Physicality 2012

Proceedings of the

Fourth International Workshop on Physicality

In conjunction with BCS HCI2012 conference
University of Birmingham, UK
11 September 2012

Devina Ramduny-Ellis, Alan Dix & Steve Gill (Eds.)

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PREFACE

http://www.physicality.org/physicality2012/

Our physical interaction with the world involves every part of our bodies. Physicality 2012 is the Fourth in the international workshop series aimed at exploring design challenges, theories and experiences in developing new forms of interactions that exploit human physical interaction with digital technology. Physicality-based interactions extend feedback beyond the visual, thus emulating the experiences gained through our interaction with the world via our non-visual senses and control capabilities such as gesture, speech and touch.

CONTENT

As in previous workshops in this series, this year's range of papers and participants is both diverse and diffuse. The authors' interests include aspects of technology, design, embodied interaction and interactive installation.

As befits such cross-disciplinary workshop, the invited keynote by Fabian Hemmert from Deutsche Telekom Labs is one with some relevance to most. Fabian will be discussing his explorations of the possibilities of haptic interaction in future visions of feeling digital content. He will also be covering the potential impact on the human condition of an age of information abundance.

The authors' contributions also cover a broad spectrum which we have categorized under the following themes:

Bodily Interaction. We interact with physical objects using our own physical bodies. Altakrouri and Schrader focus on the role and use of the body, drawing from a large range of design considerations, from the basic body movement description to adaptation mechanisms, through disabilities and composition of interactive solutions. Hood utilises choreography to analyse movement in the gaming world while Furbach and Maron looks at how people interact with a public display through gestures.

Framework for Rapid Prototyping. Rapid prototyping mechanisms are central to the design of computational products and systems. Bellucci, Malizia and Aedo introduce a new prototyping approach using various sensors and effectors to bridge the physical and digital worlds. Zampelis, Gill, Loudon and Walker instead propose a mixed reality based approach to prototyping.

Interactive Installation. This group of papers proposes various installations that explore different aspects of the human body and its senses and how they influence interaction and design. Clarke and Hornecker present the design of an interactive exhibit that enables the creation of collaborative sketches through the use of tangible devices with an interactive display. Murray-Rust and Jugenfeld propose an artwork installation which functions as a ludic interface to provide a series of sensory experiences mediated and extended by digital technology. Meanwhile Hollingworth *et al*. address the creation of digital objects as a means for exploring museum artefacts and heritage sites, with particular focus on providing people with learning difficulties with a more engaging experience.

Design Space. Moving out from the body, we are also constrained and influenced by the design of the spaces in which we live and interact. Jäeger, Schnädelbach and Glover discuss a prototype adaptive architecture that provides responsive biofeedback environments and explore its physiological impact on people. In contrast, Forshaw, Cruickshank and Dix put forward the notion of Physical-Cyber Environments to bridge hybridity and design and propose a method to develop design ideas for such environments.

Devina Ramduny-Ellis, Alan Dix, Steve Gill

September 2012

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Special thanks to Andrew Walters, Director of Research, PDR, Cardiff Metropolitan University

KEYNOTE

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Embodied Interactions

When we get in 'touch' with the digital world, we often do not feel more than cold glass - and an occasional vibration. While audio and video are going HD, and 3D, haptics are often neglected. In his talk, Fabian Hemmert will explore possible future visions of feeling digital contents, and discuss their potential impact on the human condition in an age of information abundance.

Towards Dynamic Natural Interaction Ensembles

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ABSTRACT
Exploring the potential of whole body in motion is inevitably important for natural interactions. People are expected to use different body parts to simultaneously interact with multiple interactions techniques. Therefore, interactive ecosystems in interactive spaces become a real challenge. We have identified three closely related issues to be solved for better adoption of natural interactions in ambient systems: assessment of anthropometric physical abilities and disabilities, interaction ensembles and orchestration, and finally community-based designing and sharing of interactions. In this paper, we present an integrated concept for realizing interaction in ambient systems using natural interaction ensembles. Interaction modalities from different devices are tailored at runtime to maximize the adoption of interactive systems according to the users' physical abilities, needs, and context.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *ergonomics, interaction styles, input devices and strategies.*

General Terms
Design, Human Factors.

Keywords
Ambient Assisted Living, Natural Interactions, Kinetic Interactions, Anthropometry.

1. INTRODUCTION
Pervasive computing technologies have paved the ground for the development of future interactive environments consisting of a plethora of interconnected smart objects realizing new context-aware services in a seamlessly integrated physical and virtual world. This imposes new challenges for human computer interaction (HCI). The goal of HCI research for pervasive environments is to create user-friendly interaction means for essentially invisible technology. Technology should therefore adapt to the natural interaction abilities and practices of humans.

Human users will continue to interact with pervasive systems using physical body interactions and intermediaries, because major body activities such as touching, holding, and moving physical objects are the foundation of the long evolution of tool use in the human species. Similarly, voice based communication will continue to be used due to its essential part of our culture. Therefore, interaction using Natural Interfaces (NI) is frequently being proposed solution to support a flow of (inter-)action patterns in the hybrid world similar to the human patterns in the physical space.

The definition of natural interaction varies in the literature as noted by [9]. Nevertheless, those definitions generally refer to the use of users' natural abilities, practices, and activities to control interactive systems. Such definitions inherently include activities such as but not limited to gestures, physical and virtual objects manipulations, body movements, and postures [9]. NI resembles closely forms of human's communicative abilities [1] and enables more natural and intuitive communication between people and all kinds of sensor-based devices, to enforce interactions that would "feel right". NI definition can be shortly devised from Wachs et al. [19] as voice-based and kinetic-based interactions.

The improved integration of sensing and actuating technologies into commodity devices has set a strong ground for NI to be preponderant in pervasive environments such as experience centers and museums [6]. The authors' research interest is currently focused on kinetic-based NI, therefore other types of interactions are excluded intentionally from the discussion in this paper. As natural interactions between the physical and virtual spaces widely take place by means of gestures, manipulation and tangible artifacts as defined earlier, it is important to acknowledge that the core concepts covered in this paper can be still be applied to relevant and closely related interaction types in ambient spaces such as tangible interactions, interaction with 3D interfaces, ambient interactions, etc.

