wristband could, be used, for example, as a trigger for delivering personalised content to a visitor, in her native language/

The CHPs working together with the technology experts in small groups of 4-5 people came up with concepts for applying the technological prototypes to the exhibit concepts and then set out to rapid prototype the application of these technologies to the content (Figure 6). By working together in an iterative manner to tweak the content to augment the selected prototypes, this activity allowed both the technical and CHP participants to explore in detail the technology potential for different types of museums and to view it in very practical terms. In having to apply the technology to specific exhibition concepts and content, the prototypes become more nuanced so as to allow for the articulation of a complete story. Exposure to the prototypes stimulated the imagination of the CHPs that, by following the same method, initiated new co-design sessions for more advanced ideas/prototypes.

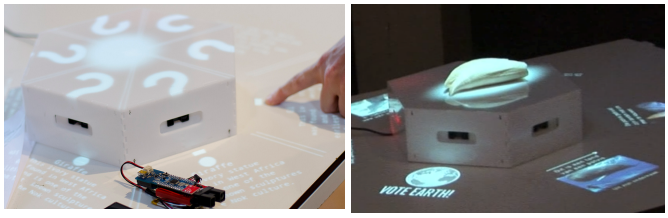

Figure 6. Testing (left) and demonstrating (right) the interaction capabilities of the plinth with a whale tooth as an exhibit

In addition to the practical implications discussed above, this co-design session was also instrumental in the articulation of a number of interaction typologies that are important to the future design of the authoring tool. The interaction typologies include:

- Helping visitors to better find their way, thematically and/or in a personalised way, within a cultural heritage institution (e.g. "dynamic wayfinding", functioning as a compass rather than a static map)
- Augmenting objects or locations either visually or by auditory means; such augmentation would be triggered by visitor actions (e.g. content multi-layering, adding perspectives, zooming in)
- Eliciting visitor physical actions in space (e.g. performing, role playing, tracking)
- Offering a (linear) story line (e.g. narrating, dramatising, guiding)

- Facilitating a personalised (visitor) experience and allowing visitors to share experiences (e.g. making, collecting, rearranging, redistributing).

5. DISCUSSION

In the previous sections, we have presented examples of some of the different co-design activities that were adopted as part of the meSch project. By adopting such a collaborative and participatory approach, the aim of these co-design activities is to allow the cultural heritage professionals to influence and shape the design of the authoring toolkit that the project will create, enabling them to realise and customise interactive installations at their own cultural heritage institutions and museums. Throughout the course of the first year of the project, a variety of techniques were employed based on the diversity of skills and expertise of the different participants involved and also on the constraints and possibilities regarding the use of technology for the different heritage settings. The outcomes of these activities have helped to generate design concepts and have led to the creation of several working small exhibit prototypes. In broader terms for the research, the co-design activities have also brought about a set of requirements for the DIY toolkit.

The rapid physical prototyping activity was practical in terms of educating the non-technical users of the capabilities offered by pervasive and embedded computing. Showing that there is now the possibility of offering interactive experiences that are embedded and distributed in space and artefacts was key to encouraging the CHPs to think of technology in a fundamentally different way from their current screen-dominated experiences.

The hands-on nature of the rapid physical prototyping was also beneficial to the workshop facilitators, as it provided an initial first-hand insight into the technical expertise of the CHPs who would ultimately be the final users of the intended DIY platform. It was clear that the current level of programming skills needed to realise such a prototype would need to be of a more advanced level than that as demonstrated by any of the CHPs participating in the workshop. Uncovering this information was essential to understand the knowledge and skill gaps that the project needs to address if it is to empower CHPs to create their own interactive exhibits as part of the DIY platform.

Coincidently, it is important to acknowledge that a technology driven activity such as this prototyping session also has its limitations. While demonstrating the technology is valuable in highlighting potential applications, it is imperative that the application of technology does not obscure the 'real' needs of CHPs or become applied for the sake of using technology. To this end, a more productive solution would be to begin with a specific museum-related challenge and then to consider how technology could be applied to resolve this specific issue. This scenario requires the CHPs to adopt a much more design-orientated thinking process.

The discussion of possible scenarios of use, as instigated through working directly with the physical artefacts, was constructive in generating questions and much needed debate across the members of the multidisciplinary team. If, on one hand, the designers and technologists were enthusiastic towards the possibilities of digital content being delivered when visitors manipulated an artefact, the cultural heritage professionals, on the other hand, were concerned about the augmented objects being too active and providing too much interaction and possibly distraction, with the risk of not offering a more reflective self-directed exploration. Therefore designing while working directly with the physical artefacts proved to be both stimulating and constraining, while supporting the team to focus the design on potential, but realistic situations.

Working with physical artefacts and re-enacting possible scenarios of use for the smart exhibits, also raises questions of the design communication capabilities of CHPs. If the control over design is really to by handed over and the CHPs are to be empowered to design interactive exhibitions, they need first to be able to communicate their vision. Because of the sequential nature of the intended interactive exhibits, this requires that they be able to communicate interaction concepts, as they would occur over time and spatially. Equipping CHPs with time-based communication techniques - such as storyboarding and stop motion animation - is therefore an important step in empowering them to design and create their own interactive exhibits.

The local co-design workshops allowed for more dedicated time to explore the specific issues concerning the individual cultural heritage participants who represented different kinds of heritage institutions. In turn, this allowed for the development of specific prototypes that the individual cultural heritage participants felt were particularly relevant to their own institutions.

Overall, the co-design activities as employed within the project, have led to the cultural heritage professionals sharing ownership of the concepts and prototypes for interactive exhibitions with the other project partners. As the ultimate goal of our project is that of delivering a toolkit that will enable cultural heritage professionals to design and realise their own interactive exhibitions, it is essential to empower these end users within the design team throughout the process, from exploration to realisation.

6. CONCLUSION

In this paper we have outlined the co-design approach and some of the co-design activities conducted thus far within the collaborative project. The insights on co-design and on the results, issues and challenges arising from it are an illustration of the potential that such an approach to empowering end-users as decision makers in the design process.

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Using Lifelogging to Help Construct the Identity of People with Dementia

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ABSTRACT

While there is much interest and work around the topic of how technology shapes our lives, there is less work around how technology can record our lives and how we can use that recording to remember, in cases when our own memories fail. Our work explores the incorporation of lifelogging technology into a therapeutic approach to support people with dementia. SenseCam therapy aims to stimulate the cognition of a person with dementia, with maintenance of their personal identity as its primary goal. SenseCam images are used as cues to meaningful discussions about the person's recent memories, thus constructing a particular version of the participant's identity during the therapy sessions. The constructed identity was enriched by uncensored details from the day-to-day life of the SenseCam wearer and hugely influenced by the content of SenseCam images. This reflects how the identity of people with dementia transforms but continues despite the disease progression, thus illustrating how technology goes beyond just shaping the wearers' lives. This paper reports details of three case studies carried out as part of a qualitative study exploring the potential of lifelogging technology in supporting health care professionals and relatives to develop a more holistic version of the identity of people with dementia than during other therapies.

Author Keywords
SenseCam; Dementia; Identity; Lifelogging

ACM Classification Keywords
J.4, K.4.1, K.4.2

General Terms
Human Factors; Design

INTRODUCTION

It is difficult to think of an aspect of our lives, which is not now shaped by technology. Our communications, entertainment, education, healthcare, transport, even our art and culture are all increasingly availing of rapid developments in technology. There are still portions of populations to whom technology may not be as easily accessible including the elderly. Nevertheless, they are still surrounded by advances of the digital world. Deeply embedded in this inexorable embracing of technology that we are all part of, is the question of who we are, what is our identity, how can we control or even manage our own identities and what now defines our identities in this modern world. Nowadays much of our communications are not face-to-face but based on email, teleconferencing, or phone, many of our social interactions happen online with people we may rarely see, and much of the footprint we leave behind us, our digital estate, is created, captured and stored using technology. In such a world, what actually defines us and our identity is an almost philosophical point of discussion.

One of the things that technology is starting to do for us is to help us to get more access to our own identities. We can use various technologies to capture what we do, say, and present to others, and we can then look at that ourselves and see what others think of us. Lifelogging is an emerging phenomenon of recording ourselves digitally, for our own uses, much of which involves us interacting with our own identities.

We work with a special case of lifelogging, or perhaps an extreme example, where we help in shaping personal identity for people with dementia. While we can all use technology to get more access to our identity, for people with dementia or their carers lifelogging is a way of enriching the care relationship. The paper reports a study about how lifelogging can be used to shape identity, and literally not just to represent it but co-construct a strict new identity.

Dementia is an umbrella term for many different diseases, all of which have similar symptoms, but different aetiologies. The symptoms include a serious loss of cognitive abilities including: impairment in short term and episodic memory of recent events; deficiency in language skills due to decreased verbal fluency; and damage to the

visuospatial abilities. All impairments are beyond that which might be expected from normal aging affecting social activities, relationships or employment [1].

However, the most debilitating effect of dementia is diminishing identity, which usually occurs simultaneous with the disease progression [12]. Every person's identity is constructed based on their memory resources, their language and their social interactions with others, all of which are impaired even early on in dementia. The nature of identity and its relation to memory date back to the 18th century when Locke [9] described the memory theory of personal identity. According to Locke the present self is only the same as the self of the past if the present self remembers the events of the past self.

"As far as this consciousness can be extended backwards to any past or action or thought, so far reaches the identity of that person; it is the same self now it was then" [9].

In other words, a person's identity is composed of the accessible past memories and a person who has no memories of their past thus has no identity. The notion that identity has foundations in episodic memories has been supported by other research [2, 12]. Post [15] also states that the only way a person can experience a "full self-identity" is when their memory is intact so that it connects the past and the present together.

The life narratives that we use in everyday storytelling and which are created by the use of language in communication are also viewed as foundations to the persons' identity [11]. Communication is a process of social interaction through which people make sense of themselves and of the world around them [8]. Thus, life narratives as representations of one's identity, cannot be discussed independently to memories and social interactions. Memory is essential to the ability to relate with others through communication about one's past [7]. Equally the ability to communicate is necessary to making sense of the reality by constructing narratives about one's memories [13]. This connotes that the combination of memory, narrative and social interaction is essential to individuals forming, reliving and creating meaning of their life experiences and to maintaining their identity [16]. Accordingly, maintaining the sense of identity by a person with dementia will be challenging as the disease impairs memory, communication and social interaction. This result in an inability to relive, form and share their life narratives, thus leading to identity loss in dementia, which is the problem we address.

Given that identity may be one of the early casualties of cognitive decline, we carried out a study, the focus of which was to explore an intervention aimed to provide resources for the person with dementia, which can be used in forming memories, in communication with others and in social interaction, with maintenance of the person's identity as the overarching goal.

Alike many other aspects of our lives, healthcare interventions are influenced by current developments in technology. The practice of lifelogging, which is automatic and ambient digital capture of life experiences typically through mobile sensors or wearable devices, is one way the technology can be incorporated into memory interventions for people with dementia. Lifelogging results in personal, recent and meaningful prompts from our past, encouraging sharing of personal memories [5]. The lifelogging devices are usually wearable and the data capture happens automatically and ambiently in the background without requiring any action on the part of the wearer.

The device of particular interest to our research is the SenseCam. This is a small camera plus a number of other, simple sensors, worn around the neck by the use of lanyard at chest level and facing forward. It does not have a viewfinder and automatically captures images every 30 seconds, resulting in thousands of recorded images per day, each taken from a first person viewpoint, i.e. the images never include the wearer but capture the wearer's view of the world in front of them.

The potential of SenseCam technology as an aid to memory problems faced by people with dementia is increasingly being recognized [3]. Previous research reported many memory-related benefits showing that SenseCam images can act as effective cues to recall of episodic memory, as well as improving recall of an event reviewed using the SenseCam images [3]. Earlier research also suggested that SenseCam images mimic episodic memory in being: personal and meaningful to the individual; of recent past, captured from the first person's point of view, captured automatically without requiring mindful awareness [5].

However, there is limited reported research on using SenseCam directly to help maintain the identity of people with dementia. Massimi *et al*., [10] used SenseCam images alongside music, narratives and movies to build ambient biographical displays aimed to improve quality of life for persons with dementia, including enhancing their sense of identity. The findings were positive, implying an improved sense of identity after using the display [10].

SENSECAM THERAPY

For the purpose of this study SenseCam was used within a therapeutic framework named "*SenseCam therapy*". The therapy involved the participants wearing SenseCam to collect images of events from their everyday lives and reviewing them with trained therapist. The therapist was a psychologist trained in dementia specific therapies including the well-known Cognitive Stimulation Therapy (CST). The main aim of the therapy was to stimulate the cognition of people with dementia in an implicit way. The therapist explored whether SenseCam images can cue the person's recent memories and encourages meaningful discussions about themselves during therapy sessions. This in turn, had an anticipated effect of supporting the construction of their identity, for people with dementia.

The SenseCam therapy adopted some aspects of CST framework, including the ground rules stating the focus should be on on opinion based discussions rather than

factual prompting. Moreover ensuring respect and inclusion of people with dementia and their beliefs and encouragement of implicit learning. The CST format of 14 sessions running over a seven-week period was also adopted for the delivery of SenseCam therapy [17]. For the period of these seven weeks, participants in our study each wore SenseCam every day while they went about their everyday life. Participants, who each had some form of dementia, decided with the help of their carers when they wished to wear the SenseCam and under what social conditions (e.g. when alone at home, during leisure-time activities, when socializing with others, etc.). Participants were also made aware of a privacy button on the camera allowing them to switch the SenseCam off at any time they wish.

The therapist who coordinated the study visited the wearers at pre-arranged appointments twice a week, for 45 minutes each time. During this time the therapist reviewed the images and engaged the participant in discussions about the images using software, which automatically structures the thousands of SenseCam images, captured each day, into discrete "events". The event-based browsing software developed in the CLARITY centre [6], allows huge amounts of SenseCam data to be navigated easily. The images were not reviewed prior to the sessions in order to ensure they were representative of recent events. The participants were encouraged to self-select images they wished to review from the events organised by calendar dates.

The participant, the carer and the therapist kept a journal each reflecting on observations throughout all sessions during the seven-week period. The therapist observed the participant engaging in the therapy, noting reflections in the journal regarding the process of administration, enjoyment and reflections on the construction of the person's identity.

METHOD

This research was conducted in an exploratory and descriptive approach using the multiple case study method. The case study is a method of empirical inquiry that enables investigation of a phenomenon within its own real life context [18]. Three individual case studies were conducted to collect in-depth data about the complex issue of SenseCam use as means to help in the construction of the identity of people with dementia thus exploring how technology can do more than just shape our lives, it can record it so we can remember it and thus help to define ourselves.

John, David and Dolores were the participants of the three cases. John was an 87-year-old frail man with a diagnosis of early stage Alzheimer's disease. He lived with his wife Mary who occasionally took part in the therapy sessions. David was a 57-year-old man with an early onset dementia following a myocardial infarction. Patricia – his wife sporadically participated in the therapy sessions. Dolores was an 87-year-old woman with a diagnosis of early stage vascular dementia. She lived independently and coped with her memory impairments by using a written diary.

The case study methodology enabled collection and analysis of both qualitative and quantitative data. The qualitative data included medical and social history, collected during an audio recorded semi structured interview with the carer and the person with dementia before and after the course of the therapy and journals kept individually by the therapist, the carer and the person with dementia reflecting on observations throughout the sessions from the perspective of their author. The detailed field notes collected by the therapist reflecting on the processes of the therapy, type of discussions and interactions that took place. The content of the images was not considered as data informing the study, thus it was not analysed independently. However, the discussion matter cued by the images formed the data collected and analysed for the purpose of this study. Quantitative data included responses to psychometric measures on cognition, quality of life, depression, communication and anxiety collected before and after the therapy course. Non-parametric tests of repeated measures were used on the quantitative data with no significant differences recorded.

The data were analysed by placing the quantitative results in arrays with the qualitative data, which were grouped chronologically and thematically. Three individual case study reports were completed based on individual case study analysis. They provided clear and in-depth descriptions of the person, their context and the processes and their responses to SenseCam therapy. The data was further combined and recombined in several different ways across the three cases in order to get a thorough understanding of the nuances and the different points of view in each case. This process is known as cross case analysis. Taken together, the cases were instrumental to acquiring an understanding of how SenseCam therapy enabled the construction of a version of participant's identity.

CONSTRUCTING SENSECAM IDENTITY

Through the delivery of the therapy, a particular version of each of the three the participant's identity was created. This version was constructed by discussing SenseCam images of the participant's recent past within social interactions, directly with the therapist. The content of the images guided the discussions to be both recent and unveiling of different aspects of the participant's lives. This led the therapist to appreciate a more holistic version of the participants' identity than a version that may have been revealed without the use of prompts derived from SenseCam images. Thus, we named this version a "SenseCam identity". The SenseCam version is not the ultimate identity of people with dementia as predominantly it was created and enriched by the triggers derived from the content of SenseCam images. Additionally it was also confined to the timeframe within participants' lives during which the images were captured, and the narratives shared within the interactions

with the therapist. Thus the perceived identity could have been different depending on the means and processes used to unveil it. The process by which the content of SenseCam images guided the construction of SenseCam identity is divided by two main patterns discussed below.

1. Discussing current identity as influenced by recentness of images

Firstly, recent content captured by SenseCam images guided the construction of the participant's identity to include aspects of their current life. The images reviewed, presented events from the preceding days of participant' lives, which mainly consisted of mundane details of daily routines. Thus, the narratives shared with the therapist during the therapy sessions were based on these recent memories about everyday life as cued by recollections from the images. This was unusual when compared to the narratives produced in the before-therapy interview, which predominantly consisted of details from distant rather than from recent past. The narratives collected during the before-therapy interview, offered each participant a freedom of choice with regard to what details about their lives and identities they wanted to share. Typically the details they discussed concerned their distant past where they exemplified themselves by their achievements, occupation roles, enjoyments and fruitful stages of their life.

In the case of John, during his before- and after-therapy narratives, he described his love for travelling, his life career in accountancy and his love of sports.

"...I've travelled and seen around the world and when I think of it and I lived in J in Cape Town in South Africa I have been working for a company and ehm I lived in New York and ehm another famous city San Francisco… and ehm played golf and tennis and some rugby and ehm been keen on sport really…"

Without the cues from SenseCam images, John described himself as having been a very active man with love for international travel. The narratives cued by SenseCam images showed how this identity continued, but also transformed over the years. They portrayed a slightly different, more sedentary view of John. They showed John still enjoyed a lot of outings however these were now narrowed to the city he lived in. His love of sport was also represented in John viewing it on television or by an occasional game of golf.

Similarly, in his before-therapy narrative David focused on his love of wildlife, his various occupation roles and in general presented himself as a hardworking man.

"then I went to work I went to X and got a job in X for a few weeks and then I got out of that and I worked for a landscape gardener we used to do the maintenance of a lot of the hotels and we used to we had a contract in the airport and an awful lot of banks in Z like used to maintain all that stuff"

Both the cues from the SenseCam images coupled with his wife's encouragement, helped David to discuss more recent details about his life, which, in turn conveyed a more complete picture of his identity and not just of his past. The narratives shared during the sessions showed that while he was no longer employed or had the ability to work on complex projects, he maintained other important but less demanding aspects of his identity. They included his passion for wildlife and healthy diet as displayed by seemingly endless SenseCam images from various nature trips and wholesome food dishes he would prepare and eat.

Yet again, Dolores narrated her life story in a beautiful manner giving the impression it was a very well rehearsed story. She concentrated on the years she spent in college and in training, which seems to have consisted of a vibrant social life. A major part of her narrative was also devoted to her occupation, and to her children. There was little focus on the present except for a statement at the end saying she is happy where she is.

"There was plenty of work and ehm I came back to X and worked all around the different hospitals and doing locums here and there"

"Great life it was in C they were all bachelors ... and they'd all go to the river and we'd do the sandwiches and the lunch and the thing for the meal and we'd take it out with us and we'd do that every week"

"I'm very happy here and I'm going to stay and that's where I am up to this day"

The discussions cued by SenseCam images portrayed Dolores' life as more relaxed, with her no longer working or having as exciting a social life as in the past. Nonetheless, the narratives shared during the sessions also revealed she sustained some aspects of her identity including her passion for knowledge represented by the great amount of time she still devoted to reading and writing.

Other aspects of identity continued but altered over time including replacing her professional occupation with voluntary work overseas.

Collected, these narratives enabled the therapist to perceive a more holistic version of participants' identity. In other approaches and interventions like reminiscence or life story, little attention is given to recent events, which in turn results in creation of a particular version of participant's identity from the past, very different to the one constructed within SenseCam therapy sessions. The narratives shared with the therapist as cued by SenseCam images, enriched the identity, which had been presented in the before-therapy interviews and revealed how it continued and transformed through the participants' lives.

2. Discussing unexpected details of participants' identity as exposed by SenseCam images.

The second manner in which the content of SenseCam images guided the construction of participants' identity was

when the technology didn't just shape our lives but also exposed unforeseen details of the participant's lives. The participants had full control of when they wore the device as they were advised to wear SenseCam only at times during which they were comfortable with what the camera might capture. However, even within the controlled periods of wear, at times the type of content SenseCam had captured was unexpected and surprising even to the participants themselves. The controlled wearing provided ethically safe boundaries ensuring private or intimate moments weren't captured. Yet, the power over the content of the images was still limited, due to the passive and automatic manner in which the camera captured the images. The SenseCam images exposed uncensored contents from the participants' recent pasts which differed significantly to the content normally presented in standard staged or posed photographs they might have been used to.

Furthermore, it seemed that if the participants had a chance to select the content captured by SenseCam images these unexpected details might have been excluded. However, using SenseCam within a therapeutic approach enabled an intimate but temporary partnership to be formed between the person with dementia and the therapist that allowed conversation of events that under normal interview circumstance may have been considered undesirable for discussion. Thus, it is assumed the particular version of identity constructed during the sessions is distinctive and unique to SenseCam images and trusting interactions as compared to depiction of one's identity during a standard interview or even via the use of common posed photographs.

For John and David these unexpected revelations included capturing and discussing certain practices that seemed to be considered as undesirable by their carers. John accurately recognised wine glasses in the images and commented on them with joy, despite having trouble recognising most other objects captured in the images. It was also observed that anytime John did mention wine, his wife tried to justify why he has done so. It seemed that at first she was a little self-conscious by John's positive reaction to wine being displayed in the images.

"...we must have been having some vino"

For David, this exposure consisted of SenseCam images capturing previously unmentioned David's pipe-smoking. In both cases the exposures were handled carefully and ethically and treated in a non-judgemental manner. The participants seemed at ease and comfortable discussing these revelations, despite their disclosure being so unforeseen. In the case of David and Patricia, they were even able to find humour in it. Mary opened up about some issues related to alcohol use in dementia, which highlighted this was a sensitive issue for them and may not have been discussed without the exposure which arose through SenseCam image review.

In the case of Dolores, there weren't as many particulars revealed by SenseCam that she may not have chosen to discuss as one of her identity components. This was due to her being very selective about SenseCam wear. However, a strong theme about her came through when reviewing the images that may not otherwise have become evident. There were many images of Dolores' reflection in the mirrors throughout the images. Initially Dolores ignored them but as the therapy progressed and a friendly relationship was built up, she commented on them.

"oh yes that's me doing my make up, I always do my make up in the mirror in the room"

"I was probably checking how visible the thing (SenseCam) was, and it's not noticeable at all"

Without the use of SenseCam images, it is possible these details would never have been revealed during a standard interview or by using generic images. The content of the images unveiled some uncensored details that may have never been freely chosen as identity components. This further differentiates the version of identity constructed during the therapy sessions and displays how it was dependent on the content of SenseCam images. This SenseCam identity seemed more holistic and freed from the limits one may impose on their identity by the unforeseen content of images. This highlights the potential of SenseCam use as a tool to support construction of a current and more exposed version of the identity of a person with dementia.

While the SenseCam images guided the construction of a more holistic version of the participants' identity as perceived by the therapist, the people with dementia themselves didn't seem to fully associate with this version. In all three cases the participants seemed to have a stronger association only with the identity from their distant past, for example with that of their main occupation in earlier life. This varying perception of person's identity between the therapist and the person themselves is in line with the constructivism objection to the universal version of truth, and acceptance that truth is merely a subjective view, a more or less coherent way of understanding things as dependent on individual interpretations.

The participants' association with distant past was apparent through direct references to aspects of their past identity and indirect displeasure in certain more up-to-date aspects captured by SenseCam images. John often seemed a little confused by the SenseCam images, however it is difficult to argue this was due to him dissociating with his current identity. John's episodic memory of recent events was so severely impaired he had very little insight to his current life. Although, in the perception of people in John's life the recent events continued to create a version of John's identity, they had little impact on John's awareness of this current version. John mainly associated himself with his identity of the past. There were occasions when John recognised the images and had the understanding they were of his recent past, but he purposefully avoided discussing them by distracting the therapist with other items in his house. These avoided images often included sedentary

behaviour like watching television. John often remarked that they were very uninteresting and used items like the world atlas as distraction and hint to discuss his history of his travels from his distant past.

In the case of David the idea of associating with distant identity was called upon by his wife and carer more often than by David himself. This could be due to David's denial about memory problems. Patricia, his wife and his carer often referred to David in conversation as "*The way David used to be" "Before this all [David's diagnosis] started"*. Additionally when asked if SenseCam portrayed a version of David's identity to the therapist, Patricia answered that it did but only partly. When probed further she explained:

"well I suppose she would have picked up that he's not out he's not in big crowds or he's quite alone he's quite a reserved guy compared to before but he is very calm he's very quiet and he's a very gentle person … I hope she picked up his whole love of nature that's all really and lots of quietness…"

The idea of SenseCam portraying Dolores's identity was explored directly with her, initially by asking if there was anything in her life that helped her or re-enforced her identity. After giving it some thought she answered, saying that when she looks at photographs she had collected over the years they remind her of all different stages of her life and of who she became. Dolores was then asked if the SenseCam images represent her identity in a similar way to her collection of personal images. She revealed that the SenseCam images portray a different part of her – which is only the present one. She reflected that her identity is represented more accurately by the collection of photographs from her life. She further stated that SenseCam images represent what she does now as oppose to who she is as a whole. She also revealed that viewing SenseCam images alone without the interaction and discussions about her present and past doesn't hold as much meaning.

"They are different in that they show more of what I do now as opposed to what I have worked hard to achieve/ become… they make me realize that I am a lot less active and I don't do as much volunteering or walk that much anymore … I don't get up that early as I feel tired then whereas I used to be up very early"

Similarly as in the case of John, it was also observed that Dolores showed reluctance reviewing images of sedentary behaviours. Frequently she remarked about the time she wasted during any activity she thought of as insignificant. For example if the images showing her eating her breakfast were reviewed for too long she would comment: "*Am I still at it?"*

These observations suggest that participants associate with their past identity. They also appear displeased by certain aspects of the more current version of their own identity, being classed as elderly, inactive or with memory impairments. It is important to be aware that differing versions of identity can be constructed and that people with dementia tend to see their past identity as more preferable even though it might be outdated and misrepresent their current status. Consequently, if people are asked directly about their identity they may present a particular version that may be misguiding to the interviewer. This further highlights the usefulness of SenseCam to enrich the version of identity that may be presented using the standard interview methods.

DISCUSSION

SenseCam therapy helped to construct more holistic versions of the identity of the participants. It included references to both distant past as well as the recent past. Unforeseen details of participants lives were exposed via SenseCam images, even though they may not have been revealed by choice. The constructed identities do not represent a chronological life story or a static account of the person. They were based on SenseCam images and the associated narrations and are a mere version created by the interaction of the person with dementia and the therapist. This SenseCam identity is open to change and alteration with each additional image captured and reviewed.

This phenomenon of SenseCam therapy helping to construct more holistic versions of the identity of people with dementia implicates three main discussion points. Firstly it suggests a potential to use SenseCam as a tool to learn and discover the identity of persons with dementia. The people surrounding the person with dementia are often disinterested, and forget to acknowledge the person within the disease. Medical professionals often depersonalize the individual in light of the symptoms and their medical interventions. As a form of digital technology SenseCam offers a way of bringing the person back the surface within the circle of people around them and is an example of how the interaction between humans and technology can be used to enhance how a person is viewed by others. One way to achieve this is to use the SenseCam similar to the methodology used in this study. By reviewing and discussing images of recent past, healthcare professionals as well as people with dementia themselves learn about their identity in the present. Additionally, another possibility is to use SenseCam in order to collect life logs before an identity of a person with dementia diminishes. These life logs can then be used to feed back or curate identity once it starts to erode alongside the disease progression [4]. In later stages, once the identity is much weakened and the ability to express it is minimal, the life log can be used to enable the direct carers to get to know who the person is. Thus we could have technology not only shaping. But preserving our lives.There are some ethical concerns with SenseCam enabling the construction and perception of this more current version of identity to the researchers. People with dementia focus on distant past whereas SenseCam encourages a focus on the recent past and it also unveils unexpected details which may not have been discussed had they not been exposed. Regardless of people with dementia making the choice not to, or being simply incapable of

remembering certain events, their forgetfulness or their age should be respected.

Secondly clear recommendations on how to use SenseCam with people with dementia needs to be developed for professionals as well as for the informal carers and loved ones. We have found that identity exposure can be involuntary to the research aims and happens by the proxy of using SenseCam with the participant. The types of details revealed by the images are not always the ones participants would want to share voluntarily. Thus, professionals using SenseCam as a therapy with people with dementia need to be prepared for such exposures and how to handle them sensitively. This highlights the need for consideration of the strong ethical implications of SenseCam use with people with dementia. The study reported in this paper was guided by the principles of CST in order to ensure there was always an ethical review of SenseCam images. They include rules like showing respect to the person with dementia and making him/her feel of equal importance and never exposing their difficulties [17]. Similar ethical guidelines need to be developed specifically for SenseCam use by people with dementia.

The overall findings from this study identified a number of issues, which should be considered when using SenseCam with people with dementia, which can be summarised as follows:

- Consider the contextual factors of the person with dementia including the level of cognitive impairment, existing coping mechanisms to memory impairments that they may have developed and the presence and existing interaction patterns with the carer;
- Tailor the therapy to suit the individual needs of the persons with dementia and their carer;
- Use SenseCam within a therapeutic framework;
- Develop a trusting therapeutic relationship with the participants;
- Anticipate discussing intimate and unexpected details from the person's life;
- Ensure that personal details revealed by SenseCam are dealt with sensitively and ethically;
- Appreciate the version of the person's identity as constructed during the therapy but respect their perception of identity.

Finally the last point to note in this discussion is the need for developing a study protocol for a randomized controlled trial (RCT) to test the success or failure of the SenseCam therapy. The development of such a protocol should be guided by similar protocols developed previously to evaluate home-based psychosocial interventions for people with dementia, mainly the study protocol developed to evaluate the individual cognitive stimulation therapy for dementia (iCST)[14]. Issues of treatment adherence are the main concern when delivering therapy like SenseCam at the scale of an RCT – with participant numbers reaching the hundreds. It is necessary to ensure that the therapy delivered to the people with dementia is in fact the therapy intended to be delivered [14]. In order to ensure the treatment was implemented as intended the treatment integrity model was followed in the RCT of iCST and should also be followed when designing the protocol for SenseCam therapy. The treatment implementation model sets out that specific components of an intervention including delivery, receipt and enactment are a requirement to assessing whether a valid clinical trial of a therapeutic intervention has been conducted [14]. If a RCT on SenseCam therapy for people with dementia would indicate that the therapy is beneficial, a recommendation for its use could then be issued.

CONCLUSION

SenseCam therapy enriches the details participants share about their identity in a standard interview. It exposes a more holistic identity version, which includes aspects of both the distant and the recent past. Using SenseCam to help in construction of the identity of people with dementia is an important discovery in the use of lifelogging technology for dementia interventions, and possibly for other applications also. It offers a potential to use SenseCam to inform healthcare professionals and family carers about who the person really is. It also highlights the need for strong ethical implications of SenseCam use with people with dementia. The choice of the type of details revealed about each participant is greatly reduced when using SenseCam, and the professionals using this technology with people with dementia need to be aware of unexpected exposures about participants' lives. Lastly with clear recommendations of how to use SenseCam with people with dementia, a need for protocol development to test its success has been identified.

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An Offline Web App for the Self-Management of Diabetes and Obesity

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ABSTRACT
The amount of people being diagnosed with diabetes is ever increasing and smartphone applications allow such patients to self-manage their condition through documenting their readings for analysis and future reference. These management applications are designed to enable users to take charge of their condition and to promote healthy living. Many of these diabetes and obesity monitoring applications are native to a specific operating system, which may restrict other users using them. Web applications provides a solution to this. Many mobile web applications require network access to fully operate. The proposed diabetes and obesity management system utilises a hybrid methodology that will be both native and web based. The system is developed using the latest web technologies with a strong focus on utilising responsive design and offline storage capabilities that can be uploaded to a cloud based database.

Categories and Subject Descriptors
D.3.3 [**Programming Languages**]: JavaScript, HTML5, PHP

General Terms
Self-Management, Offline, Responsive, Hybrid, Performance, Mobile, application

Keywords
Offline, human computer interaction, storage, browser, operating system, monitoring, IndexedDB, HTML5, JavaScript

1. INTRODUCTION
Diabetes is a growing issue that needs to be addressed. A report published by www.diabetes.org.uk stated that a person is diagnosed as diabetic 'roughly every three minutes' in the UK [1]. Statistics from Diabetes UK have recorded a year on year increase in diabetes in the UK. Diabetes UK state that 'since 1996, people diagnosed with diabetes has increased from 1.4 million - 3.2 million' [1,2]. The IDF (International Diabetes Federation) state that globally '382 million people have diabetes and that this figure will increase to 592 million by 2035'. IDF along with Diabetes UK state that type 2 diabetes is increasing in every country and the age group 40-59 holds the greatest number of people living with the condition [3].

In Northern Ireland, there are an estimated 70,000 people living with the condition, which brings an economic burden to the Northern Ireland Healthcare service [4]. During 2010 the treatment and care associated with diabetes provided cost the government £1,000,000 per day [4]. Diabetes is a growing issue and with the rate of people being diagnosed increasing year on year [4]. From 2006 – 2010, the number of individuals diagnosed with type 1 and type 2 diabetes, increased by 34% [4]. There is a huge financial burden undertaken by health services across the world to facilitate treatment of diabetes and the conditions that come with it. A report conducted within the UK stated that diabetes cost the UK £23.7bn in the year 2010 to 2011 [5]. The report stated that complications associated with diabetes account for a great amount of the health costs and that this cost will continue to increase if care regimes put in place are maintained [5]. According to NHS Choices, type 2 diabetes and obesity are very much linked [6]. A major contributing factor of type 2 diabetes is linked to the lifestyle of the individual. Individuals who are obese have an increased chance of developing the condition [5]. NHS Choices state that if an individual has a body mass index that is 30 or over, then there is an increased chance of developing type 2 diabetes. NHS highlights the importance of maintaining a healthy diet and exercising regularly in order to lose weight which in turn reduces the chances of developing type 2 diabetes [5]. The National Statistics Office published a report in 2012 describing the growth rate of obesity within the UK. In 2010, 26% of both men and women aged over 16 were classified as obese and 42% of men were classified as being overweight and 32% of women being the same [7].

Diabetes self-management are designed to enable individuals to take charge of their condition and to help themselves make informed decisions using clinical guidance. Traditional methods of diabetes self-management employs the use of a logbook. These logbooks allow patients to manually record their blood sugar before and after meals as well as recording insulin administered. However technology has enabled users to use a myriad of management applications instead. Smartphone and web applications are available which allow users in record their readings in an online account or locally within the application. Analysis techniques can be employed as well as visually representing user readings through graphs.

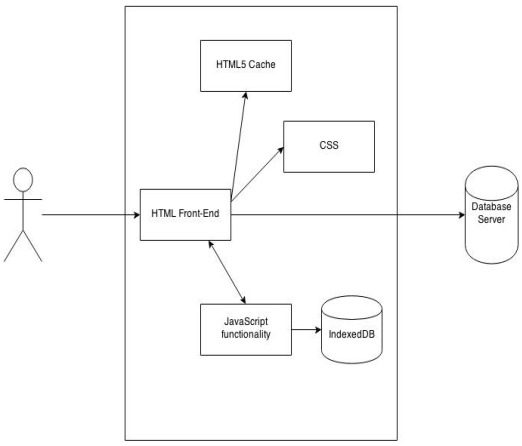
A report entitled ‘The Value of Information Technology-Enabled Diabetes Management’ discusses the use of IT-enabled diabetes management (ITDM) in order to improve diabetic processes [8]. The report highlights the technologies used by patients within the area of ITDM consisting of learning resources and data input methods to track progress. The report states that diabetes management offers a range of benefits for the patient by improving care processes to help prevent the development of complications associated with diabetes. Another study was

conducted [9] which focused in on 7 diabetic individuals using technology to share blood glucose readings with healthcare providers. The results of the study shows a decrease in blood sugar levels from month 1, which on average was 146.5 to month 3 which was 141.1. This study shows that active diabetes management can have a substantial impact on blood glucose readings. Other research in using diabetes management applications state that data shared between the patient and the medical professional helped save time and also reduced the cost of care [10]. The patients were able to take advantage of savings in time in visiting healthcare professionals by allowing users to share their data through the application. The main focus of this research is to develop an diabetes and obesity management application that is not native to any particular operating system. The application will employ modern offline web technologies to allow patients to save their readings offline without the need for network connection. Utilising offline technologies will promote convenience for the user. For example, if a user is using a web based application to save their readings (blood glucose, insulin) to then find out there is no network connection to upload their data, this would cause problems. Using offline technologies (IndexedDB and HTML5 Cache) this issue wouldn't occur, as the application would be cached to allow for offline use. The proposed application will allow users to save their data offline initially and synchronise the data to their account once they have a network connection. The application will also use responsive technologies to allow scalability.

2. METHOD

2.1 Technologies Used

To develop the diabetes and obesity self-management system various web technologies were used. The application was developed using the bootstrap framework [11]. Bootstrap allows the system to become responsive in relation to the device accessing the application. The application will employ offline technologies to enable users to save their data offline. IndexedDB was utilised and this allows data to be stored within the user's Internet browser [12]. IndexedDB will play a major role in enabling data to be saved in an offline database and allowing users to use system functionality regardless of network access. HTML5 cache is used to enable web pages to be accessed offline. HTML5 cache consists of a manifest file that contains a list of different items to be cached within the browser. Local web storage will also be employed to store data in local storage objects. The objects are able to be accessed across the system. The application also enables users to upload their data to their account and ultimately share their data. PHP and MySQL are used to enable users to upload their data and store it within the database [13].