The remainder of this paper includes an introduction to kinetic-based interactions, NI in pervasive environments, and NI and human physical abilities. Section 2 covers in detail the concept of anthropometric framework for NI ensembles. Section 3 presents the system design, issues and challenges. Sections 4 and 5 present some identified research challenges and conclusions respectively.

1.1 Kinetic-based Interactions
Kinetic interactions are caused and characterized by motion and movement activities, e.g., running, walking, or dancing. They are natural and interesting for simulating physical activities and providing eyes-free interactions, i.e. interacting confidently in the absence of graphical feedback [12], for controlling devices. Hand-based kinetic interactions, for example, utilize tilting for scrolling photos, shaking for moving dices realistically, and hand gestures for drawing. Gesture-based interactions, another form of kinetic interactions that vary greatly in form and usability, promise new

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natural interaction techniques and lead to gesture-based systems as reported by [15].

Different classifications of gesture interactions are proposed by literature. Herein we elect device-based and body-based gesture classifications. The first refers to any gesture involving direct touching or moving of a typical interaction medium such as a mobile device. The later refers to any gesture involving direct movements of the body without the use of a typical interaction medium.

Researching this type of interaction is a challenging task. To our best knowledge, the literature still lacks published research on motion-based interaction primitives classification and design space of motion-based interactions, despite some recent research effort to end-user elicitation of motion gestures as reported by [18]. The authors provided a strong evidence for the importance and acceptability of kinetic-based NI, as a high percentage of respondents (up to 82%) were willing to use motion-based gestures at least occasionally.

1.2 NI in Pervasive Environments

NI foster a set of important interaction qualities [19] including high accessibility, engagement, familiarity, easiness, intuitiveness (clear cognitive association with the functionality performed), come as you are, ubiquity and wearability without requiring long periods of learning and adaptation. Particularly, NI is able to solve a number of challenging aspects in pervasive systems:

- overcoming physical handicaps,
- exploring big data,
- and finally accessing and conveying information, meaning, and intentions while maintaining high sterility, where users are able to embrace such new, alternative interfaces and interactions.

Despite the novel research contribution in this area in the last few years, the fusion of NI techniques into ensembles of interaction techniques is still a rather unexplored area. The combination of hand and foot input for example has gained only little attention according to Daiber et al. [4]. Much of the literature focuses on using a limited part of the body. Interactive systems that incorporate the gross motor skills and utilize the kinesthetic sense have not been thoroughly investigated despite the growing number of implementation examples [6].

There is a strong emerging motivation to explore new potential in designing for the whole body in motion as in Kinesthetic Interactions by [6]. Against this background, users are expected to interact with multiple interaction techniques simultaneously employing multiple body parts and different motor skills. Hence, NI is expected to not only play individually but also to play as part of an ensemble. We therefore endeavor to investigate the theoretical concept of NI ensembles and the potential realization technologies, which we believe will be part of the enabling technology for interactive pervasive systems.

Interaction with ambient systems is becoming increasingly more challenging as user population grows to include users with varying intrinsic sensorimotor capabilities, ranging from injuries, ageing, or other disorders. Interest in specially tailored applications for health related sensorimotor deficits have come to the fore. Lately, home care research and industry are opting for more intuitive support for elderly and disabled people i.e. elderly people with physical limitations are actively using Wii for fun and rehabilitations [2]. Nevertheless, this effort is still considered modest as vast research studies, i.e. surface computing, are still made for the general audiences with little focus on older adults [13].

Reviewing the literature reveals an extensive effort in the area of user interfaces adaptation in terms of context modeling, user modeling, automatic generation of interfaces, etc. One of the well-established concepts is plasticity [3]. This concept refers to the capacity of an interactive system to tolerate changes in the context of use while retaining usability based on adapting the graphical user interface according to three factors (input, output, and platform). The WWHT framework [16], on the other hand, is based on a rule-based system, which matches different communication channels to a given context model based on 4 levels of adaptation (What, Which, How, Then.).

Interface adaptation is a hot topic in HCI and covering more concepts is out of the scope of this paper. Nevertheless, most available adaptation approaches fail to satisfy four enduring of challenges drawn from the natural characteristics of ambient environments, namely heterogeneity, distributivity, dynamic media mobility, and user mobility [14]. Moreover, most adaptation approaches focus on interfaces issues such as information presentation but not the interaction per se.

There is currently a growing interest in investigating interaction adaptation. Recent work by Pruvost et al. [14] focuses on interaction adaptations in ambient environments. They have suggested the concept of interaction ontology where semantic information about the interface, user and the context are used for interaction adaptation. They focus mainly on the structural adaptation of user interfaces and the adaptation of running interaction dialogs.

1.3 NI and Human Physical Abilities

It is vital that anthropometric based analysis of NI leads to match users' physical abilities and disabilities to the current environment and interaction context. This match is very essential for designing interactions "for all" instead of focusing on a limited population percentile.

One of the most demanding user populations for NI is the senior citizen population, due to the notable effect of ageing in one's physical and motor abilities. The performance of interaction tasks is defined by the frequency of use, discretionary usage, computer familiarity, user knowledge, general abilities, physical abilities, and skills. Elderly adults experience an overall slowing of movement and major problems with fine motor activity and coordination often resulting in inaccessible interfaces (e.g., mobile interfaces) according to Kane et al. [10]. NI are affected with wide range of physical impairments and disabilities including visual, hearing, and mobility impairments such as arthritis, paralysis, and Parkinson's disease contribute to vast range of symptoms affecting kinetic interactions greatly such as limited range of motion, pain, tremors, impaired balance, gait, etc.

Fogtmann et al. [6] call for conceptual frameworks to identify unexplored possibilities when designing interactive systems addressing the body in motion. Hence, the theoretical gist of our research proposal is to study anthropometric driven ensembles of natural interaction techniques.

This proposal herein argues that the concept of NI ensembles is a necessary adaptive interaction enabler and a major technological player in interactive ambient assisted living systems. This paper presents our ideas, motivation, and the current work progress.