In order to illustrate the system, a high level system design was created. Figure 1 shows a high level view of the system illustrating the offline repositories that allow for offline usage. The system comprises of a multi tier architecture including the client, logic, and server application. The application will contain functionality within the local client tier for offline usage and also allows users to back up their data to MySQL database. In order to help with the requirements of the application, a number of already existing applications were analysed. A range of popular applications were chosen across a variety of different operating systems. Each feature that was present in each application was listed. If any of the other applications contained this feature then this was noted. This process was carried through to attain a popular list of features that could then be included within the prototype for the offline mobile web application. It was after when the technologies and functional requirements were defined then the implementation could commence. Before implementation it was important to determine which tables were needed for the database. The relationship between each table needed to be defined to promote data integrity. An ER (entity relationship) diagram was created and used throughout development. Figure 2 shows the ER diagram that was developed during design.

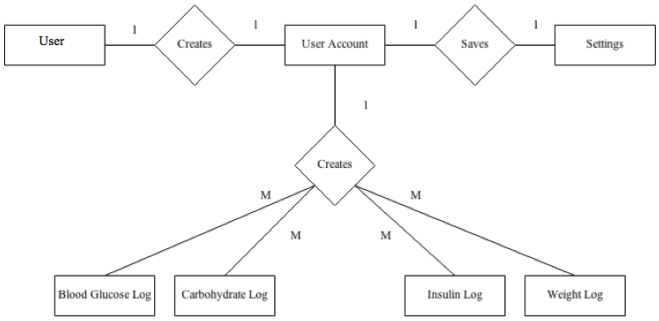


Figure 2: Entity Relationship Diagram

2.2 Implementation

Bootstrap is used as a framework for the prototype. This increases the accessibility and usability of the system across different devices. The client-side development consisted of using CSS and HTML. The forms to store the data within the prototype uses HTML5 element types and validation to help define correct data input. IndexedDB local storage was developed using an IDBwrapper [11]. This wrapper allows IndexedDB databases to be created easily through the use of the jQuery API. IndexedDB was used to store data from each form within the application. The IDBwrapper implements a database within the browser, which is able to store these items. Each item within the database store has a unique ID. This unique ID can then be used as a *keypath* for deletion using JavaScript. HTML5 will also be used within the prototype application. HTML5 adds greater interaction to web pages through the use of different features and elements.

HTML5 is used to graph data from within IndexedDB to visualise user logs. A HTML5 graph plug-in was used as a way in which data could be visualised. To plot the data from the IndexedDB store, each item within the store was stored within an array. The

array was then referenced within the HTML5 graph JavaScript function in order to plot the data [15]. HTML5 cache was also used to ensure that the application is able to perform its main functionality regardless of no network connection. This was achieved by linking a manifest file within the opening `<HTML>` tag in each HTML file. The files and web pages referenced within this manifest file are saved to allow user access regardless of the Internet connection. Figure 2 is a screenshot of the glucose log input page in the prototype application.

The application also provides an option for users to back up their logs saved within IndexedDB. Figure 4 provides an overview of the schema used in MySQL. Each table within the schema represents a data input form in the application. Blood_glucose table represents the 'Add blood glucose log'. The settings table represents a form in which users are able to input their personal details. User table stores the usernames and passwords. The username is then referenced throughout the schema to identify ownership of each record. Insulin_logs and weight_logs contain fields relating to other input form on the client side.

Uploading user data is achieved through using PHP and MySQL. Each log that the user creates within IndexedDB is timestamped. The data within IndexedDB are saved to a JSON string. The JSON string is then saved to a variable. This variable is then posted to a PHP file for parsing using AJAX. The data stored within the JSON string is then put through a `foreach` loop to assign values to PHP variables. The variables are then referenced within a SQL query to store within the database. If the user is uploading a set of logs that may include a log that has already been uploaded, the SQL query uses the timestamp and username as a way of skipping this log to prevent duplicate data. This process is used for uploading other log types (weight, carbohydrates and insulin).

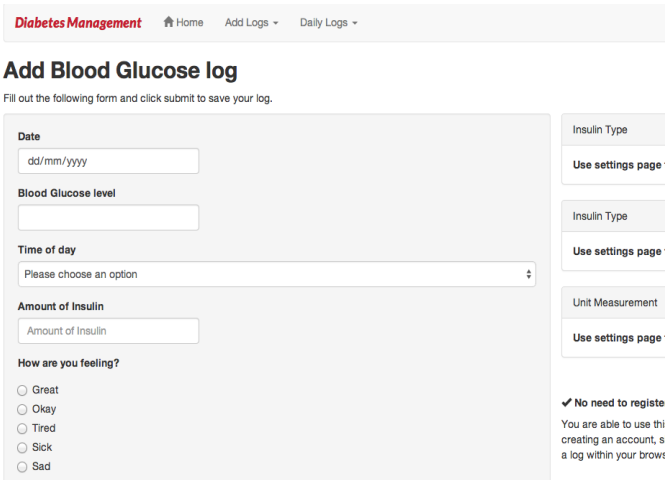


Figure 3: Add Blood Glucose Log screen

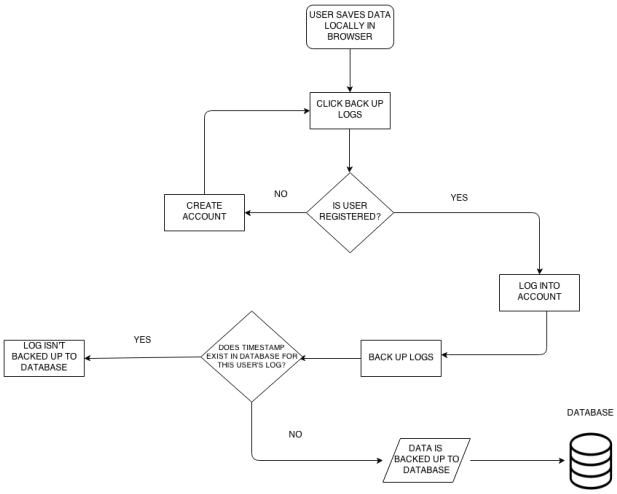


Figure 4: Flow chart describing how data is uploaded.

Web storage was also used as another way to store data offline. Web storage objects allow data to be registered and stored within the user's browser. This functionality was used within the user's settings page. When the user saves settings, the data is saved within an IndexedDB file. It is also saved within web storage objects. These objects can then be accessed throughout the system to personalise each form page and to remind the user of their measurements and readings.

2.3 Functional Testing

Once development of the system was complete, it was important to ensure that the application was compatible with the main Internet browsers. The five main Internet browsers, Firefox, Google Chrome, Internet Explorer, Safari and Opera were used for cross browser testing. Several tests were conducted to ensure that the system's main functionality was working correctly. Browser testing revealed that the system loaded correctly on each. Elements within each webpage rendered correctly when accessed by the browsers. Positioning of system navigation menu also loaded correctly within each browser. The Bootstrap framework was working accordingly in each browser also.

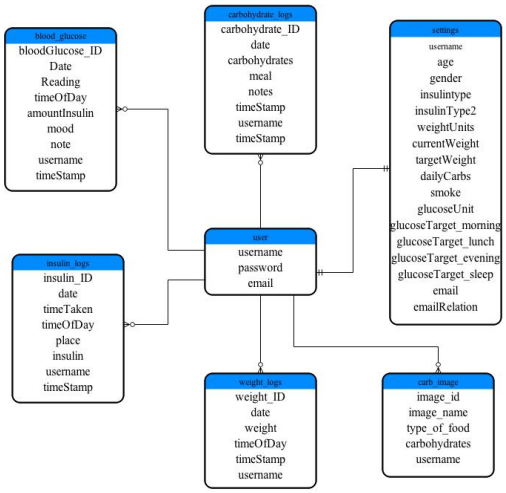


Figure 5: Final database schema for prototype

There were certain areas that were presented differently in relation to each browser. HTML5 elements were used to allow users to input dates. This enabled users to select a date from a drop down list. This HTML5 element did not load within Firefox or Safari. HTML5 application cache worked correctly within each of main browsers. The Internet browsers were still able to access the system functionality without network connection. Each browser was able to store user data using IndexedDB local storage.

It was also important to test the functionality using different devices. The two most popular mobile operating systems were used with this testing phase (Android and iOS 7). The main system functionality was tested as well as ensuring that application was able to scale to the device's resolution using the Bootstrap framework. Android 4.4 and iOS 7.2 tablet devices and their smartphone counterparts was used throughout this testing process. When the system was accessed by these devices, the application scaled to the screen size. The design elements along with the font within the system rendered correctly. There was a minor issue that was discovered when the application was accessed using iOS tablet device. The navigation buttons shifted below the other buttons when viewed in portrait mode.

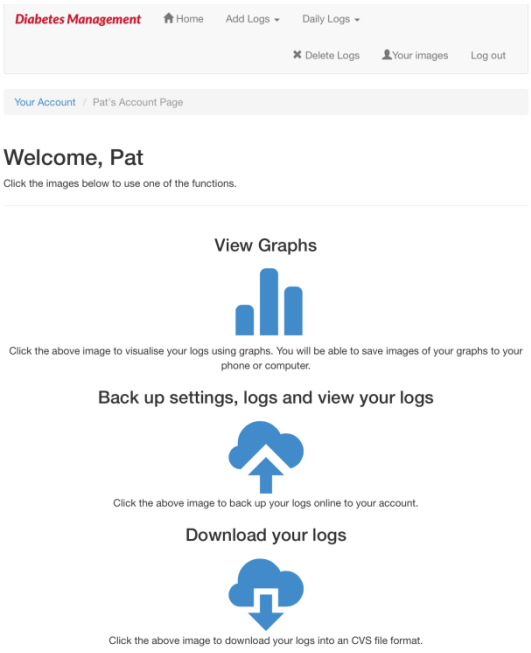


Figure 6: Screenshot showing user account area using tablet

Figure 5 shows how the user account area is rendered when viewed using an iOS Smartphone device. HTML5 cache also worked appropriately within each Smartphone and tablet device. IndexedDB was also tested within each Smartphone and tablet device to ensure that it was able to store data within the browser. iOS 7 device used Safari as the main browser for testing IndexedDB and the default browser was used in Android 4.4. The Android tablet that was used for testing was able to save data locally within the browser using IndexedDB. Further investigations found that earlier versions of Android (before 4.4) had issues utilising IndexedDB [16].

2.4 Usability Testing

To test the usability of the system different usability measures were utilised. Time to completion (TTC) metric was used in conjunction with scenarios. Each scenario was based on different functionality in the system. Users were asked to complete the scenario and they were timed in relation to how long it took them to complete the task. Task completion rate (TCR) was also used in conjunction with TTC. TCR can be used as a binary metric to find out what tasks the user could and could not complete. The criteria for not being able to complete a task was defined as the user asking the expert for help to complete a task. The scenario would then be catergorised as a 1 representing the user needed help and 0 stating the user did not need assistance.

The scenarios used within TTC were based around the main functionality of the application. The expert noted the start time of when the user started the scenario and the user signaled when the task completed. The time was noted for when the task was completed. This was then used to find out how long it took the user to complete the task. Five users were asked to complete the set of scenarios using a Mac OS X laptop. The data from TTC was then collated together to find out what tasks the users had issues with the most to help assess how usable the application is. As well as using the described metrics, the users were asked to complete a questionnaire. The questionnaire allowed users to rate the system and to give their own opinions. The questionnaire also facilitated an area to allow users to give future recommendations.

3. RESULTS

3.1 Usability Results

During TTC usability test, each task was measured in seconds. The results were collated together once the process was completed. The average was then calculated for each task along with the average task completion for each user. If users needed help to complete a task then this was noted next to the completion time. The task completion rate table was use to document how many tasks needed assistance. The standard deviation was also used as a means of assessing variability from the usability tests. The results show that task 6 took the longest for users to complete with an average of 97 seconds. Task 6 asked the user to create blood glucose log and upload it to their account. Once uploaded the user was asked to check to see if their log was indeed uploaded. The task with the shortest average was task 17 with 8 seconds. This task asked the user to log out from their account once finished with the system.

Users were able to complete majority of tasks without assistance. 80% of users needed assistance with tasks 4 and 6. Task 4 was concerned with backing up locally saved data to their newly created account. This was the first time users were introduced to the idea of backing up data to their account within this application. Task 6 was also concerned with combining a mixture of tasks from the previous scenarios. Task 6 was asking user to create blood glucose log, upload the log and then view the data saved to their account. Majority of users were able to complete the first two stages of task 6 but many were unsure as to how to view the data saved to their online account.

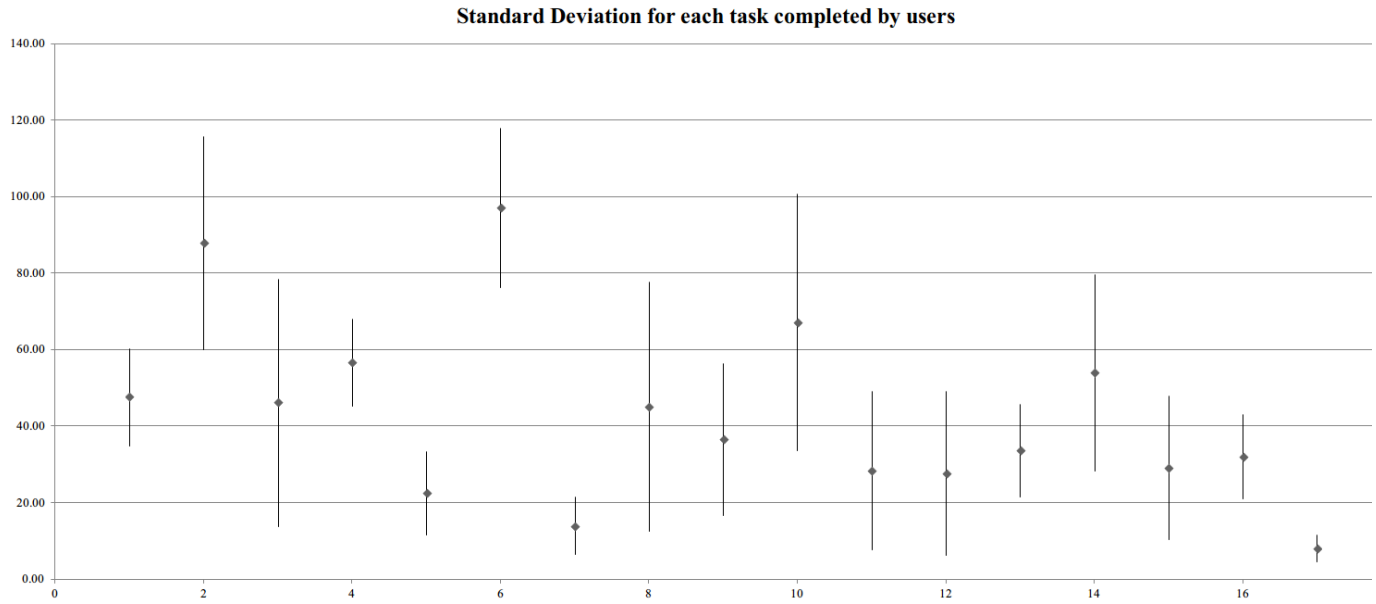


Figure 7: Table showing standard deviation for each task. Horizontal represents task number and vertical represents time in seconds.

Figure 7 illustrates the standard deviation for each task completed by the users. The standard deviation shows the amount variance in the data from the mean. From figure 7, you can see that there is great variance in the majority of the tasks. Task 7 and 17 has the least variability in comparison to the other tasks. These two tasks were relatively simple in regards to the other tasks within the study. Users may have felt that this task was straightforward which shows a low variance within the dataset.

3.2 Questionnaire Results

The users who completed the TTC study were then asked to complete a questionnaire. The questionnaire allowed the users to rate the system on functionality and design. The questionnaire also allowed users to give future recommendations and comment on the application. The questionnaire asked questions specifically relating to the functionality completed within the TTC study. The questionnaire allowed users to rate the system on a rating of 1-5, 1 being poor and 5 being excellent. The results of the questionnaire showed that 100% of users rated their overall experience as 3 to 5 (Figure 8). 100% of users rated system navigation as 4 to 5. 100% of users stated that they would use the system again in monitoring weight or diabetes (or both). Majority of users (80%) rated the account area navigation as 5.

In regards to future recommendations and improvements, a user stated that social media elements could be incorporated into the system. The user did not state what type of logs to share through social media. Sharing sensitive data such as blood glucose logs through social media would raise ethical issues and in particular the issue of privacy. Social media integration may encourage peer support and motivation for sustained behaviour change. Thus, future iterations of this application may include social media integration for sharing data such as exercise logs or calories burnt. Only specific log types would integrate social media functionality. As it stands, the application facilitates an email sharing system. The users are able to input an email to share their blood glucose logs. Users stated that instructions should be made clearer in regards to emailing logs. Another user also stated that the wording within the application should be highlighted better for instruction. This would then relate to the issue users had in viewing their uploaded logs to their account in TTC study. A user also gave the recommendation of adding a calorie counter to track food intake as well as an exercise tracker to document exercise regimes and energy expended.

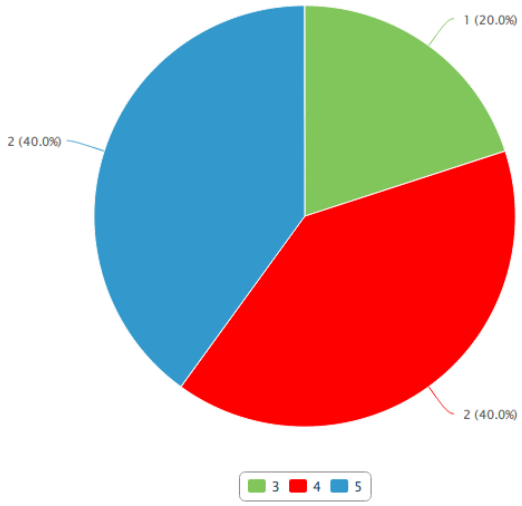


Figure 8: Results from question 'Rate your overall experience using the application'

4. DISCUSSION

The purpose of this application was to increase usability and human computer interaction by combining offline technologies to create a hybrid web application. The implemented web application integrates offline web technologies that allow the user to store data in a local database in the browser. The prototype uses web technologies to ensure that the system is easily accessible without confining to a particular operating system. Bootstrap is employed to promote accessibility and usability on different devices. HTML5 application cache allows the user to operate the

system offline without the need of a network connection. This functionality would be convenient when using the application on a smartphone device or table as it is frustrating for the user to not be able to use an application because of network connection. HTML5 application cache provides a way to overcome this issue in regards to web applications. Once the user visits the developed prototype, HTML5 cache automatically stores the necessary files in the browser in order for the system to operate. The application is then able to render of every webpage from this cache regardless of network connection. The technologies used in the application offer a novel hybrid approach that is able to be accessed by a mobile device or desktop/laptop. IndexedDB is a relatively new framework which is supported by all main Internet browsers and mobile device browsers [16].

A survey was published by Kendo UI relating to mobile app development in 2013. The survey was concerned about the popularity of desktop and mobile application development in comparison to native applications [17]. The study surveyed more than 5,000 software developers about their opinion of usage of different mobile technologies. The findings show that only 15% would develop native-only applications. 87% of the developers survey stated that they were focused on using HTML5 to develop desktop websites and web apps. The survey also wanted to find out what modern technologies are important in developing applications. Database technologies such as IndexedDB and WebSQL are listed as the second most important modern day technologies. In regards to cross-platform development, 36% of the developers stated that they would use HTML5 implementations when developing. 32% percent stated they would use hybrid technologies for mobile devices while only 15% stated they would opt for a native application. Ultimately, 70% of the developers stated that they would utilise HTML5 to build applications to reach all platforms instead of developing native applications. Although this study was limited to 5,000 developers, there is overwhelming support to adopt the use of multi-platform and hybrid technologies.

The application developed brings together a range of different technologies noted within the survey discussed. The technologies used try to address some of the issues experienced by native applications. Issues such as cross compatibility across different operating system. As stated, network accessibility is a major issue in regards to mobile devices. If a user is going to input their blood glucose reading but discovers that there is no Internet connection, this then is going to prevent usability. The developed application provides a solution to this problem using local storage and HTML5 technologies. Using the developed application, the user is still able to store their blood glucose reading without the need for any Internet connection.

5. CONCLUSION

The results of this research show that IndexedDB and other offline technologies can be incorporated together to create a diabetes self management system. HTML5 and JavaScript were used to promote cross platform usability and to allow users to use the system regardless of browser or device. Testing revealed that the developed application was able to function efficiently across the five main browsers. IndexedDB and HTML5 application cache operated correctly across these browsers however various HTML5 input form elements did not render correctly (Safari desktop web browser and Firefox).

Results from device testing on the two main mobile operating systems Android 4.4 and iOS 7 showed that the main functionality worked correctly. Responsive framework also worked efficiently to promote usability and accessibility. Preliminary results from usability testing showed that users were able to use the system comfortably. All users stated they would personally use the application to help monitor diabetes and/or obesity. Users felt that the system was easy to navigate around to find key functionality. However, in order to attain a more detailed analysis regarding the application, an extended trial period with a larger group of users is needed.

5.1 Future Additions

The questionnaire completed by users resulted a valuable insight into different recommendations. Activity tracker/log was suggested by users. Google API could be incorporated with this exercise tracker to allow users to track an exercise (running or walking). This would allow visualisation of movement within the application. Users would be able to document their exercise regimes and distance travelled. Users suggested incorporating a calorie counter with the already developed carbohydrate tracker. Future iterations of the application may integrate social media for specific log types (exercise logs, and calories burnt). The user would be able to share calorie expenditure or distance travelled. Another future addition would also be a medication alert/reminder. The reminder system would allow users to configure reminders for a specific time. An alert could then be presented to the user. This addition would be useful in reminding users to check blood glucose levels or to administer medication. In regards to usability testing, a greater number of people would be used to assess the system over a longer period of time. This would allow for greater usability analysis. Future work would also include a usage analysis of the application as well as a user satisfaction survey to understand how users view the aesthetics of the application. This would also be used for further improvements of the application.

6. ACKNOWLEDGMENTS

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Electronic Health Record Systems: The Need to Consider Patient Privacy Concerns

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ABSTRACT

The success of innovative technologies is dependent on their adoption by a critical mass of individuals. However, in developing such technologies and systems, the concerns of the end user or person whom the technology is supposed to benefit are often overlooked, leading to a distrust of the system that inhibits its adoption. This has been the case with many electronic health record (eHR) systems to date, in relation to Information privacy. It is widely acknowledged that eHRs would provide a transformative benefit to the Irish health system resulting in improved patient care, greater transparency, and resource efficiencies and improved decision making.

The purpose of this paper is to first make the case for the value of a national eHR system in Ireland by outlining the benefits of these systems and the current status of eHealth in Ireland. The paper will then seek to highlight the importance of considering Information privacy concerns when implementing eHRs. This will be achieved by acknowledging the role Information privacy concerns have played in eHR implementation in other countries. However, Information privacy research is marred with inconsistencies in terms of how to best measure privacy concerns. Following a review of the most popular measures of privacy concern, a proposal for the applicability of the IPC instrument to examine privacy concerns in the context of eHRs will be outlined.

Keywords

Electronic health records (eHRs), Information privacy concerns, Multidimensional Developmental theory, eHealth in Ireland.

1. INTRODUCTION

Healthcare today is transforming in many ways. The relationship between healthcare providers and patients was traditionally based on the doctor possessing information regarding the patient's health and administering treatment based on this information. However there is a shift towards a dyadic relationship, with patients becoming informed, active participants in their healthcare. This shift is facilitated largely by the emergence of eHealth applications. eHealth can be described as the use of Information Technology to combine various sources of health and patient information [13]. eHealth technologies include e-prescriptions and e-scheduling technologies and applications which facilitate patient access to their health record. This paper focuses on the implementation of one eHealth system in Ireland, namely an eHR.

2. IRELAND & EHEALTH

Ireland currently ranks 14th among the 28 EU member states with regards to healthcare [5]. This ranking is in part attributable to an underperformance and underinvestment in eHealth. Approximately 0.85% of Ireland's healthcare expenditure is apportioned to IT, considerably less than the European average of 2-3% [13]. Calls have been made for greater investment in eHealth, including the Information Society Commission's 2004 report, which recommended a large increase in Irish spending on health IT [27]. The impact of this legacy of underinvestment is apparent. In an annual European healthcare report, Ireland's performance was weakest in the patient rights and Information category, which measures the application of eHealth technologies such as e-scheduling, e-prescriptions and eHRs [5]. While there is an underperformance across all these applications, the focus of this paper is on eHRs, as these systems are often described as pivotal in facilitating future eHealth advancements [13]. At present in Ireland, patient records are often comprised of a mix of paper-based records and electronic records stored on standalone systems in doctors' offices and hospitals. This means that there is no shared patient information between healthcare providers. The lack of a single electronic record for every patient and the information portability and sharing this enables may hinder Irish patients who wish to avail of Cross Border Healthcare as envisioned by the EU Cross Border Healthcare Directive. Directive 2011/24/EU pertains to the rights of European citizens to obtain healthcare in any Member state. The Directive explicitly highlights the importance of ensuring patients' health data flows from one member state to another, while safeguarding the privacy of this data [15]. Thus, both the need to introduce an eHR in Ireland and the importance of protecting the privacy of the health data stored in eHRs is supported. Future plans to reduce the deficit between Ireland and the rest of Europe are detailed in the recently published eHealth strategy for Ireland, which acknowledges the criticality of eHealth [13]. The report also outlines plans to increase spending and details eHealth applications to be implemented in Ireland, which include e-scheduling, and e-prescription applications, a patient accessible eHR and a citizen health identifier system [13].

3. ELECTRONIC HEALTH RECORDS

3.1 Benefits of eHRs

eHR systems facilitate the electronic viewing of a patient's health data [38] and are used to create, update and share patient health

records [2]. These systems are increasingly replacing paper-based records that can cause medical errors due to a loss of paper or illegible handwriting, for example. Every year, approximately 50,000 to 100,000 deaths in the US are attributable to preventable medical errors [6]. While many healthcare providers store patient information in both paper-based and computer-based records, eHRs go beyond traditional standalone systems to facilitate the sharing of health information among healthcare providers [13]. In addition to removing the risk of errors posed by paper-based records, many additional benefits of eHRs have been discussed, such as increased efficiency in accessing patient information, ability to monitor patients' health over time and providing patients with access to their own medical record can empower them to be informed about their health [13]. The potential information exchange enabled by eHRs can also result in benefits, such as reducing duplication and contradictory patient information [3]. In addition to noting the potential benefits, cases where benefits have been realised are shown in Table 1 below.

Table 1. Examples of implemented eHRs

Country/ Organisation	System Details	Results
National eHR: Scotland [22]	Includes patients' medication details & demographics 100% GPs	System widely accepted due to national and local level involvement and awareness campaigns
National eHR: Northern Ireland [22]	Same data as Scottish system 100% GPs	System received acceptance due to engagement through national and local campaigns
US VHA: Veteran Health Administration [18]	1999: Fully implemented comprehensive record for all patients including all medication, consults and laboratory results.	Experienced reduction in cost per patient of 0.2% despite large increases in the medical Consumer Price Index in the US at the time.
National eHR: Estonia [17]	2008: First national comprehensive eHR. Record for every patient with all health data	System has led to increased efficiency in the delivery of healthcare, reduced administrative work and facilitates access to real time patient information

Table 1 illustrates the various benefits which can be achieved by eHRs, both in terms of improved health services provided and financial gains. Due to the potential benefits and reduction in costs promised by eHRs after initial investment, they have become increasingly popular. Many countries such as Holland, Australia, Denmark and Austria have either implemented or are in the progress of introducing eHRs that can share health information on a national scale [44]. The experiences of countries and healthcare organisations like the VHA that have implemented eHRs provide many lessons to guide the implementation of an eHR in Ireland. As this paper pertains to the role of privacy concerns in eHR implementation, it can be noted that failure to address the privacy concerns of both healthcare providers and citizens has hindered eHR implementation in a number of countries.

3.2 Privacy and eHRs

As with many technologies that facilitate the collection and dissemination of large volumes of data, systems that digitise health information often foster Information privacy concerns. For example in a recent study, the majority of respondents stated that they believed eHRs to be less private than paper-based records [34]. The importance of addressing privacy when implementing these systems is shown in Table 2 below, which outlines the experiences of various countries who failed to adequately address Information privacy concerns when implementing eHRs and other eHealth applications.

Table 2. Experiences of other countries

Country	System Details	Role of Privacy
England [22]	Health summary linked to all healthcare providers Not 100% implemented yet	Some GPs refused to participate in eHR due to privacy concerns. Platform for sharing health information care.data recently to allow time to address the privacy concerns involved
Wales [22]	2012: 65% GPs linked to system. eHR is a summary of patient details	Comprehensive eHR record initially proposed but rejected following negative press associated with eHR implementation in England
Germany [13]	2011: Began rollout of medical card with chip containing health information and linking all healthcare providers	Postponed due to privacy and security concerns. Staged implementation recommenced at the end of 2013
Australia [24]	Introduced a personally controlled eHR Slow implementation: 85,000 by 2013	Received a great deal of criticism for failure to acknowledge privacy issues related to eHealth initiatives

As noted, Ireland can glean a lot from the experiences of other countries regarding the implementation of eHRs, including the importance of addressing a number of human factors. The focus of this paper is on one human factor which warrants consideration when implementing these systems namely; the Information privacy concerns of those the health information pertains to. As shown, the Information privacy concerns of healthcare providers and citizens have hindered the implementation of eHRs in numerous countries, thus illustrating the importance of addressing privacy to ensure successful implementation in Ireland. Few studies have directly examined the impact of Information privacy concerns on intention to use eHRs, the majority of which focused on the impact of Information privacy concerns on physicians' intentions to use these systems, as opposed to citizens, who form the focus of this study. A recent study found that concern for Information privacy had a significant impact on Austrian physicians' intention to use an eHR [44]. It has been argued that the biggest barrier to successful eHR implementation is achieving citizen acceptance, with Information privacy representing citizens' biggest concern regarding eHRs [8]. These findings coupled with the lack of attention citizens' Information privacy concerns have received justify the examination of same.

3.3 Ethics and eHRs

Prior to discussing Information privacy in detail, the issue of ethics and eHRs is briefly acknowledged. Discussions around the importance of considering ethics are found in the majority of conversations around new technologies. eHealth and eHRs are no exception, with authors such as Layman [26] stressing the need to consider how these technologies impact the various dimensions of health ethics. The dimensions of health ethics which warrant consideration include; the need to respect patients' autonomy or their right to make decisions and self-govern their healthcare, beneficence and non-maleficence, which consider the need to ensure the net medical benefit received by patients outweighs the loss or injury patients experience, and justice in healthcare [20].

The introduction of eHealth systems such as eHRs can potentially impact ethics in numerous ways, both positive and negative. With regards to autonomy, it can be argued that eHRs can reduce autonomy through increasing the use of databases and reducing patient-doctor interactions [26]. However on the other hand, one could argue that allowing patients access to their health record improves their ability to make informed decisions about their healthcare. With regards to beneficence, eHRs can improve healthcare by enabling healthcare providers to efficiently access patient information, as the treatment received by a patient is dependent on the information available to the doctor [26]. However, this becomes potentially damaging to patients if unauthorised personnel can access their information. With regards to justice, eHRs can be positive, as increased access to healthcare services is often cited as a benefit of eHRs in terms of monitoring health trends for example. Furthermore, it can be debated that in order for a health system to be fair and just, patients should have some autonomy over who can access their health information. Patients in Estonia and other countries have the ability to do so. However, this access itself also brings with it some ethical debate regarding the potential anxiety that some of the health information in a patient's health record may cause. On one side of this debate, many, including advocates of the quantified-self movement may argue that access to one's health information empowers all individuals to monitor all aspects of their health. Others may argue that some individuals may experience anxiety when viewing their health information and this should be avoided.

This debate, while relevant to patient accessible eHRs, may be more pertinent to discussions regarding eHealth apps. With regards to eHRs, it can be argued that provided the correct measures are in place to ensure only patients who are deemed mentally stable can access their records and patient-doctor interaction is maintained for some purposes such as delivering diagnoses, allowing patients to access and review past information can empower them to be more active in their personal health and wellbeing. It is evident based on this brief discussion that ethical considerations are important when introducing eHRs. However, the focus of this paper is on making the case for the need to understand the privacy issues at play in this context. The remainder of the paper focuses on same.

4. INFORMATION PRIVACY

4.1 Privacy and Security

Prior to discussing Information privacy and how it can be examined, it is first important to dispel any confusion between privacy and security. While it is paramount that the security of the information stored in eHRs is protected, there is a distinction between security and privacy. Security can be described as the technical measures in place to secure the data stored in a system [28]. The two are connected in that, security in the sense of eHRs refers to the technical measures in place to protect the privacy of data stored in an eHR [24]. Privacy however, is a separate construct and one which is complex and difficult to define [42]. This distinction has not been made in many previous privacy studies in the area of Health Informatics. A systematic review of empirical Health Informatics studies examining privacy in the context of eHRs revealed that all of the studies in the review failed to distinguish between privacy and security [39]. This poses questions regarding the conclusions to be drawn from the findings of these studies and further illustrates the need for studies that seek to gain a comprehensive understanding of Information privacy concerns in this context.

4.2 Defining Information Privacy

Despite the large volume of research and discussion privacy has attracted over the past century, there is still no definition which effectively and comprehensively describes the concept [42]. The focus of this paper is on Information privacy, which is considered as a subset of the overall privacy construct [4]. While the concept of privacy in the physical world has been observed and discussed for centuries, Information privacy has come to the forefront of attention within research and society far more recently. Conversations among members of the public, increased presence in government policy and research around Information privacy can be traced back to the 1960s [37]. At this time, Information privacy research was nascent and all Information privacy research conducted prior to the late 1990s is considered early research [11]. Based on the relatively recent emergence of Information privacy research, it is unsurprising that definitions of Information privacy are largely influenced by definitions from other disciplines such as Psychology and Law. Many definitions of privacy place control at the centre of their explanation. Two influential definitions from the psychology field are control-based namely; Altman's description of privacy as controlling the selective disclosure of oneself to others [1] and Westin's view of privacy as an individual's ability to control what is known about them [46]. The influence of control is also seen in more recent definitions of Information privacy. For example, Clarke argues that individuals should have the ability to exercise a great deal of control over the way information held about them is used by organisations [10]. Basing their views on this, Bélanger & Crossler describe Information privacy as an individual's desire to have more control over the collection and dissemination of their information [4]. This is a comprehensive definition as it doesn't imply that individuals have control over the information they disclose, but that they desire to have more control or they perceive they have less control than they desire. These two definitions of Information privacy form the guiding definition of Information privacy used in this paper. Due to the focus on health information, privacy is viewed as the desire of citizens to be afforded a degree of control over the collection and dissemination of their health information.

5. THEORETICAL BACKGROUND

In addition to being influenced by a number of disciplines, various theories have been applied to the study of Information privacy. In both IS and Marketing, various studies utilise social contract theory to guide their research (eg. [32], [33]). Social contract theory assumes that individuals will enter a social contract with organisations when they believe the benefits outweigh the risks of the relationship [16]. Social contract theory also relates to

individuals' perceptions of fairness and assumes that under this social contract, the organisation will act in accordance with social norms to protect the privacy of the individual's data [30]. However, this theory relates to social norms of how data should be treated. This does not consider the individualistic view of privacy, which states that the need and desire for privacy vary from individual to individual [40].

Another theory applied to the area of Information privacy is the Multidimensional Developmental theory (MDT) [25]. Under this theory, privacy is viewed as a multidimensional construct which is developed as a result of an internal disposition and the influence of various external factors. This theory complements the dominant views of the Psychology discipline, where privacy is viewed as a self-developmental process. Furthermore, a host of researchers across disciplines have found empirical support for the influence of various external factors on Information privacy concerns, such as media coverage [43], culture [9] and privacy regulation [29]. Also, it has been shown that individual factors such as health status impact Information privacy concerns regarding health information [2]. Thus, MDT offers a more flexible lens from which to examine privacy. MDT considers an individual's ability to manage both their personal information, and their interactions with organisations [25]. This complements the above definition of Information privacy.

6. INFORMATION PRIVACY CONCERNS

As privacy as a construct is so complex, it cannot be quantified and thus, cannot be measured. The widespread empirical examination of Information privacy concerns is attributed to this murkiness surrounding the conceptualisation of privacy [14] and the availability of various supported scales for measuring Information privacy concerns. Despite the existence of various measurement scales, current knowledge is marred with inconsistent and inconclusive findings. It can be argued that a great deal of these inconsistencies is attributable to the lack of an agreed upon set of dimensions or factor structure for empirically measuring Information privacy concerns [23]. The various existing measurement scales and typologies measure different dimensions and name variables differently despite similarities to variables in other studies .In order to decide on the most appropriate measure for examining Information privacy concerns in the context of eHRs, the most popular dimensions of Information privacy concern must be discussed. However prior to entering a discussion of the various dimensions to be measured, what is meant by the term Information privacy concerns must first be ascertained. Information privacy concerns can be explained as the concerns of individuals that arise from the potential loss of privacy they may experience following an interaction with a company during which they disclose personal information [47]. Alternatively Information privacy concern can be described as the level of concern an individual has with regards to how organisations use their personal information [35]. For the purpose of this paper, a culmination of the both these definitions is used. Information privacy concerns are thus described as the concerns of individuals regarding the collection, use and dissemination of their personal health information by different healthcare entities.

6.1 Measuring Information Privacy Concerns

Due to the large number of studies examining Information privacy concerns, it's unsurprising that a large number of measures emerged. While they all measure different dimensions of Information privacy concern, there is a large volume of overlap across these measures. The most popular dimensions examined in past literature are collection, improper access, unauthorised secondary access, errors, control and awareness [23]. Each of these dimensions will now be briefly discussed along with their relevance to examining Information privacy concerns in the context of eHRs.

6.1.1 Collection

The collection of personal data is often included in Information privacy concerns studies, and can be explained as an individual's concern regarding an organisation's collection and storage of a great deal of their personal information [43]. Collection is a dimension in the two most widely used privacy concern measures namely; CFIP and IUIPC. In the context of health information, collection relates to an individual's concern regarding the collection and storage of health information by healthcare providers [2]. Health information is often considered to be sensitive information, with 93% of Irish citizens viewing their personal health Information as sensitive [5]. Thus, it can be argued that Irish citizens are likely to express concerns if they perceive healthcare providers are collecting a large volume of this information. Therefore, collection should be examined in the context of Information privacy concerns pertaining to eHRs.

6.1.2 Improper Access to Information

Improper access is a dimension of privacy concern in various studies (eg. [12]) and in the CFIP measure. It can be described as concern that an organisation does not have the measures in place to protect unauthorised individuals from accessing personal information [43]. With regards to health information, individuals repeatedly express concerns that employers or non-healthcare organisations might access their personal health information [3]. Individuals have also expressed fears that their mental health or sexual history may be accessed by malicious employees or hackers [36]. Furthermore, patients were extremely concerned about individuals and organisations accessing their mental health history, and the stigmitisation this could lead to [19]. Due to the sensitivity of the information stored in eHRs, it is expected that citizens will be concerned about the repercussions of unauthorised access, thus this dimension warrants investigation.