2. ANTHROPOMETRIC FRAMEWORK FOR NI ENSEMBLES

We propose STAGE framework for anthropometric driven ensembles of NI techniques. Interaction modalities from different devices are tailored at runtime to maximize the adoption of interactive systems according to the users' physical abilities, needs, and context. STAGE utilizes detailed anthropometric data and human ability profiles for maximizing the usability of kinetic-based NI for acting on the stage of an ambient environment.

2.1 The Disability Challenge and Interactions

A lot of devices specifically exist to support people with motor impairments such as oversized trackball mouse, and adaptive keyboard (for non-reliable muscle control and lack of precise movements, e.g., tremors). A study by Kane et al. [10] on mobile interactions with motor-impaired people nevertheless reports a clear mismatch between the available devices and abilities of the motor-impaired participants, since none of them used accessibility mobile devices. One participant reported successful use of accessibility keyboards designed for children to interaction with her home PC. Nevertheless, she rejected the use of other accessibility devices such as mobile phones in public. Another participant illustrated some privacy issues with using a portable magnifier in public preventing her from interacting with a phone screen in public.

Obviously, designing NI devices is challenging because it does not fully explore the potential of motor interaction, even when optimized for considered impairments. This is mainly due to the following restrictions. First, these devices are usually designed with a specific impairment in mind but still compromising the variation of degrees of disabilities. Second, these devices are usually context-agnostic; resulting in one-design-fits-all approach e.g., the average car seat height fits almost nobody.

2.2 Natural Interaction Ensembles and Orchestration

Wachs et al. [19] presented very useful interaction qualities that can be used to measure interactions against each other when applied in different contexts. This is to avoid the extremely poor use of the potential of the human's sensory and motor systems as in human operated machinery (e.g., automobile) as noted in Fogtmann et al. [6].

We suggest de-coupling the close binding between devices, interaction methods, and applications. Alternatively, we suggest to utilize dynamic compositions of NI ensembles, assembled and configured based on user capabilities and situational context in an ad-hoc manner. Hence, the STAGE vision fosters soft-wired applications and devices. By using adaptive NI ensembles, the limitations of the static binding can be overcome, and one of the most challenging requirements in pervasive environments, the "come as you are", can be addressed. Moreover, mismatch problems between user's needs and device's offers can be avoided by employing the best matching NI to the given context, hence user independence (acceptability by permitting customizability) and usability as required by Wachs et al. [19] are inherently enhanced.

STAGE in ambient environments is a runtime environment for natural interaction techniques and ensembles deployment and delivery based on a number of anthropometric and physical ability matching algorithms. STAGE treats each NI as a standalone interaction interpreter entity called **Interaction Plugin (IP)**. We define Interaction Plugin as "an executable component in ambient interactive systems that encapsulates a single natural interaction technique with a set of interaction tasks as input and delivers higher level interaction primitives to applications based on specific interaction semantics". Therefore, IPs allow for NI techniques to be discoverable, exportable, exchangeable, plug-able, and sharable. We refer to interaction tasks as the unit of an entry of information by the user and occur repeatedly such as position, select, etc. Moreover, we refer to interaction primitives as the basic interaction units that glue between physical I/O devices and interaction and consumed by application such as panning, pinching, swipe, tap, etc.

Interaction Ensemble on the other hand is defined as "multiple interaction plugins grouped together to adapt the available interaction resources and possibilities to the user's physical context and abilities". So far, interaction ensembles are identified as being useful in 5 different cases (Figure 1):

1. full-similar substitution (replace an IP with another IP with the same set of interaction primitives and interaction tasks). This is useful when a better implementation or specially tailored IP to a particular disability or situation is available.
2. full-different substitution (replace an IP with another IP with the same set of interaction primitives but different interaction tasks). This case can be illustrated when two interaction tasks exist but with different nature (e.g., one based on rotation and the other based on linear movement.) Due to situational disability for example one of them is more accessible by the user or less affected by user's disabilities.
3. full-similar re-composition (replace an IP with composite set of interaction primitives with the same interaction tasks from multiple IPs).
4. full-different re-composition (replace an IP with composite set of interaction primitives with different interaction tasks from multiple IPs)
5. partial re-composition (substitute partial set of interaction tasks from other IPs). This can be illustrated when for example only limited sets of interaction tasks are utilized by other IPs. For example, the user is capable of performing all interaction tasks other than the selection task by hand rotation. The system suggests other similar interaction tasks possible without hand rotation.

Ensembles will enforce better performance and integration of users within their known physical abilities and will also be increasingly useful in physical therapy and rehabilitation, e.g., maintaining and improving mobility, flexibility, strength, gait speed, and quality of life.

2.3 Community-based Designing and Sharing of NI

Community-based designing and sharing of NI are very important in order to easy the use of NI in application development, enhancing application adaptability, and promoting wide deployment of NI based applications. To our knowledge, there is no research specifically targeted at community-based creation and sharing for natural interaction techniques (as Interaction Plugins). This puts STAGE forward to be the first framework to study this concept rigorously. STAGE aims at community-based description of NI techniques and contexts, supporting both ambient interactive system designers and application developers.

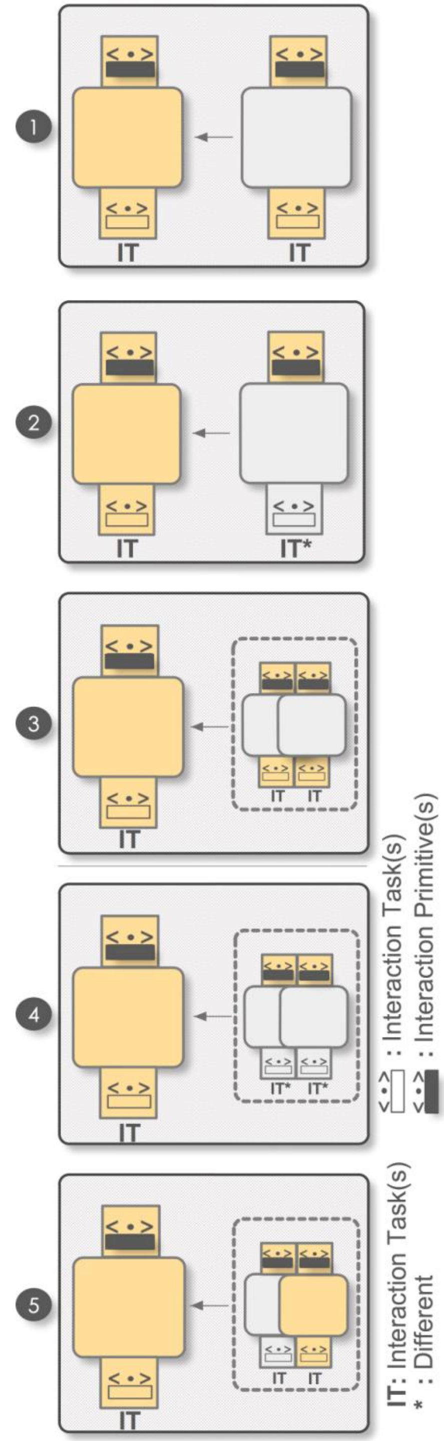

Figure 1: 5 Useful Cases for NI Ensembles

The presentation and readability of interactions are of equal importance to users, designers, and interaction recognition systems. Currently, most research papers use written descriptions, graphical sketches, and videos for the transmission and preservation of NI techniques. Videos, for example, are very powerful to show relationships between movements and excel in transmitting emotion. Even though fields that relay heavily on movement description, such as drama, and dance, do find the aforementioned methods useful, they avoid relaying on them heavily due to a number of inherent problems associated with those methods such as:

- inability to capture detailed description of the movements required,
- affected greatly by the production quality (e.g., videos are affected by lighting conditions and filming angle),
- inability to illustrate timing perfectly (e.g., parallel movements may be obscured by each other),
- and inability to utilize different medium to convey the movement (e.g., movements presented in a sketch are only provided in that form).

For successful transmission (sharing) and preservation (description) of NI techniques, recording and analyzing physical movement methods should be applied. Our research fosters the use of Labanotation (Kinetography) as a system for documenting physical movements required by NI. Labanotation is a system of analyzing and recording movement, originally devised by Rudolf Laban in the 1920's. It is then further developed by Hutchinson and others at the Dance Notation Bureau [8]. Labanotation is used in fields traditionally associated with the physical body, such as dance choreography, physical therapy and drama.

Labanotation comprises a symbolic notation where symbols for body movements are written on a vertical "body" staff. Even though this system is very relevant to HCI research, only few research projects have demonstrated the use of this system to describe interaction techniques such as [11]. This can be the result of many reasons including but not limited to the researchers' lack of familiarity with reading and writing labanotation, the lack of tools for editing labanotation for interaction design, and limited recognition of the importance of documenting and sharing NI techniques. In STAGE, we do not only use Labanotation, but we exceed and extend the adoption of Labanotation in NI interaction design with anthropometric and physical ability profiles which is very important for adapting to the user's physical context in action.

Labanotation as a recording system for NI movements is very useful and has a number of relevant features such as it:

- is an extensive and flexible notation system,
- is easy to read and write (once familiarity is gained with the notation),

- is very logical and systematic,
- specifies movements from very simple and high level description to very specific movement description,
- has a great expressive power due to it's comprehensive symbol set,
- enables choice for designers, about what they represent as significant and relevant aspects of movement.

The richness of the current Labanotation model serves wide range of purposes but at the same time requires enormous learning effort and results into an arbitrary complex notation to read. While preserving the extensibility and richness of the notation, we have opted for a subset of the notation to reduce its complexity and simplify its readability. To this end, the Labanotation subset models interaction sequences to include different parallel and sequential movements of body parts governed by the Labanotation score, which insure accurate time and sequencing of actions.

Labanotation as a graphical language is very powerful for human readers. It is nevertheless not readable by machines as to our knowledge there is no published research or standards on machine-readable representations for Labanotation adapted by the community. MovementXML was presented in a master thesis [7] but it was neither dedicated to natural interaction techniques nor was the project completed. Therefore, part of our current work is to create XML (Extensible Markup Language) representation for Labanotation in order to be able to adapt the system in our proposed approach. We are planning to then extend Labanotation descriptions with the physical ability profiles introduced in section 3.2.1. This combination will be one of the essential driving wheels in the NI matching and decision algorithm in the process of creating NI ensembles based on the physical context and physical abilities required by interactions.

The reminder of this section will illustrate briefly how Labanotation is used in our approach to model one interaction technique as an example. We have selected the DoubleFlip interaction technique, introduced by Ruiz and Li [17], as a simple technique for illustration. The authors define this technique as "a unique motion gesture designed as an input delimiter for mobile motion-based interaction." The authors document the technique using the following written description "the user holds the phone right-handed, he rotates the phone along its long side so that the phone screen is away and then back". Moreover, they supported the description with an additional sketch as shown in Figure 2.

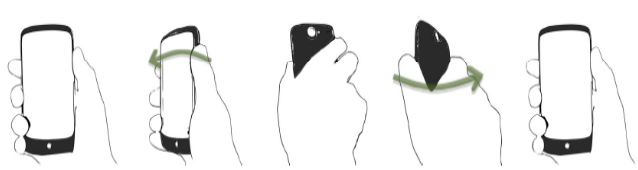

Figure 2: DoubleFlip interaction technique as in [17]

While it was relatively sufficient to relay on text and sketch descriptions for documenting this interaction, it is still relatively hard to explain clearly and insure that the user understands the steps to execute this technique. For example, neither the description nor the sketch clearly illustrates the manner and timing required for this interaction to work. Does the interaction work with very slow hand movement? Is there any break "pause" between the clockwise and counterclockwise movements? Etc.

We have modeled the same technique using Labanotation as in Figure 3. The figure is read as follows: (1) the body balance is equal on both legs and (2) stays that way through out the interaction. (3) The starting position of the right is at rest position along side the body and (4) the position of the lower arm to middle front, where arm and lower arm form "L" shape. Both positions are (5) held through out the interaction. Symbols (6) and (7) illustrate the starting position of the hand palm facing up. The wrist performs strong 180-degree counterclockwise rotation (8) and then returns back with palm facing up by a strong 180-degree clockwise rotation (9). Finally (10) the movement is split in terms of timing the described rotation movements.