6.1.3 Unauthorised Secondary Use

Unauthorised secondary use of one's information involves collecting the information for one purpose and subsequently using it for a secondary purpose without obtaining permission [43]. This dimension is also included in CFIP and studies (eg. [12]). With regards to health information, it is often posited that individuals are less concerned when initially disclosing information due to the trusted relationship with doctors, however when this information is shared, concern sets in [3]. In England, plans to upload health information to an online platform care.data, were postponed due to public and political outcry regarding privacy. It is highlighted that individuals aren't aware of how many individuals and organisations view their health information [3]. The introduction of eHRs which make sharing of information easier are likely to introduce concerns about unauthorised secondary use. Thus this dimension should also be examined in this context.

6.1.4 Errors

Errors relate to an individual's concern that the organisation storing their personal information does not have the measures in place to prevent errors in the data [43]. This dimension is relevant to health information privacy concerns, as errors in medical data could potentially impact the individual's health if they were prescribed medication they were allergic to for example. Furthermore in a recent study which gave patients access to their eHR, 32% found errors in their personal medical information [36].

This dimension also relates to the Improper Access dimension, as it could be argued that if individuals express concerns about potential errors in their health information, they may be more concerned about potential improper access to this information. Thus, this dimension is extremely important in the health context.

6.1.5 Control

As control is placed at the centre of many privacy definitions, it is unsurprising that control has been examined in numerous privacy studies and is included in the IUIPC measure. Control can be described as an individual's concern regarding the lack of control they have over their data [30]. In the context of health information, many studies have found that citizens desire control over their health information. It has also been found that when eHRs did not offer individuals some degree of control, they expressed higher concerns for their Information privacy [28]. It has also been argued that individuals should be able to exercise control over who can access their eHR [31]. This was supported by a recent study where all respondents expressed desire to control what healthcare providers could access what parts of their eHR [7]. Patients in Estonia have this ability. Control is relevant in the Irish context as the eHealth strategy outlined plans to introduce an eHR which patients can access [13]. Due to these findings and the dominant role of control in Information privacy, it is argued that control should be examined in the context of eHRs.

6.1.6 Awareness

This relates to an individual's concern regarding their lack of awareness of how an organisation uses and protects the privacy of their personal information, and is included in the IUIPC measure [30]. In the context of health information privacy, awareness has been found to be extremely important and lacking in many cases. For example, a large number of respondents from New Zealand were unaware and uninformed regarding eHRs and thus were more concerned for the privacy of their health information [8]. The lack of awareness of patients regarding how their health information is used by healthcare organisations has been repeatedly highlighted (eg. [3] [21]). Therefore it is argued that the impact of awareness should be included in the examination of Irish citizens' Information privacy concerns regarding eHRs.

6.2 Information Privacy Concern Measures

Prior to discussing the most relevant measures of Information privacy concern, it must be noted that many privacy studies in the area of Health Informatics measure Information privacy concerns using one item scales which ask respondents to rate their concern for the privacy of their health information on a scale of 1-5. It is argued here that this approach does not provide a comprehensive understanding of Information privacy concerns. Thus this paper seeks to identify the measure which will provide a comprehensive view of Information privacy concerns in the context of eHRs.

6.2.1 CFIP

CFIP is the most utilised measure of Information privacy concerns [4]. Smith et al. (1996) developed this scale to measure an individual's concern regarding their Information privacy in the context of an organisation and their Information privacy practices, and thus termed the instrument concern for Information privacy or CFIP [43]. CFIP includes four dimensions namely; collection, unauthorised secondary use, errors and improper access. In 2002, CFIP was reexamined to examine its validation in light of advances in both technology and research [45]. This reexamination found support for the original four first order constructs, but also for the second order factor of CFIP which Stewart & Segars theorised [45]. CFIP has been utilised broadly to measure Information privacy concerns.

6.2.2 IUIPC

In 2004 Malhotra et al., built on CFIP to create the Internet User's Information privacy concerns (IUIPC) measure. IUIPC measures the privacy concerns of consumers online and their reactions to risks online [30]. IUIPC has three dimensions namely; collection, control and awareness. However, when reexamining IUIPC, support was not found for two of the relationships proposed in the original measure and this reexamination concluded that IUIPC isn't valid when measuring individuals' internet privacy concerns [41]. Future research to examine both IUIPC and CFIP and the differences in the antecedents and outcomes of both measures has been called for [4],[41].

6.2.3 IPC

The six dimensions measured by CFIP and IUIPC (collection is measured in both) were combined and empirically tested in four studies by Hong and Thong (2013), with the aim of finding the most comprehensive measure of Information privacy concerns. Support was found for a framework comprised of three dimensions of internet privacy concerns which are; interaction management, information management and awareness [23]. The six dimensions measured by CFIP and IUIPC lie within this framework. It is asserted that this framework can be utilised in a nomological model to examine all elements of Information privacy concerns from the antecedents causing these concerns to the outcomes of these concerns in a specific context [23], such as the context of an eHR as discussed in this paper.

7. PROPOSED APPROACH

It is clear that these three measures each have limitations to consider prior to utilisation. With regards to validation, CFIP appears to be the strongest measure as it was reexamined and supported [45]. IUIPC, on the other hand only received partial support upon reexamination [41]. IPC has not yet been reexamined, as it is quite nascent. However despite the continuous application of CFIP, it was noted by the authors themselves that as technology and research progresses, older measures such as CFIP will need to be regularly reexamined for continued validity. The four dimensions included in CFIP have been examined in the health context previously [2]. However based on the discussion above, it is argued that control and awareness also warrant inclusion when examining Information privacy concerns pertaining to eHRs. Based on the applicability of these six dimensions to this context, the IPC measure will be adapted in an upcoming study to measure Information privacy concerns related to eHRs in Ireland. It is noted that this measure has not previously been applied to this context, however due to strong conceptual fit and the inclusion of dimensions from the most popular privacy measures, it is deemed appropriate to apply IPC to examine Information privacy concerns regarding eHRs. The authors of the IPC measure assert that it can be utilised in context specific studies which aim to gain a comprehensive view of privacy from antecedents to outcomes, this adds support to its utilisation in this context. The table below outlines the six dimensions of IPC, the original explanation of each and the explanation in the context of Information privacy concerns regarding eHRs.

Table 3 Dimensions of Privacy Concerns

Dimension	In IPC	Health context
Collection	Concern that exhaustive amounts of personally identifiable information are being collected & stored [43]	Concern that large amounts of health information collected by healthcare providers is being digitised and shared with all healthcare providers [2]
Improper Access	Concern that data are readily available to unauthorised people [43]	Concern that unauthorised individuals may access one's health data
Errors	Concern that protections against deliberate and accidental errors in personal data are inadequate [43]	Concern that protections against deliberate and accidental errors in one's personal health data are inadequate
Unauthorised Secondary Usage	Concern that information is collected for one purpose and used for another without permission [43]	Concern that information collected in the course of healthcare is used without the patient's permission for other purposes (both related or unrelated to health)
Control	The degree to which a person is concerned that he/she does not have adequate control over his/her personal information held by websites [30]	An individual's concern that they cannot exercise control over the dissemination of their sensitive health information
Awareness	The degree to which a person is concerned about his/her awareness of information privacy practices by websites [30]	Concern regarding an individual's perceived lack of awareness regarding how the privacy of their health information is maintained by healthcare providers

8. CONCLUSIONS

The aim of this paper was threefold. The need for an eHR in Ireland was highlighted by examining the current position of eHealth in Ireland and outlining the benefits of eHRs. The importance of human factors, specifically Information privacy concerns, in terms of their influence on citizen adoption of new technologies was discussed. The last aim of the paper was to ascertain and justify the most comprehensive and appropriate means for measuring citizens' Information privacy concerns in the context of eHRs. It is argued here that the IPC instrument is an appropriate measure for application in this context as it captures the six dimensions of Information privacy concerns as discussed most frequently in the literature. The IPC measure will be utilised in an upcoming study to examine how Information privacy concerns impact Irish citizens' intention to adopt a national eHR.

9. GLOSSARY OF TERMS

Term	Explanation
eHRs: Electronic health record system	System which is comprised of digital records for healthcare patients. Can range in comprehensiveness and can facilitate sharing among healthcare providers as well as patient access
eHealth technologies: Electronic health	Use of IT to combine sources of health data. Examples: e-prescriptions, e-scheduling, eHRs
VHA: Veteran Health Administration	The healthcare provider for US veterans
CFIP: concern for information privacy	First measure developed in 1996 by Smith et al. to examine privacy concerns
IUIPC: Internet users' information privacy concerns	Developed in 2004 by Malhotra et al. to measure privacy concerns online
IPC: Internet privacy concerns	Developed in 2013 by Hong and Thong, combines CFIP and IUIPC to comprehensively measure privacy concerns

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Towards the Development of AudioAuth: An Auditory Authentication System

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ABSTRACT
In this paper, we describe a novel approach to support the traditional PIN-based user authentication process, through the selection of a sequence of abstract sounds. We conducted two studies as part of the research. The first study examined the user's ability to discriminate between sounds. Results highlighted the benefits of timbre as a differentiator. We also found manipulations of pitch, rhythm, and spatial position further compliment a capacity for discerning between sounds. Using findings from the first study, we conducted a second study that examined the usability of a sound-based authentication interface, AudioAuth. Insights gained from the research, including methodological lessons, offer guidance to interface designers interested in exploiting the potential of abstract sounds to support the user authentication workflows.

Categories and Subject Descriptors
H.5.2. User Interfaces – Input devices and strategies.

General Terms
Human Factors.

Keywords
Auditory interfaces, Multimodal interfaces, Non-visual interfaces.

1. INTRODUCTION
The notion of an auditory interface for user authentication lays at the intersection of several dimensions of information system design and development. Such a position requires the coalescence of interaction, interface, and security design considerations in a manner that duplicates – and preferably enhances – the ubiquitous experience of logging into a system via traditional methods (i.e., keyboard input of alphanumeric passwords). Novel designs of this type face the problem of successfully altering the mechanisms of an interaction pattern with strong mental models among users (i.e., as certain interaction patterns become pervasive and users universally begin to forge strong mental models of how those patterns "should work", they also slowly shed their willingness to adopt alternatives despite their advantages). Further complicating the problem is the relative immaturity, in general, of non-visual computer interfaces, the need for high levels of accessibility among a diverse user population, as well as the host of issues regarding cognitive limitations and security trade-offs (e.g., "strong" passwords are often recommended in order to reduce the likelihood of successful rudimentary attack methods [1], however, recollection of long or complex alphanumeric strings can be difficult and encourages users to bypass or ignore precautionary measures).

Despite these challenges, the benefits of developing effective auditory interfaces are obvious. Apart from providing alternatives to users when their visual channel is blocked or restricted (e.g. individuals who are blind, or impaired by a given situation or environment), auditory interfaces offer the opportunity for richer multi-modal interaction patterns among the general user community [8]. Moreover, especially when addressing an interaction pattern as pervasive as user authentication, a successful auditory interface stands to benefit a large population by helping to universally reduce the overall barriers to technology usage.

Our research aims to identify ways in which audio can be used to support the user authentication interaction pattern, with a view to providing an alternative to alphanumeric passwords. While past research has explored the use of auditory icons and short bursts of music for purposes of authentication, these designs may suffer from security tradeoffs resulting from the recognizability and inherent biases of such sound libraries. In contrast, we have examined the feasibility of abstract sounds, which are more difficult to describe and therefore disclose to others. We have aimed to identify their potential for retention over an extended period, and to better understand the usability considerations inherent to such an interface.

2. RELATED WORK

2.1 Understanding Aural Perception and Memory
Researchers have investigated the cognitive limitations related to human aural perception and memory, and the implications on the design and development of auditory interfaces. This research is fundamentally rooted in the seminal works of psychologists interested in the structure of human memory [3, 4, 21], and provides the necessary insight into how those characteristics of human cognition impact the design and development of effective auditory interfaces. In particular, research into the functional independence of memories resulting from visual and aural stimuli has revealed the robustness of aural perception and memory, and suggests that aural memory supports improved recall [23, 24, 25].

Research has also shown a surprising human capacity for training of abilities related to aural perception and memory [23, 24], and

links between the various parameters of sound (especially timbre) and cognitive abilities. Specifically, Sanchez et al. designed and evaluated an application, AudioMemory, which supports the rehearsal of phoneme and grapheme discrimination (i.e., the differentiation of the atomic units of spoken and written language), and short-term memory [24]. Results suggest that both domain knowledge and general capacity for aural memory, is improved by use of the researchers' sound-based interfaces. While perhaps intuitively obvious that rehearsal of certain tasks would lead to improved performance, such findings seem to justify the use of the aural sensory modality as a viable alternative to traditional graphical interfaces, especially those interfaces that rely on recall as a principal mechanism for use (e.g., authentication systems). Indeed, the idea that the aural modality seems to be both highly suited to recall tasks, and demonstrates a capacity to be practiced and improved would indicate that a sound-based interface could be an ideal alternative to traditional alpha-numeric password authentication systems.

2.2 Leveraging Non-speech Audio Interfaces

Earcons are auditory messages built using sound motifs (i.e., structured musical abstractions) with no explicit semantic value [7]. Unlike auditory icons, there is no intuitive link between the earcon and what it represents; the link must be learned [2]. The value in such a mechanism is the freedom to design earcons without distinct regard to rigid mental models that may exist among diverse populations of users (i.e., a C# note is not subject to the same personal biases, associations, or cultural influences as a recording of a mooing cow or a gentle feminine voice). Moreover, as earcons are constructed from musical primitives, their design can benefit from a variety of complex musical characteristics (e.g., rhythm, pitch, timbre, register, mode, tempo, dynamics, and, when using robust output mechanisms, balance).

Researchers, such as Brewster et al. [9, 10], have sought to rigorously assess the efficacy of communicating information through earcons. The researchers identified that memory for complex earcons (varied across timbre, pitch, and rhythm) seemed to be high among participants. The researchers also found that musical earcons resulted in superior performance over unstructured bursts of sound in certain groups. For example, musicians did not appear to have a significant advantage over non-musicians in any of the experimental tasks.

Beyond the notion of simply leveraging earcons as interface elements, Walker and Kramer [26] investigated the more generic guidelines that should guide the mappings and metaphors that could effectively link data to auditory displays. The researchers specifically wanted to measure the impact of various audio-to-data mappings (e.g., pitch to temperature) on performance of a generic process-control task. The overall conclusion of the study was that audio-to-data mappings are perhaps not best served by generalized design patterns, and that, rather, empirical data should be relied upon for any given task set or interface.

2.3 User Authentication Interaction Patterns

Researchers have advanced earnest evaluations of the delicate balances presented by the task of creating novel authentication systems [13], and have begun to propose various solutions to address the challenges ordinarily faced recalling alphanumeric passwords [5, 14]. These latter studies, and the image-based authentication studies that they extend [2, 12] offer an alternative to traditional authentication mechanisms, addressing the challenges associated with memorability of authentication sequences.

In terms of auditory interfaces, Gibson et al. [14] developed Musipass, which has a user make four sequenced selections from a set of musical clips in order to authenticate themselves. The researchers present an experimental design for their usability study (a familiar training phase, testing, interruption period, and final testing pattern), and while information regarding the design of musical clips is limited within the paper, the quantitative and qualitative data collected supports the findings of similar studies conducted using image-based password systems (i.e., memorability and general usability appeared to be higher with the novel design). The researchers further argue that the potential for security compromises due to "guessability, observability, [and] recordability" may be mitigated by the use of special hardware (e.g., headphones), constraining the library of sounds used, and the generally enhanced memorability of musical passwords.

While the work conducted exploring novel interaction patterns in user authentication has been substantial, research has yet to resolve the balance between security, memorability, and usability.

In this paper, we describe a sequence of studies to determine the feasibility of abstract sounds to support the authentication process. The research is presented in two parts. The first investigates the relationships between the musical characteristics of sound (e.g., timbre, pitch, spatial position, and rhythm), and the capacity for differentiation. The intended goal of this first study was to identify those traits that could be optimally manipulated for the production of a library of easily recognizable sounds, advancing previous work in the area. The second study extends the first with the design, development, and analysis of a prototype sound-based authentication interface, AudioAuth, which uses sounds differentiated across timbre and rhythm (the two foremost qualities for enabling differentiation of sounds, as identified in our first study) to provide a sound-based authentication interface.

3. STUDY 1: DIFFERENTIATION OF SOUNDS

We conducted our first study with the aim of determining which parameters of sound (i.e., pitch, timbre, rhythm, and spatial position), and combinations therein, could be manipulated to produce easily identifiable and distinguishable sounds. Our peripheral intentions were to identify a library of varied and easily identified abstracts sounds for use in a sound-based user authentication interface prototype; more precisely, we hoped that identifying those sounds which are easily discernible would increase the user's success with a recognition-based authentication scheme.

Each of the tasks throughout the study asked participants to listen to and rate the degree of similarity or difference between two sounds engineered to vary across combinations of musical qualities. In order to provide a deeper insight into the reasoning behind their decision, participants were also asked to contribute free-form written descriptions of the sounds with which they were presented. The general design of our study follows a common pattern in auditory interface design, wherein parameters of sound are varied according to certain constraints and data from participants is collected at various points in order to draw conclusions on the perceptions of different stimuli [11, 16].

Moreover, owing to the success of previous work in the auditory interface space that made use of online collection of participant feedback data [22], our study design made use of a web application that participants could log into from home, as well as several online qualitative surveys. This enabled participants to

access materials under more realistic conditions (e.g. with background noise or distractions present), providing a more realistic view of how authentication technologies may be used in real world scenarios.

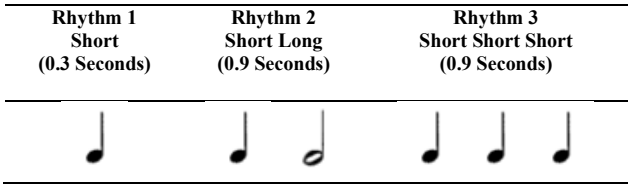
3.1 Sound Selection

Sounds were varied along a number of dimensions in order to discern the most effective combination of parameters to manipulate that would enable easy identification of individual sounds from within a collection. Findings from previous research highlight timbre as a primary musical variable of interest (i.e., a characteristic of sound that listeners tend to make note of) [5, 7, 10, 18, 19], and as a primary perceptual mechanism for sound source identification [15, 20]. As such, a simple sinusoidal waveform and a clip of white noise (commonly referred to by participants as a "beep" and a "buzz", respectively) were selected as the sound timbres to be used throughout the study, as they were deemed to be reasonably different from one another in our pilot studies.

Once base timbres had been selected, short clips of sound were generated with variations in pitch, spatial position, rhythm, and combinations therein. In total, 60 sound clips were created for use throughout the 30 listening tasks that participants were asked to complete. Variations included "falling" and "rising" pitches, length from single sounds measuring 0.3 seconds to multiple sounds lasting up to 0.9 seconds (a consideration informed by prior work [10]), and changes in stereo output channel (e.g., a static spatial location or moving from the left to center to right channels).

Sound stimuli were designed using the following characteristics:

- Timbre (2): White Noise, and Sine Tone
- Pitch (2): Glissando Sweep Up, and Glissando Sweep Down
- Spatial Position (4): Left, Center, Right, and Moving (L-C-R, and R-C-L)
- Rhythm (3):



In total, we created 60 sounds and paired them randomly to generate listening tasks for participants to complete.

3.2 Participants

We recruited 19 participants (11 males and eight females, aged 22-51) from an online student forum, and asked to complete a brief demographic survey, with several additional questionnaire items regarding musical training background, and sensory impairments that may have affected completion of the later experimental phase. Fourteen participants stated that they had received some level of musical training (i.e. learning to play an instrument). None of the participants reported auditory or visual disabilities.

3.3 Procedure

We asked participants to complete 30 interactive listening tasks, and rate along a four-point Likert scale the degree to which two presented sounds differed. Tasks and sound pairs were played in a randomized order to minimize the likelihood of an order effect. We also gave participants the opportunity to contribute free-form verbal descriptions of the two sounds, and the ways in which they differed from one another.

At the conclusion of the study period, we coded participants' free-form written contributions and calculated basic descriptive statistics for further analysis. We found this open-ended approach for data collection as advantageous over more "forced choice" styles of participant feedback, as it virtually eliminated the need for researcher follow-up after the study period, and the highly qualitative nature of the verbal descriptions given by participants provided a much richer idea of how participants perceived various sounds.

3.4 Results and Discussion

3.4.1 Timbre-Inclusive Tasks

Twelve of the 30 listening tasks varied timbre between the two presented sounds, with three of those tasks being exclusively timbre-varied (i.e., with all other musical characteristics held constant, the sound pairs differed only with regards to whether they were constructed from the basic sinusoidal waveform or white noise timbres), and nine varying timbre in combination with other musical characteristics (e.g., timbre/pitch, timbre/rhythm, timbre/pitch/rhythm/position). Examples of sound differentiation tasks are shown in Table 1.

Table 1: Examples of Stimuli Presented

Tasks	Description of sounds presented
Task 01	Sound 1: White noise played for one measure through the center channel. Sound 2: Sinusoidal waveform played for one measure through the center channel.
Task 05	Sound 1: White noise with ascending pitch pattern played for one measure through the left channel. Sound 2: White noise with descending pitch pattern played for one measure through the left channel
Task 30	Sound 1: Sinusoidal waveform with ascending pitch played for three measures through the center channel. Sound 2: White noise with descending pitch played for one measure through the left channel.

Basic summary statistics revealed that, in all listening tasks where timbre was one of the varied musical parameters in the presented sound pair, participants on average rated the sounds as "Very Different" (of the 12 timbre-inclusive tasks, the average was 2.7 on a four-point Likert scale). A review of the coded written responses reveals a similar trend, with participants seemingly providing the richest characterizations of sound in tasks where timbre was manipulated. These findings hold with previous work [7], where timbre is described as one of the most immediate and easily recognizable characteristics of sound.

In terms of qualitative response to the presented tasks, participants overwhelmingly identified timbre as a differentiating factor over

other musical characteristics. Specifically, across the 30 tasks, our 19 participants made mention of timbre 367 times (i.e., either explicitly through the Likert scale or in their written responses). With regards to the participants' free-form written responses, use of figurative language was prevalent and many participants used varied techniques to express their impressions of the presented sounds. Specifically, participants used comparative metaphors, and frequently depended on onomatopoeia to describe "whoosh" (P108) white noises and "beep" (P110) sinusoidal waveforms, while others used poetic metaphorical language such as P105 who described one sound as "the hush of wind". Timbre was also the most correctly identified musical characteristic on tasks where it was a differentiating variable, with participants correctly making mention of timbre on approximately 81% of timbre-inclusive tasks. For comparison, the second most recognized musical characteristic, rhythm, was only correctly identified about 66% of the time.

Interestingly, even in timbre-exclusive tasks, there seemed to be a tendency for participants to provide written responses that made mention of timbre. Specifically, participants mentioned timbre 183 times on various tasks where timbre was not a variable musical characteristic. Often times, these mentions were descriptive metaphors characterizing the "swoosh" (P114) and "whoop" (P101) sounds used for various tasks along with mention of their similarity, rather than explicit references to sound timbre or quality (i.e., figurative language seemed to dominate participant descriptions over more literal characterizations). The fact that participants consistently used timbre as a tool for characterization confirms previous research in music perception that timbre is the primary perceptual mechanism for the recognition, and identification of a sound source [15]. These findings support previous work that indicates the quality of various sounds is a principal differentiator of sound [10].

3.4.2 Timbre-Exclusive Tasks

Of the 30 listening tasks, 18 eschewed variation of timbre, varying instead the pitch, rhythm, and/or spatial position of the presented sound pairs. A review of the summary statistics calculated for these timbre-exclusive tasks revealed that participants tended to rate the sound pairs as "Similar". On listening tasks where only spatial position was manipulated, participants rated sound pairs as "Very Similar" on average.

The data collected also reveals that pitch and rhythm are suitable parameters of sound to be varied if differentiation is a key intention, but not in themselves as effective as variations of timbre. In themselves, pitch and rhythm were differentiable by participants, but the data consistently reveals that a failure to vary timbre coincides with sounds being characterized as more similar. Moreover, coding of participant written responses indicates that pitch is the least correctly identified musical characteristic, with a 23% accuracy rate across 247 task trials. However, this low rate with regards to identifying pitch may be due to difficulty expressing differences in pitch beyond describing such sounds as "low" (P102) or "high" (P114). Such a phenomenon emphasizes the need for querying participants in multiple ways to avoid any potential hurdles between perception and expression.

3.4.3 Qualitative Results

The collected data show that participants tended to rank sound pairs with varied rhythm and spatial position as similar while at the same time providing written feedback indicating their differences in free-form responses. Specifically, in listening tasks 08-11 (i.e., single-condition [rhythm]), 12-20 (single-condition [spatial position]), and 24 (double-condition [rhythm/position]), participants tended overwhelmingly to rate presented sound pairs as "Similar" or "Very Similar" (approximately 83% of 266 responses) (summarized in Table 2); however, written responses from participants on average seemed to successfully reference both rhythm and spatial position as being dissimilar.

Table 2: Average Similarity Ratings (from four-point Likert scale)

Task(s)	Musical Parameter	Average Rating
01-03	(T)imbre	2.3 (Very Different)
04-07	(P)itch	1.2 (Similar)
08-11	(R)hythm	0.9 (Similar)
12-20	(Pos)ition	0.5 (Very Similar)
21	T/P	2.5 (Very Different)
22	T/R	2.9 (Very Different)
23	T/Pos	2.7 (Very Different)
24	R/Pos	1.3 (Similar)
25-28	T/R/Pos	2.9 (Very Different)
29-30	T/P/R/Pos	2.9 (Very Different)

Rhythm was the second most correctly identified musical characteristic, with a near 66% accuracy rate across 228 rhythm-inclusive task trials. Spatial position was the third most correctly identified variable, with a rate of 64% across 209 task trials.

3.5 Conclusion

The study found various musical characteristics of sound can impact the differentiability of sound pairs. We also found timbre and rhythm to be two of the strongest differentiators. Findings from Study 1 directly informed the design of a library of abstract sounds (composed to be distinctive in order to enhance the likelihood of users correctly identifying their selected passwords in an auditory authentication system). A second study was then performed to determine the usability of a sound-based user authentication interface prototype, AudioAuth, and to see whether this mechanism would address the security/memorability challenges associated with alphanumeric passwords.

4. STUDY 2: USABILITY OF A SOUND-BASED AUTHENTICATION SYSTEM

4.1 Background

Our authentication system, AudioAuth, is a Java web application designed to capitalize on the user's ability to recognize a self-selected combination of abstract sounds. Specifically, passwords in AudioAuth were implemented as a pattern of four distinct abstract sounds from a library of 36 possible sounds. Examples of sounds are shown in Table 3.

Input into AudioAuth is managed through mouse-based selection of icons, arranged in 3x3 grids, across four screens. Each of the four screens contains nine sounds, including the user's preselected sound, all of which could be triggered to play by a mouse hover

(Figure 1). Sounds are arranged in a randomized order within each grid upon each successive entry to the system, to prevent onlookers from visually observing a password entry.

Figure 1: The AudioAuth Interface

To successfully authenticate, the user is required to correctly recognize and select, in correct sequence, each of the four sounds in their pre-selected auditory password. Users have three opportunities to authenticate successfully before an account lockout is triggered, and participants are prompted to reset their passwords.

We designed and selected sounds in AudioAuth based on ease of differentiation and memorability (Table 3). All sounds in the AudioAuth system are based on either a short clip of white noise or a sinusoidal waveform (varying timbres that are almost always easily distinguishable among listeners based on the results of our first study). Beyond the two timbres used for AudioAuth sounds, sounds also varied across rhythm and spatial positioning (i.e., manipulation of stereo channels); based on the results of Study 1, this combination of musical parameters when varied would produce sounds that are easily identified and differentiated across by participants.

As pitch (glissando sweep) was not identified as a strongly distinguishing parameter in our previous study, it was omitted as a variable in the AudioAuth sound stimuli set. We added an additional rhythm to replace the omitted pitch parameter, and added an additional moving spatial parameter (i.e., allowing sounds to pan right to left and left to right). The spatial parameters that moved (across two or three positions) were only applied to the three rhythms that had more than one beat so that a change of spatial position coincided with a new beat.

To summarize, sounds for Study 2 were designed using the following parameters:

- Timbre (2): Noise and Sine Tone
- Spatial Position (5): Left, Center, Right, Moving Three Positions (L-C-R, and R-C-L), and Moving Two Positions (L-R, and R-L)
- Rhythm (4):

Rhythm 1 Long (Dur: 1.0s)	Rhythm 2 Short Short (Dur: 1.0s)	Rhythm 3 Short Short Short (Dur: 1.0s)	Rhythm 4 Short Long (Dur: 1.0s)
			

Table 3: Example of AudioAuth Authentication Process

Screen	Examples of one of the nine mappings presented
Screen 1 of 4	User searches for and selects white noise played for two measures through the left channel.
Screen 2 of 4	User searches for and selects sinusoidal waveform played for one measure through the center channel.
Screen 3 of 4	User searches for and selects white noise played for three measures across the three channels (left to right).
Screen 4 of 4	User searches for and selects sinusoidal waveform played for two measures through the right channel.
Screen 5	User Authentication Success Page

4.2 Participants

We recruited 18 participants (11 males and seven females, aged 20-49) for our study. We screened all participants prior to participation, and none claimed any visual or aural impairment (the latter of which may have disqualified them from the remainder of the study). Only one participant had prior musical training.

4.3 Procedure

Upon registering for an account with AudioAuth, participants were asked to create a sound-based password that they were then repeatedly challenged to remember and input upon subsequent accesses to the system. The initial audio password selection followed a "wizard" interaction pattern wherein participants were presented with a sequence of four screens, each of which prompted a selection from a grid of nine randomly arranged sounds. The series of sounds selected comprised the participant's audio password.

Participants were asked to login to AudioAuth daily, and we encouraged that they did so in a consistent manner (i.e., at similar times in the day and using similar devices throughout the study). Following two weeks, participants were asked to take a two week break (to simulate a break in usage from the system as might occur in real-world situations, and to offer insight into the effects of irregular usage patterns on memory), and then prompted for one final login attempt to the system. The scheduling used in this

study design was adapted from several previous studies investigating novel user authentication interfaces [2, 12].

All login attempts, failures, and related actions were logged for later analysis. Following participation in the prototype trial, participants completed a short survey questionnaire regarding their experience with AudioAuth. Shortly thereafter, we invited participants to a focus group session to share their experiences selecting authentication stimuli, strategies for memorizing stimuli, and to discuss their perceptions of the AudioAuth interface and the sounds used.

We coded data from all three phases of the study (i.e., the trial usage period, the post-trial survey, and the post-trial focus group session), and searched for salient themes of user response to AudioAuth as well as the general notion of auditory interfaces (e.g., regarding the selected sounds, and the implemented interaction pattern).

4.4 Results and Discussion

4.4.1 Password Selection

Analysis of usage logs revealed that participants showed a tendency towards selecting sounds with a sinusoidal waveform timbre, with only three of the top ten selected sounds consisting of the white noise timbre. The four most popular sounds selected throughout the study were all sinusoidal waveforms, each selected by five participants each. Overall, participants chose sinusoidal waveform sounds over white noise for their passwords by approximately 150%. Additionally, participants seemed to favor sounds played through only one channel, with only four of the top 18 most popular sounds capitalizing on multiple spatial positions (i.e., panning) of sounds. Tendencies in sound selection may reduce the overall diversity of passwords, and by extension the security of their authentication scheme, but as with other schemes the risk of password compromises is reduced by other controls (e.g., attempt logging and limiting).

4.4.2 Password Usage

A total of 149 login attempts were made to the system. The average participant made an average of about two failed login attempts throughout the course of their participation, with one participant making six errors in a row before successfully logging in. Of the sessions that eventually led to successful login, participants managed to successfully input their sound-based password on the first attempt 82% of the time, on the second attempt an additional 8% were successful, and on the third an additional 7%.

The average input time for successful login attempts was 67.0s (SD: 48.0s), with the fastest participant successfully logging in in only five seconds. Variations in input times were attributed to the design of the interface, and the randomization of sounds within grids. Participants were observed moving sequentially over each square, listening to each sound to determine whether it matched a sound from their pre-selected sequence. Depending on the position of the pre-selected sounds, this could be a time-consuming process (i.e., a user might potentially have to hover over and listen to eight sounds before finding the one they had previously selected).

4.4.3 Recognition Rate and Types of Error

The number of errors and aborted attempts offer an insight into the usability of AudioAuth. In total, participants made 56 erroneous attempts to login to AudioAuth throughout the course of the trial period. Among those 56 attempts, an average of 2.6 out of the four sounds comprising a standard audio password were input in error, with 14 login attempts made in which the participant failed to identify a single password sound correctly. Across all participants' login attempts, there were only six aborted attempts (i.e., users pressed an interface button indicating they wanted to begin input of their password again from the beginning).

Additionally, at least with several participants, errors appeared to be fairly consistent across multiple failed login attempts. For example, participant P204, P206, and P213 incorrectly selected the same audio password two, four, and five times respectively. In each case, the participants made several other failed attempts that were only slightly different than their consistently made errors (i.e., there was only a small amount of variability between their failures).

Participants also made erroneous attempts at logging into AudioAuth that did not appear to follow any consistent pattern. For example, participants P203 and P217 made a combined 19 erroneous attempts with no apparent similarities between attempts (i.e., the participants chose multiple incorrect sounds in multiple states of disorder).

As discussed earlier, we selected sounds for the AudioAuth interface for ease of differentiation based on our previous study. As such, the sounds used throughout AudioAuth differed according to timbre, spatial positioning, rhythm, and combinations therein. Errors seemed to support previously proposed notions of timbre being a primary differentiator between sounds, with over one half (57%) errors in sound selection being made between sounds that differed only according to spatial position and rhythm, or a combination of the two. For example, one participant incorrectly selected sound #13 rather than #10 across seven (non-consecutive) failed login attempts (the sounds only differed in spatial position). Similarly, another participant incorrectly identified sound #25 rather than #26 four times, failing to identify the correct sound despite the difference in spatial position and rhythm. No errors were made where sounds differed only in rhythm, a fact that supports previous findings that counting beats, or "numerosity", may be an effective musical characteristic for differentiation even when used alone [6]. We noted 27 errors (19%) were made where the correct sound and chosen sound differed across all three musical characteristics. This result is surprising, as sound pairs with such diversity in musical makeup might be assumed to be immediately discernible from one another; however, there was not a single instance of a participant incorrectly selecting a sound that differed across all three parameters more than once, suggesting that these incorrect selections were accidental (e.g., "click slips").

4.4.4 Usability of the Solution

Following the trial period for AudioAuth, participants completed a survey questionnaire. Response to AudioAuth appeared to be largely positive with regards to the memorability of sound-based passwords. Participants largely disagreed with statements that their sound-based passwords were difficult to remember throughout the duration of the trial (μ=0.9 σ=1.6), and that remembering their passwords required a considerable cognitive effort (μ=1.5 σ=1.6). Participants also strongly agreed with statements that their sound-based password was easier to remember than randomly generated alphanumeric passwords (μ=3.5 σ=0.7); however, they generally disagreed that AudioAuth was easier to remember and use than a traditional PIN-based interface (μ=1.8 σ=1.5).

Despite general acceptance of sound-based password memorability, participants were largely neutral towards the perceived security and general usability of AudioAuth (μ=2.25 σ=1.3, and μ=2.6 σ=1.0, respectively). The time required to scan sounds before making a selection, and the potential for having passwords overheard when headphones were not available were cited as specific shortcomings of the system.

4.4.5 Eliciting Detailed Responses

In order to more completely understand the challenges and benefits experienced by participants during their use of the AudioAuth interface, a small focus group (n=5) was formed from participants who had participated in the study. They were prompted to share their general password usage habits, as well as opinions of the AudioAuth interface. The following trends were identified among the AudioAuth study participants:

Length of Authentication Interactions – The recognition-based mechanism of randomizing the location of sounds on a 3x3 grid of icons was thought to be superior to traditional numbered keypads, as it alleviated fears of "shoulder-surfers" snooping password entry. However, the relatively lengthy period of time required to scan over and recognize password sounds, was found to impact usability.

Long-Term Memory for AudioAuth Passwords – Participants indicated that following a long break from using the AudioAuth interface (approximately three months) that they were able to remember the general characteristics of their sound-based passwords (e.g., types of sound, patterns in channel playback), indicating the long-term viability of such authentication schemes.

Troubles with the Chosen AudioAuth Implementation – The AudioAuth interface's method of presenting a series of scrambled sounds proved cumbersome. Specifically, participants expressed concern with having to repeatedly scan through the sound sets to identify their specific sound-based passwords; this process is viewed as time-consuming, and prone to error. Researchers have examined ways to expedite the process, through presenting cues within a temporal sequence to reduce the scanning time [17]. Participants also indicated that while the two sound types used by the AudioAuth interface (i.e., "buzzes" and "beeps") are easily differentiated, the general quality of the sounds are not as pleasant-sounding as they could be. Moreover, participants believed that sounds with greater musicality, or that more closely resemble common instruments would lend themselves better to the AudioAuth interface. While the sine tone and white noise were chosen to optimize the differences between stimuli, the results from the authentication study indicate that more complex timbres (such as instruments) should be incorporated into the design of the sounds.

4.4.6 Review of Evaluation Approach

In terms of study design, the focus group proved to be helpful. In addition to providing the present research with candid impressions of AudioAuth's usability, the focus groups hinted at the benefits of including participants in future design initiatives. The tendency of focus group participants to help each other express ideas, extend each other's thoughts, and speak to their individual personal habits and preferences suggests that participatory design may be a fruitful endeavor when designing auditory interfaces.

5. DESIGN IMPLICATIONS

Timbre was found to be the most effective differentiator of sounds in both studies. When designing an auditory authentication solution, interface developers should consider the use of easily discernible timbres (e.g., sinusoidal waveforms and white noise), as results have highlighted their superiority compared to other characteristics of sound such as pitch, rhythm, and spatial positioning. On the last characteristic, spatial positioning, it is worth noting that the need for peripheral devices (e.g., headphones) further complicate the potential success of systems, as users are not always properly equipped to use such systems. Supports integrated with the interface would be needed to minimize the risks associated with improper headphone usage. For example, the system could play a test sound and ask the user to verify which ear that the sound was presented to. Based on this, a message could be generated highlighting whether the headphones are worn correctly.