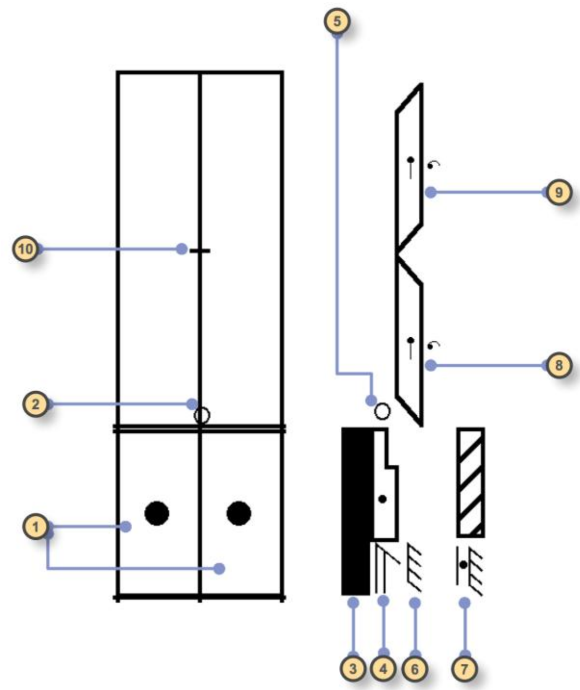

Figure 3: Labanotation representation for DoubleFlip interaction technique

In STAGE, an XML model of this technique is generated and extended with ability profile information needed to execute the model correctly by users. More detailed take on this part of our research is out of the scope of this paper but it is clear that NI technique transmission and preservation become more robust and standardized. More importantly, in the context of STAGE interactions steps and movement become well contained in a movement description entity, which can be also parsed using the STAGE ensemble engine (the core component of the STAGE runtime system, which is responsible to orchestrate and initiate NI ensembles).

3. SYSTEM DESIGN, ISSUES, AND CHALLENGES

3.1 Conceptual View

Edwards et al. [5] explain that technological infrastructures that don't consider full range of human centered concerns present a fundamental tension for HCI and user experience designers. STAGE overcomes this problem by targeting developers and HCI designers equally. It avoids reductionist infrastructure design by taking a deep approach [5] to involve interaction and technically orientated metrics. Pervasive environments inevitably inherent cross-platform challenges. Thus STAGE adopts a cloud-based approach for hosting and processing NI ensembles. This imposes a number of technological challenges to investigate: managing on-device resources (low-level NI capture and preprocessing), eventing and networking problems, and addressing extensibility and modularity needs.

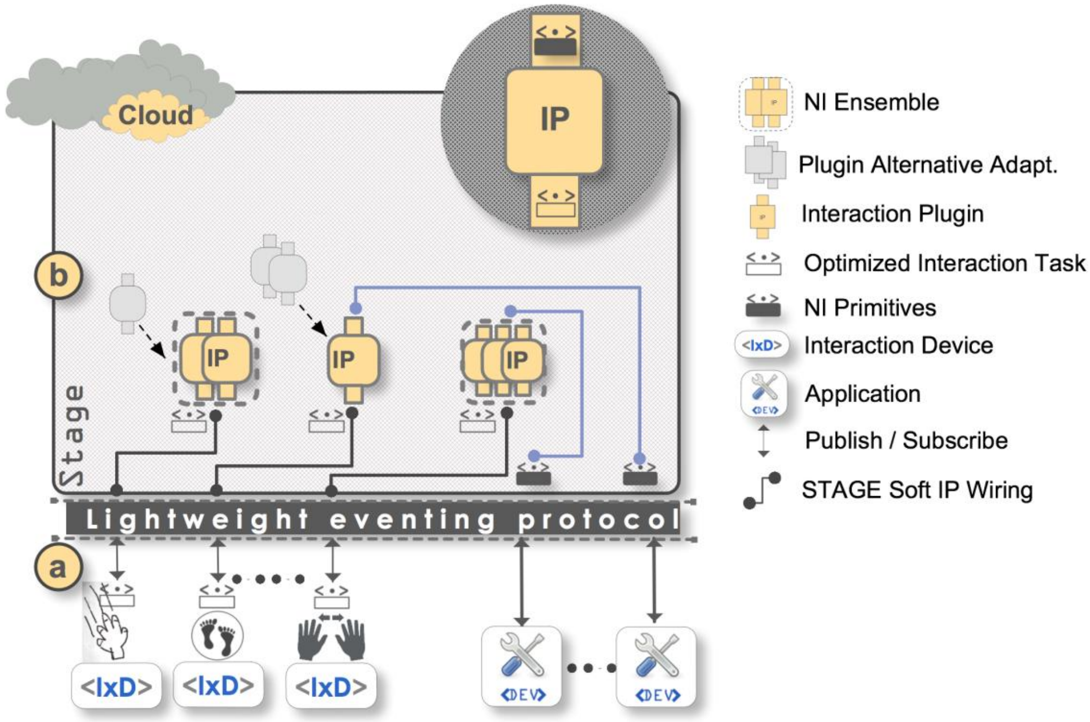

Figure 4: Stage Conceptual Diagram

In Figure 4(a), both interaction devices (interaction providers) and applications (interaction consumers) are based on arbitrary technical platforms, built by interaction designers and by application developers respectively. Both are connected to STAGE via lightweight publish/subscribe eventing protocols such as Extensible Messaging and Presence Protocol (XMPP) aiming at a high level of interoperability and compatibility. STAGE prevails communication problems by avoiding bandwidth intense payloads e.g., images. It uses highly optimized interaction tasks data types based on an extended list of primitives including position, movement, rotation, etc., and optimized interaction primitive data types for the consuming applications such as selection, panning, etc. As indicated in Figure 4(b), interaction designers and HCI researchers create their IPs and publish them using STAGE interaction publishing front end. IPs are controlled by the Ensemble Controlling Unit. Moreover, interactions are provided by a single atomic IP or by an ensemble of IPs orchestrated by STAGE. Interactions provided by an IP may well have a number of implementation alternatives if multiple interaction resource provides alternative implementations of the same IP as shown in section 2.2.

3.2 Assessment of Physical Abilities and Disabilities

Major part of our current effort on STAGE is channeled to develop an interaction-in-context matching algorithm to activate and ensemble the best matching NI for a given user's context. The algorithm utilizes three main concepts: ability profiling, interaction profiling, and ability matrix.

3.2.1 Ability profile and interaction profile

Ability profile (Figure 5) contains quantified anthropometric abilities tested by specialists or the user herself. It is defined by four key elements:

Physical qualities: indicate the required physical skills for the interactions e.g., voluntary movement and range of motion.

Disabilities (quantified by impact scores): indicate the quality and duration of the interaction. Impairment symptoms are normally quantitatively rated with physical assessment and rating scales. Documenting physical disabilities research provides a strong background in this direction. The core matching algorithm in the ensemble engine utilizes then different physical assessment and rating scales to reason about the severity of the symptoms and their impact on the interaction quality.

Major life activities: In our model, each interaction is linked to one or more major life activities such as walking, balancing, seeing, lifting, etc. The ability to perform the required activity is a good indication on the ability to perform the respective interaction.

Major interaction primitives: linked to physical abilities such as selecting, zooming, positioning, shaking, panning, etc. On the other side, interaction profiles shortly describe the interaction generally by indicating the main body part or parts involved in the interaction, type of movement, range of movement, capture method, disabilities, major life activities, interaction primitives, and hardware.

3.2.2 *Ability matrix*

The ability matrix presents disabilities and their direct impact on the major life activities. Major life activities may be affected by one or more disabilities but with different degree. Therefore, the impairment score is used to prioritize the impact of each disability of the interaction quality. The ability matrix (Figure 6) should be developed by physical assessment and diagnoses specialists e.g., physical therapists and physicians, and will be used as a tool by interaction designers and HCI researchers while designing NI.

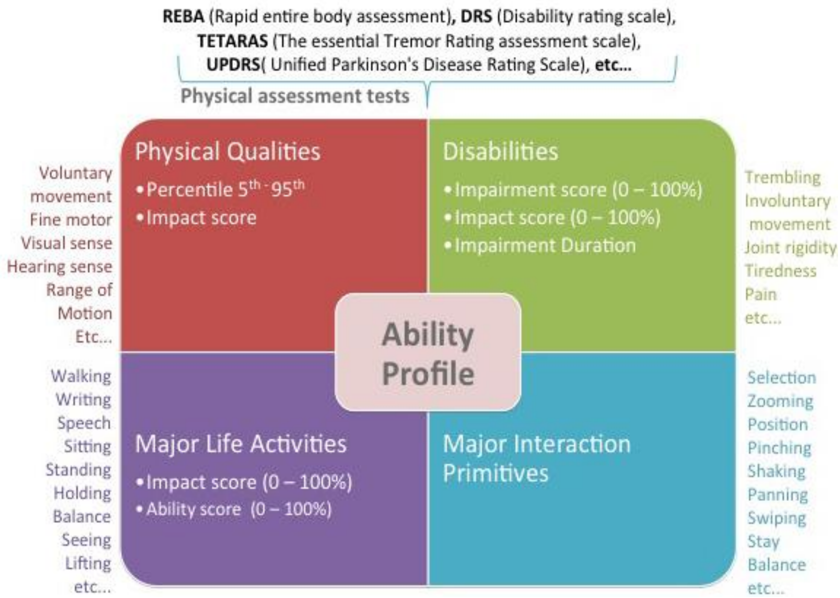

Figure 5: Ability Profile

4. DISCUSSION OVER RESEARCH CHALLENGES

Within this section we examine four challenges relevant to the presented concept of this paper.

- Interaction performance and viability: Performance measures (QoS) such as response time and latency of NI ensembles is affected by the design and implementation of STAGE. Therefore, special attention should be paid to meet an acceptable threshold to hold a smooth, useful, and meaningful user experience.
- Interaction and ability profile matching: There should be a semantic matching between the physical profiles of users and interactions in order to match the user's context and fulfill the interactions primitive required. Physical action required by the interaction should be made part of the interaction semantic. Moreover, the flexibility of movement description in Labanotation triggers challenging aspects such as the complexity of describing movement in fine details and the danger to lose important aspects of interaction in rough descriptions. It is important for the interaction designers to illustrate and stress the main and essential movements for the interactions.
- Interaction sharing: Authoring interactions independently from a specific application is a very challenging aspect in interaction design. Moreover, interaction should be natively designed for orchestration and fusion with others, therefore high adaptability should be maintained.
- Application development: Designing soft-wired applications is more challenging due to NI resource management issues such as NI priority management, conflict resolution, affordance, user involvement and preferences.

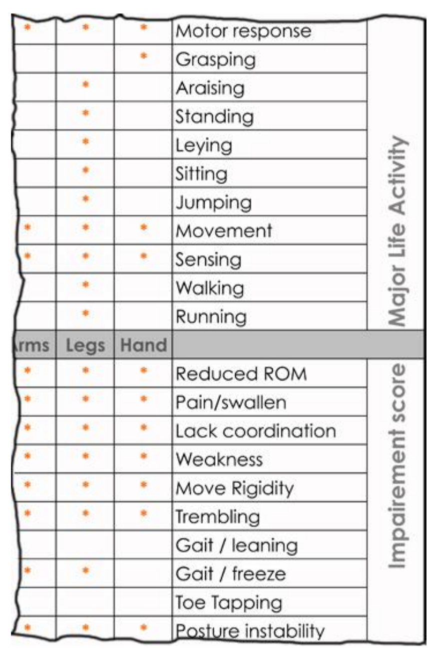

Figure 6: Ability Matrix (excerpt)

5. CONCLUSION

This work is part of the community effort towards utilizing our body in motion for better integrated interactions in ambient systems. We call for Natural Interaction Ensembles as an adaptive model for natural interactions based on physical abilities and anthropometric qualities. This approach opens many important questions regarding developing, deploying, adopting, and sharing interaction techniques. We believe that this area of research could provide new and powerful means of interactions in ambient spaces and can be similarly applied to closely related types of interactions such as tangible interactions.

6. ACKNOWLEDGMENTS

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Choreographing the glitch

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ABSTRACT

glitching is a digital installation and performance art project that attempts to re-describe movement derived from characters in contemporary sports and action computer games.