6. CONCLUSION AND FUTURE WORK

We have described a novel approach to support authentication through the design of abstract sounds. AudioAuth was found to be a useful proof-of-concept for the use of abstract sounds in simple authentication interfaces, and provided further evidence for the efficacy of timbre and rhythm. Despite the challenges experienced throughout the length of the study, several methodological lessons became quite evident. Specifically, the use of qualitative methods (i.e., participant surveys and focus groups) proved invaluable in determining the true nature of participants' experiences with AudioAuth and can be extended to remote audio-interface focused studies in general.

In terms of future work, we aim to conduct a study where users are required to remember multiple auditory passwords over a year-long period. The aim is to better replicate the demands faced by individuals when recalling alphanumeric passwords.

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Evaluation Of Early Prototypes For Social Mobile And Pervasive Computing With Scripted Role-Play

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ABSTRACT
As mobile and social computing is integrated with pervasive computing, new potentials for dynamic social and community interactions and sharing of data and services across real and virtual spaces emerge. Whilst including end users in the design, development and evaluation of such complex socio-technical systems is widely recognised as valuable, reliable methods for managing evaluations of medium fidelity prototypes for dynamic pervasive community services are not yet established. Traditional usability evaluation approaches may be insufficient, or too time-consuming, for user evaluation of these services since the functioning of such complex socio-technical human computer environment ecosystems is dependent on rich data sets, and multiple users engaging in multiple different activities. This paper reports on the use of role play as an experimental approach used in a mixed methods evaluation of early prototypes of enterprise networking services for dynamic pervasive communities in a conference scenario. Evaluation of these medium fidelity conference services with a small set of workshop participants in a short space of time posed a challenge in attempting to define interactions that would ensure users could experience and understand the novel features of the services. We observed that participatory role-play facilitated deeper user engagement with, exploration of, and discussion about, mobile social and pervasive community services for evaluation purposes than would have been possible with traditional usability approaches under our time-constrained conditions.

Categories and Subject Descriptors
H.1.2 [User/Machine Systems]: Human Factors.

General Terms
Human Factors.

Keywords
Participatory approaches, social computing, pervasive computing, user evaluation, communities.

1. INTRODUCTION
As smart phones become almost ubiquitous, User Experience (UX) is increasingly recognised as a significant differentiator for applications in a crowded marketplace. Thus, the inclusion of User Centered Design (UCD) processes which can deliver excellent user experience is ever more significant in the design and development of mobile and social Information and Technology (ICT) services. Understanding users expectations, experiences and perceptions is particularly important in the case of context-aware pervasive computing, where context-of-use is directly meaningful for human system interactions.

While traditional usability approaches, such as Think Aloud [20], or Cognitive Walkthrough [19], evolved to learn about one user's interactions with a particular pre-defined set of tasks in one computing application, these and other usability approaches are not easily adapted for multiple-user multiple-service mobile social and pervasive systems, such as the SOCIETIES platform and third party services which we use for a case study discussion in this paper. Attempting to list tasks and functionalities is more complex in the case of multiple user social and context aware systems, as network effects such as feedback and community dynamics and creative appropriation (which are properties that emerge in such systems through relevant data population and usage) are not easily modeled. Social and pervasive systems are evolutionary, and data gathered and generated through monitoring users actions in particular contexts, and interactions with services and other users is: 1) particular to the specific users, enabling personalisation; and 2) significant to the emergence of opportunities for sharing of data, services and things offered through the identification of shared interests across communities of users in particular contexts. Therefore, it is difficult to present random users with opportunities that feel sufficiently authentic for them to experience the system from within.

Large extended field trials are often proposed as the preferred evaluation approach for context aware pervasive or social systems using mobile applications, as they allow for ecological validity for complex social technical systems—natural use with the myriad of distractions and interruptions associated with active usage 'in the wild', where trial participants use services in everyday life, rather than in controlled laboratory conditions [9][10][11]. In-situ trials also allow for the observation of natural socio-technical complexities with community adaptation. However, in the case of early prototypes, which are not yet sufficiently robust or mature for extended deployment with multiple users, more creative solutions are required.

In order to evaluate two medium fidelity Enterprise focused services designed for a conference scenario, based on a novel social and pervasive platform, with a small number of participants in a workshop setting over the course of one afternoon, we elected to use scripted role-play, combined with other participatory demonstrations and games. A mixed methods approach including surveys, cognitive walkthrough, games, role play and focus group discussion, afforded us the necessary flexibility and adaptability to glean insights and invite feedback from participants at various different points of the evaluation, from initial expectations and impressions, to immersion in usage, and final considered reflections. Role-play allowed us to simulate situated use and condense conference type interactions to a few hours. We found that it enabled participants to engage in-depth with the presented technologies, whilst also facilitating developers to gain useful insights.

The paper is structured as follows. In section 2 we discuss related work with regard to role-play for business innovations, and

participatory approaches for complex mobile, social and pervasive technologies. In section 3 we describe the SOCIETIES project, to which the trial in this paper belongs. In section 4, we describe in detail the trial in which the role-play approach was used. In section 5 we describe the conference services in the trial. In section 6 we explain how we employed role-play for evaluation of the services and system, before the conclusion in section 7.

2. Related Work

The evaluation of pervasive computing systems has been recorded by various researchers as challenging, time-consuming, expensive and imperfect [6][8]. Realistic conditions for trial usage are important but it is difficult to avoid unintentional bias of demand characteristics [1], and there are no approaches immediately apparent which support such ecological validity while preserving internal and external validity [10]. In other words, whilst mobile and pervasive systems and services need to be tested 'in the wild' in order to account for the circumstances and context-of-use, as a myriad of factors can influence a users experience with a service, such as: location, people nearby, interruptions, attention and focus, and even being a willing participant in a field trial. Thus, it is difficult to attribute observed or reported user experiences solely to service interactions; in addition, the increasingly personalised nature of the services based on each users unique digital footprint, makes it unreliable to generalise from any findings. Moreover, social and mobile networking services require a minimum subset of users in an evaluation in order for naturally occurring social networking phenomena, such as community creation, friend lists, sharing different resources in different communities, to occur. If the number of users is too small or bounded these networking effects cannot happen [7].

Role-play has often been employed as a useful tool in Human Computer Interaction (HCI) for generating design ideas through improvisation and through evaluating design prototypes where access to users or environments is limited. These examples are well documented elsewhere [11][5]. Davidoff et al. [4] for example developed user enactments, a type of role play, with need validation for their speed dating approach. Thoring and Muller [17] present a thorough and interesting argument for the potential use of role-play for service design. They consider role-play as an extension and combination of other design knowledge exchange approaches, including experience prototyping [2], improvised role-play, body storming, "informative performances," interactive dramas and walkthroughs. They identify five potential uses for role-play in business to evoke new ideas, gather feedback, communicate a concept, represent an intangible object, and train specific behaviours. They emphasise that role-play can provide users with tangible experiences for envisioned systems, whilst also creating new knowledge in reflections about those experiences. They list the advantages for role-play as fast, cost efficient, easy to do, easy to understand, fun, providing an empathetic experience, whilst noting that role-play also presents challenges in the form of ambiguity, archiving, reproducibility, and company culture.

Whilst Participatory approaches are well documented for their use in design they are rarely applied for evaluation. Sanders and Strappers in their influential work "Co-creation and the new landscapes of design" [13] propose that engaging with users in co-design activities is moving towards a collective creativity which will enrich the services and products. Drawing from cross comparisons between the various approaches involving users, like User Centred Design (UCD), Computer Supported Cooperative Work (CSCW), Participatory Design Research, they outline the growing acceptance and appreciation of the role of users as experts of their own domain, in design processes. They suggest that enhancing design with users is less about regarding the user as subject and more about sharing control of the creative process. The authors note for example, how co-design practitioners Von Hippel [18] and Seybold [16] have harnessed 'lead users' to discover innovation opportunities, and contemplate how Internet-enabled creative user input has translated into innovation trends for highly customised products. They find that: "the relationships between new technologies and future human experiences have just recently become very complex and integrated." They propose that whilst users increasingly operate on a continuum between consumerism and creation, designer and researcher roles are blurring, and changing from translators (of user requirements) to facilitators.

3. The trial in the context of SOCIETIES

This trial was part of the SOCIETIES project (http://www.ict-societies.eu/) which included users in the form of three distinctive communities, namely Disaster Management, Enterprise and University at every stage in the project lifecycle; from initial scenario development, on through early paper prototype storyboarding, first prototype trials (as described in detail in this paper) and ultimately final prototype trials. It combined following a User Centred Design (UCD) approach with an Agile approach to software development.

SOCIETIES had the goal of integrating social networking services with pervasive computing, and leveraging the innovations that this merger of technologies enabled, in the development of relevant services connecting people, resources and things across digital and physical spaces. The design of these services was informed through iterative feedback from people representing the projects target domains, at various points during the development process. A central concept underpinning the SOCIETIES software platform and the services built upon it was that of pervasive communities, wherein groups of two or more individuals who have agreed to share some, but not necessarily all, of their pervasive resources, i.e. personal information, context data, services, devices, with other members of that community. For more information on this platform and services see [14].

3.1 The SOCIETIES Enterprise Community

The Enterprise Community was drawn from one large organisation, which offered employees the opportunity to engage with the project's participatory design research activities. These employees are highly educated, being experienced engineers and business executives. They all gave written consent and were advised they could leave the trial activities at any point. Many people said they chose to be involved because they shared an interest in the novel technologies.

A conference scenario was selected in the early design stages as a flexible and accessible tool to investigate the potential of enterprise networking services for the envisioned social and pervasive system. Initial enterprise user research comprised of open group discussions, and a 'quick and dirty' ethnography conducted through shadowing 'lead users': three enterprise delegates, and participant observation at a busy conference event.

This followed with the production of a set of detailed animated storyboards demonstrating executives interacting using a selection of seamless social and pervasive enabled services before, during and after a conference. These storyboards were presented to the enterprise community at a group screening in their workplace, after which focus group discussions took place, and in addition a

customised and anonymised written questionnaire was conducted. The feedback provided from these activities served to refine requirements, and support focus in the agile development of a suite of enterprise services.

The same workplace based venue, was again used for the first prototype workshop and user trial about which this paper is concerned, and some of the participants also were engaged in earlier participatory activities. This first prototype is the first system with working functional applications that can be put in the hands of users.

The design and development of the final enterprise prototype, called Relevance, was informed by insights and feedback gathered during the participatory evaluations described in this paper. It was available from Google Play as a downloadable customised Android conference application, which supported personalised agendas, suggesting relevant communities, events and meetings to end users. Relevance was later trialled, at a large conference event (the ICT 2013 event in Vilnius).

4. First Prototype Trial & Participatory Workshop Description

The trial took place over one day, at the site of the participant enterprise organisation. It was organised as a participatory workshop. In the morning presentations were given about social and pervasive computing research topics, which attracted around twenty people. Following that session, six attendees, which was the maximum technical capacity at that time, volunteered to take part in a participatory demonstration. These participants were each given a mobile device with pre-installed software, and led step-by-step as a group through an overview description of the system and sample activities of service applications. Then they engaged in a location and context-aware treasure hunt game using the services. Four participants were available to continue the trial with role-play exercise and focus group discussions in the afternoon.

4.1 Participants

All of the trial participants were technology literate engineers and executives aged between their twenties and forties. They were colleagues who for the most part knew each other in a limited capacity beforehand. As frequent conference organisers, or attendees, they were all familiar with the conference scenario, and each one brought his particular knowledge, expectations, experience and preferences about such events to the trial.

In addition, as they worked in Internet and Communications Technology (ICT), they had realistic expectations about the maturity and finish of trial prototypes. They were familiar with encountering bugs and were not put off by any minor roughness. Most were familiar with the distinguishing project concepts. They were particularly interested in the innovative and novel aspects of the social and pervasive experience. All those who took part in the participatory activities and role-play exercises were male. The participants were all engaged, participative, and responsive to trial activities.

4.2 Data Capture

Several opportunities for data sharing were provided to participants during the trial. Comment spaces were made available on scripts and walkthrough sheets. A System Usability Survey was conducted. Post-its and a white board were available throughout. Individuals could discuss their impressions with assistant researchers present. The trials were videoed. We also conducted closing focus group discussions. In addition data was captured by system logging at various points during the trial. However, the system activity feed only recorded some limited events and could not provide a detailed map of journeys taken during the trial.

The layering of different data types, recording participants individual, and group experiences, both from self reported 'in the moment' comments, and later reflections, provided researchers with a deeper understanding of the participant experiences than logging alone could have provided.

4.3 Site Deployment

The user trial took place in the enterprise workplace. The deployment of infrastructure to the lab was designed to support the scenario of a conference workshop, splitting the physical area into virtual zones, which were to be used by the indoor location system. The created zones included a presentation zone, breakout zone and showcase zone, which were mapped to physical areas and rooms in the lab.

The indoor location system is based on detecting or 'sniffing' Wi-Fi signals from registered mobile devices such as the smart phones used by the users in the trial. A network of sniffer devices were positioned and configured within the zone areas to enable the detection of a user's device as they moved between the different zones. The accuracy of this detection depended on the number of sniffer devices that were deployed and how close a user was positioned to the shared boundary of two or more zones. The detection location was communicated from the sniffer devices to particular presence zone server and then to the system context management system, which allowed other platform components and third party applications to receive updates on the user's location. During deployment testing the latency of the location updates when fully operational varied between five seconds and thirty seconds.

The software deployment for the trial involved the installation and configuration of the cloud nodes and applications on the mobile user end devices. The software deployment and testing plan involved setting out clear cut off development deadlines for deployment testing and a controlled upgrade procedure of the deployed software with bug fixes and refinements. The cloud node software, which included a full deployment of the pervasive communities platform and the third party services backend, was installed on multiple VMs (virtual machine) to Amazon's AWS EC2 (Amazon Web Services Elastic Compute Cloud) hosted in Ireland. The first VM was the primary server and a second VM was configured as a backup server for redundancy purposes. The mobile devices connected via a Wi-Fi network to the publicly addressable VMs to enable user login and all other communication.

The user devices were Android based (Samsung Galaxy S3, Motorola Razr-I and Orange San Diego smart phones) and were pre-configured with the pervasive communities platform application, the Networking Zones application and the Context Aware Wall application.

4.4 Pilot Testing

Deployment testing began six weeks in advance of the trial, although initial delays were incurred due to problems acquiring the correct infrastructure hardware and configuring the cloud VMs. Pilot testing of the deployed software revealed issues due to immaturity of some modules within the platform and connectivity issues. These delays had a knock-on effect to the preparation time

for the participatory workshop evaluation. Pilot testing continued throughout the pre-evaluation phase and until the start of the trial.

Usability feedback was provided by the evaluation team during the pre-evaluation phase and as many improvements as possible were made to the applications before the trial. The technical deployment, testing and end user evaluation served as a very valuable learning opportunity into the software stability, deployment requirements and readiness for end users. All details were captured and communicated back to the project's technical teams.

As a result of the pilot testing, it was decided to provide technical support during the trial and actively monitor the system to ensure technical issues would not constrain the users' activities. Also, as many usability issues had been identified and logged and it was decided to try to not focus on these during the user trial but instead to try to gain insight about how users might view and value the potential of the services and system presented.

5. Enterprise Pervasive Communities Conference Services

The specific third party services deployed on the social and pervasive platform for the trial, in addition to the pervasive communities system's proprietary mobile and web applications, were Networking Zones and Context Aware Wall.

Networking Zones Service—this service provides the backend and client components that realise the concept of a networking zone. Users are able to detect a virtual networking zone based on their location, which provides details on a 'topic of interest' for each zone; information about other users (and relevant details) in the zone; and a map showing existing social network connections between users in the various zones. Networking Zones offers the following features to conference end-users: zone detection and navigation; zone topics and an attendee list (to be displayed on a display screen); a personalised view ordering the attendee list based on relevance; map based view for the most relevant attendees; zone based view with ranked list of relevant attendees. In addition users can: view a 'relevance chain' for each other attendee; add private, shared or public comments, tags, notes or reminders on other attendees or the session; assign selective sharing to their profile or data.

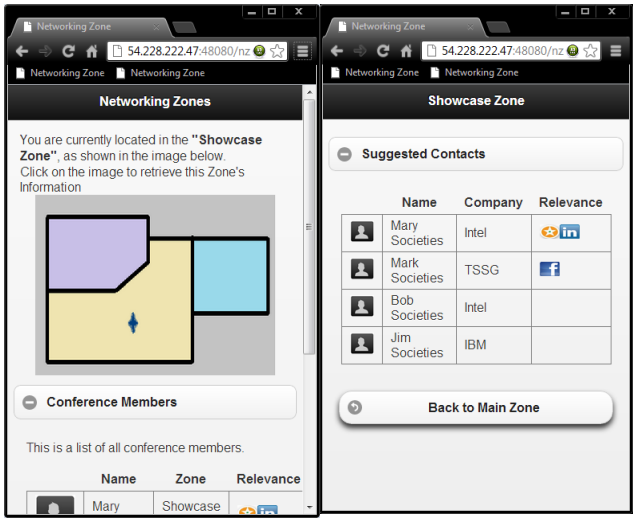

Figure 1: Screenshot of the Network Zones Service.

Context Aware Wall Service—this service facilitated communication on a pervasive screen specific to the members of a given community present. Thus, on approaching a screen, the information presented to an individual was selected automatically by the system to only include messages for communities in which he was a member. It enables users to post messages in the area (zone) they are in, targeted to any communities of which they are a member. The message stays in the zone (or on the wall) for a while, but is visible only to others who are also in the target group or intended community, and who are also in, or walk into, the same physical zone. Thus the messages displayed on the pervasive screen are contextually filtered based on a given user's location and community membership.

Pervasive Communities Platform Service—a specific platform application was provided for end users with web and mobile interfaces, which gave an overview of their profile, communities, and information about their activities and interactions with services. It is through this application that users were able to join communities, control which data and information to share, manage with whom they preferred to share certain profile information and access different context-aware services and review their system interactions through an activity feed.

6. Role-play as an Evaluation Tool for Social, Mobile and Pervasive Systems and Services

Role-play was adopted as a technique for the evaluation of conference networking enterprise services described above, which were medium fidelity mobile application prototypes. These services leveraged features made available through the social and pervasive platform, which was itself also an immature prototype. It was difficult to ensure platform robustness, stability, or scalability at this stage, so any in the wild trial would have been unfeasible**.**

Typical conference-related social behaviour, such as communicating with colleagues, trying to connect with relevant people, asking a speaker a question or navigating an unfamiliar landscape to the next session; could not be expected to occur during circumstances of the short workplace trial with a small number of participants. Therefore we anticipated that it would be unlikely for any participants to discover the extent of the system presented without some artificial signposting and motivations. We sought to recreate a conference situation in the workplace; role-play—through the suspension of disbelief empowered by narrative thrust and play—made this imaginative leap across technical, environmental and social constraints possible.

Role-play allowed for complex socio technical experiences to be modeled during the participatory workshop, in such as way that facilitated people gaining insight into particularly interesting aspects of the project, with imperfect prototypes, whilst protecting participants from having to divulge personal information. Role-play simultaneously allows participants entry into a playful safe experience and provides a self-reflexive distance from the experience where there is room for the question: *"What would I do in a real world situation?"*

Role-play straddled the requirements for the enterprise trial to manage a dialogue between teaching the participants enough about the system and applications, so that they were understood and usable, while simultaneously requesting their feedback on the system.

6.1 From personas & privacy to characters & social graphs

An active social and pervasive system requires copious and continuous streams of real user data for its algorithms to work. However for privacy and security reasons the enterprise trial participants were not requested to input or associate their real personal data and social network accounts on an incomplete and unverified system. In addition, due to the technical constraints of the immature system, user accounts needed to be created and configured in advance of the trial.

6.1.1 Protecting Personal Data with Socially Connected Fictional Characters

However, role-play allowed us to protect real identities, and preload user accounts on the system, though simulating existing social network connections between a cast of fictional characters.

Role-play was realised through the development and use of scripts and characters. Characters and their social graphs were created, along with social media identities and social capital. This facilitated the provision of sufficiently networked connections and narrative links between fictional characters to encourage the types of pervasive communities interactions, which are of interest to the project - such as: dynamic community formation, filtering profile lists based on personalised relevance, location-context-aware communications, and making connections - to be staged. Even if participants were willing to provide personal data, the short duration of the trial would not allow for the collection of enough real data about user preferences and behaviour over time, to fuel meaningful realisations of the user intent, and learning aspects of the social and pervasive system. Inviting participants to role-play with such personas could then illustrate meaningful motivations, allowing for trial participants to get a condensed complex view inside a situated staging of the system in a conference setting, at no personal risk.

Personas or characters also provide some protection against the risk of groupthink. As the trial participants were from one organisation, it might be reasonable to assume that real roles and relationships might influence trial behaviour. Fictional masks allowed people to avoid this to a large extent.

It was an accepted caveat that, while the mechanics of privacy would be included in the enterprise trial, and the distinctions between the various privacy templates and customisable privacy options designed in the system would be seen by users, the circumstances would preclude any real opportunity to observe whether those privacy policies succeeded, or not, in meeting real people's expectations for privacy with regard to real sharing behaviour on the social and pervasive system.

6.1.2 Experiencing and Reflecting on the Reach of Context-Aware Pervasive Communities

Another objective that the role-playing fulfilled was to direct trial activities to interesting and innovative aspects of the project's enterprise applications. The expectation was that the fun aspect of the role-play would also encourage trial participants to have more intense interactions—involving emotion and decision making—with other participants and the system, than passively watching a demo. Role-play encouraged participants to reflect on their own internal negotiations in making interaction decisions for example: *"Should my persona share more identity information with the community in an effort to be pushed up the relevancy charts of others, or should I be more cautious?"*

We also considered it was particularly significant to augment quantitative data monitoring from system logs and activity monitors within the system itself, with qualitative human reflections, as the nature of the system is one *where both social and information needs are intermeshed.* We found it was necessary to provide opportunities for both immediate in the experience feedback and reflection discussion about observations and notes, after the role-play exercise has concluded.

In some respects facilitating role-play participation at this stage in the development of social and pervasive system, where the prototypes are not fully formed, is more revealing because the jolts caused by the uneven user experience, act as reminders to participants to be self-reflexive in their reflections. This un-fluid experience within the socio-technical interactions continuously reawakens both participants and researchers alike to the social technical aspects of their constructed roles as evaluators, and developers of a proposed system during the trial, which reminds people to share their thoughts, and feelings about the experience, rather than be lost-in-play.

6.1.3 Scripts for Engagement, Fun and Illustration

Light personas and potential scenarios were improvised during pre-trial on-site meetings by a small group of researchers, to tease out how meaningful stories of discovery, connection and organisation might evolve with the pervasive communities system. These personas were then developed further offsite, and the improvised ideas developed into outline scripts.

6.1.3.1 Character Development

Earlier work in the project observing user behaviour and groups in the conference context provided us with ample research findings on which to base credible personas. However, we decided that for the purposes of a motivational narrative and role-play drama, these personas should transform into easily grasped stereotype characters. At the trial, we presented users with a limited set of definite characteristics and motivations. For example in the case of the character "Dan" (pictured in Figure 2) he was described as follows.

***Background**: Dan is an angel investor - a secret millionaire.*
***Goals**: He is attending the SOCIETIES conference to discover potential companies, in which to invest. He is going to make an offer to the most relevant person.*
***Challenges**: He is employing the SOCIETIES applications to help him discover and connect with most relevant person.*
***Interests**: Green IT, Internet of Things, Cloud Technology*
***SNS contacts**: He has just one social media contact, LinkedIn connection with John who he doesn't know very well.*
***Personality traits**: Secretive, confident, decisive.*

We created a set of ten persona characters, and drew up sample profile cards. Researchers used these cards to improvise possible storylines in preparation for the trial. The social aspect of the pervasive communities platform required multiple users, doing multiple different things concurrently. Social connections for the characters, both historical and current were mapped and available to participants through friends lists integrated with the pervasive communities service via fictional social media accounts. Each character in the script has a unique journey navigating through the pervasive communities system, which affords the group of characters as a whole to experience a large extent of the system.

Figure 3: Examples of personal cards for characters in the role-play exercise.

The creative process for the role-play narrative required maintaining an overview of all possible connections, tasks and communities. This became cumbersome. It was necessary to continuously refer to written notes and the persona design artifacts. Yet role-play, as an approach, was flexible enough, to cope with changes. The staged scenarios could have managed anywhere between four to ten characters easily, but we feel it might have become unwieldy for any more characters or participants. These characters were eventually reduced to four who interacted through one storyline. Also, when it became apparent that there would only be male participants attending the trial, female characters were eliminated as we assumed they would be more comfortable taking on the roles of male characters.

6.1.3.2 From Scenarios to Scripts

Initially, a small group of researchers came together on site during the pilot trial deployment and improvised some short scenario ideas, with reference to the projects earlier enterprise storyboards. The ideas were then further developed into rough draft scripts by one researcher offsite. Following that, we generated a list of all the possible functions afforded by the current iteration of the prototypes and mapped these to tasks or activities in the basic script outlines. We spent several days devising how to create meaningful stories and conference scenarios around the available tasks, which could be played out by participants in a reasonable span of time. Our scripts needed to condense the temporal duration of a daylong conference into an hour or two of trial activity.

The scripts were designed to motivate participants, whilst also engineering user interactions that were considered significant to the project. Thus the scripts directed people to experience creating groups, making friends, and organising meetings, and by doing so also gave them access to some of the unique attributes of the system with regard to: personalisation (implicit and explicit), social network integration, context awareness, and discovery of relevant data, friends and communities.

We understood that the role-playing exercise would be a staged and artificial simulation of situated use. We knew, within the trial environment, users would be focused on the project's suite of applications for the duration and would therefore not be immersed in a myriad of distractions and interruptions which one could expect in a 'real' 'in the wild' situation. The trial did not aim to be strictly ecologically valid.

The final themes for the role-play scripts diverged considerably from the initial scenarios in the project's enterprise storyboards in response to both a reduced suite of services, a limited number of participants, the necessity to direct trial activity toward more innovative areas and creative input. The characters diverged too from the personas in the storyboards, as characteristics such as goals, motivations, and personality traits were included to make the role-playing exercise more engaging and meaningful.

6.1.4 The Secret Millionaire Angel Investor and the Apprentice Head-hunter conference scripts.

The premise of the primary script was that an angel investor was attending a conference, with the objective of discovering and assessing potential companies for investment. It included seven characters initially. There were two different companies who had three employees each, and four other individuals attending a conference, including an angel investor, who did not want to be identifiable. This theme was colloquially referred to as the 'Secret Millionaire' script, within the project, in reference to a popular reality television program in the UK and Ireland.

A secondary theme script was that a headhunter from one company was looking for jobseekers and was attempting to entice potential future employees to contact him without the knowledge of their colleagues. This became known as 'The Apprentice' script, in reference to another reality television program. A third subplot suggested for inclusion was that some characters were aiming to discover and organise funding proposal partnerships.

Pre-existing relationships and links from private and professional social networks assigned to each persona and set up in actual social media accounts. Some characters were predisposed to have an advantage in achieving a particular goal, whether that be seeking investment for their company, or discovering new career opportunities. However, the choices and responses made by trial participants during the exercise, with regard to sharing data and connecting with relevant others, networking though the networking zones application, and communicating with the context aware wall, would decide the ultimate outcome.

Working through script ideas with working prototypes, was challenging due to many usability, technical and deployment constraints, and finally just one theme only was selected for inclusion in the final trial – that was the 'secret millionaire' script, as it illustrated innovations around relevancy and learning.

Direction, Freedom and Guardian Angels

There was a tension evident between the dual functions required of the scripts. On the one hand the role-play was expected to provide direction to the interesting aspects of the platform, whereas on the other, the role-play was also intended to accommodate more freedom for the trial participants to interact with the system. Role-play also served as a to support evaluation and reflection within the project development team. Closer to the trial, a near final script was evaluated in a 'dry-run' collaborative group walk-through involving more people; thus enabling other researchers, developers, and trial managers to physically engage with the pre-trial system. They reported experiencing some difficulties, with usability and coordinating individual journeys through the scripts. It was suggested to include key-point timing, or forced waiting or pauses to ensure people followed scripts in a similar timeframe. The scripts were then adapted to include this along with detailed instructions on how to perform particular

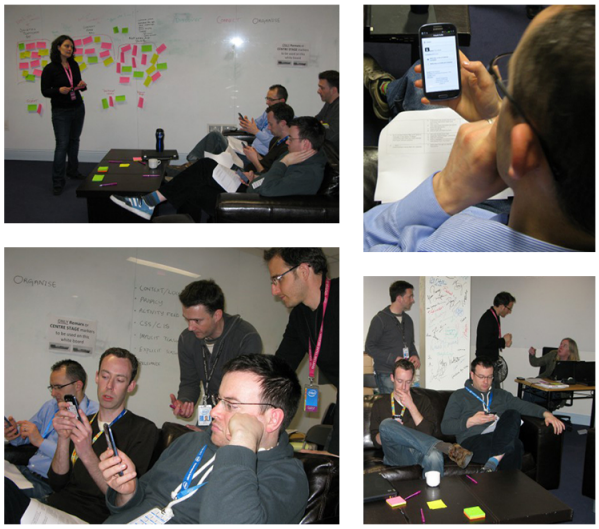

Figure 3: Participants engaged in Role Play.

activities such as selecting a particular community, or how to post on the Context Aware Wall.

We decided to include more researchers in the role-play activity to perform the roles of guardian angels—one assigned to each participant—who guided users following scripts. Participants were very focused on following the trajectory of the script and were enthusiastically engaging with the services and system. Guardian angels noted difficulties, and answered participant requests. Participants and guardian angel team journeys were unique and not directly comparable with other guardian angel teams. This created additional trial data, and provided researchers with valuable insight into participant user experiences.

6.1.5 Focus Group Discussion And Findings

A focus group discussion took place, following the role-play exercises. Together, participants and researchers reviewed the feedback and observations collected throughout the day on post-its and displayed on the large whiteboards in the meeting room. Comments from the morning session had been organised into areas titled: "the SOCIETIES platform app" and "Context Aware Wall", with any addition comments set outside these areas. Additional sections were drawn for the afternoon session to include: "Networking Zones Application", "Comments on the script"; "Technical Issues", "Questions for Discussion" and "Known bugs".

The project value proposition: "Discover, Connect, Organise" was written on the board along with some other words to encourage feedback such as: "What about?", "Why…?", "Nice to have…", "What I don't like is…." and "Thank you!". The atmosphere was relaxed and friendly. The role-pay exercise had swept away any initial inhibitions about participation. People were engaged with the subject matter, eager to share their experiences and a lively discussion ensued.

Participants considered if they would use the project services if they were available in a real world setting. Most participants could envision future use of the system in a conference scenario, but felt that the current applications were not yet intuitive. Several mentioned that a large number of users would be required to experience the real potential. When they discussed if the value proposition of discover connect and organise was attractive, a participant said that his experience was that *"it was hard to see the value without putting in work to share"*. This participant mused that he was not sure if he would have shared so much, with the system if it were his own data. As he was role-playing he went along with the game, and so had experienced some of the benefits, but that it would have been impossible to see value of the system without first sharing his own data.

The focus group facilitated a useful exchange of ideas for refinements and enhancements to the applications. Participants could see the advantages that the Networking Zones application could offer in a busy conference session, and were particularly interested in the functionality to sort lists of people in particular areas based on personalised relevance. They discussed the possibilities of giving the user more controls to filter suggestions from the system based the user's goals and generic categories.

With regard to the Context Aware Wall service one participant *"liked the fact that two things were changing – location and notice board – but it was not obvious"*. A discussion ensued about how access to context information like location and community provided a matrix of possibilities, which led participants to express a desire for services to discover relevant or sought out others at a conference. While the Networking Zones, it was agreed provided information regarding people who are present in a zone, one user wanted more specific tools to find known contacts. *"I just want to know where (relevant) people are. Where are the people I already know?"* Some participants suggested that they would like to have a map overview in the user interface where the location of people or communities relevant to them could be indicated, through use of photos and how this might be realised was discussed with the developers present.

Participants wondered if social interactions facilitated by pervasive communities services might cause some awkwardness or social unease, as well as social facilitation. They imagined a scenario where one was scanning a room in a conference scenario to discover relevant people, and discovered the most relevant person to them was sitting in the seat beside him. "What would one do? Would it be socially awkward—like approaching a well known personality?" They considered how would they feel if someone else approached them?

It was clear that bugs or usability issues in the immature prototypes did interrupt the user experience of the system and caused confusion. Many new usability issues were uncovered through dynamic social use by multiple users accessing the system concurrently. For example, one user noted that friends who had already been accepted, still appeared in the list of suggested friends, or that swiping notifications did not dismiss those notifications in the app. Most users would have liked more integrated user-to-user interactions. The privacy aspects for people interacting with social and pervasive systems was considered very important in discussions but yet participants felt being asked to respond for each instance of data sharing via the system's privacy notifications was confusing. Some users frustrations with using the prototypes, where user actions resulted in unexpected system responses, caused confusion and lack of faith in the system to perform. This might have led some participants to prematurely abandon interaction with the applications if it were not for the dynamics of the group role-play.

7. Conclusion

We have outlined how we consider role-play to be an approach suitable for the evaluation of medium fidelity prototypes, particularly in the case where the system under evaluation has

social, mobile and pervasive dimensions. We have described how we adapted role-play with scripts for a small group of users for a short enterprise trial. We propose that role-play can support people in imagining, experiencing and observing dynamic social interactions—such as those supported by the conference networking services and the pervasive communities system we were developing—and thereby facilitate more far-reaching evaluation of these complex systems.

The intermeshing of ubiquitous, social and mobile computing, requires sophisticated socio-technical perspectives to be considered for evaluation purposes. Whilst field trials are irreplaceable for mature systems; immature systems and services, can benefit from participatory approaches which enable both target end users and researcher developers to engage in a shared envisioning of future systems, in order to appreciate and access the particular characteristics of a medium fidelity prototype. Role-play offers the advantages of simulating situated use, which is more achievable, than full ecological validity at this stage of development when systems are not yet technically robust. It provides a safe space too—enabling participants to engage in guided discovery of unfamiliar technologies. Participative group role-play is flexible enough to support active developer involvement, where they may act as guides to the most interesting features. It can allow participants in evaluation activity to time travel in play, and fast forward to more interesting scenarios, which could only otherwise occur with sustained use and data sharing over time, due to the evolutionary nature of social and pervasive systems. A disadvantage to this approach is that it requires intensive preparation, and script walkthroughs require several researchers to be present. It generates large amounts of data, which then require careful analysis. Future approaches using this technique, would ideally allow more time for discussion. Iterative or repeat use of this participatory evaluation approach, perhaps interspersed with group walkthroughs, with different prototype iterations could also build into more comprehensive tool for mapping dynamic human social interactions.

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Introducing ViNAR (Visual Neglect Assessment and Rehabilitation) using the Leap Controller and Processing

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Abstract

Visual Neglect is a common neuropsychological deficit associated with a person having a Stroke [1]. Stroke is a brain injury caused by a disruption of blood supply to different areas of the brain. In the case of visual neglect the brain area responsible for visual spatial processing is damaged [2]. Visual neglect is manifested by a Stroke patient's inability to notice things usually in the left hand side of their visual space. Currently in a clinical setting, pen and paper-based techniques are used to assess the presence of Visual neglect in patients and in addition to this there have been a number of rehabilitative programs developed to try and ameliorate the symptoms of Visual Neglect with limited success [3]. Using the Leap Motion Controller, the associated SDK and the Processing programming language, this project sets out to develop a novel measurement paradigm for the mapping the spatial distribution of visual neglect as well as laying the groundwork for developing a novel rehabilitative intervention (a means of helping stroke patients to recover from visual neglect).

Categories and Subject Descriptors H.1.2 [*Models and Principles*]: User/Machine Systems Human factors, Human information processing, Software psychology.; H.5.2 [*Information Interfaces and Presentation*]: User Interfaces Evaluation/Methodology, Ergonomics, Input Devices and Strategies, Prototyping, Audio Feedback (non-speech), Bench Marking.

General Terms Human Factors, Measurement, Experimentation, Design

Keywords Stroke, Visual spatial Neglect,Injury,Brain Injury Assessment and Rehabilitation, Brain Lesion, Leap Motion Controller, SDK, Processing Framework, Cognitive assessment.

1. Introduction

Visual Neglect (VN) is a neuropsychological phenomenon that commonly occurs after stroke (brain injury) and results in a failure of patients to report, respond or orient to stimuli presented to their neglected visual field [4]. VN occurs more frequently in association with right hemisphere stroke and tends to be more severe in these cases [25,26]. VN which is associated with a right hemisphere stroke (injury to the right half of the brain) results in a neglect of the left side of the visual field (contralesional) [4]. This apparent mismatch in the side of damage versus deficit is due to the nature of the brain and the cross control of the hemispheres; i.e. the left hemisphere of the brain controls the right side of the body and the right hemisphere the left [5]. It manifests as an imbalance in spatial attention biased towards the right, leading to a relative neglect of the left side of space which can have various real world implications depending on severity. VN has a serious impact on the daily life of patients; they will often fail to dress themselves properly or only shave the right half of their faces or eat half of their meal. They also have a tendency to bump into objects on the left and as a result, hurt themselves or they can fail to find objects they leave in their left visual field [6]. More seriously VN impacts on the rehabilitation of other domains, such as motor deficits [7], [8]. As a result many otherwise capable patients are consigned to life in nursing homes and institutions, increasing financial and familial burdens above and beyond what fellow patients with similar lesions but no neglect would experience [9]. It has been suggested that correct assessment and rehabilitation of neglect could dramatically reduce the demand for related services in cases of stroke [4]. Regarding assessment there are numerous pen and paper measures currently in use as standard in clinical settings such as cancellation tasks [10], [11], line bisection [12], and figure copying and drawing tasks (see Figure 4). In the line bisection task patients are required to estimate and mark the mid point of six horizontal lines of different length. In this task, visual neglect is assessed as the patient's deviation from the actual mid point (see Figure 1).

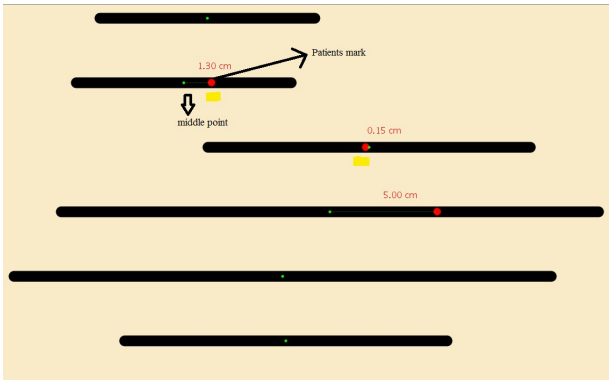

Figure 1. Line bisection test.The patient must estimate the midpoint of each line.

There are number of different cancellation tasks which require the participant to cancel or cross out particular objects in the configuration of different objects. For example, in the letter cancellation task the participant is required to cancel a particular letter (e.g "A") on a page containing other letters.

Another example is the Bells test which requires the participant to cancel silhouettes of a bell among a configuration of different silhouettes of objects. In both of these tasks neglect is assess by counting the number of missed cancellations of the letter or the bell respectively (See Figure 2). One item missing is still considered .as being within the normal range of functioning.

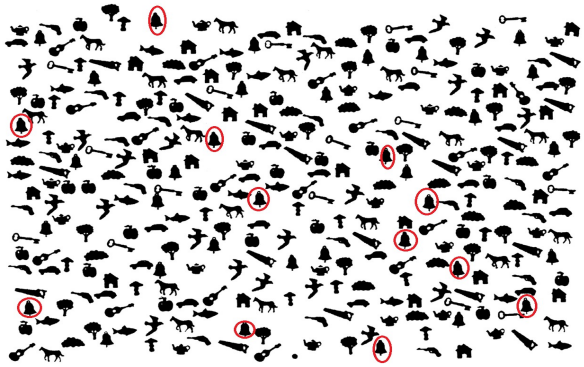

Figure 2. The Bells Test.The patient must circle each silhouette of a bell.

However these only give a binary classification (i.e. neglect/non-neglect). Rorden and Karnath (2010) developed a piece of software called the Centre of Cancellation (CoC) to address this issue [13]. The CoC takes into account the number and spatial position of each object canceled in the task and calculates a positive or negative number from 0 to +/- 1 based on this information. The closer to 0 the score, the less severe the neglect, and the further away the more severe. This not only shows the clinician the binary classification of neglect positive/negative but also gives an indication of how bad the neglect may be [13]. However, at least in the Irish context, this approach to assessment has not been widely adopted. It is with this sensitivity and severity indication in mind that the ViNAR was developed.

ViNAR was developed using the Leap Motion Senor, ViNAR test, Leap SDK and the processing programming language. The basic task requires a patient to transfer a two dimensional ball represented on a screen, from the non-affected field of view across to a target location in the neglect affected field of view using an index finger pointing across the sensor field.

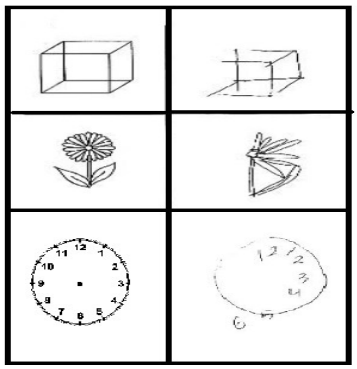

Figure 3. Copying tasks, here patients are asked to copy different pictures on the left side of the figure. Patients who have spatial hemi-neglect are not fully able to copy the drawings, preserving only the detail on the right hand side of the picture (the patient's attempts are in the right column). Adapted from [2].

The movement of the index finger is transduced to represent the ball moving from the initial point to settling on its final target location (See figure 4).

The reason the ball over the wall paradigm was chosen was because it was considered *ecologicaly valid*. In other words there is a stronger real world element in this task than other standard tests of neglect which have been criticised for lack of ecological validity [25]. Other tests vary in sensitivity and some may fail to pick up subtle neglect [28]. Reaching and pointing are everyday movements that people perform. Therefore, it is more natural to use these sorts of movements in perceptual tasks. The act of moving the ball across the wall was chosen because if its inherent simplicity and obvious goal. This paradigm is easy to explain to participants and visually clean and simple. There are also no extraneous details in the field of vision which could otherwise potentially interfere with spatial attention or visual scanning processes. Regarding the size and colour of the wall, there were no previous examples in the literature to help guide the decision on these attributes. The position of the wall in the centre of the screen was chosen because that reflects the normal centre of the visual field that corresponds to the fovea at the back of the eye [29].

The ViNAR is designed to go beyond binary classification for the presence or absence of the neglect to be able to identify the specific sections within the left field of view that are most affected by neglect. ViNAR makes an assessment of the extent of visual neglect for each of the 36 sub areas in the left visual field (4 quadrants each containing 9 elements, see Figure 12). It does this by comparing the performance (time-to-target) of the patient under test with that of healthy participants from data which has been pre integrated into ViNAR.This paper outlines the design, implementation and use of ViNAR to assess the phenomenon of visual neglect.

Section one of this paper introduces the phenomenon of visual neglect by describing how it is manifested. Section two the methodology section describes how data are collected with the ViNAR and with standard test of cognition as well as neglect.Section three provides information about the technologies which are used to implement ViNAR. Section four deals specifically with the software implementation of the ViNAR solution.Section five explains the ViNAR's mean matrix calculation and how Z values are used to assess the performance of the participants. Section six outlines the future use of ViNAR in hospital setting and further gathering of normal healthy data.Final sections summarizes ViNAR's ability and plans for future functionality to possibly help rehabilitate visual neglect.

2. Method

2.1 Participants

The control group participants for this study were recruited by word of mouth and advertising from the NUIM student body and in the Maynooth, Co. Kildare area. All participants spoke English as their primary language

and had normal or corrected-to-normal vision. There were 8 males and 7 females ages ranged from 20-43 years (mean 28.33), all were right handed.

2.2 Procedure

Each of the participants was asked to sign a consent form and then asked to complete a number of standard pen and paper-based cognitive tests and tests for visual neglect [14]. These cognitive tests were as follows; the National Adult Reading Test (NART) which measures general intelligence, Trail Making Tests (TMT) which assesses executive function and the Cognitive failure questionnaire (CFQ) used as a self-assessment of everyday memory and slips of action. In addition to these tests a sample of the participants (n=7) were administered the Star Cancellation Test and the Line Bisection Test for visual neglect. All the tests above were administered to verify that the control group members had normal cognitive status and were free from an undetected visual neglect deficit. After completing these tests the participants were asked to sit 70cm in front of a 21 inch LED screen Samsung Syncmaster 245B (1920x1200 screen resolution) and await instructions. The Leap Motion controller, was positioned 30cm in front of the screen which was connected to a Dell laptop Intel core i3 with Windows 7 running the ViNAR software. (see Figure 4)

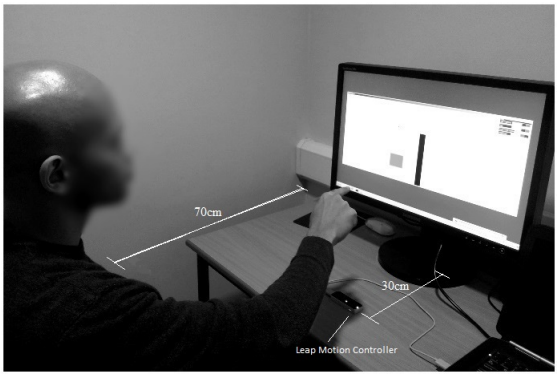

Figure 4. A control participant using the ViNAR. The task is to engage with and move a ball from the right side of the screen to a darkened square area in the left side of the screen by moving his index finger over the Leap Motion Controller.

Each test trial requires the participant to move a ball from a location on the right to a random gird box on the left.Each control participant was tested with the ViNAR on two trials for each of the 36 grid elements of the left visual field. When the test was complete, the performance (time to target) results for each participant were saved to a file. The key output file for each participant contained the average trial time and individual trial time for each target grid element of the ViNAR test.

2.3 Ethics approval and consent

Ethical approval for this research was received by the National University of Ireland Maynooth Ethics Committee. Participants gave informed consent for the collection of their data and as well as for the future use of their data for research publication and dissemination purposes.

2.4 Statistics

The ViNAR data files from each participant were initially collated in MS Excel and SPSS 19 for Windows (SPSS Software, Seattle, WA, USA). Using the mean performance for each participant (average of 36 grid elements and 2 trials over the 15 control participants) a series of Kolmogorov Simirnov tests were performed to determine if these data were normally distributed. The data from the cognitive function tests were analysed in excel to yield mean and standard deviations values. These values were compared to standard tables of normative data for the corresponding tests [8].

2.5 Results

The Kolmogorov-Smirnov test yielded a value of 2.0,which according to [24] indicates that these control data are normally distributed.The control group means scores for the CFQ, TMT and the NART were within age appropriate norm ranges for these tests. The test of neglect on the sample of participants revealed that no participants had neglect.

3. Leap Motion Controller, Analysis and Limitations

The Leap Motion Controller (LMC) enables people to interact with the computer using hand and finger movements [15]. The LMC is only able to detect hands and simple objects such as pen. The LMC can detect at most two hands and 10 fingers and the manufacturer claim that it is highly accurate at detecting fingers (track finger movement within 0.01mm) and complex hand gestures such as clutching hands [17]. It is not possible to achieve the theoretical accuracy of 0.01mm under real conditions [16]. However, the LMC still provides high precision compared with other similar products in the same price range on the market.The LMC was chosen for this study because it is cheap, sufficiently accurate, easy to deploy and it is a compact device. In later sections there are discussions on the precision, accuracy and responsiveness of the LMC to hand movements and other configurations. Standard mouse could have been used in the ViNAR paradigm but the use of the LCM provides more ecological validity to the paradigm. Reaching and pointing and the gross motor movements that go with both are more akin to movements made in real life than the fine motor movement required for a mouse click. Regarding rehabilitation, the motion required to engage with the LMC involves the motor system and the visual system as well as activating the body schema and the systems responsible for integrating all this information. Previous research has suggested that the motor and visual systems are linked and that rehabilitation of motor impairments following stroke can improve visual neglect at the same time [4]. Mouse movement does require motor activity but the LMC paradigm requires a greater degree of movement to make it work. Furthermore, it requires visual engagement with an awareness of not just the screen but the arm and hand manipulating the object on the screen. It is this combination of visual and motor activity that will best facilitate the rehabilitation of neglect.

3.1 Coordinate System used by the LMC

The Leap employs a right handed Cartesian coordinate system. Values reported are in units of real world millimeters.The origin is centered at the centre of the Leap Motion Controller. The y-axis is vertical, with positive values increasing upwards which is unlike most computer graphics coordinate systems. The z-axis has positive values increasing away from the computer screen and x-axis values are increasing towards the right side (See Figure 5).

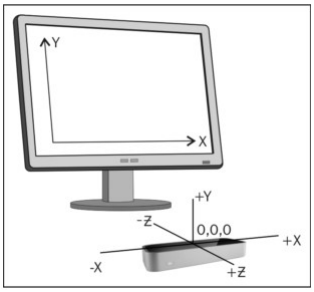

Figure 5. Coordinate system of the controller [18]

Due to a mismatch between the way a point is represented by the controller coordinate system, and the way it is represented in the programming environment, an adjustment was needed to reconcile these systems. This adjustment involved rescaling of the LMC coordinate system with the processing programming coordinate system.

3.2 Hand Model

The hand model provides information about the position, characteristics, and movement of a detected hand as well as lists of the fingers and tools associated with the hand [19]. The Leap API provides a large set of data

about a hand. However, it is not possible to obtain certain details. For example, the controller is not able to determine whether a hand is a left or right hand by default [19]. Some algorithms could be developed to overcome this issue for certain conditions. For example, if there are two hands in the detector field of the controller, the hand appearing on the right most position could be aligned as right hand or an algorithm could be implemented to detect which hand it is depending on the vector direction of the thumb. LMC tracks both fingers and tools within its field of view in addition to the hand. The controller classifies finger like objects according to their shape. A tool is defined as something which is longer, thinner, and straighter than a finger. Moreover, the LMC provides gesture recognition for certain gestures which could be used in applications. The controller reports gestures observed in a frame in the same way that it reports other motion tracking data like fingers and hands [19].

3.3 Limitations of the LMC

The software that is provided by the LMC is called a diagnostic visualizer and it was used in order to demonstrate the functionality of the controller . In tests it was observed that the controller had difficulty sensing four or five fingers. The controller did not pick up all four or five fingers at a time especially when fingers were close to each other or even though the controller was able to detect 4 or 5 fingers at the same time it lost track of the fingers from time to time. Moreover, it was observed that the controller was sometimes not able to detect some pointable objects such a pen and the hand control was clumsy. Another critical issue was that the LMC behaved erratically with different lighting conditions especially with fluorescent light which is generally used in clinical environments and hospitals. Since the controller is uses the infrared spectrum, the lighting conditions in which the device is used appear to be affect the way it works. Moreover, even the reflecting surfaces (i.e. ceiling of a room covered with reflective material) in the environment could affect the device. Therefore, in order to get optimum results from the device suitable specific lighting conditions should be prescribed during the operation of the Leap controller ViNAR system.

4. ViNAR Software Structure

4.1 System Design

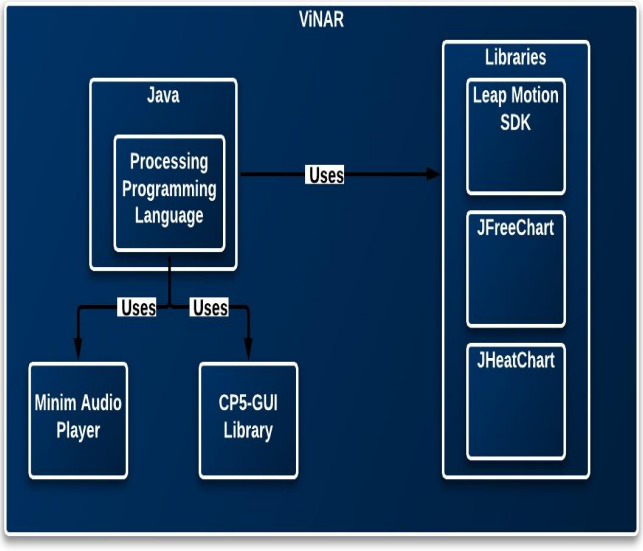

Figure 6. ViNAR Software components

To summarise, the ViNAR system uses the Leap Controller, Leap Controller SDK, and the processing programming language in conjunction with a standard laptop to provide a testing paradigm for Visual Neglect. (In the future it will also act as a rehabilitation paradigm for Visual Neglect). The basic idea of this system is that a patient must move a simulated object from their unaffected (right side) field of vision to a target location on the left side of their field of vision. The system will track how successfully the patient achieves this over a number of trials (configured by the testing professional). This tracking information is then used to map the areas of visual neglect in the patient's left sided field of view (assessment) and will also input into the elements of the system designed to help ameliorate the effect of visual neglect (rehabilitation). The results for each patient are displayed as bar graphs, displayed in a heat map and exported by the system in various formats. (i.e. excel file, for graphics .jpg). The following is a description of each of the main software components and libraries used in the ViNAR software.

- *Leap Motion Sdk:* Enables developers to interpret the data which is obtained from the leap motion controller.
- *JfreeChart:*JfreeChart: JFreeChart is Java library which helps developers to create various types of diagrams easily on Java swing components.
- *JheatChart:* JHeatChart is a minimalistic Java library for generating heat map charts and export in various formats.
- *Processing programming language:* Will be explained in following section.
- *CP5:* Cp5 is a library for processing programming language which enables the creation of simple GUI elements on the processing sketch.
- *Minim:* Minim is a library for the Processing programming language which plays various audio formats for processing programs. ViNAR uses the Minim library to provide sound feedback to the patient since their visual field may be neglected. For instance, whenever the stimulated object hits the obstacle a warning audio is played using the Minim library and ViNAR will give feedback to the patient.

4.2 Processing Programming Language

Processing is an programming language which provides an easier way to work with graphics for technical students [20]. Processing is built on top of the Java programming language therefore, it allows the use of all the Java features. In fact every Processing sketch is actually a subclass of the ***PApplet*** Java class which implements most of the Processing language's features. There are two main methods used to create a processing sketch. One of them is ***setup( )*** block which runs once, and the ***draw( )*** block runs repeatedly like an infinite loop. ***setup( )*** is generally used for any initialization. The ***draw( )*** block is used to handle dynamic actions during the runtime such as animation [20]. The Processing Programming Language was chosen because it is easy to learn; allowing the programmer to work with many other devices. Moreover, Processing allow developers to work with three dimensional environments in addition to two dimensions.

4.3 Developing Gesture Models

The user has to complete the ViNAR test by simply moving the ball into target area while avoiding the obstacle barrier using the cursor controlled by the LMC (See Figure 7).

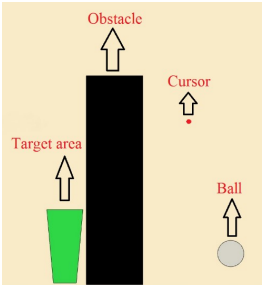

Figure 7. Items on the test environment for the first prototype. Colours are chosen deliberately. For instance, the target area is indicated with the colour green because the human eye is most responsive to this color [21]. Three different models for controlling the object on the sketch were evaluated.The model with the maximum usability was selected.

4.3.1 Palm based models

In this model, the cursor (red circle in Figure 10) was designed to move according to the center position of the palm of a user. The center of the palm is measured in millimeters from the LMC's origin. The user (test participant) controls the cursor, and when the cursor is on the ball the user can stimulate the ball by performing a grabbing gesture (See Figure 7). The user should keep this (See Figure 8 right side) gesture while moving the ball. A number of problems were identified after implementation. First of all, participants reported that it was very tiring to use their palm in order to interact with ViNAR's test environment. This may be because the whole arm has to move in order to move the palm. Secondly, an algorithm was developed for the grabbing gesture, however, when the fingers are close to each other the leap motion controller is not able to detect fingers and most of the time this gesture fails.

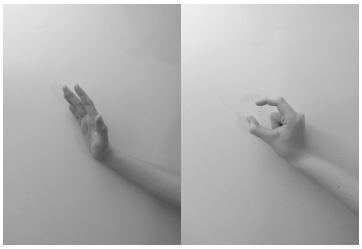

Figure 8. User could move the cursor with his palm (left) and stimulate the ball by performing a grabbing movement (right)

As a result the user is not able to move the ball. Therefore, this approach was abandoned in favor of simpler models.

4.4 Finger based models

This model aimed to be simpler and easy to use compared with the previous palm based model. In this model, the cursor moves according to the index point's position (See Figure 9). The user moves the cursor over the ball using his/her index finger and the thumb is used to stimulate the ball whilst the cursor is on it. Then using both the index finger and the thumb the user is able to move the ball towards the target area. (See Figure 9 right side of the image)

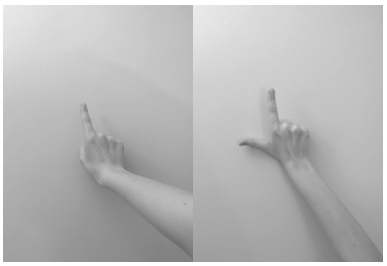

Figure 9. User can move cursor with his/her index finger and stimulate the ball using his/her thumb

Controlling the cursor with this model was shown to be easier compared with the previous one. However, when the user uses their index finger and thumb in order to move the ball the thumb disappears from the view field of the leap motion controller. This can cause some difficulties in terms of usability. Normally, this problem could be tolerated. However, since this software is designed for use with people who might have impaired motor function, a higher accuracy requirement needed to be met. Therefore, it was decided to abandon this model.

4.4.1 Finger and time based models

The final model that was developed has a minimalistic approach in order to have high level of accuracy. In this model, the user uses only his/her index finger in order to control the cursor. Whenever the cursor is on the ball, a countdown timer will appear above the ball (see Figure 10) and it will count for a second whilst the cursor is on the ball. Then, the cursor will lock the ball and the user will be able to move the ball by moving his index finger. This time based model proved to be quite robust and provided a high level of usability. The only thing that the leap motion controller has to monitor is the position of an index finger. All other things are handled by the algorithm. For instance, if there are extra elements in the view of the LMC such as second hand. The algorithm does not allow the user to proceed until second hand disappears from the view of the LMC.

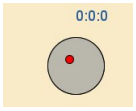

Figure 10. Countdown appears whilst user engaged with the ball.

4.5 Measuring Patient Performance

The task measure for the ViNAR assessment is time taken for the ball to reach the target grid element on the left. More specifically, ViNAR measures the time from **T0** until the ball has at least settled in the box for 0.5 seconds (See Figure 11). A person recovering from motor paresis (whose fingers shake when they attempt to move them) may reach the box but have difficulty settling in the box and therefore record a time indicating that there is visual neglect when no neglect is present (The next iteration of ViNAR which will be implemented include a feature to tune out this motor effect the patient results).

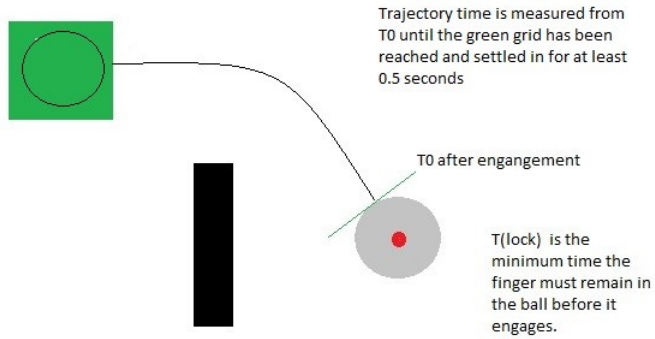

Figure 11. Time measurement in ViNAR

This timing-to-target function will timeout if the patient is not successful. For instance, at the beginning of an assessment process the clinical professional sets a timeout parameter for a patient and if the patient is not able to move the ball to the target area within the time set by the professional, ViNAR saves this information and reflects this result in the patient reports. This information could indicate that the patient is unable to find the target area due to visual neglect. The timeout should be set to reasonable number depending on patient's situation. If the patient is having problem in his/her motor skills, it is better to set the timeout to be greater than 30 seconds.

4.6 Dividing the left measured area into a grid

ViNAR maps the areas of visual neglect in the left hemi-field or the left side of a person's visual field with a degree of precision. In that way, it will be possible to obtain more details about the patient's neglect compared to the binary classification provided by existing pen and paper tests. It was proposed to divide the left visual field into 36 distinct units in order to be able to map the areas of neglect for a patient (See Figure 12). Randomizing the position of the target trails is an important aspect of diagnosing visual neglect. This is because if a patient follows the same pattern all the time they might develop an unconscious behavior to complete the task and the diagnosis would not be valid. Therefore, ViNAR was designed so that for each of the divided areas, the target area will still be selected randomly. The professional will set the number of times (trials) that each target area will be presented to the participant. If the patient is not able to move the ball into the target area, the target area will change to another different area (Timeout occurs). Different kinds of data will be collected for each area separately. Data collected for each area are; **a)** How many times the patient was/not able to reach the target area **b)** For each trial how much time the patient took to put the ball into target area **c)** For all trials, for specific area how much time did it take the patient take to put the ball into the target area .(**t** for trajectory time **n** for the number of trials for each area) **d)** How many times the ball hit the obstacle to reach the target area.

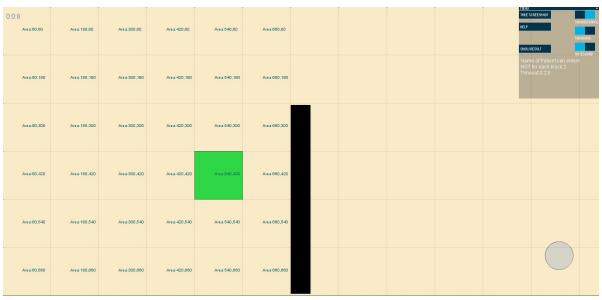

Figure 12. Left side of the field of view is divided into 36 areas (grid elements) to assess which area shows signs of visual neglect.

Each area is represented as a square on the sketch and each Area object holds different information about a patient's performance.

4.7 Displaying results

The data are presented to the professional and stored at the end of an assessment session. ViNAR exports all the data into an excel file for the professional to evaluate later on. Data are also represented in a graph format in order to allow the professional to better visualize the patient's assessment. Data obtained from ViNAR are quantitative and discrete. Bar charts are one of the most suitable ways to represent quantitative and discrete data [22]. It was decided to use Heat Maps for some parameters such as total time spent for each area to place the ball into a target destination. A heat map is able to provide an immediate visual summary of information. By using the heat map it is possible to map each Area on sketch with a member of heat map's matrix data and provide a quick feedback to a professional about which areas of the patient might be neglected (by internal comparison with control data). Figure 14 shows different graphical representations of the same information obtained by ViNAR. This figure is a heat map which provides an overall summary to the professional and highlight the areas which might be problematic in the patient's visual field. Also in figure 14 there is a grid presentation of Z values, representing the performance of a participant on each area.

5. ViNAR Calculations

5.1 Mean Matrix Calculation (MMC)

The ViNAR mean matrix calculation (MMC) is used to determine how a participant performs on any particular left sided grid element [i] compared to the mean and standard deviation (std) values for a group of healthy participants on that corresponding grid element [i]. The simple MMC is described below. The values described below are processed for each of the 36 grid elements in each of the matrices, input **A** which contains two control data parallel arrays: (1) averages **A.1**, (2) std values **A.2**), input matrix **B** are patient data averages and outcome matrix **C** which are patient assesment values. All of these are two dimensional arrays. The output matrix C contains the Z[i] value, or the number of standard deviations (or partial standard deviations) calculated by getting the difference between **[A.1]** and **[B]** and then expressing this difference in terms of multiples of **[A.2]**.

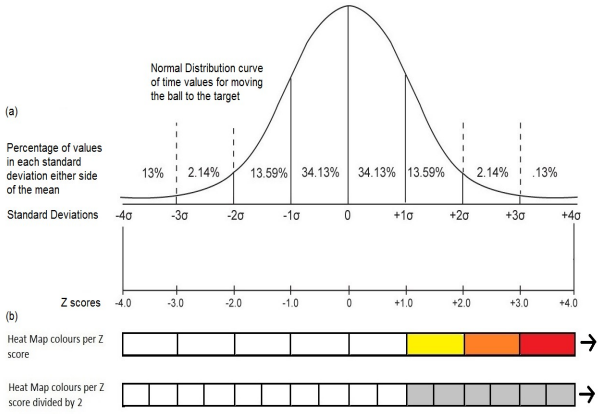

Figure 13. (a) Normal distribution of the control performance time values used to assess a patient [23,24]. (b) The Z value is used to visually present a left visual field grid element score on a heat map. The number of discrete presentation levels can be increased by using a fraction of a std instead of a whole std. Scores less than the mean are marked as normal. Note: The [C] output values represented on the Heat Map provide a visual method to present data in a two dimensional left sided format showing areas of normality or neglect which depends on how far the measured value [B] is from the mean value [A.1]] in terms of Z values.

5.2 Heat Map presentation of results

The Z value or the standard score is the (positive or negative) multiple of standard deviations that a measured data point is above or below the mean of the comparison population (The healthy control group data in this research). If the Z score is positive for a measured data point then this indicates the number of standard deviations that the measured data point is greater than the mean value of the healthy population (healthy control data). Conversely, if the Z score is negative, then this indicates the number of standard deviation that the measured data point is less than the mean value of the healthy population. Therefore, the Z scores inputted into a heat map give a visual presentation of the relative performance between the patient under assessment and the performance of a healthy person for each and every one of the 36 sections of the left visual space.

5.3 ViNAR Evaluation

In order to be able to say something about a person's performance on the ViNAR comparisons need to be made between their performance and the average performance of members of their peer group. In other words if it requires to evaluate or say something about the relative performance of a 40 year old male Stroke patient who has visual neglect, then it is necessary this person's data for completion of trials of the 36 grid ViNAR target areas with ViNAR performance data from a control group comprised of other similarly aged healthy males without Neglect. (E.g. 35-45 year old). The current version of the system has data from 15 healthy controls in the age range of 20 to 43 years integrated back into the ViNAR. After a participant patient is assessed using ViNAR, their Z value results data are calculated. The Z value gives a meaningful indication about how much a piece of data, for example the performance of a patient on reaching a particular grid element over a number of trials, is different from what could be termed the expected or normal performance for a person matching that person's profile performing on the same grid element. To support this evaluation, it is important to assess the patient's cognitive status and test for neglect to make sure that a patient's performance with ViNAR is not due to factors other than the presence or absence of visual neglect.

5.3.1 ViNAR Evaluation with additional control data and patient data

ViNAR will be evaluated with Stroke patients in a hospital setting. These patients would have a clinical diagnosis of neglect obtained by occupational therapists or neuropsychologists using the traditional pen and paper-based neglect tests. ViNAR will be used to assess these patients by internally comparing their test data with the performance of the healthy aged matched healthy group which is integrated into ViNAR. The patient's performance is presented both graphically using bar charts but also visually using the ViNAR's use of the heat map (See Figure 14).

At the time of writing, this research did not have access to patients to assess using ViNAR. In other words, it was not possible to test for true positives. However, it was possible to test for true negative by testing 6 healthy participants with ViNAR (which was preloaded with control data from 15 healthy participants, see section 2).

Participant Number	Letter Cancellation	Bells Cancellation	Line Bisection	ViNAR
p001	N	N	N	N
p002	N	N	N	N
p003	N	N	N	N
p004	N	N	N	N
p005	N	N	N	N
p006	N	N	N	N

Table 1. Performance of 6 controls participants on the traditional test for visual neglect and on ViNAR . N = Normal Peformance

The Healthy participant group used for evaluation consists of 3 males and 3 females ages aged from 23-45 yrs (mean 33.5), all were right handed and all reported normal or corrected to normal vision. The participant evaluation and assessment procedure is described in section 2.

Participants received the standard paper based tests to complete. After these tests were completed, each participant was tested using ViNAR (See Section 2). The results of these tests revealed that all the participants had normal performance (See table-1).The ViNAR result data for each of the 6 participants also indicated normal performance . The ViNAR results and the paper tests results indicated that the 6 healthy participants are neglect free as expected. This amounts to ViNAR being successfully evaluated against *a true negative* test (i.e ViNAR correctly indicated that the healthy participants did not suffer from neglect).

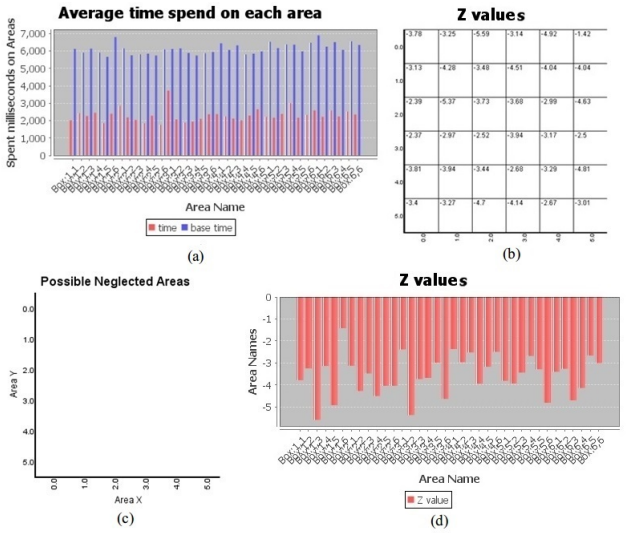

Figure 14. ViNAR results of a healthy participant.(a) a bar chart showing the average time on each area compared to control data. (b) a 2 dimensional representation of the Z values for each of the 32 target location areas (c) a heat map displaying the colour coded Z values. (d) bar chart comparison of the assessed participant's performance for each target location against the control performance in terms of Z values.

6. Future Work

It is scheduled to evaluate ViNAR in two hospital settings in September 2014, these are the William Stokes Stroke Unit, in AMNCH Tallaght Hospital (Tallaght, Dublin) and the National Rehabilitation Hospital (Dunlaoghaire, Dublin). As the ViNAR evolves, it will accumulate integrated databases of control data of different aged bands. The data from a test patient will be compared with the appropriate control data for their age. It will also accumulate databases of information from the testing of patients of brain injury due to Stroke and closed head injury and this will improve the efficacy of ViNAR to map visual neglect. The next iteration will also have a post assessment rehabilitative mode to help a patient become aware of their problem areas in their left visual field and help them to retrain their attention to these problem areas.

7. Conclusion

ViNAR is designed not only be able to act a binary classifier for the presence of absence of neglect but also to determine the spatial area of neglect in the left patient's left hemifield. Once it is established where in the visual field a patient has attention difficulties, ViNAR can then be updated to make the patient aware of this area of neglect and used to retrain attention resources to this area which will help rehabilitate neglect and other stroke deficits that a patient is suffering from.

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Short Papers

An exploration into the use of video games to facilitate locomotor development in children

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ABSTRACT

With the advent of 3D sensor interfaces, gaming controls have moved from sedentary finger tapping activities (mouse, control pad, keyboard) to full body, gross motor control systems (Kinect). A new genre of *Exergames* that motivate players to become physically active and perform a range of gross motor tasks have become increasingly popular. Video games, often cited as a barrier to gross motor development, can now become a useful environment for *deliberate practice* of fundamental motor skills (FMS).

A meta-analysis of literature on gross motor development was conducted. Arising from this, 12 *Conditions of Locomotor Development* (COLD), pivotal for effective attainment of fundamental locomotor skills, were articulated. A series of games, informed by COLD components to target *locomotor* (hop, skip, jump) development in children, were designed. These games were created in response to the absence of many conditions necessary for effective gross motor acquisition in currently available *Exergames*.

A case study with 40 normally developed primary school children was conducted. The cohort was split into two groups: a) a control group exposed to daily participation in Exergames already in the public domain; b) an experimental group exposed to specifically built *Locogames* designed by the authors. Preliminary results indicate that the children who participated in these purpose built games improved their gross motor performance by significant margins whilst children exposed to Exergames already on the market showed little improvement. This study highlights the potential for children to develop and improve their locomotor skills in a video gaming environment; it identifies 12 essential COLD components that must be present in the design of these Locogame*s* in order for effective motor development to occur and highlights the absence of these conditions in a range of popular Exergames already on the market.

Categories and Subject Descriptors

K.3 Computers and Education, (CAI); K.8.0 Games

General Terms

Performance and Design: Designing for specific groups (children).

Keywords

Gross motor development, locomotor development, object control skills, Exergames, Locogames, 3D sensor interface

1. INTRODUCTION

Recent studies outline links between poor gross motor development and poor performances elsewhere including academics [26] language [15], behaviour [3] and health [16]. At a micro level, relationships between subsets of gross motor development and specific cognitive tasks have also been identified. For example, poor **locomotor development** (hop, skip, jump, slide) and poor **reading fluency** are linked by numerous authors [24, 25, 26] whilst poor object control skills (bounce, throw, catch) and difficulties with problem solving tasks/mathematics also suggest causality [24]. For the most part, these links are made on the basis of several common factors, most notably a shared developmental timetable where a particular burst of learning occurs between the ages of 5-10 years [1, 8] and perhaps most crucially, a shared set of brain processes [13, 23] that may be developed in one domain and distributed to the other [4]

Conversely, a significant decrease in the gross motor performance of children has been identified worldwide [18]. This is broadly attributed to an increased sedentary lifestyle, fundamental shift in self generated play patterns and an increased amount of time spent watching television and playing computer games. However, with the advent of new interfaces, computer game playing now provides users with opportunities to move from minimal levels of motor activity, to full body and gross motor simulated interactivity. The emergence of these control systems could see the video game industry switch from environments that typically block motor development to a potential training ground for *deliberate practice* of fundamental gross motor skills.

Section 2.1 of this paper outlines the importance of deliberate practice for the attainment of gross motor skills; with a focus on the gross motor subset of locomotor development, which refers to *hopping*, *skipping*, *jumping and sliding*. A meta-analysis on a large number of studies is then presented to describe a framework of 12 essential *Conditions of Locomotor Development* (COLD). **Section 2.2** examines a number of Exergames already on the market to ascertain whether they incorporate COLD components. An outline of *Locogames*, designed by the authors follows with a presentation of the conditions of locomotor development that informed the gaming design. **The final section** discusses the preliminary results of our case study involving 40 normally developed children aged between 5-6 years. We conclude with the assertion that video gaming platforms for deliberate practice of locomotor skills and development are only a hop, skip and jump away.

2. LITERATURE REVIEW

2.1 Locomotor Development

Modern children live an increasingly sedentary lifestyle with limited opportunities for motor development. Nearly a third of children around the world spend at least three hours a day watching TV or on their computers [12]. Higher levels of locomotor development, linked to more effective self-generated play habits, were attained by children in the past through games such as *hop-scotch, skipping or ring a rosie* (fig.1).

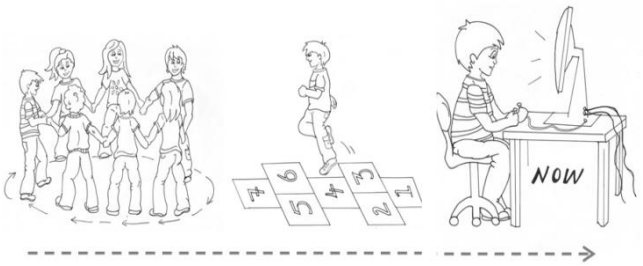


FIGURE 1: GAMES OF THE PAST FACILITATING LOCOMOTOR DEVELOPMENT VERSUS CURRENT PLAY

Children require *deliberate practice* of locomotor skills to attain skill acquisition. Deliberate practice is an activity designed with the primary purpose of attaining and improving a specific skill leading to expertise [11, 19]. This differs to other types of everyday activities (including self generated play) from which learning is an indirect result [7]. We know that learning is *hierarchal* [9] and motor learning is no different. In order to develop motor skills, one must already be in possession of less complex abilities [17]. It is therefore essential for a child's *baseline ability* to be established and used to inform effective instructional activities that meet the child's individual *developmental* and *instructional needs* [10]. Fundamental locomotor skills as outlined by *Testing Gross Motor Developmen-2 (TGMD2)* [22] have many components and are initially best practised in parts and progression with skills broken into smaller tasks that are mastered at the learner's own rate [21]. Once individual parts of a skill have been attained and blended together, deliberate practice of the motor task as a whole is required to form long lasting pathways.

Time is another significant variable in motor development and deliberate practice**.** Daily practice that is high in effort leading to fatigue combined with an opportunity for repeated/sequential attempts and adequate recovery are crucial for effective development [11]. Therefore, deliberate practice begins with low levels and increases slowly over time.

Finally, effective deliberate practice cannot occur without immediate, informative *feedback* that provides information highlighting the effectiveness of the learner's performance [19]. Concentrating solely on the skill and its components is often detrimental to attention, focus and acquisition [27]. Thus moving attention away from an internal focus (i.e., "you need to rotate your hips more") to an external focus (i.e., "move the hula hoop faster") leads to faster, more successful attainment [27]. A meta-analysis of over 100 studies on motor development in children (table 1) highlights 12 *Components of Locomotor Development*: Where these COLD components are present, locomotor development will take place at a rapid rate.

The following section examines whether these conditions of locomotor development are present in a new wave of digital 'exergames' and investigates the potential use of purpose built video games as a platform for locomotor development.

TABLE 1: THE COLD DOZEN

CONDITIONS OF LOCOMOTOR DEVELOPMENT (COLD)
1. Targets the instructional needs of the learner: Via baseline assessment
2. Targets smaller tasks within locomotor skill (specific to learner)
3. Builds to whole skill at learner's own rate
4. Provides opportunities to repeatedly perform the same or similar tasks
5. Results in fatigue
6. Involves high effort during practice activities
7. Is sustained for a limited time each day without leading to exhaustion
8. Is mindful of the balance between effort and recovery
9. Highlight the effectiveness performance (Knowledge of results)
10. Instructional focus on movement effect (external)
11. Provides a platform to observe successful others (modelling).
12. Provides normative feedback/information about others' performance (peers).