Gaming characters of the 21st century have an extraordinary embodiment, fluidity of movement and naturalness, becoming more and more realistic and convincing, thanks to constant improvements in technology. However, there are always exceptions; disruptions, imperfections and glitches, whether through unexpected programming errors, forced "cheats" or the users' inability to control the characters in seamless game-play. There is still the potential for awkwardness, otherness and instability between spells of perfection.

glitching re-focuses the artificial nature of these disruptions by employing highly trained real bodies i.e. professional dancers, to re-stage them. The project attempts to interrogate how real bodies cope with, and interpret into sequences of choreography, the limits of such foreign and unnatural movement and subsequently, how this physically re-enacted choreography can be embedded and re-imaged within a responsive digital environment.

Appropriating the premise of the latest home entertainment dance and training games, *glitching* employs the motion-sensor controller Microsoft Xbox Kinect, large-screen display and a pseudo game interface, to create a full-body, skeletally controlled, interactive experience. The audience is invited to step into the digital shoes of a 'lead dancer' character, and attempt to follow the awkward and intricate, glitch choreography performed by the dancing troupe on screen.

In conjunction with the installation there are a series of *glitching* live performances featuring dancers Tony Mills, Hannah Seignior, Felicity Beveridge, a performance soundtrack devised by Martin Parker and the interactive installation as backdrop.

General Terms

Algorithms, Performance, Design, Experimentation.

Keywords

Glitch, glitching, Kinect, performance, art, physical interaction, choreography, installation.

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1. INTRODUCTION

To reflect on the intersections between humans and machines, and wonder what the unceasing developments in science and technology might mean for being human. [18]

This eloquently simple yet astute statement from Alex Taylor, Sociologist at the Microsoft Research (MSR) Cambridge Lab, about his research goals, resonates with for my own aspiration as an artist, having spent the past sixteen years creating digital media projects that interrogate the impact of technology on the body, relationships and human experience. This has resulted in a diverse body of work, with a range of forms and media including: websites, real-time 3D, animation, interactive installation, digital prints, mobile short films and game art.

Figure 1: Doppelganger 2012. Digital prints. Copyright: Beverley Hood.

Throughout this time, I have undertaken numerous collaborations with a wide array of practitioners from within the fields of art, science, and technology, including dancers, writers, programmers and dermatologists, in an effort to explore human interactions and interfaces with technology.

Although, I would argue that my scrutiny of our complex relationship to technology is current, I also recognise that this creative line of enquiry is not a novel undertaking. Extraordinary historical works from a range of creative practices, including Mary Shelley's *Frankenstein* (first published in 1818), are significant demonstrations of much earlier investigations into the implications, influence and pressure exerted upon human existence by technology, development and industry.

Mary Shelley's Frankenstein makes the first post-human life form of a modern age… Shelley writes far in advance of the digital computers which later begin to effect such developments, but she clearly feels the stirrings of artificial life even as industrialization begins and does much to programme the dreams and nightmares of the next two centuries… [15]

My digital art projects operate as both as both cultural artefacts and practice based research, existing within and beyond the academic framework, into the gallery, museum and wider art world. Through my creative practice I attempt to generate projects that are both recognised research outputs and cultural manifestations. This requisite for academic creative practitioners creates a continual struggle, wrestling with the expectations and conventions of divergent worlds. The projects that I create are distinct from early twenty-first century positivist influenced research, dominated by "a paradigm based on an invisible observer, conducting unbiased, objective, repeatable, verifiable experiments." [9] Central to my approach to creative practice is an attempt to question, interrogate and often problematize through the utilisation of artistic process, as a critical tool of engagement and method of enquiry. I attempt to interweave theoretical research within discerning artistic methodology, closely linking process of production, form and media to the concept being explored and interrogated. The aim is that artistic form and process develop in parallel and resonate with concept. My practice, I would argue, can be seen as an example of Kozel's interpretation of a phenomenological approach; exploring the possibilities highly subjective, intuitive, and experiential ways to negotiate technology that can resonate on many levels: cognitive, emotional, physical. It is a practice that revels in "the seemingly illogical, nonsensical, ambiguous, or even the preposterous or the sublime." [10].

2. COMMISSIONING GLITCHES

My most recent artwork, *glitching*, is a digital installation and performance project that attempts to re-describe the movement derived from characters in contemporary sports and action computer games. Commissioned by the Scotland & Medicine partnership for the exhibition *Human Race: inside the history of sports medicine* (with additional funding from Creative Scotland and Edinburgh College of Art), the project tours museums and galleries in Scotland throughout 2012, as part of The Scottish Project, an official part of the London 2012 Cultural Olympiad. The exhibition presents historical artefacts alongside newly commissioned artworks to examine the relationship between sport, exercise and the body, organised around themes such as pushing limits and breaking boundaries [4].

My approach to this commission was to scrutinise contemporary manifestations of sports, exercise, training within gaming, the technology that has emerged around this, and the wider impact that contemporary gaming has upon our perceptions of the body, physicality and presence. Central to my enquiry was a focus on malfunction, interference instability, i.e. the glitch.

The gaming world is voracious in harnessing, driving and implementing, the constant and rapid improvements in technology. As it grows ever more sophisticated and ubiquitous, the movements of characters become more and more realistic and convincing. Gaming characters of the 21st century have an extraordinary embodiment, fluidity of movement and naturalness. This virtual physicality is often derived from the real; games such FIFA, use motion capture and body scanning of professional sports players to create convincing, highly distinct individualistic motion sequences to be used within real-time gameplay [11].

However, there are always imperfections, interference and glitches, whether through unexpected programming errors, the users' inability to control the characters in seamless game-play (resulting in bumping into walls, misfiring, etc.) or the fully intentional cheat. There is still the potential for awkwardness, otherness and instability, between spells of perfection and it is this unintentional, uncontrollable disruption that I am interested in.

Glitches are a rich area of artistic enquiry, with entire publications and virtual museums devoted to artists and designers inspired by the glitch, for instance the *IdN: Glitch Issue*, 2011 and Mark America's project *The Museum of Glitch Aesthetics.* The American artist, Clement Valla, used the glitch as source and reference for a series of digital images, *Postcards from Google Earth* (see Figure 2), which exploit the disruptive, imperfect, and problematic rendering of certain physical terrains by Google Earth. Valla sites his interest in glitches deriving from the fact that "Glitches generate forms that no individual has thought of or set out to create. Rather, they result from the interaction of the material processes (glitches due to hardware), the code (glitches due to software), and the user or programmer." [20]

Figure 2: Postcards from Google Earth 2011. Digital image. Copyright: Clement Valla.