2.2 Exergames

Over the last two decades, video game playing has found itself at the fore of young children's self generated play and described as a contributing factor to rising obesity levels and rapidly decreasing gross motor ability in children [20]. New devices such as the *Microsoft Kinect*, *Wii balance board* and *PrimeSense* sensor have moved game playing from a sedentary activity to a full body gross motor workout [2].

There are 12 conditions of locomotor development (COLD) fundamental to the success of motor training programs. However, an assessment of six of the most popular Exergames found a range of these conditions to be absent (table 2). Thus, challenging the hypothesis that Exergames could be used as gross motor training platforms.

TABLE 2: ANALYSIS OF COLD COMPONENTS PRESENT IN EXERGAMES ON THE MARKET

	Conditions of Locomotor Development											
	1	2	3	4	5	6	7	8	9	10	11	12
Kinect Sports	x	x	x	√	-	x	-	x	√	x	x	-
Wii Fit	x	√	x	√	√	x	-	x	√	x	√	-
EA Sports	x	√	x	√	-	-	-	x	√	x	√	-
Just Dance	x	x	x	x	-	x	-	x	√	√	√	-
Your Shape	x	√	x	√	√	√	-	x	x	x	√	-
Yourself Fitness	x	√	x	√	√	-	-	x	-	x	√	-

The main issue being that video game physical exercise programs do not measure baseline gross motor ability; instead, they aim to track and develop the fitness level of the learner. For the most part, Exergames have generic 'one size fits all' content and are generally based on a handicap system of *easy*, *medium*, *hard* determined by the user's level of fitness [5].

However, all games provided some aspects of COLD and within each Exergame series there were some standout activities that showed particular promise. For instance, the *100m Hurdles* from **Kinect Sports** (figure 3).

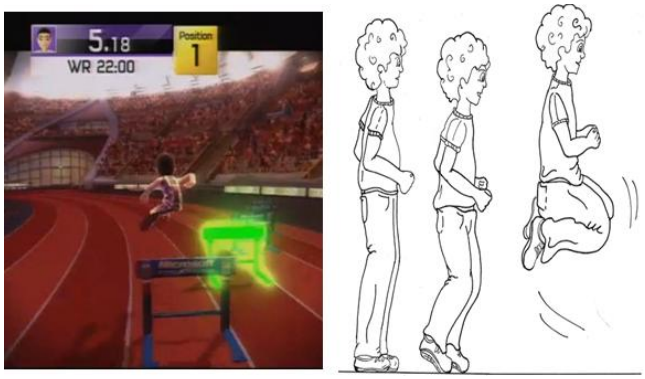


FIGURE 3: HURDLES (KINECT SPORTS) AND THE LOCOMOTOR OUTPUTS REQUIRED TO CONTROL THE GAME

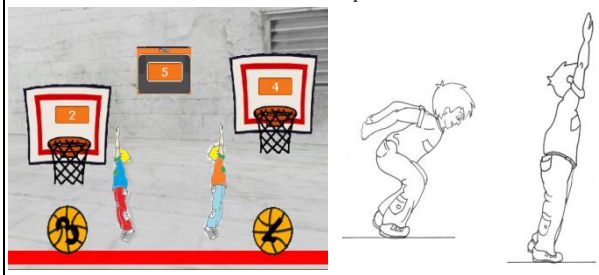
The *Kinect Sports* game, 100m Hurdles, is controlled by combining running and a whole Jump. Five whole jumps are required to complete the level. However, the 'Jump' required is a simplified/cheat version that omits crucial components of the skill and therfore requires less 'step processing'. This game often leads to fatigue and effort but it is a one size fits all that fundamentally aims to improve fitness levels as opposed to gross motor skills. Notwithstanding their limitations, the games examined indicate these platforms are potentially available with *specific* and *informed* design. .

2.3 Gross Motor Development Games

Four *Locogames* were developed to target development of four locomotor skills, hop, skip, jump and slide. The games can be modified (table 3 & 4), to differentiate for individual learners and draw their focus to different parts of a skill, 'on the fly'; often **during** play.

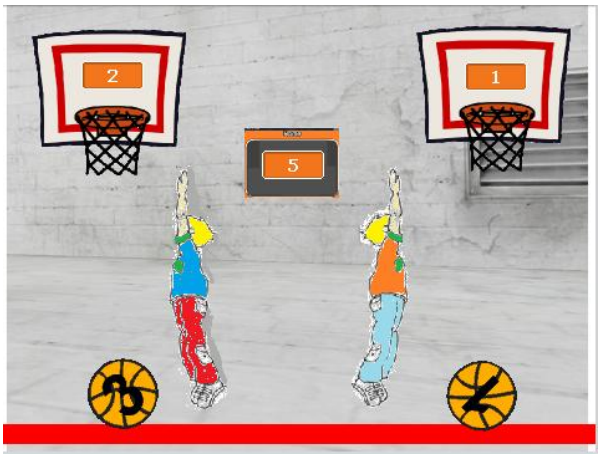
TABLE 3**: JUMP BALL: FOCUS ON 1ST PART OF SKILL**

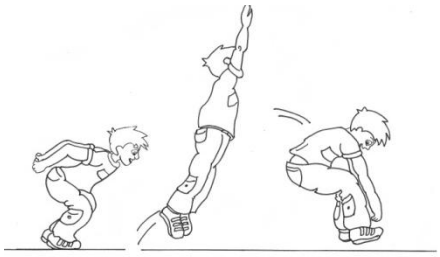
First Part of Jump Skill



- Squat with a deep knee bend to pick up ball
- Low net height means that a point is scored following a simple extension of the legs
- The game is two player providing normative and motor-cognitive feedback
- The child on the right has a higher net to evoke a higher stretch as child is more able.

TABLE 4: JUMP BALL: FOCUS ON WHOLE SKILL AND REPEATED PERFORMANCE





1. High net elicits full jump, as outlined in the TGMD
2. Game length altered, depending on individual need, 1.5 minutes of consecutive jumping leads to significant fatigue for even the most capable child.
3. Normative feedback present via multiplayer mode
4. Musical background provides strong compound rhythm, suitable to instigate and maintain a steady and repeated jump sequence

Locogames were developed using *Scratch* with a Kinect interface that is linked through the implementation of *Kinect2Scratch* [14]. These tools allow for the effective design of games that are controlled by any number of gross motor movements, from part skill to whole skill. Furthermore, any component of gaming design can be altered, even during game play, with ease and speed to better suit the needs of the individual child. The height of a target or barrier can be adjusted to alter the required locomotor output, time settings increased or decreased to maintain appropriate levels of fatigue and effort whilst point systems can be altered to maintain knowledge of results and provide false positive scores between peers.

The case study was split into two groups of senior infant children aged between 5-6 years from a primary school. A control group (20) exposed to daily participation in popular Exergames, namely Wii Fit and Kinect Sports, whilst the experimental group (20) were exposed to specifically designed *Locogames* (to target locomotor skills) designed by the authors. Both groups were pre-tested on locomotor development before the case study using TGMD-2 [22], two more times during the research period and one more time upon completion.

Preliminary results found that the children who participated in our purpose built games improved their gross

motor performance significantly. Whereas those exposed to Kinect games already on the market failed to improve by a significant value. This study highlights the potential for children to develop and improve their gross motor skills in a video gaming environment. It identifies 12 essential COLD components that must be present in the design of these games in order for effective motor development to occur and outlines the importance of attaining baseline assessments throughout the practice period to continuously meet those developmental needs.

3. ACKNOWLEDGMENTS

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Social Skills Training for Autistic Kids - STAK

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ABSTRACT
This paper describes a personalised dual-adaptive learning system developed for carers to help them meet the challenge of teaching social skills to children diagnosed with an autism spectrum disorder (ASD). It explores the social interaction difficulties experienced by individuals with ASD and outlines how the application harnesses the carers' knowledge by creating profiles for both carer and child. It focuses on how technology can facilitate the matching of child profiles with appropriate educational resources and teaching strategies, while at the same time providing carers, when using those recommended strategies with support at levels consistent with their own profiles to suit their individual needs.

Categories and Subject Descriptors
K.3 [**Computers in Education**]

K.3.1 [**Computer Uses in Education**]: *computer-assisted-instruction [CAI]*

General Terms
Design, Human Factors

Keywords
Autism Spectrum Disorder, social skills, personalization, adaptive learning system, teaching strategies, educational resources

1. INTRODUCTION
One in every sixty-eight children is being diagnosed with an autism spectrum disorder (ASD) [11]. The prevalence of this condition in Ireland is also on the increase [12]. Social interaction difficulties lie at the core of this condition [41, 10]. Due to their social-cognitive learning disabilities children with ASDs are unable to develop social skills or interpret the social nuances around them [33]. The need for carers to tackle the issue of social competence is important for the overall development of children with ASDs so that they can participate fully in school and in society.

Since carers are familiar with the distinctive nature of these children's problems and the varying levels of difficulty children experience when interacting with the people around them, they are best placed to help this group [31]. However carers are not aware of what specific skills they need to teach their children to help them develop social competence and unravel the 'hidden curriculum' (the dos and don'ts of daily life) [32]. Moreover most do not know how to employ teaching strategies to achieve vital learning outcomes for their children and it is difficult for them to find trustworthy resources that best suit children's individual social capabilities due to the long-standing problem of unproven educational interventions in the field of autism [23].

A review of sixty social skills training programmes shows that they are used mainly to teach language, pragmatics, and communication skills. This approach, based on teaching specific social skills in isolation from other aspects of social development, does not deal adequately with the social deficit in ASDs [21]. Moreover since each autistic child is unique a 'one size fits all' solution which these programmes tend to provide will not be as effective as an intervention that recognises individual differences [31]. The challenges facing carers working with children with ASDs highlight the necessity for the design and development of a learning system which adapts to the needs of both carers and children all at once.

This paper discusses social interaction difficulties experienced by children who have been diagnosed with ASDs. It outlines the challenges facing carers teaching social skills to their children. It describes how a dual-adaptive learning system can support carers during the learning experience by providing them with resources which match the profiles of both carer and child simultaneously and it presents STAK, our dual-adaptive system.

2. LITERATURE REVIEW
Children with ASDs present with difficulties in two core areas: (a) social communication/interaction and (b) restricted and repetitive behaviours [15]. Although they share these symptoms and a common style of learning and thinking each individual child with ASD is unique because the severity and pattern of his/her autism and intellectual ability are unique [24]. Up to twenty-five per cent of children with autism present with additional learning difficulties while many children at the higher-functioning end of the spectrum have an IQ above average [5]. Evidence also suggests that children with ASDs have a short attention span [18] and display heightened sensory sensitivity [20, 3].

2.1 Learning Style
The way an individual approaches learning and studying is known as his/her learning style or preference. In general children with ASDs have a visual learning style [25, 20] and display good visuo-spatial skills that do not involve language [40]. There are a number of instruments available for assessing people's learning preferences including the VARK system which classifies learners into four groups: visual, aural, read/write and kinaesthetic [17, 16].

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2.2 Language & Comprehension Abilities

Children with ASDs tend to use language in very concrete, literal and inflexible ways [24]. Their development of spontaneous usage and expressive language is tied to talk around their special interests [30] as some of these children become intensely interested in unusual topics almost to the point of obsession [37]. For them visual information can be easier and faster to process than verbal information. However they are unlikely to attach meaning to these words without assistance and they have a difficulty understanding abstract information [24].

2.3 Social Skills Training Programmes

Due to their neurodevelopmental condition children with autism are difficult to teach so it is essential to plan in advance, deliver the content meticulously and devise individualized education programmes [23]. Thus, certain guidelines should be followed when educating children with autism including [28] (a) systematic planning of activities with specific objectives, (b) use of hybrid strategies, (c) strategic adjustment of programme to meet the needs of individual children, (d) active engagement of children in learning opportunities and (e) on-going evaluation of progress. Sansosti [29] argues that a structured approach is more effective: breaking down skills into small chunks of information, modelling the skill steps, asking the child to role play the skill in different scenarios, commenting on the child's performance of the skill, giving the child positive reinforcement via tokens or praise, helping to increase the child's concentration using motivational games and offering the child many opportunities to practise the skill in order to achieve fluency and expertise [29].

2.4 Teaching Strategies

Bellini [6] recommends that carers have a large repertoire of tools and strategies available to choose from when teaching social skills as it is often a combination of strategies from a behavioural, cognitive, cognitive-behavioural and social-learning theory perspective that proves to be most effective rather than one single intervention when teaching autistic children how to be successful socially. Social skills acquisition should be viewed as a continuum with children progressing from the novice stage, when a great deal of cognitive effort and attention is required to complete a task, to the advanced stage, when tasks are completed with little or no cognitive energy and very little attention to task is required [6].

2.5 Adaptive Learning Systems

Personalised learning exploits the potential of information and communication technologies (ICT) in education to improve the quality of the support provided to learners [34]. Adaptive educational systems (AESs) have been successful in providing this support by creating internal representations of users by analysing their behaviour including their knowledge and characteristics [9] and integrating pedagogical strategies in the design of these systems to provide cognitively richer experiences [14]. The resulting profiles are used to adapt the learning environment to cater for the individual needs of learners where evidence suggests that a 'one size fits all' approach is not appropriate [8]. In general AESs cater for single users although a web-based AES combining dual domain models and dual user models and a novel adaptive engine with pedagogical and presentation models has been developed [26].

3. STAK

Social Skills Training for Autistic Kids (STAK) is a personalised dual-adaptive learning system (PALS) designed to support carers[1] teaching social skills to children with ASDs either at home or in school settings by:

- matching teaching strategies to his/her learning stage in each social skill: novice, intermediate, advanced or acquired
- matching educational resources to the child's learning style, language ability, comprehension ability and special interests
- linking the support level consistent with a carer's prior knowledge and experience to the teaching strategies recommended for a given child.

3.1 Social Skills

Ten specific skills are required for successful social interaction. These comprise initiating interactions, conversation, play, reciprocation, problem-solving, reading non-verbal cues, mind reading, self-control, self-awareness and behaviour management [4]. Furthermore a number of intervention strategies can be used to promote skill acquisition or to enhance social performance [39, 7, 4, 6] such as direct instruction, modelling, role play, feedback, positive reinforcement, motivational game and practice. In our intervention, these strategies are applied as part of a logical sequence corresponding to the child's skill level and not in an ad hoc fashion (Figure 1). Therefore it is crucial at the outset to establish the child's prior knowledge and to build on that knowledge.

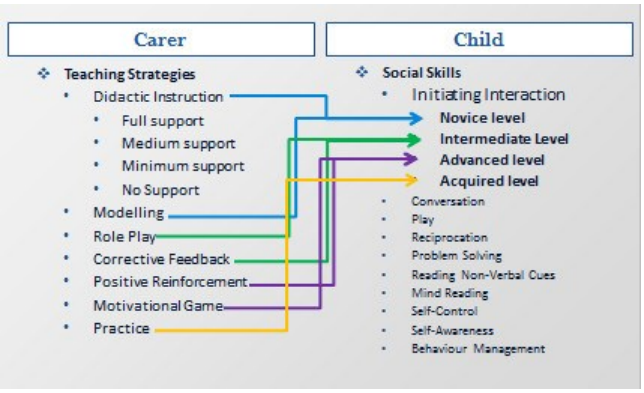

Figure 1. Teaching Strategies link to Learning Stages

3.1.1 Learning Stage

Before teaching a child any skill his/her prior knowledge of the skills and context in which it will be applied is established. Thus, the learning system is designed around the child's prior skill knowledge and competence when using ten specific social skills[2]. The rules regarding the selection of the teaching strategies are built around the child's profile (specifically the skill level/learning stage in each of ten social skills) by creating a 'strategy learner profile'. The system thus provides the carer with the level of support he/she requires using teaching strategies linked to a specific child's learning stage. This support level is

[1] Teachers, parents, key workers or any person with responsibility for a child who has been diagnosed with an ASD

[2] Initiating interactions, conversation, play, reciprocation, problem-solving, reading non-verbal cues, mind reading, self-control, self-awareness and behaviour management

determined by the carer's responses to questions posed during the creation of his/her Carer Profile. Similarly the rules surrounding the recommendation of resources are based on the child's learning style, language ability, comprehension ability and special interests by creating a 'resource learner profile'.

3.2 Implementation of STAK System

The STAK learning system is launched through a Joomla! content management system (CMS) and consists of five main sections:

1. The **Introduction** contains the registration and login programs.
2. In the **Carer Profile** section carers create their own profiles by responding to questions devised to establish their prior knowledge of teaching strategies.
3. In the **Child Profile** section carers build profiles for the children they are teaching; a record of children's learning stages, learning styles, language abilities, comprehension abilities, and special interests is stored in a MySQL database.
4. In the **Activity Centre** carers access support material and educational resources which the system matches to the profiles they have created according to set rules.
5. The system administrator has editing rights and updates data controls in the **Administration** section.

3.2.1 Carer Profile

The system is designed to ascertain the carers' prior knowledge of each of the seven teaching strategies which will be recommended to them to employ during the course of the child's progress from novice to mastery of the ten skills. To assess this knowledge forty-nine questions, validated by experts working with children with ASDs, have been formulated based on the fundamentals of each strategy [4, 6]. By responding to the questions posed carers assist the system in establishing the baseline value from which to measure progress and to determine which level of support (full, medium, minimum or none) is the most appropriate in each case.

A rubric has also been constructed based on the correlation between positive responses and support level required. The support provided by the system can be broken down into several components: recommendations, explanations, examples and review material.

3.2.2 *Child Profile*

The first step in creating a profile for a student is to establish the child's knowledge of the skill. The system confirms the child's learning stage from the responses the carer gives to twelve questions which were based on Bellini's criteria for skill acquisition [6]. The fewer the affirmative responses recorded the less competent using the particular social skill the child is deemed to be. Thus children are categorized by the system as at either the novice, intermediate, advanced or acquired learning stage.

The **Child Profile** is completed by selecting the child's learning style (visual, aural, read/write or kinaesthetic learning style (VARK) [16] from a dropdown menu and by responding to a sequence of questions formulated from four existing inventories used to assess expressive and receptive language development in typical children[3]. Carers may also choose topics that interest the children to help focus their attention on learning content.

3.2.3 *Activity Centre*

When the carer has selected the child identifier and social skill to work on, the child's learning stage in this particular skill is indicated. Accordingly the system will recommend the two most appropriate strategies to use to teach a skill at this learning stage and will provide the carer with support at the level consistent with his/her own personal profile. This support material can be accessed simply by clicking on the icons displayed in the Carer Supports window.

3.2.4 Educational Resources

Educational resources are categorised according to the Sansosti's guidelines on training programmes [29]. Thus STAK helps carers to teach children through a number of interventions in a structured manner:

a. **Discrete Trial** involves breaking skills down into separate (discrete) components and then teaching them over the course of many attempts (trials) [38].

b. **Steps to Success** divides each social skill into a list of concrete and tangible steps which children find simple to visualise and understand [13].

c. **Social Skill Picture Stories** model general social skills through pictures [4].

d. **Cognitive Picture Rehearsal** includes cartoon-like drawings or pictures of the three components: the antecedents to a specific problem situation, the targeted desired behaviour, and a positive reinforcer [22].

e. **Social Stories** describe situations, skills or concepts according to ten defining criteria [21].

f. **Motivational Games** promote interaction and present relevant aspects of real-life situations [19].

g. **Video modelling** allows individuals to imitate skills that have been demonstrated in videos [27].

When the system receives a request for 'Resources' it displays materials that most closely match an individual child's profile while adhering to this structured teaching approach.

3.2.5 *Technical Implementation*

The learning content models are stored in multimedia format and individualised user models are stored dynamically and continually within a MySQL database. The adaptive engine is developed using PHP and relies on a complex rule system. The pedagogical manager is implemented in Javascript and is responsible for analysing feedback from users, updating user models, retrieving information from user models, communicating with the adaptive engine and making decisions about which instructional strategy to use and which educational resource to recommend. Ajax is used to send data to, and retrieve data from, a server asynchronously. The presentation model receives input from the pedagogical manager and manages the presentation of information through the use of cascading style sheets. This model also observes, monitors and handles all feedback from the user in the form of links activated, buttons pressed and text entered. The

[3] ASHA [2], University of Michigan [35], VB-MAPP [36] and ABLLS™-R Protocols [1]

system audits all supports and resources selected by the carer in order to track whatever progress is being made by both carer and child during the learning process.

3.2.6 Pilot Study

A pilot study was conducted recently with a small representative sample of carers and the feedback received was positive. The researchers plan to carry out an action research inquiry over the coming months to answer the research question.

4. SUMMARY

Today one in every sixty-eight children is being diagnosed with an ASD. Regardless of whether they are on the higher end or the lower end of the spectrum these children will have difficulties interacting socially. The aim of this research is to design, develop and implement a web-based PALS to support caregivers teaching social skills to children with ASDs. Although autistic children share common types of symptoms, each individual is different because the severity and pattern of his/her autism and intellectual ability are unique. In order to help them improve their social skills, caregivers should find a way of personalising educational resources to meet their particular needs.

Since ICT has been used to personalise the learning experience in other domains, STAK was designed to bridge the gap in the existing interventions by personalising educational content according to the level of support that caregivers require and the specific needs of the children involved. STAK harnesses the knowledge and experience of carers in individual profiles and matches these profiles to educational content in an innovative way that benefits both carer and child involved in the learning experience.

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Flexible CATs: Classroom Assessment Techniques Using Mobile Touch Devices

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ABSTRACT

Classroom assessment techniques (CATs) are ungraded activities in a classroom setting that provide feedback to the teacher and to the students themselves, on the current state of student learning and understanding, which can subsequently drive corrective actions where necessary. Student response systems (SRSs) provide a technological solution for CATs whereby students can respond anonymously and instructors can provide instant feedback. However, existing systems have tended to suffer from constrained input, limiting the quality of the student responses. In particular, existing SRSs typically only employ well known form based input metaphors such as the multiple-choice selection and text-box input. These input types are not well suited to responses that require significant graphic or symbolic elements such as equations, circuit diagrams, and other drawings. These SRSs also have logistical issues in relation to portability and ownership of the equipment.

In this paper, we present an SRS designed from the ground up to support CATs with freeform input to fulfil the needs of the engineering and science classroom (though the solution is applicable to any learning environment in which freeform input is valuable). To mitigate logistical issues, the solution employs touch based Android tablets and smart phones commonly owned by students and a freely downloadable student app. This paper details the design of teacher and student interaction, including instructor preparation prior to class. We also examine some of the issues surrounding freeform graphic and symbolic input on a range of device form factors and the particular solutions that we found effective. A brief summary of our ongoing evaluation of this system is also outlined within.

Keywords

Classroom Assessment Techniques (CATS), Student Response Systems (SRSs), Technology in the Classroom.

1. INTRODUCTION

As teachers, we are all well aware that the final examination occurs too late to be of any use in addressing the learning needs that our students may have had during the taught module or programme. Classroom Assessment Techniques (CATs) [1] offer a solution in this regards, as these formative and ungraded activities are designed to provide almost immediate feedback to the teacher and, indeed, to the students themselves about what the students are learning and what deficiencies may exist in their knowledge and understanding of the current material. Obtaining this information allows the teacher to take *just-in-time* corrective action to address any such deficiencies and, thus, improve and enhance the student learning experience. To date, the most comprehensive overview of CATs can be found in [1] where fifty different such techniques are presented. Traditional examples include the *one-minute paper* (a frequently employed CAT that requires students to answer two questions, namely what was the most important thing learned and what remains unanswered), the *muddiest point* (students are required to answer what the muddiest point in a lecture or a section of notes, for example, was), the *classroom opinion poll* and the *student-generated test questions*.

The CATs are typically conducted using paper and pen and often carried out in one lecture, with the information processed and reviewed after the lecture and subsequent action carried out in the following lecture. The advent of student response systems (SRSs) [2-4] provided a technological solution for the implementation of a selection of the CATs [5] that significantly simplified the data gathering and reviewing process. In addition, students could truly respond anonymously (as the issue of recognising one's handwriting was no longer a possibility) and in the case of some of the CATs (such as the classroom opinion poll), feedback could be obtained practically instantly.

The wide range of existing SRSs and their educational benefits are well documented in the literature [6-11]. However, existing systems suffer from constrained input which typically involves a multiple choice selection or a text-box input and thus limits the individual feedback that could be obtained. For example, these input types do not cater for graphic or symbolic elements such as mathematical equations, circuit diagrams, flow charts, etc., all of which are particularly important in the science, technology, engineering and mathematics (STEM) disciplines. The SRSs also have logistical issues surrounding the equipment requirements – does the teacher have to carry the equipment to class on a regular basis, does the student have to purchase the transmitter, what happens if a transmitter is lost or misplaced?

In this paper we present the design and implementation of a unique SRS that supports flexible CATs that better fulfil the needs of the STEM disciplines, at both second and third level education. In addition to the typical multiple choice questions, instructors may also issue questions designed for freeform input. Moreover, the teacher can decide between giving students a simple "blank page" or a custom template (itself designed using freeform input) which students subsequently mark up. Indeed, the final solution is of use to any learning environment in which freeform input has value. The solution employs touch based Android tablets and smart phones commonly owned by students and a freely downloadable student app. This helps to alleviate some of the logistical issues associated with conventional SRSs, as mentioned above. The final system has been evaluated by various classes of electronic engineering students and initial results have been largely positive, both from the students and the teachers involved.

The rest of the paper is structured as follows. The next section details the design of the mobile touch device based SRS and

documents the typical use case for the system. Section 3 gives an overview of the implemented system while section 4 briefly presents some initial evaluation feedback obtained. The paper concludes with suggestions for future work in section 5.

2. BASIC DESIGN OF THE MOBILE TOUCH DEVICE BASED SRS

In general terms, the system is designed to operate in a similar fashion to existing SRSs, such as clickers [5, 9]. In other words, it must allow a classroom of students an electronic means of responding to questions in an anonymous fashion and, in turn, it must allow the teacher to gather instant feedback of the student's knowledge of the material covered. However, the fundamental design difference with the proposed system is that, unlike clickers, the students will have the option of a flexible freeform input that, in turn, presents the teacher with instant and highly relevant (particularly in the context of STEM disciplines) feedback of the students' knowledge. The multiple choice selection (as used with clickers) must also be available as a student response option for questions at the teacher's choice.

The design of our system is based on an environment where both the teacher and the students have mobile touch devices and is focused on the following principle use case scenario. A teacher issues a question to a class of students either by sending the question from their device to the students' devices or by simply announcing it verbally or in written form in the classroom. Students will individually, or as part of a team, attempt to solve this question and post a response using their devices. As is common with existing SRS solutions, responses are anonymous so as to encourage student participation. The teacher can immediately view all posted responses on their own device (typically a tablet). The teacher can quickly glance through the responses, determine how well the students, in general, have understood the covered material and respond appropriately.

It was decided that the system would be designed for Android and use a native interface rather than a web-based interface on the teacher and student mobile touch devices. (There were two pragmatic reasons for this decision: Android devices are more prevalent among the student population and our familiarity with Android made us confident about developing a sufficiently functional system in the time available to the project.) Realizing the use case required a separate teacher application and student application. Moreover, we also intended to operate the system in remote classroom environments where the teacher and students would be in different physical spaces using different networks. For this reason communication between the student and teacher applications would be via a cloud based service rather than via a local area network.

The primary interaction of the student with the system is to create responses to teacher questions using freeform input, similar to that available in sketch applications. However, the available sketch options were intentionally restricted so that the application is easy to use and the user interface is easily discoverable while achieving required functionality. More specifically, we want students concentrating on solving the problem posed by the teacher rather than exploring the various extra features that are available in typical sketch applications but that are not necessary here. Furthermore, as we intend using mobile touch devices, the touch screen provided will be the only means of input to the system. Therefore, since students use devices with a variety of form factors, it was important that the requisite precision of free form input could be achieved on all devices.

The teacher app features the same freeform input as the student app. This is used for two distinct purposes. First, teachers may create a question template or framework that can be sent to all connected students. For example, a teacher may draw a diagram which students must annotate, or they may write a partial equation which students must complete. Second, the teacher may use free form input to edit or mark up student responses for the purposes of analytical discussion within the classroom.

To manage and make constructive use of responses from even tens of students, the teacher app needed to support mechanisms for viewing responses en masse to get a quick overview and drilling down to more detailed views to focus on individual responses. Adopting ideas taken from photo-management applications, the teacher can view all the responses in the form of a scrollable grid. When a particular response is selected, for further analysis for example, an expanded view of the selected response is presented but a side panel containing a list of responses is retained to ensure that the teacher can still rapidly navigate to other responses. The grid overview and detailed view are shown in Figure 3 and Figure 4 respectively.

The third, and final, component of the SRS is the back end which facilitates communication of questions and responses between the student and teacher apps. For this system, we use a cloud based service (based on Google App Engine) to implement the back end. This allows us to work with non-Android systems in the future, i.e. student and teacher applications could be written for other devices, such as the iPad and the iPhone, which would seamlessly integrate with the current mobile touch device SRS. As the back end component of the system is largely invisible to users it will not be discussed further.

3. THE MOBILE TOUCH DEVICE SRS

The key operational features of the final implemented SRS are now presented.

When the teacher and the students open their respective applications, they are both presented with a standard log in screen. The teacher uses this screen to create a working session for the class by simply entering a suitable session name. If the session does not already exist, then a new one is generated. The teacher then communicates the name of the session to the students. It is only at this point that the students can actually log in to a given session. This setup is simple and intuitive for teachers to understand and it allows multiple different sessions (e.g. different teachers and classes) to run in parallel if need be.

Once logged in, the teacher can choose to start a new question; the teacher may alternatively delete the session, or log out, leaving the session intact for future logins and use at this point.

When the teacher starts a new question, the app presents a screen similar to that in Figure 1. At this point, two default question templates are available to the teacher. One is a blank canvas, the other a MCQ (multiple choice question) option. The former presents the student with a blank screen suitable for unstructured freeform input, and allows the teacher to ask any ad-hoc or on-the-spot questions that they may think of during the class in addition to any planned CATs. The MCQ option provides the students with a selection of generic options (such as 1 to 10), to choose from. Here, the teacher once again poses a question during the class but, in this instance, must also provide a selection of

possible answers from which the students must choose. This is akin to the solutions offered by existing student response systems, such as clickers. For both freeform questions and MCQs, the teacher would typically present ad-hoc questions verbally or write them on a board. It is also perfectly normal to have questions prepared in advance, integrated into hand out notes for example.

In addition to the default question templates shown in Figure 1, the teacher may create their own template questions in advance of the class. This allows them to have several prepared questions (or more commonly, the outline of questions) ready for immediate use in the classroom. The 'create' option presents the teacher with a blank canvas on which to draw and save a template question. The 'delete all' option simply deletes created templates. Figure 2 shows an updated version of Figure 1 after some template questions have been created.

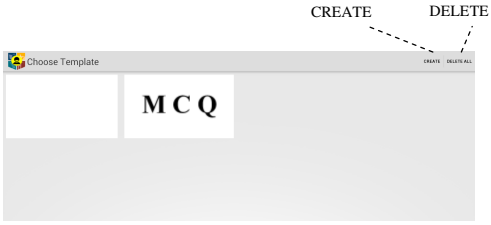

Figure 1. Default question templates.

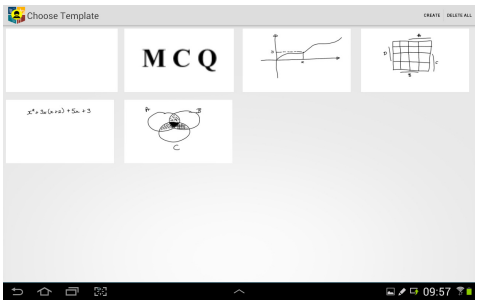

Figure 2. Sample template questions.

To finally start a question, the teacher simply selects the default or custom template they wish to use. This is then communicated to all the connected student devices. Thereafter, the teacher app awaits incoming student responses and the question remains active until the teacher closes the question, at which point the students are no longer able to submit a response.

Figure 3 shows the teacher's overview of a set of responses received for an arbitrary question. The responses are displayed in a grid format that facilitates quick scanning and overview. A quick scroll through the responses readily reveals whether most of the students have responded with the correct solution or not. Selecting any single response opens the detailed view shown in Figure 4. In this view, the teacher can also make edits, if necessary, by marking up the chosen response. The teacher also has the option of sharing an edited response back to all student devices. This allows the teacher to present samples of correct and incorrect solutions to the students. This is of particular use in a distributed classroom environment where some students may not be physically present in the classroom. On completion (or later), the teacher can start a new question and they are returned, once again, to a screen similar to that in Figure 2.

When the student logs in to a session, they are prompted to start a question. If no question has been activated by the teacher, the student will be informed. When a question is active and the student chooses to start the new question, they will be presented with the question template posted by the teacher which they can then proceed to answer. On completion, the student chooses to submit their solution to the teacher. Once submitted, the student will then be presented with three options, as shown in Figure 5.

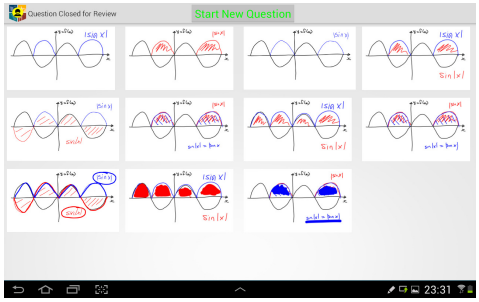

Figure 3. Grid overview of received student responses.

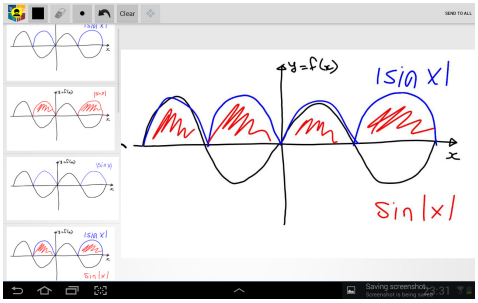

Figure 4. Two-panel view of received student responses.

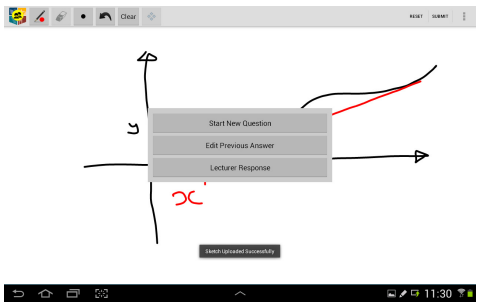

Figure 5. Student app - options after a submitted response.

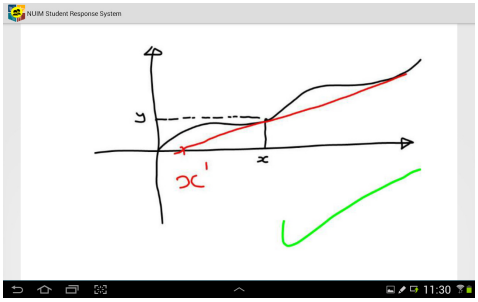

Figure 6. A sample teacher's marked up response.

They can start a new question (if one is already available), they can revisit their previous response to edit and resubmit it or they can choose to download the teacher's marked-up response, if it is

available. An example of such a teacher's response is shown in Figure 6. The student can only view the teacher response and cannot edit it further.

Students and teachers both use the touch screen of their devices to sketch free form input using their fingers (or a stylus if available). Teachers will typically use larger form factor tablets where finger drawing precision is sufficient. Students on the other hand will more commonly use smaller form factor devices such as smart phones and with such devices it is harder to create sufficiently precise input. For this reason, it is possible to zoom in and out during free form editing so that extra precision can be used if necessary. Figure 7 illustrates the zoom feature in operation. In general, if a stylus is available it is preferable to finger input as it facilitates drawing a finer and more detailed sketch.

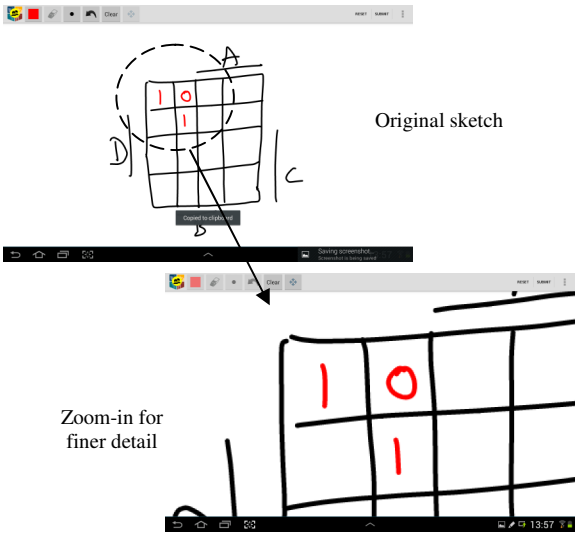

Figure 7. Student app with zoom-in zoom-out feature.

4. BRIEF EVUALTION OF THE SRS

The mobile device SRS has initially being evaluated by electronic engineering students at the National University of Ireland, Maynooth. The evaluation typically involved using the SRS to carry out flexible CAT-style exercises. In other words, students were presented with various questions and required to respond with appropriate sketches in order to determine how well they were following the current material. For example, a second year Digital Systems class, comprising 13 students, was asked to illustrate the process of Karnaugh Map minimization for a specific logic function. In another case, a first year Computing class, also comprising 13 students, was required to illustrate the bitwise AND of two 8-bit numbers. Both set of students were asked to complete a survey form in order to obtain feedback in relation to the use of the SRS system.

The feedback obtained was largely positive from both the students and teachers involved. The students approved of the flexible form of input, noting that they "*liked the freedom of drawing*" their "*own answer*" and felt that it allowed the teacher a better insight to their understanding of the material. Furthermore, they noted that the "*fact that all submission were anonymous*" allowed them to provide responses without the fear of being identified and meant that they were "*less worried about the answer being wrong.*" Most students found the SRS relatively straightforward to use and recommended its use in future classes. The teachers also found the SRS easy to use, felt that it significantly improved the student interaction within the classroom and found the concept of freeform input extremely useful for eliciting relevant methodology information from their students.

5. CONCLUSIONS

This paper has briefly presented a mobile device based student response system that allows students utilize their smart phones in a classroom environment, as an effective means of providing immediate and high quality feedback to the teacher, through the use of freeform response. This is of particular relevance in STEM related subjects that exploit the use of classroom assessment techniques (CATs) for the purposes of formative feedback and improved student learning. Future work involves the development of the SRS on non-Android based devices as well as conducting a thorough evaluation of the existing system across a range of different classroom disciplines.

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A Prototype Interactive Tactile Display with Auditory Feedback

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ABSTRACT

Tactile surfaces can display useful information in a variety of applications for blind, visually-impaired and even sighted users. One example is the use of paper-based tactile maps as navigational aids for interior and exterior spaces; visually-impaired individuals may use these to practice and learn a route prior to journeying. The addition of an interactive auditory display could enhance such tactile interfaces by providing additional information. This paper presents preliminary work on a prototype multi-modal interface which tracks the actions of a user's hands over a tactile surface and responds with sonic feedback. The initial application being considered is an *Auditory Tactile Map* (ATM); the auditory display provides verbalised information as well as environmental sounds useful for navigation. Another proposed implementation adds interactivity to reproductions of museum exhibits, making these more accessible to the visually-impaired and allowing exploration of their tactile affordances while preserving the original works.

Categories and Subject Descriptors

H.4 [**Information Systems Applications**]: Miscellaneous; H.5.M [**Information interfaces and presentation: User Interfaces.**]

Keywords

Tactile Interface, Auditory Interface

1. INTRODUCTION

Tactile displays are those which can transmit information through features that can be determined by touch e.g. a Braille display encodes data through a series of raised dots on an otherwise flat surface. Interactive versions exist, such as electronic devices using mechanically-actuated pins to dynamically generate shapes and textures as 'touchable images' or emerging technologies using ultrasonic interference mechanisms [1]. These are comparatively expensive and technologically complex when compared to tactile displays which use specialised paper; for example *microcapsule* paper uses a special *fuser* oven to create raised textures on printed areas produced with a normal photocopier or printer[1]. Interactivity may now be added to these paper displays by tracking the hands of a user over the tactile surface utilising relatively inexpensive camera-based sensing devices. This can have several advantages for visually-impaired users who rely on such displays by facilitating an additional auditory feedback channel. For example, paper tactile maps have been shown to be useful in helping visually-impaired and blind individuals to navigate [2]. More generally, interactive tactile surfaces can form part of a multi-modal interface for information exploration. We present an early version of such a system here, initially targeted at several applications which would benefit from the addition of an interactive auditory display to a paper tactile surface. The first implementation provides an *Auditory Tactile Map* (ATM) to aid navigation for the visually-impaired. Other proposed examples include the provision of tactile experiences of artwork and museum exhibits, which cannot normally be touched for conservation purposes.

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2. INTERACTIVE MAPS FOR THE VISUALLY-IMPAIRED

Portable electronic devices equipped with *Global Positioning System* (GPS) technology allow visually-impaired travellers to receive direction while in transit via an auditory or a tactile display. In the case of the former however, research has found that synthesised verbal delivery can be distracting [2]. A review highlighted the value of such systems in outdoor environments [3], but later work stressed that alternative methods must be considered for indoor spaces where GPS does not function robustly [4]. An example of this type of system is *Open Street Map for the Blind* (OSMB), an open-source user-maintained map system which is audio-based and delivered via some mobile phones equipped with screen readers[2]. In contrast to systems providing navigational information while travelling, research supports the benefits of pre-learning of routes and formation of *cognitive maps* prior to journeying [2]. *AmauroMap* is one example system, being an on-line map project that lets the user navigate by interactively exploring digital city maps [5]. The authors note the importance of orientation points in way-finding for the visually-impaired, but caution that the

[1]e.g. see the products at www.zychem-ltd.co.uk
[2]wiki.openstreetmap.org/wiki/blindmap [May, 2014]

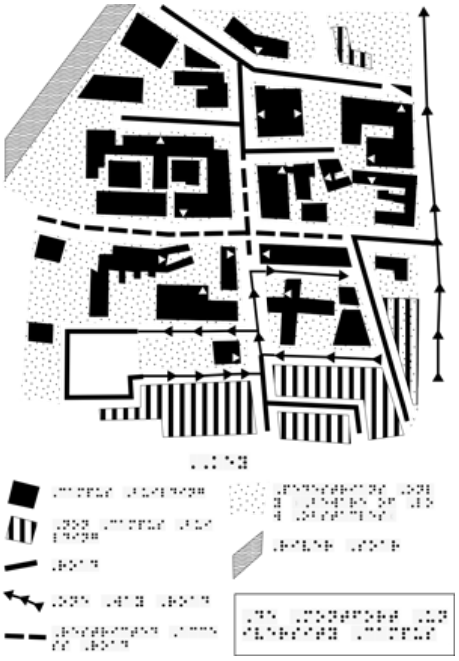

Figure 1: Campus map of DMU used to produce a tactile map. The key at the bottom provides Braille descriptions of the various textures used to signify different features

points of interest chosen are highly individualistic (particularly in the case of acoustic features). Users access textual information that is automatically annotated by the system from spatial description information, which can be presented through a screen reader or a Braille display.

2.1 Advanced Auditory Display

In addition to a purely verbalised information, previous work has studied how auditory display of environmental information can aid the formation of cognitive maps [6]. In one study, participants were asked to recreate an auditory scene in an immersive audio virtual environment, to assess their performance with spatialized audio cues and active exploration of the space versus purely verbal direction. It was found that the former reduced some errors in the placements of virtual sound sources, suggesting that this can aid in the construction of accurate mental maps. As such, the inclusion of non-verbal spatialized audio feedback has the potential to enhance a tactile map and provide relevant guidance information for a space before entering it. Some notable research investigating the provision of more sophisticated auditory feedback include the *Blind Audio Tactile Map System* [7] which uses auditory icons and a keyboard/ pointer interface. A more recent study examined how multi-modal maps may be used to provide audio feedback with a tactile map display [8]. This latter system uses heat-reactive paper maps superimposed on a touchscreen tablet for interactivity. A similar approach is used in the *Talking TMap* project, which aims to develop web-based software tools for rapid production of tactile street maps [9]. The project uses geographical databases (for locations in the USA) and existing technologies; a version is available for the *Talking Tactile Tablet* device, which also uses a touchscreen peripheral as the sensing component[3]. So far, none of the available systems attempt to emulate the types of acoustic cues found in real spaces. It is usual in everyday environments to hear sound sources with some level of reflection. Under certain conditions, multiple acoustic reflections from the same source can often provide information regarding the surrounding environment. These include dimensions and material properties, as well as cues improving sound source localization; the reader is directed to a previous summary of the mechanisms involved [10]. The ability to directionally analyse the early reflection components of a sound is not thought to be common in sighted individuals, but a blind individual can use this to gather knowledge about the spatial configuration of an environment. Observations in experiments highlighted that blind individuals even made use of self-produced noises, such as finger-snapping and footsteps, to determine the position of an object in a space.

3. AIMS AND OBJECTIVES

The long-term aim of this project is the development of a low-cost computerised system with an interactive multimodal interface suitable for multiple applications. The first of these is the provision of an ATM to aid navigation for visually-impaired users through pre-navigation cognitive map formation. This is to be accomplished with the help of sophisticated auditory information embedded in the map. This example is to be extended to more general provision of tactile experiences of artistic works and exhibits. The goal of this first stage is the implementation of a prototype system with basic interactive functionality.

4. ATM PROTOTYPE

A prototype interface system has been developed which provides an auditory display for users interacting with a tactile map. The use of comparatively inexpensive camera technology in place of the types of multi-touch devices and tablets used in other systems keeps the system low-cost. In addition, this technology has the potential for tracking interaction with objects other than low-relief paper tactile maps. The first map used is a portion of the campus of De Montfort University (DMU) Leicester, including buildings, streets and the nearby river. As shown in Figure 1, various textures indicate specific features and a key written in Braille is provided at the bottom.The current software provides two categories of feedback for this map. The first presents the user with information about specific landmarks and can be used to find out about buildings, roads or other key features. The second is designed as a navigation mode presenting the user with an interactive, sequential route to a chosen location. Intermediate auditory way-points are provided which describe nearby landmarks and features, helping to create a cognitive map of the route.

4.1 Hardware Set-up

Figure 2 shows the mounted tactile map portion of the current hardware set-up. A Leap Motion device[4] is used to track the hands on the tactile map (not shown). This device has a pair of cameras and illumination technology contained within a small form factor enclosure, making it

[3]www.touchgraphics.com/research/ttt/ttt.html [May 2014]
[4]www.leapmotion.com [May, 2014]

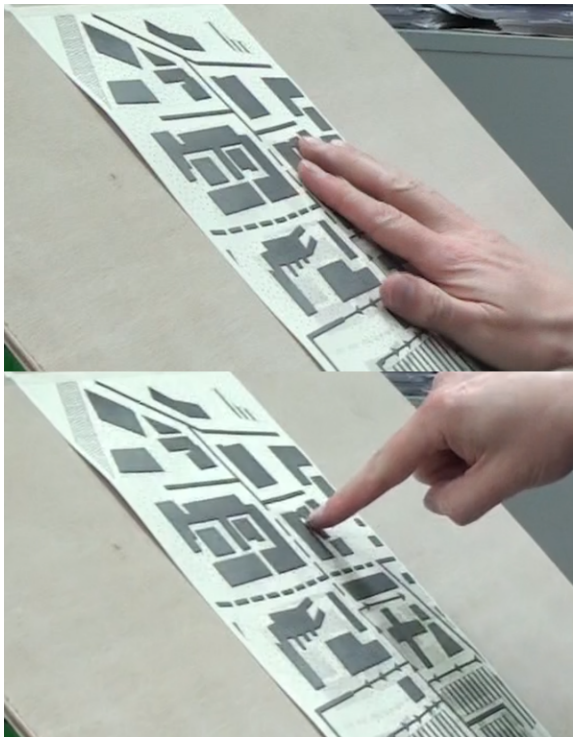

Figure 2: The prototype ATM map used in preliminary tests. In the top photo the user is using a natural hand posture to explore the map, in the botton he is making a distinct selection gesture

unobtrusive and well-suited to the current application. The coordinates and orientations of hands, fingers and tools in view of the device are transmitted to a computer. Due to the robust nature of the tracking, multi-platform Application Programming Interface and the low cost of the device, it was seen as a viable sensor for our experimental prototype.

4.2 Software Architecture

To facilitate rapid-prototyping while maintaining flexibility, the current software was developed in the Java language and consists of a number of modules, as illustrated in Figure 3. A digitised map and data files are loaded and the map is analysed using an image processing module to automatically extract regions of interest of arbitrary shape. In the present example, each of the campus buildings is segmented and labelled. Building labels are combined with associated meta-data such as the building name and audio files for that map location. At run-time, a software ZONE is specified for each building; tracking data is projected onto the map coordinates and a ZONE returns its information when selected. The system has a graphical user interface (GUI) that displays information for sighted individuals and also provides administrator access to system settings and metadata. The current system tracks hands over the map but selection is implemented via a large push-button switch.

4.3 Auditory Feedback

The ATM system delivers spatial audio over headphones (but with mono-compatibility for loudspeaker playback) and uses audio in two ways; text-to-speech synthesis of map

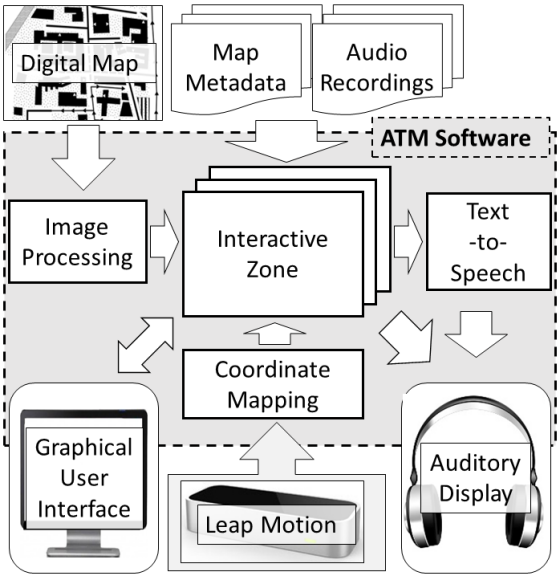

Figure 3: Functional overview of the ATM prototype.

meta-data and sounds of characteristic acoustical features of spaces. Interaction with the map produces audio feedback and the nature of sounds produced is context sensitive. When a user selects a map feature, the information contained in the associated map zone is rendered using a basic text-to-speech engine. For example, when a building is selected on the ATM of DMU, its name is synthetically spoken first, followed by any additional stored information. Audio is also provided as environmental and 'self-produced' sounds. An example of the former is the river to the top left of the map, which triggers sounds of flowing water when selected. In the case of the latter, some interior spaces have recordings of hand-claps, finger-clicks and and footstep sounds embedded at their locations. All sounds were recorded using binaural microphones at the associated locations on campus, as this allows for the reproduction of realistic 3D soundfields using a pair of headphones [11].

5. PRELIMINARY EVALUATION

In order to assess the performance of the physical set-up and functional software implementation, a preliminary evaluation was carried out with a visually-impaired individual.

5.1 Test Set-up

The test system used the set-up shown in Figure 2. The subject was a visually-impaired male staff member of DMU not directly involved in the project. The interactive map was used in a semi-automated 'Wizard of Oz' experiment; hands were tracked by the system but a building was selected by the tester pressing a key on the computer keyboard. This was to test the tracking system only, rather than a combination of tracking and selection gesture. Audio feedback was limited to a basic text-to-speech rendering of building information. The test was video recorded and the subject's qualitative comments were transcribed manually. The prototype system was introduced to the subject, who was encouraged to experiment with it. Without giving any

instruction, he was asked to specify what gesture he would choose to select a building. The suggestion received was the application of additional pressure to the raised map areas; 'to push harder on the buildings'. To test the tracking system, the subject was asked to select a random building from the map and verbally indicate when it was selected. In the first trial, no additional direction was given to the subject, so he used his natural hand posture for exploring a tactile map and indicated a location of interest with a forefinger as shown in the top photo of Figure 2. In this use-case, finger-tracking was not successful; for 10 selected locations, only 1 successfully returned the correct auditory information, indicating that tracking had been lost for the other 9 locations. A second trial was then undertaken, with the subject having received a short instruction to on how to make a more distinctive pointing gesture towards a feature of interest, as shown in the bottom photo of Figure 2. The system correctly returned information on 7 out of 10 randomly chosen locations for this set of actions, with performance increasing after initial efforts. While this is still not an entirely satisfactory detection rate, it does show that a suitable gesture is quickly learned and easily replicated. The subject suggested that a better text-to-speech library be used to improve clarity. He was also asked if additional acoustic information including environmental sounds and characteristic architectural sounds would be beneficial to navigation using the map. He had not used an interactive map with this type of audio but responded that this would be of benefit, particularly to totally blind users who relied more on the acoustic qualities of spaces.

6. FUTURE WORK

The current system is initially seen as a test-bed to establish how an auditory display can help visually-impaired individuals form cognitive spatial maps to aid navigation, and testing with a significant number of subjects is being undertaken in that regard. More sophisticated treatment of audio content is being implemented, including dynamic, real-time acoustical rendering of sounds reproduced by the user during map exploration and integration of head-tracking facilities for a more realistic binaural rendering. However, we see good potential of the approach for the creation of multi-modal interfaces for users of all levels of visual ability. For example, DMU has an ongoing project to digitally reconstruct medieval campus buildings to show how they would have existed historically. The acoustic and tactile affordances such buildings offer are being incorporated into our system to bring them to a wider audience. Museum exhibits and artworks can be made interactive using our approach, providing a richer experience for the gallery patron.

7. CONCLUSION

Tactile surfaces may be produced using inexpensive heat-reactive paper, providing touchable information display for a variety of applications. The addition of off-the-shelf, camera-based sensing devices can add interactivity through a suitable software system. We presented our development work on such a system; a prototype Auditory Tactile Map that provides specialised audio feedback based on user interaction with the tactile element. The auditory display is used to provide the user with both verbalised information and environmental sounds for map locations. Previous research has shown that these can be beneficial for the formation cognitive spatial maps in visually-impaired individuals and can aid in navigation. We have carried out some basic initial testing and are now iteratively improving the system for a number of target applications.

8. ACKNOWLEDGMENTS

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Designing a mobile ambient awareness display application to support the elderly and their caregivers.

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ABSTRACT
This paper presents a case study of the process of designing an interactive system to support the elderly and their caregivers. The case study shares general insights on designing tools for caregiver/elderly interactions specifically in the area of alleviating the emotional stress of dealing with repetitive questioning. Many elderly people acquire memory impairments and are unable to live independently because they cannot remember what they need to do. This case study outlines the design, prototyping and evaluation of an ambient awareness display application, with the working title "*The Help*". This responsive web application aims to coordinate the elderly and their caregivers. This application provides the elderly user with a list of daily activities on a large, easy to read touchscreen and holds details of the elderly user's medical records. The application was designed and implemented in a participatory manner. Early usability evaluation results suggest the application is user friendly for users of all capabilities. Qualitative evidence suggests that concerns around the adoption and use of the application by elderly users could be addressed by family members.Deeper discussion of the themes that emerged in the Focus group has the potential to offer design guidance in considering ambient display technology for elderly users.

Categories and Subject Descriptors
K.4.2 [**Computers and Society**]: Social Issues – *Assistive technologies for persons with disabilities*.

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *Evaluation/methodology*, *user-centered design*.

General Terms
Design, Experimentation, Human Factors.

Keywords
Memory aids, elderly, caregivers, user interface design, touchscreen.

1. INTRODUCTION
The Central Statistics Office in Ireland (CSO) predicts that the number of people aged 65 and over in Ireland, will rise to almost 1.4 million by 2046 [5]. As the population ages, more people will need care due to various impairments. Memory impairment can have a profound and disabling effect on individuals [13]. A large proportion of memory-impaired individuals are unable to live independently. Prior research indicates that family members carry much of the responsibility for caregiving. They also initiate the adoption, use, and maintenance of assistive technologies [6].

This paper presents the design and evaluation of an ambient awareness display application called *The Help* (see Figure 2). The concept for this application was inspired from real-life experience caring for an elderly relative with memory impairment. This person experienced anxiety being left on their own and coordinating their daily activities involving other people.

The initial concept for *The Help* evolved from an idea to use a small A4 whiteboard (see Figure 1), similar in size to a 10 inch tablet. The day and date was written on the whiteboard as well as a list of activities scheduled for the day. These activities included where the caregiver was gone, the time they would return, if someone was calling to visit, someone's birthday or simply the time and channel of a favourite TV program. The aim of the whiteboard was to offer the elderly user reassurance by reminding them of different events throughout the day and reduce the number of repeat questions. The elderly user quickly adapted to using the whiteboard and referred to it regularly. After a short period of time, it was noticed that questions were not asked as frequently and the whiteboard was providing reassurance.

Based on this initial concept, *The Help* application was then designed in collaboration with this elderly user, their family members and a participatory design team. The issue of accessing important medical details in the event of the primary caregiver being unavailable was considered and built into the application, together with communications functionality. The portability of the application enables the user to use it everywhere, either in their own home or any unfamiliar surroundings such as a hospital or a respite care facility. *The Help* was evaluated in a real-world deployment with one family over 2 months. Usability testing was conducted with a number of caregivers and a focus group conducted with elderly users to garner feedback.

2. RELATED WORK
2.1 Memory Aids
Research has been carried out on developing and designing memory aids for the elderly suffering from various forms of memory impairment. Some aids help the sufferer by improving memory function using cognitive rehabilitative intervention [3]. Compensatory memory devices use cognitive stimulation by adding content to the device which is relevant to the elderly person such as photos and videos taken throughout their lives. This is known as reminiscence therapy that facilitates access to old memories prompted by visual aids. Rempad is a new software for reminiscence therapy for Alzheimer's and other dementia sufferers [11].

SenseCam is a small device worn around the neck, which has a digital camera and an accelerometer, to measure movement. It takes, records and replays hundreds of photos of the daily activities of the wearer. It is believed that reviewing these daily

activities will help the user remember what they did during the day, where they left things, who they met and would be a very powerful retrospective memory aid [10].

Repetitive questioning can be one of the most stressful behaviors a caregiver has to cope with and one recommended method of dealing with this behavior is to write down answers to the most frequently asked questions or use signs, clocks and calendars. The reason for this behavior can be memory loss, not remembering the question was previously asked and feeling anxious, confused or insecure [8].

The aim of *The Help* application is to provide both a prospective and retrospective ambient awareness application, detailing what is scheduled to happen during a particular day, as well as serving as a reminder of what has already happened. The research question being explored in this case study is whether this ambient awareness application will be of benefit to caregivers and family members of the user by reducing stress through the number of repeat questions and thus helping the user to recall events from their short term memory. The aim is to alleviate confusion and frustration at not being able to remember even the simplest of events that happened during the day. This case study process aims to ensure that the application is not only useful and usable but that it is also desirable.

2.2 Mobile Technologies

Research was carried out on the direct impact of touchscreen technology providing a user friendly tool for reminiscence therapy and restorative memory intervention for people with dementia [12]. The objective of the research was to assess its effectiveness on the daily lives of not only the people with dementia, but also on those who care for them on a daily basis. A key factor associated with the use of touchscreen technology was that it increased interpersonal interactions between the sufferer, caregivers and family members.

The evaluation of a collaborative memory aid called Family-Link demonstrated how it could support family members by using shared calendars to schedule events and daily activities together and how it helped coordinate the care for the elderly and gave better support to the caregiver [14].

Another survey of issues and technologies [7] looks as "smart home technologies" and "assistive robotics" which all provide personal care and assistance for the elderly. It also highlights how technology can be used to alleviate some of the stress and emotional burden of the caregivers. The report concludes that the greatest challenge for developing technologies in this area is to provide an interface for users of wide varying capabilities and constraints.

The aim of *The Help* application is to provide a mobile ambient display touch screen interface to coordinate events for users of wide varying capabilities and constraints.

2.3 Designing for the elderly user

Prospective memory research concluded that the design of a memory aid for an elderly user should be based on the needs of the older person, tied into their daily routine and should include features more beneficial to an older target audience, bearing in mind how they use technology [4].

The ELDer Project outlines how it addressed the challenges in usability research when designing interfaces and technologies to be used by the elderly who may have a range of needs and capabilities and the importance of meeting these needs. It illustrates the importance of taking into consideration user perception when designing assistive technologies and the social and emotional aspects of the elderly user's experience. [9]. Understanding the specific needs of the elderly is crucial to designing successful assistive technologies.

3. DESIGN

3.1 Participatory Design

The challenge, as outlined in this paper, was to design and to develop a working prototype that would serve as an ambient awareness display application to co-ordinate the elderly person and caregiver. The aim was that this application could be used easily by an elderly user and updated and managed by caregivers, independent of their technical ability

We assembled a participatory design team [12] consisting of four elderly users, one user interface designer, one graphic designer, one neuropsychologist and the two authors. Several family members also participated in two design sessions. Our design team met for weekly and completed 12 design sessions. These sessions covered concept design, requirements analysis, high-level and low-level design, and low-fidelity prototyping. Feedback at each stage was incorporated into the system design.

3.2 The Help

Although *The Help* was designed for the elderly user who lives at home with either family or caregiver, with no prior exposure to mobile technologies, it is being developed to be used by the next generation of elderly who will, given present adoption rates, be more at ease with mobile technology [9]. Based on researched design factors [2], this application was developed with a simple, clearly laid out design with easy to read screens that use good size fonts and colors that promote a sense of calm – all catering for a target audience of elderly users. It does not contain elements that might distract or confuse the user.

The whiteboard concept (Figure 1) simply displayed the day, date and a limited number of activities that would happen during the day. It was positioned within easy reach of the elderly user so they could see it and easily read it. The main issue with the whiteboard was it had to be regularly updated throughout the day.

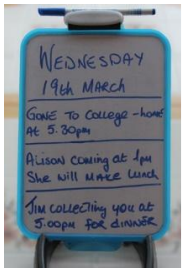

Figure1. Whiteboard

The main Activities page of *The Help* provides the elderly user with the current time, day and date and a list of the activities that are scheduled to happen throughout the day. Activities can be added, edited or deleted either on the elderly user's device or remotely from a PC/Laptop, smartphone or tablet.

In the working prototype (Figure 2), the list of Activities takes up the full screen and is ideal for a "read only" user who would not interact with the application. This page also has a messaging feature, which allows the carer or family members to send messages to the elderly user. The menu is contained within a button on top of the list of activities and provides navigation to the other pages in the application.

These pages include a Chat feature, where the user could text chat with other family members or carers, who are logging into the application at the same time. The medical records page contains a list of any allergies the user may have, a list of the medications they take, the name, dosage and frequency. There is also a page containing the user's personal details.

An iPad has been used for this prototype as it displays the Activities page (Figure 2) clearly. It also has a "never" sleep function allowing the screen to display constantly.

The Help was implemented using responsive web technologies to run on PC, mobile or tablet (HTML, JavaScript, Bootstrap framework) and works on any device that supports network data connectivity.

Figure 2. Activities Page

The server component was written using the Slim Micro PHP framework and MySQL.

4. USER TESTING

The evaluation of the prototype was carried out in a local community center with 12 caregivers and 10 elderly users. The elderly were aged between 74 and 86 years, with no evident neurodegenerative conditions. There were two sessions in the evaluation process.

In the first session, the 12 caregivers were asked to browse through the application freely and then they were asked to perform 8 tasks in a usability test. For the second session, the 10 elderly participants in a Focus Group were asked to discuss *The Help* application. All the participants were shown how to navigate through the application, but none were willing to try and add a new item or delete or edit an existing item. Of the 10 elderly users, 2 were also caregivers.7 out of the 10 elderly users had mobile phones, none had smartphones and one had an iPad.

4.1 Participants in usability test

For the usability testing, a total of 12 caregivers tested *The Help*. All were smartphone users and were broken down into two categories. *Novice* are those testers who had been using a smartphone for up to one year. The category of *Experienced* describes those using a smartphone for over a year.

4.2 Materials

Each tester was given a brief demonstration of the application and a demo of all the pages. They were then given a pre-test questionnaire, a set of tasks to complete and a post-test questionnaire. Three quantitative goals were established by the researcher prior to the testing process for each category of user - Performance, Ease of Use and User Satisfaction.

4.3 Procedure

A target time for completion of the 8 tasks was set to reflect the times it should take to complete each task for the levels of experience of each group of users. *Novice* testers were given 16 minutes – allowing 2 minutes to complete each task and *Experienced* testers were give a target 8 minutes – allowing 1 minute to complete each task.

4.4 Results

4.4.1 Performance

The average time taken by *Experienced* testers was 7.25 minutes and 12 minutes by *Novice* testers. Completion times were faster than the target set for each category indicating that the application was straightforward and tasks could be completed relatively quickly by each user type.

4.4.2 Ease of use

Testers were asked to score ease of use on a scale of 1-10 [where 1 is very difficult and 10 very easy]. Based on the level of experience of each group, targets were set for *Novice* at 6 out of 10 and for *Experienced* at 8 out of 10. The *Experienced* testers rated the application at an average of 8.5 and *Novice* at an average of 6.5. Again ease of use scores were better than the targets set indicating both category of users found the application easy to manage and update.

4.4.3 User satisfaction

Testers were asked to score user satisfaction on a scale of 1-10 and the target for this category was the same for both groups and was set at 8 out of 10. The level of experience should not impact on the level of user satisfaction. *Experienced* testers gave an average of 8.67 and *Novice* gave an average 8. The results indicate that overall the users were satisfied with the application – its features, functionality and usability.

4.4.4 Focus Group

Thematic analysis was carried out on the qualitative data collected during the focus group to help identify, analyse and report patterns within data [1]. Although this group was small with only 10 participants actively taking part in the discussions, five themes were identified and they are listed in Table 1 with some comments from participants:

Table 1. Thematic Analysis

Theme	Comments
1. Technical Competence *Difficulties obtaining the application and setting it up. Requirement for training to use it.*	How could they buy application? Would they be able to set it up? Who would show them how to use it? Would training be provided? Is there a manual?
2. Communications *A tool for communicating with family members, caregivers and the elderly user.*	Notes and Chat features would be good for keeping in touch with family members living abroad, especially if the elderly user had to go into hospital
3. Centralization of Data *A repository for medical records and emergency contacts*	Very useful to have all medical records and daily routines in one place should anything happen carer.
4. Costs *The physical device, the application, running the application – Wi-Fi and keeping it charged.*	Worry about cost of buying iPad /smartphone. What was cost of Wi-Fi? Was it safe to keep device charging overnight? How much would the "application" cost?
5. Concept and Design *Usefulness. Ease of reading main pages. Navigation*	Liked the concept. Liked the Activity items being boxed off so could clearly see what was happening and the time. Would use it in their own homes.

The Technical Competency theme presented as the main area of concern for all the participants in the focus group .Concern was expressed over how they would get the application, set it up and learn how to use it. Emerging from the Costs theme, several participants wanted to know how much the application would cost and only one man (mid-70s) was concerned at the cost of buying

an iPad. He was also concerned about keeping the device on charge overnight due to risk of fire.

One key beneficial factor emerged from the Centralization of Data theme for two women (one 74 years and the other 83 years) who looked after their husbands suffering with Alzheimer's. They could use the application to keep details of their husbands' daily routines, as well as medical records. This would be crucial should anything happen to either of them. From the Communications theme, one of the women (74 years) whose husband has Alzheimer's thought that it would be very useful to post notes about her husband to keep her children up to date as they all live abroad. The caregivers in the group stated that it would be very useful to be able to update the application remotely in real-time. They also perceived that the application would be of great benefit to the elderly user if they were in hospital, relieving some of the anxiety of being in unfamiliar surroundings.

5. DISCUSSION

5.1 Usability for caregivers

The tests were designed to assess the different user capabilities and the results of these tests conclude that the application has been designed with an easy to use interface that will suit users of all capabilities. All tests were performed within the targets set as a guideline to measure usability. Two elderly users (mid-70s and late-70s) were also included in these usability tests and although no actual targets were set for them due to age, experience and apprehension about using the application, their test results were captured and are marginally outside the targets set for the Novice user.

5.2 Elderly users

The data collected from this Focus Group concluded that all the participants liked the application and would be happy to use it and would find it beneficial. Although there were several areas of concern raised under the Technical Competence theme, given the ages of the participants, the majority could use this application as a "read only" device with minimal interaction. As the results from the usability testing conclude that *The Help* is an easy application to use, training issues could be addressed by family members.

5.3 Field study evaluation

The Help was evaluated in a real-world deployment with one family over 2 months. The research question was explored in this case study context. Feedback by the family in the case study was positive. The ambient awareness application was of benefit to caregivers and family members of the user by reducing stress in the number of repeat questions. It was learned that *The Help* increased awareness of other family members' schedules. For caregivers, this meant a greater sense of security, increased time savings and less stress.

6. CONCLUSION & FUTURE WORK

The field study and usability testing of the application was comprised of a convenience sample and so the results may not be representative of all elderly users and their caregivers. Testing on a larger more representative population using the application over a longer period needs to be conducted. Future work will include elderly adults with memory impairments as well as participants with normal cognitive functioning. In future investigations, error rates will be monitored for both user groups to improve time to task completion. The usability test results and the Focus Group thematic analysis provided feedback for the future development of the application which is designed for two specific audiences – the caregiver and the elderly user. The concerns raised in the thematic analysis will certainly be explored more thoroughly with regard to the actual device used for the application in the next phase of testing.

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Exploring Historical Cemeteries as a Site for Technological Augmentation

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ABSTRACT
Tangible and embodied technologies can enrich cultural heritage sites. Their design requires a solid understanding of the specific site, the needs and interests of user communities and stakeholders. Many types of heritage sites have been studied by HCI researchers, however our work focuses on a little-known one: historical cemeteries. Here we describe some early investigations of how the physical and socio-cultural contexts influence potential design solutions for two historic cemeteries, despite of a seemingly similar setting.

Categories and Subject Descriptors
H.5.m. Information Interfaces and presentation (e.g., HCI): Miscellaneous

General Terms
Design.

Keywords
Design, tangible, situated, cultural interfaces, cultural heritage.

1. INTRODUCTION
As part of a larger project, we investigate tangible and embodied technologies to enrich cultural heritage sites, using a co-design approach in order to understand and engage the user communities. Within the project, a number of different cultural heritage sites is being explored. Together with settings that are well-known to HCI, such as museums, historic buildings and outdoor sites [4; 6; 7; 8; 10], our work is also focusing on lesser-studied domains. In this paper we present our research taking place at two historical cemeteries situated in different countries. In order to understand how the concrete socio-cultural context and the unique features of the physical context influence potential design solutions despite of a seemingly similar setting, we decided to follow-up a study of the Sheffield General Cemetery (UK) which resulted in a set of design prototypes [1] with a second study of another historical cemetery, Weimar Historical Cemetery in Germany. The two sites are both historical cemeteries, but nevertheless differ in some characteristics, which, as we anticipated, might provide us with insights on which of the design prototypes might be transferable, or require adaption.

The comparison thus informs our work on two levels: firstly, in attaining a finer sense of how sites of seemingly similar denomination might differ, and what kinds of constraints or opportunities this entails; secondly, in identifying factors that determine how design prototypes would need to be adaptable in order to be useable across such contexts. The latter will become relevant at a later point during the overall research project, when we aim to develop templates for curators who want to develop their own tangible installations [12]. Here we present some initial findings from our parallel cemetery studies

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2. ENGAGING WITH TWO HISTORIC CEMETERIES
In the meSch Project [12] we explore the challenges of visitor access, interpretation and appreciation at heritage sites. We not only focus on museums, but include non-standard sites in this investigation, in particular open-air sites. Historical Cemeteries are an interesting example. They may contain celebrity graves, or the architectural site in itself is a part of heritage. Furthermore, such sites may play a role for local history, or may be of nationwide or global relevance. But unlike museums, they tend not to be curated. Cemeteries as open-air heritage sites have so far been the focus of relatively few examples of previous work in HCI and related disciplines [2, 11]. We saw the opportunity to complement the Sheffield General Cemetery study with a smaller study of another historical cemetery, Weimar Historical Cemetery, serving as contrast foil. We aimed to mirror some of the core activities and methodology of the team working in Sheffield.

2.1 The Sheffield General Cemetery
The Sheffield General Cemetery (http://www.gencem.org/) is a historic parkland cemetery opened in 1836 and closed for burials in 1978. It is now a free and open-access historical, architectural and natural conservation area. It is managed and maintained by a community group/trust, who also organize thematic tours of the

site (on architecture and landscape, local and social history, or bird watching and fungi). The cemetery was landscaped to be the burial place for people from all parts of society, from prominent upper-class families to people from workhouses, and has monuments, chapels, and catacombs (Fig. 1). It has also become a wildlife and nature reserve. Some of the newer graves have been cleared of headstones, and people now use part of the site as a peaceful park, for exercising, going for walks or relaxing. It is also utilized as a shortcut between neighbourhoods.

The meSch project team conducted several observational visits to the site, took part in guided tours, and interviewed eight volunteers from the trust that cares for the site, asking them to show their favourite places and other points of interest on-site. The team collaborated with the volunteers to document and understand the site as well as their practices, and to explore design ideas and discuss rapid prototypes developed by the research team that would fit with the site's materiality [3].

Figure 1. Gravestones and memorials at Sheffield General Cemetery

2.2 The Weimar Historical Cemetery

The Weimar Historical Cemetery was opened in 1818. It consists of several sections, one of which is part of UNESCO world heritage, and hosts the graves of several famous writers and composers, as well as of persons of local relevance. It is visited by a lot of tourists to the city, usually wanting to see the grave of a famous author in the world heritage section. Unlike Sheffield, it is still in 'active use' as a burial site (bar the world heritage section). Many sections have a mix of patches of new and older graves (some quite elaborate or architectonically relevant, see figure 2). Starting from the city centre, one first enters its oldest part, reaches the main cemetery (with a mix of old and new graves) and finally comes to the contemporary section. A wall encloses the site, and all gates are shut at night. As the cemetery is in use, 'graveyard peace' is to be kept, and signs prohibit bicycling and dogs (albeit this is not fully obeyed). The cemetery is managed by the city, but funding for its upkeep is limited, considering the size of the site. We anticipated that Weimar being an 'active' cemetery as well as historic heritage would have subtle consequences for what design ideas might be viable. A larger part of our study thus consisted of extended observational tours as well as brief informal interviews with randomly selected people passing through the front gates of the cemetery. The latter aimed at understanding who uses the cemetery in which ways, and to probe into potential tensions between these uses.

A charity has begun to care for some of the historically and architecturally interesting graves outside of the world heritage section that are beginning to crumble and decay because nobody pays for their upkeep. They meet several times a year to clear such graves, and sometimes collaborate with official city workers to restore structures (e.g. re-erect a boundary). Their largest project is an attempt to find sponsors to pay for the upkeep of 'un-owned' graves and thereby earn the right to the grave. The volunteers also organise some guided tours for the annual 'day of the cemetery'.

Figure 2. Weimar Historical Cemetery, example of older grave

To get a better sense of the charity work and their inside knowledge and views, we took part in a charity meeting, and helped out at a work session, removing heaps of ivy. We also attended tours of different parts of the cemetery at the 'day of the cemetery'. This quickly revealed, that, differently from the Sheffield charity, the Weimar charity group has a more narrow focus, and many of its members seem to have a professional relationship to the topic (e.g. one is a renovator, another an art historian, one an undertaker). A few of the people who sometimes help out seem to do so in order to overcome their apprehension of graveyards.

From our observations, we could easily determine which parts of the cemetery were frequently visited to attend graves (presence of water bottles, fresh flowers, gardening tools). As the cemetery is in the middle of the city, its lower section is popular as a 'scenic route', although it is not a shortcut. From the 18 short interviews we conducted, we found a fairly equal distribution among what seem the main user groups: tourists, relatives/friends tending graves, and residents using it as a passageway. We also encountered a few residents using it for a walk or showing it to visitors, as well as ex-locals showing friends around, who emphasize that they consider the entire cemetery worth of a leisurely walk. Interviews further revealed overlaps between the shortcut/walk and grave-tender category. While we do not know how far into the main cemetery sections tourists and strollers go, these do not seem to enter the newest areas, which are furthest out.

Residents seem to tolerate the tourists, but there is a subtle tension exemplified by a lady telling how she responds to tourists asking 'where are the important graves' that 'everyone here is important'. One of the interviewees had a strong opinion: he wanted everything to remain as it is, and seemed to prefer the site to just be a cemetery, having no interest in its heritage aspects, and expressing displeasure about its use as a shortcut or for walks. While the majority thus seemed to have a neutral relationship to tourists on the site, these reactions indicate that any design intervention needs to take account of such sensitivities.

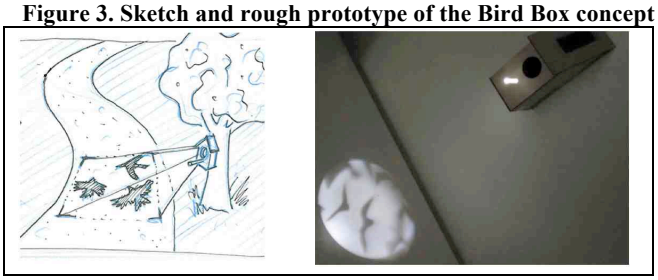
An issue that turned up a lot in discussions with the volunteers and with locals interviewed on-site was theft, with vases, flowers,

decorations and, in particular, metal lettering being stolen from graves. This was not quite as large an issue in Sheffield as the graves are not tended to anymore, however pieces of sculptures and decorations are sometimes stolen there as well.

3. TRANSFERRING DESIGN IDEAS

The Sheffield team developed several design ideas (for an extended description see [1]) and turned these into prototypes. The first is the "Bird Box" (figure 3), meant to grab the visitors' attention without demanding direct interaction: it simply hints that there is more to be discovered and encourages people to move in a particular direction around the Cemetery. The Bird Box is a standalone, solar powered box that projects an animation of birds in flight to attract the visitor's attention towards certain paths.

Figure 3. Sketch and rough prototype of the Bird Box concept

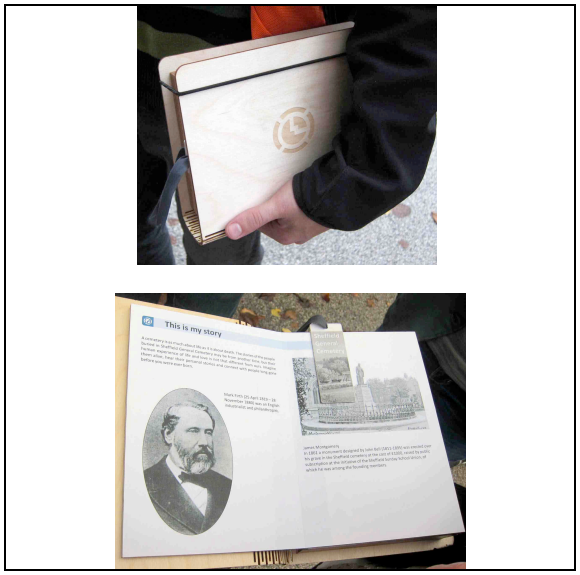


It would probably often be too bright for projections in a much less overgrown site such as Weimar, also as the cemetery closes overnight. Also, the metaphor of the Bird Box, to follow the flight of birds, might be specific to the Sheffield cemetery as a nature reserve. On the other hand, Weimar Historical Cemetery is not being associated with wildlife, and the Bird Box image thus does not resonate with people's expectations. While the Sheffield volunteers loved the concept, the Weimar charity volunteers, on the explanation of the Bird Box, did not see any sense for it in their cemetery.

The second idea addresses visitors who want to engage more deeply, exploring more information during a prolonged visit. This device has been further developed and tested. The Companion Novel (figure 4) is a book-like device that is carried during a visit. A different narrative theme is selected by placing a magnetic bookmark on a page of the book. This is complemented by Bluetooth speakers located at points of interest, which play the according auditory information for that theme when the visitors come close. The distributed and localized audio adds a new sensory layer to the site, allows visitors to focus on the site, and avoids the problem of social isolation commonly found with audio guides [4]. The form factor of a book is meant to support intuitive handling and to fit in with the environment in an unobtrusive way. The themes accessible by placing the bookmark on a page correspond to topics revealed in the engagement with charity volunteers such as, nature in the city, stories of people buried, 'weird and wonderful' anecdotes, 'favourite spots'. Initial evaluation sessions showed that notification sounds attracting visitor attention when nearing a 'hot spot' need to be loud and unexpected in order to be noticed within the environment as birdsong can be very loud and lush vegetation can also deaden sound.

An issue with the companion novel at Weimar cemetery would be that, unlike a human guide, it would not be sensitive to what else is going on in the direct vicinity. For example, a visitor might be close to a neighbouring grave that is being attended by a relative/mourner. A guide can hush his/her voice, skip the location, or wait for an appropriate moment. This means that open audio would only be permissible where there are *only* historic graves. Loud and 'unexpected' notification sounds would aggravate this issue. Outside of these areas earphones would need to be worn, resulting in individualized audio instead of open shared sound.

Figure 4. The Companion Novel closed (top) and with example thematic pages (bookmarked) (bottom)



Another design concept is 'Mourning Jewellery', inspired by the Victorian tradition of mourning jewellery to be worn to remember someone who has passed away: visitors wear a jewellery piece that is linked to a particular person buried in the cemetery (fig. 5). It gives increasing haptic and/or visual feedback the closer you get to that grave. Once you reach it, a simple gesture quietens the jewellery piece as acknowledgement.

Figure 5. The Mourning Jewellery concept: the jewellery piece grows warmer as it approaches a grave. The user acknowledges reaching it.

This is for a scenario where people do not want a lot of information during the visit and want to focus on the peaceful and reflective atmosphere of the site. It could also encourage visitors to discover interesting and important people that have been buried in the cemetery and to find out more about them after the visit. This could be used in Weimar to lead people to some of the important graves outside of the world heritage section (which are

in sections that have newer burials), but in a quiet and reflective way. Given that some parts of the cemetery are not easy to navigate, thus creating a need for guidance, this could also be a useful tool for subtle guidance. As we would like people to retain a sense of exploration [9], such a design could serve both goals. Moreover, this might enable ways to deliver guidance in a way that leads tourists *away* from areas with very recent burial activity. This could be a useful mechanism for the Weimar cemetery with its mixed usage, but would not be as relevant for the Sheffield site.

4. CONCLUSIONS

Similar to how requirements for museum exhibits tend to differ although their overall design might follow certain general principles, outdoor heritage sites have very individual requirements and constraints. As we saw, even sites that at first might appear to be very similar, can differ in subtle ways. The socio-cultural context here is more than just that of 'a historical cemetery', but has to consider the various uses and user groups, with potentially conflicting interests. The physical context also matters as one site has been unchanged for decades, whereas the other is constantly being added to. Truly embedded technology not just needs to be embedded in physical contexts, but also has to be sensitive to the specific socio-cultural setting.

In our case, some of the prototypes could be modified. The Companion novel, for example, might only provide open audio in some areas, and require headphones elsewhere. Similar issues with open audio might arise in other settings. A template to create such a tool for visitor engagement should thus be adaptable to allow for a mix of open audio and personal audio delivery. In contrast, the Mourning Jewellery appears to be highly suitable to the Weimar context, and could even serve additional goals, such as subtly discouraging visitors from moving into an area with recent burials or without historic elements. This could be also useful for the Sheffield site as the jewellery could steer visitors away from unsafe or very overgrown areas. It could also be relevant for themed events: for example, to direct visitors to war memorials for remembrance days. These considerations extend the functionality that needs to be considered for the software architecture of such a device, and might require the ability for curators to define which areas on a map of the site are to be sought or avoided. While the Bird Box concept does not translate well to the Weimar context in its current form, there might be other designs based on its core ideas of providing subtle guidance, triggering curiosity and, in a poetic and atmospheric way, indicating there is more to discover: for example, musical notes could be projected on the ground, directing towards composers' graves. In conclusion, this shows how any template that our meSch project might provide for curators, need to be open-ended enough to work at different sites, but has to be equally adaptable, allowing the addition of other content delivery mechanisms, or the definition of physical areas where a device might display different behaviour.

While tangible and embedded forms of digital engagement may be preferred for open-air heritage sites in order to support and augment a visitor experience that is physically and sensorially rich, each individual deployment must be conscious of the unique physical and socio-cultural characteristics of sites that are apparently similar in order to provide an appropriate and mindful type of interaction.

5. ACKNOWLEDGEMENTS

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TriVis: Visualising Multivariate Data from Sentiment Analysis

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ABSTRACT

In a time when a single sporting event can elicit millions of Tweets the volume of expressions of sentiment available is far too large to be read by an individual in real time. TriVis is a visualisation design that uses a modified scatter plot with three axes to allow the user to read and understand multidimensional data at a glance. We examined the readability of the visualisation using data collected from a golf tournament and plotted the sentiment towards golfers in real time during play. TriVis visualisations are simple, easy to understand and offer insights into the data set which are not obvious using other methods.

Categories and Subject Descriptors

H.5 [**Information Interfaces and Presentation**]; H.5.2 [**User Interfaces**]

General Terms

Data visualisation, design

Keywords

Visualisation, sentiment analysis

1. INTRODUCTION

Consider a spectator watching a golf tournament who witnesses a favourite getting knocked out of the competition. If this user wishes to understand how other spectators reacted to these events they might consider a gasp from the attendees, a criticism from the commentators or await a post-game analysis by experts. In the age of social media we have access to a rich data set of the reactions of millions of people who micro-blog on platforms such as Facebook, Tumblr and Twitter. This data set requires a computational approach such as text analysis before the results can be represented using a visualisation to convey the information to our user. The challenge is to present this analysis in real time in a form that is immediately understandable.

Using Twitter a user can rapidly read and author content without significantly interrupting their viewing experience resulting in large volumes of related Tweets during sporting competitions [1]. This compatibility with sports commentary makes Twitter an ideal platform from which to harvest data for our test case. This data is easily collected but we need to ask ourselves which elements are of interest to spectators, players, sponsors or the general public. When was the Tweet authored? How many people Tweeted? Were the authors' reactions good or bad? These reactions can be classified using sentiment analysis to determine whether a given Tweet was positive, neutral or negative. Sentiment is expressed when a user authors content that is subjective, opinionated or emotional and includes evaluation or speculation [1].

For large data sets visualisation is often a more effective way of describing the data than a table or a purely numeric representation [2]. Well designed visualisations are easier to read than tables or spreadsheets, especially for non-technical users, and can expose patterns in the data that would be difficult to see otherwise. An important principle in visualisation design is the data-ink ratio [2]: ideally a visualisation will convey a large amount of data through the use of a small amount of ink or design elements. Design elements such as shape, colour, size and position can be assessed by the user in under 250 milliseconds using preattentive processing [3]. Designing a visualisation using these elements and avoiding clutter to achieve a good data-ink ratio will allow our user to read the data at a glance.

Although visualisations such as bar charts and line charts are relatively easy to read, they struggle to convey multidimensional data since the addition of multiple y-axes complicates the display and compromises readability. Similarly separating the data by using multiple line charts gives the user more work to do to piece together the full picture. Visualisations such as scatterplots or networks are more suited for the display of multidimensional data but require an investment of time and some examination by the user to extract meaning. TriVis uses a modified scatterplot with three axes to show the full range of sentiment classifications in the data set.

In this section we have presented the difficulties in visu-

*Work carried out while at Insight Centre for Data Analytics in DCU

[1]Wimbledon causes surge in social media. `http://www.bbc.com/news/technology-23225501`

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alising high dimensional data and the motivation to design a solution to gain understanding from large data sets. In the next section we will discuss related work and examine progress in the area of visualisation of sentiment with respect to the design of TriVis. In Section 3 we provide a walk through of plotting data using TriVis before a discussion in Section 4 using example visualisations. Finally we outline future work in Section 5 and draw conclusions in Section 6.

2. RELATED WORK

Some work on sentiment analysis uses a large number of sentiment classifications such as that by Fukuhara et al. in temporal analysis of social events [4]. In this work a stacked line diagram is used to show the classifications anxiety, sorrow, shock, complaint, anger, happy, fatigue and suffering. The focus is on exploring events and sentiment over time but the visualisations are limited to showing either a range of sentiment classifications for a single event or a single sentiment classification for a series of events.

Visualisations such as TwitInfo [5] and Vox Civitas [6] use two separate graphs to show volume and sentiment while others such as VISA [7] combine the two into one graph. Including volume is preferable since the user can see at a glance if the sentiment score represents the views of many authors who are in agreement or few individuals who are outliers in the data set. The visualisation used in VISA makes it somewhat difficult to compare volume from one topic to another, although the overlaying of keywords is a useful addition. TwitInfo uses only two classifications of sentiment (positive and negative) while Vox Civitas adds two more (neutral and controversial) although both have added an element of event detection that allows for further exploration. More recent work such as Semantize [8] conveys sentiment found in a document with the use of font and background colours which are used to highlight the text.

TriVis uses three separate classifications of sentiment (positive, neutral and negative) to represent multidimensional social sentiment data. This design combines sentiment and volume in the same graph can show multiple topics distinguished by the use of colour. TriVis shows a distinction between sentiment labelled as neutral and sentiment which is composed in equal amounts of negative and positive. The latter represents a controversial or polarised sentiment and is graphed in a separate region of the visualisation to neutral sentiment. TriVis does not use time on the x-axis but instead uses a non-linear representation where time can be seen as a series of pathways which join plotted sentiment values.

3. PLOTTING SENTIMENT

In this section we outline how data was collected for the examples used in this paper, describe the algorithm for plotting sentiment and discuss how the data is represented visually.

3.1 Data Collection

The sporting event used to collect test data and test the system was the Open, a golfing tournament held in Scotland in July 2013 [2]. We collected Tweets in real time using the Twitter Streaming API and filtering for the names of golfers who took part [3]. Next these Tweets were analysed using a supervised machine learning algorithm [9] which attributed a label to each Tweet indicating whether the sentiment expressed towards the topic or golfer was positive, neutral or negative. Sentiment towards a golfer for a given time period is the relative frequency of positive, neutral and negative labels for that time. The goal is to design a visualisation that presents this analysis to a spectator of a live event such as the Open in an easily readable visualisation. This visualisation could then be overlayed on live play or added to a leaderboard to show sentiment towards the players on screen and in the tournament as a whole respectively.

3.2 Algorithm for Plotting Sentiment

After the steps outlined in 3.1 we produced sentiment tuples.

$$Sent(T)_i =< pos, neu, neg > \quad (1)$$

where pos, neu and neg are the number of Tweets that were positive, neutral or negative that exist for a given golfer or topic T at time interval i. The first step was to normalise these values as shown in Equation 2 were pos is normalised. The sum of pos, neu and neg is always equal to 1.

$$posnorm = \frac{pos}{pos + neu + neg} \quad (2)$$

These normalised values were converted to a plotable form using polar coordinates (r, θ) mapping to a conceptual wedge shape (of θ 90 degrees). The normalised neu value was used to map to r directly, meaning the height of r corresponds to the neutral value, the length of r increasing as neu decreases. θ was used to convey both pos and neg using Equation 3.

$$\theta = 90 * (\frac{neg}{neg + pos}) \quad (3)$$

This produced an angle of 0 which corresponded to the left most side of the wedge for a 100% negative score and an angle of 90 corresponding to the rightmost side for a 100% positive score.

Multiple coordinates with the same value for r would appear at different heights as the value for θ changed. We scaled the value of r to flatten out this curved presentation using Equation 4.

$$r_{scaled} = r * cos(\theta) \quad (4)$$

Data Component	Visual Dimension
positive sentiment	x,y coordinates
neutral sentiment	x,y coordinates
negative sentiment	x,y coordinates
time	trail
topic	colour
volume	area

Table 1: Mapping of data to display dimension.

[2]Muirfield - 2013 Results `http://www.theopen.com/en/History/OpenVenues/Muirfield.aspx`

[3]Twitter Streaming API `http://https://dev.twitter.com/docs/api/streaming`

3.3 Visual Representation

Once plotted in polar coordinate form the sentiment tuples appear as points within a triangular area. Each of the vertices represents a sentiment classification and proximity to a vertex indicates the composition of sentiment of each tuple. Points appearing close to the positive vertex have a higher positive score than negative or neutral. Points midway between the positive and negative vertices have a low neutral component and represent polarised topics where the positive and negative scores are of close to equal value. Multiple topics are shown using a different colour and the volume of Tweets associated with any plotted point is shown through the area of the point itself. Trails connecting points indicate a path over time. Table 1 lists how the data components map to the visual dimensions used.

The 2D visualisations shown in this report were produced using a JavaScript graphing API Highcharts [4] and the 3D visualisation was produced using three.js, a library for WebGL [5].

4. RESULTS AND DISCUSSION

In this section we discuss how sentiment data is displayed using TriVis and use a series of examples from our sample data set to explore the readability of the graph.

4.1 Sentiment in 2D

Figure 1 shows the basic template of the visualisation, a 2D triangle where each vertex represents a maximum score in one of the three SentiSense classifications of sentiment: positive, neutral or negative. A topic whose sentiment score was split evenly over all three classifications would appear in the centre of the triangle, while a score dominated by one classification is plotted closer to that corner than either of the other two. The further from the neutral vertex a point is plotted the more polarised the sentiment on that topic.

4.2 Examples

In Figure 2 the sentiment score representing Rory McIlroy (shown in orange, ranked second in the world at the time the Open began [6]) veers towards negative as he plays poorly on days one and two and fails to make the cut to progress to the weekend. Sentiment towards Phil Mickelson (shown in blue, ranked fifth in the world at the time) hovers on the positive side of neutral before surging towards positive and growing dramatically in volume after he wins the tournament on day four. In Figure 3 we see that sentiment towards Tiger Woods (shown in purple) was composed predominantly of positive and negative values which indicates that opinions of his performance and prospects in the tournament were either highly positive or negative. If plotted on a scale of negative to positive this type of score would appear in the middle and give the impression of neutrality rather than polarisation which is the case. Using TriVis polarised sentiment is clearly distinguishable from neutral sentiment. The volume of Tweets about Tiger Woods is substantial and is larger than that of Ian Poulter shown in green until the final day when he rose to third place and became the highest ranking Briton in the final hours of the game.

[4]Highsoft AS `http://www.highcharts.com/`
[5]Three.js Library for WebGL `http://threejs.org/`
[6]Official World Golf Ranking `http://www.owgr.com/Ranking`

4.3 Representing time

As the representation of time is non-linear temporal patterns appear as a footprint of pathways and points over time. Saturation of colour is used to indicate the passage of time as shown in Figure 4 where older values are more faint. Another representation is to align a series of snapshots of single time points along the z-axis, using a third spatial dimension to convey time as shown in Figure 5 although this representation is best explored by a user who can rotate and examine the 3D model.

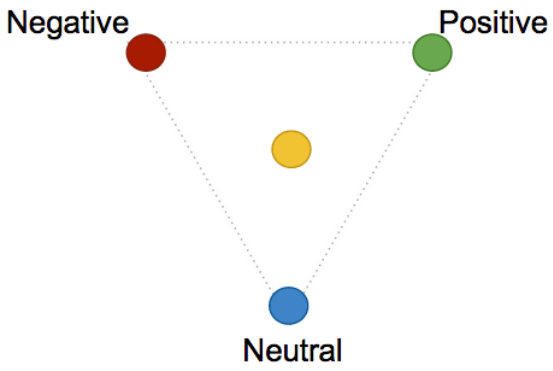

Figure 1: 2D template for plotting sentiment.

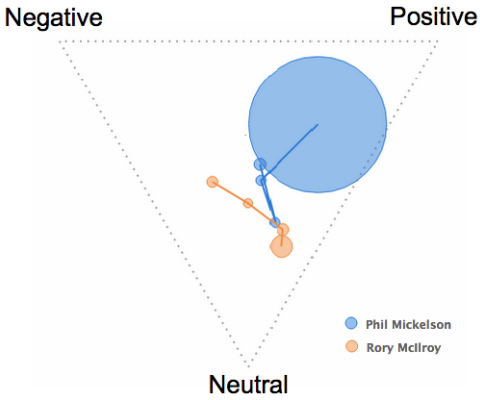

Figure 2: Sentiment towards Phil Mickelson and Rory McIlroy with daily intervals.

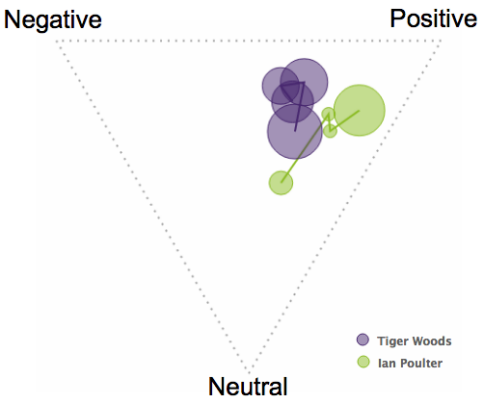

Figure 3: Sentiment towards Tiger Woods and Ian Poulter with daily intervals.

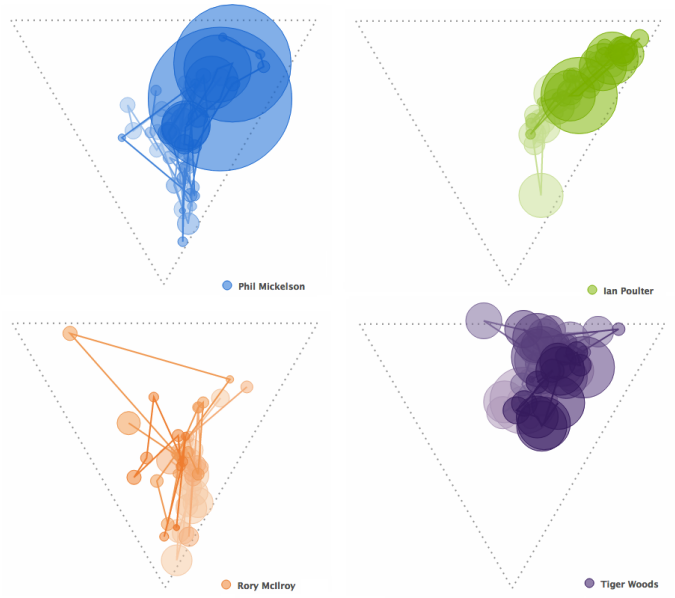

Figure 4: Sentiment towards Phil Mickelson, Ian Poulter, Rory McIlroy and Tiger Woods woth hourly intervals.

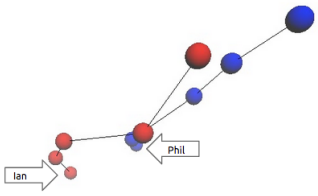

Figure 5: Daily values for Phil Mickelson and Ian Poulter plotted in 3D (sphere size does not represent volume).

In Figure 4 the transparency of the circles representing volume allows the user to see detail beneath the most recent layer, but also creates some interference as layers of paths and volume circles appear darker and more recent as a result. These footprints are useful in seeing a general profile or sentiment pattern in a large data set.

5. FUTURE WORK

We would like to investigate the application of this approach in other areas such as political debates, news, talent competitions etc. Also of interest is exploring the use of this design as an addition to a leaderboard or scoreboard, as a symbol to overlay on live television and the use of animation to update the visualisation in real time. A natural extension of this work would be to implement interactivity as part of a drill down interface to allow the user to have more control over the visualisation by zooming or filtering to explore specific times or keywords. This would allow the user to see an overview using TriVis in its current form, then zoom and filter to explore details on demand covering all aspects of the visual information seeking mantra [10].

6. CONCLUSION

In this paper we explored the challenge of representing high dimensional data using an easily readable visualisation. The data set we used was captured from Twitter during a golf tournament and analysed for positive, neutral and negative sentiment. We examined other work carried out in visualising sentiment data and designed and implemented a novel visualisation of our own. TriVis represents volume and composition of sentiment towards multiple topics over a given interval of time in one graph. TriVis can be read at a glance by a spectator of a live event and provides an understandable insight into a complex data set in real time. The implementation does not facilitate interactivity at this time but could be extended to allow a user to filter and explore the data set in more depth.

7. ACKNOWLEDGEMENTS

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eTextbook Interactivity

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ABSTRACT
As opposed to the limited interactivity needed for eBooks being read for pleasure, eTextbooks require more functionality to support demanding cognitive processes occurring when students interact with academic texts. However, a survey conducted in a college in the United Arab Emirates, which has used eTextbooks extensively since 2013, revealed that faculty viewed current eTextbooks negatively. Only one eTextbook, running on the Spindle platform on the iPad, received positive reviews from faculty and students. While this paper is limited in regard to the amount of quantitative feedback on eTextbooks, particularly on the impact of eTextbooks interactivity on student/teacher performance or satisfaction and detail about the eTextbook interfaces, it is hoped that the rationale for the design and implementation of eTextbooks and recommendations for the design of eTextbooks can be of use to both educators and publishers in future eTextbook projects.

Keywords
eBooks, eTextbooks, user interaction, reading for academic purposes, Spindle, OUP

1. INTRODUCTION
The use of eTextbooks is increasing in educational institutions. However eTextbooks, which should provide features to support students with academic reading, currently offer little more functionality than standard eBooks. This paper examines the adoption of eTextbooks providing: a brief a rationale for the design and implementation of eTextbooks; the description of a case study of a large-scale eTextbook rollout in an educational institution, and; design recommendations to enhance eTextbook interactivity.

The paper first compares reading for pleasure versus reading for academic purposes and outlines differences between eBooks and eTextbooks. It then provides the rationale for and describes the implementation of eTextbooks in a large tertiary educational institution in the United Arab Emirates. This is followed by a brief discussion on: the interactive features of eTextbooks; the perception of faculty have of them; and the features of eTexbooks which increase opportunities for interactivity. Finally, design recommendations to further enhance the interactivity of eTextbooks are made.

2. BACKGROUND
2.1 Reading for pleasure versus reading for academic purposes
Reading for pleasure is "reading that we do of our own free will anticipating the satisfaction that we will get from the act of reading" [1]. It is a form of play, or creative activity, in which we use our imaginations to experience different worlds and roles [2, 3]. It is not a passive pursuit. It involves the reader and text interacting in such a manner that meaning is framed by the reader's expectations, experiences and context [4, 5]. According to Krashen [6], reading for pleasure allows children to get "hooked on books", resulting in improvements in a variety of literacy skills.

While extracting meaning from academic texts also involves the reader's expectations, experiences and context, it encompasses demanding cognitive processes. Students need to predict, monitor and fix misunderstandings, question, image, infer, summarize, evaluate and synthesize [7, 8]. Highlighting, annotating, bookmarking, mind-mapping, cross-referencing and thinking-aloud are some of the techniques employed to interact and process academic texts [9]. When using traditional paper-based textbooks, students use separate tools such as pens, paper, sticky notes, audio recorders and so forth to aid academic reading. However, books in electronic format afford the possibility of combining these tools in a single device.

2.2 eBooks versus eTextbooks
As previously outlined, our distinction between eBooks and eTextbooks resides on the objective of reading (pleasure vs academic purposes); however, such a distinction has implications for the devices. For instance, eBooks which are read for pleasure require minimal features. The font, background, contrast and brightness should be adjustable and page flipping should have a natural feel. However eTextbooks, read for academic purposes, require more functionality to support cognitive processes occurring when students interact with texts. Interactive features such as: easy to navigate and search, ability to annotate (using text, hand-writing and audio), highlight, bookmark, ability to save as PDF and print out, interactive quizzes and embedded multimedia; have been shown [10-14] as desirable in eTextbooks.

3. RATIONALE FOR AND IMPLEMENTATION OF ETEXTBOOKS
3.1 Setting
The eTextbook implementation took place in a large tertiary educational institution in the United Arab Emirates which consists of multiple campuses spread throughout the country, with a total of almost 20,000 students. The institution provides four-year degree courses and the language of instruction is English. Given that students are non-native English speakers, they may spend up to two years in a bridging programme before entering their main course of study.

3.2 Rationale for Introducing eTextbooks
According to the Horizon Report for Higher Education, educators have started "to realize that they are limiting their students by not helping to develop and use media literacy skills across the

curriculum" [15]. Industry is now expecting college graduates to have these skills. In addition, "the workforce demands skills from college graduates that are more often acquired from informal learning experiences than in universities" [16]. These skills include critical thinking and problem solving, collaboration and communication, global awareness and information literacy, and have been referred to as 21st century skills [17-19]

The college which is the object of this study embraces the above thinking. Technology is an important feature of teaching and learning. For instance, laptops were introduced into the bridging programme six years ago and iPads only three years ago. Hence, all students are expected to bring a computing device to class. Given the prevalence of mobile devices among students, the institution decided to implement paperless classrooms as the next stage of technology adoption. So, in the 2012/13 academic year, eTextbooks were piloted in some courses at the college. The pilot was deemed successful in that it was felt that eTextbooks helped students develop and use media literacy skills, allowed for anytime, anywhere learning, encouraged sustainability by reducing paper wastage and improved overall efficiency in the ordering process [20]. Consequently, it was decided that eTextbooks would be made available for all courses during the 2013/14 academic year. In total, almost 150,000 eTextbooks were issued across the system, perhaps the largest rollout of eTextbooks in a single institution.

3.3 Implementation of the eTextbooks

When selecting the eTextbook platforms, the following criteria were used: usability; efficiency; pedagogy; scalability; and economics [20]. Furthermore, important issues such as training and support needs, administration and implementation ease, and infrastructure and preparedness were also considered. eTextbooks were accessed via four publisher platforms (McGraw Hill, Pearson, Wiley, and Cengage) and two aggregator platforms (Vital Source and CourseSmart). A single platform for accessing all eTextbooks was the preferred option; however, with the wide range of publishers and textbooks being prescribed, this proved difficult to implement. Regardless of platform, all eTextbooks were initially accessed via courses on the College's learning management system (LMS). Those using the publisher platforms allowed for direct or deep integration (course links could be embedded to certain sections/chapters of the eTextbooks); those using the aggregator platforms allowed only for indirect integration. Once students had registered for their eTextbooks, they could access them via their LMS courses for online reading. For offline access, the aggregators also provided students and teachers access to the eTextbooks via their native 'bookshelf' applications accessible on the students' computing devices such as iPads and laptops.

4. DISCUSSION

4.1 General Problems

The introduction of eTextbooks was not problem free. Students and faculty at times faced difficulties when registering for their eTextbooks. Downloading the offline versions of the eTextbooks could take much time. Due to the tight implementation schedule and availability of the titles, prescribed eTextbooks for some of the courses were not ready or not made available by the aggregator/publisher at the start of the semester. In addition, those students accessing the eTextbooks, particularly from a laptop or desktop, found some of the titles harder to read than a paper-based equivalent. These problems arose due to a number of factors: multiple delivery platforms; publisher's content coming in PDF format instead of 'reflowable text' format; the 'bring your own device' (BYOD) policy implemented at the start of the 2013/14 academic year, which meant troubleshooting challenges; and teacher/student preparedness.

4.2 Faculty Perceptions of eTextbooks

An eTextbook satisfaction survey was sent to 733 full and part-time faculty across three divisions: engineering, information technology and the bridging programme. 187 faculty responded, a response rate of 26%. When asked if students had used the eTextbook more than the previously used paper-based books, 53% of the respondents disagreed or strongly disagreed with the statement, as opposed to 30% who agreed or strongly agreed. In addition, only 28% of respondents agreed or strongly agreed, as opposed to 48% who disagreed or strongly disagreed, that the eTextbooks were easier to access and use in the classroom than paper-based books were. When asked if they felt that eTextbooks were an improvement over paper-based books, only 27% agreed or strongly agreed, as opposed to 42% who disagreed or strongly disagreed. Some of the major complaints in regard to eTextbook usability were as follows: visually unappealing and difficult to read – better font, paging and search features needed; it was easier to annotate on paper; some technical subjects require drawing – which wasn't possible in the eTextbooks; printing was difficult, limited or impossible; navigation was time consuming – quick referencing and viewing multiple pages was difficult; being online lead to more distractions; online access was sometimes difficult; iPad upgrades caused issues; and more technical support was needed.

As can be seen from the survey results and comments, overall, faculty had negative perceptions of using the eTextbooks. They found the usability, effectiveness and satisfaction [21] with eTextbooks to be less than optimal. Some of this negativity was the result of the sudden implementation of the eTextbook initiative and the technical and administrative issues related to it. Student registration for and activation of the eTextbooks was initially problematic. Technical glitches were common, mainly related to internet connectivity and browser settings. Once faculty and students realized that the eTextbooks could be used without needing to be online, technical problems decreased. Another main reason for the negativity was that most students wanted to print out the eTextbook; however printing options were restricted, for example, only two pages at a time or only 50% of the book, depending on the eTextbook platform. The reason for needing hardcopies was probably because most students were using laptops, which made reading and annotating the eTextbooks more difficult.

However not all the eTextbooks received such negative feedback. Faculty and students in the bridging programme, where iPads and limited numbers of eTextbooks running on the Spindle platform were being used, had more positive perceptions.

4.3 The Spindle Platform eTextbook

This eTextbook, supplied by Oxford University Press (OUP) and running on the Spindle platform, and designed specifically for an iPad or Android tablet, offered a much better user experience. As well as having basic features such as highlighting, searching, text annotation and bookmarking, extra functionality such as text and voice sticky notes (useful for extended notes and for recording thinking aloud), hand-written annotation (for shorter notes), split-screen capability (for cross-referencing), rich multimedia controlling features, text boxes for answers with auto score capability and an in-built mailing tool were provided (figures 1-4).

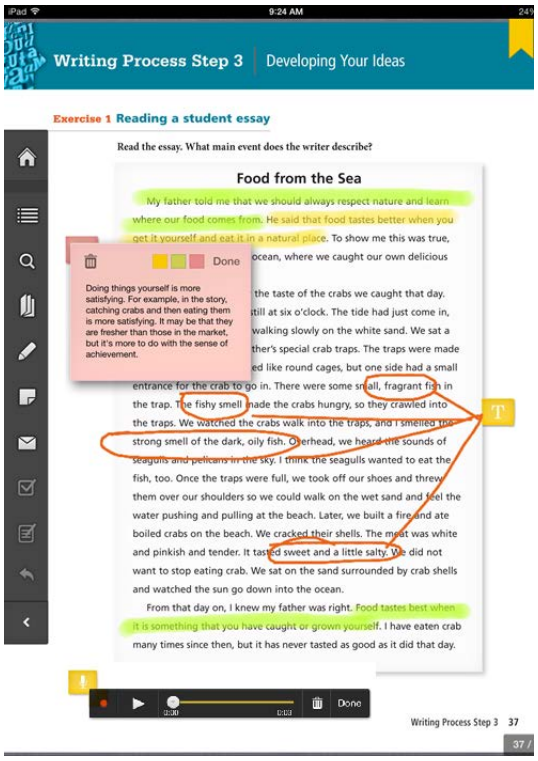

Figure 1: ePage with highlighting, bookmarking, hand-written annotation, voice and text sticky notes, and options menu

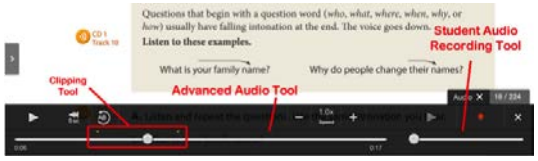

Figure 2: Rich multimedia controlling features

These features were the result of a two-year collaboration between the publisher and educators, some of whom were faculty in the college. In a survey (N=85) carried out by Al-Ali and Ahmed [22] with students in the bridging programme, when asked in which format would they prefer their textbook, 50% favoured only using the eTextbook, 39% favoured having the textbook in both electronic and paper versions, and only 11% favoured just using the paper version. Conversations with faculty also confirmed their satisfaction with the Spindle platform.

5. DESIGN RECOMMENDATIONS AND FUTURE IMPROVEMENTS

Academic reading involves the use of more cognitive processes than reading for pleasure; therefore eTextbooks require more interactivity than eBooks. As a minimum requirement, eTextbooks should have the following interactive features: easy to navigate and search, ability to annotate, highlight, bookmark, ability to save as PDF and print out, interactive quizzes and embedded multimedia. The latest generation of eTextbooks, such as the OUP eTextbook mentioned above, are beginning to incorporate these features and have been received positive feedback from both faculty and students. This positive feedback perhaps resulted from the richer set of interactive features on offer, but it may have also resulted from the fact that it was delivered using an iPad. This would suggest that for eTextbooks to be fully embraced by both educators and students, versions with richer features and tablet-friendly need to be developed.

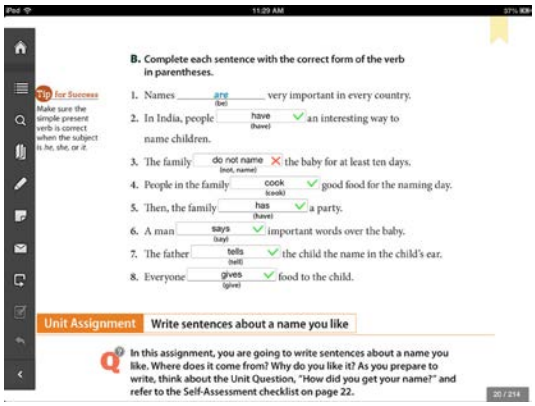

Figure 3: Autoscore activity

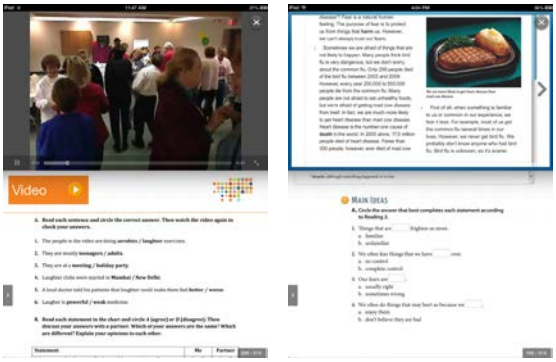

Figure 4: Video and text split screens

Despite the positive feedback for the OUP eTextbook, there is room for future improvements. For example, hand writing can be problematic on a tablet, even when using a stylus, due to limited space on the page. The addition of an expandable sticky note for hand writing, drawing, and mind mapping among others, would solve this problem. In addition, even though most faculty and students found the autoscore activities (figure 3) useful, some teachers felt that the instant answers led to students clicking without thinking. It would be better if autoscore activities could be switched on or off and scores could be recorded in an online grade centre. An enhancement to the split-screen feature (figure 3), useful for cross-referencing would be allowing two sections of the eTextbook (or even two eTextbooks) to be viewed, searched and scrolled simultaneously. Although the mail tool supports whole pages of annotated work to be emailed and certain eTextbook platforms allow for notes to be shared via a central website, an additional improvement would be an in-built tool to share notes, comments and reflections via social networking sites or blogs. For example, after reading a text, students could write a summary and automatically post it to the class blog or Facebook page.

It should also be noted that the OUP eTextbook was the result of a two-year collaboration between the publisher and educators in various locations. Publishers and educators need to work closely to ensure eTextbooks have the necessary interactive features to help students with their academic reading. Furthermore, collaboration between publishers and educators is needed to ensure that the actual content in eTextbooks is modified to make use of the power of the

mobile technologies being used to deliver them. For example, content that encourages students to use mobile technologies to collaborate and construct knowledge can help students acquire 21st century learning skills. By doing this, the full potential of eTextbooks can perhaps be realized.

6. CONCLUSION

eTextbooks require more functionality than eBooks to support demanding cognitive processes occurring when students interact with academic texts. However, the functions offered by most current eTextbooks are insufficient. In a survey done after a large-scale eTextbook rollout at the college featured in this paper, faculty perceived eTextbooks in a negative way. Only one eTextbook, running on the Spindle platform on the iPad, received positive appraisal from both faculty and students due to its rich set of interactive features.

This paper has aimed to provide a rationale for the design and implementation of eTextbooks and recommendations for the future design of eTextbooks. It is hoped that these will be of use to both educators and publishers in the design of future eTextbooks.

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