The artist collective JODI, are well known for their artistic tactics of modification, disruption and interference. In 2006, they created *Max Payne Cheats only*, a work derived from the glitches and cheats within the video game *Max Payne 2: The Fall of Max Payne*, developed by Remedy Entertainment. In this work JODI captured glitch/cheat alternatives to the prescribed gameplay choices, pathways and pursuits of the Max Payne characters, to create a series of short videos. The resulting artwork exposes vacuous characters, endlessly repeating absurd cycles of perpetual motion (jumping, loading weapons, subsuming camera), boxed into digital dead ends; in toilet cubicles, stairways and back lanes, digressing from the main game action. The characters are further isolated from their origin and purpose by the artists reorganisation of these looped video captured sequences, within a numerically organised index of webpages, an ambiguous construct that imparts no information pertaining to its derivation or meaning.

Jodi have intervened in the programme structure in such a way that absurd perspectives and effects alter the game's otherwise realistic graphics: we see the massive hero repeating idiotic movements; he dips his angular head into a virtual matrix; his body appears semi-transparent. [19]

3. FROM GLITCH TO GLITCHIING

The *glitching* project, focuses on the absurd, artificial, disruptive and unstable nature of bodily movement that transpires during gaming character glitches. My research into the occurrence of these glitches was assisted hugely, by the reams of game-play footage posted on YouTube, by gamers. The phenomena of posting video captures of individual game-play, means that a vast amount of data exists online demonstrating glitches and cheats from almost every game title on the market (see Figure 3). A simple search for "glitches" on youtube.com brings back about 344,000 results. For the *glitching* project, this immense database was filtered down into a library of approximately 75 glitch instances, by selecting best quality captures of duplicates (for example "Skate 3 Super Jump glitch" brings back 885 results).

The important question for me was how this collection of glitches (artificial, alternate, other movements), might be deconstructed, re-embodied, and re-staged by applying to the human body. Attempting to interrogate whether by taking the digital and transplanting it, re-interpreting it, embodying it within the physical body – literally re-enacting it – would it disintegrate, transform, and become something new?

To undertake this enquiry, I employed highly trained, real bodies i.e. professional dancers. The primary dancer I worked with was breakdance world champion Tony Mills, a performer of "compelling expressiveness and versatility" [2] with an extraordinary ability to interpret, create and enact awkward, extreme and atypical movements. Tony's creative practice bridges the international "breaker" world, with his BBoy crew Random Aspekts, alongside performances with international contemporary dance companies, such as Derevo, Curious Seed and his own dance performance company Room2Manoeuver.

Tony and I attempted to foster a collaborative research and production environment, which would enable us to discuss, question and create through a rigorous process of critical deconstruction and construction, across disciplinary constraints. The aim of this collaborative relationship was to foster complexity, depth and meaning in the integration of concept, process and form.

We attempted to collaboratively interrogate how real bodies cope with (and interpret into sequences of choreography) the potential and limits of the foreign, unnatural movement of computer glitches. A creative pioneer analysing the limitations of the human body, physical conventions, and potentially "redefining what the body can do" [13] is choreographer, Wayne McGregor and his radical dance company Random Dance. McGregor's 2010 production *Far*, attempted to establish a "radical cognitive

Figure 3: Skate for Xbox 360 2007. Copyright: Electronic Arts.

research process" [16] drawing upon the input of neurologists to "un-pick" conventions within dancer's individual vocabularies of movement, disrupting and challenging patterns of behaviour. The resulting work revels in absurd, unconventional, highly individualistic and idiosyncratically performed choreography.

glitching was choreographed by drawing from our YouTube video library, and establishing collectively defined glitch categories, including "jitters", "rogue limbs" and "impossible moves" i.e. movements seemingly only possible within a digitally constructed body, beyond the limits of human potentiality. Tony Mills was the physical conduit, attempting to decipher, re-structure, and enact the individual glitches, whilst continually responding to my creative critique, questioning and contribution.

Through a considered but open, focused but non-precious process of production, we collaboratively created choreographed sequences. Individual glitch re-enactments were antagonistically sequenced, to create un-harmonious, anti-flowing, provocative pairings and relationships. Once constructed and reconciled, these established sequences were deconstructed and re-arranged; transformed by an alternatives such as orientation (i.e. standing sequence translated to the floor), randomised order and adjusted duration. This choreographic process included the establishment of an overall physical texture to the re-enacted glitches, including tight muscular control based on popping techniques, non-symmetry, and offbeat tempo (i.e. not working to a typical 4, 8, 16 bar count). Furthermore, we considered the behavioural qualities of computer game characters, as potential examples of Kozel's pre-reflective state; permanently active performers, even in 'idle' mode, locked into the immediate moment. Unaware of ensuing data requests, these "non-knowing" characters are actively fixed in a series of looped data feeds or performance states, instilling them with an air of being simultaneously present and distant.

This fluid, iterative production process was established through a series of short collaborative development workshops over a period of four months. Ultimately, this activity resolved into the creation of a four minute choreographic sequence, set to a soundtrack 'Video Computer System' by Brazilian electronic music duo Golden Shower.

4. EMBEDDING THE INTERFERENCE – CHOREOGRAPHING THE INTERFACE

The *glitching* project attempts to consider how these character glitches, physically re-interpreted in to sequences of choreography, can subsequently be embedded and re-presented within a responsive installation environment, for an audience to interact with.

Initially, this entailed digitising both the physically enacted glitch choreography, and performer, Tony Mills. Central to this process was the motion controlled sensor, Microsoft Xbox Kinect. Marketed as a gaming controller but infamously hacked only a few days after its release in 2010 [1], the Kinect is an extraordinary example of gesture driven hardware, accessible and affordable, with radical potential for creating physicality based interaction. Microsoft emphasise its potential, when used in tandem with their Kinect Software Development Kit (SDK), in the hands of developers, to create natural user interfaces (NUI) [12]. I wholeheartedly recognise the relevance of developers, programmers and technologists in this area of enquiry, especially since the Kinect is not an easy tool to tackle without significant technical competence. However, I would argue that creative practitioners are equally important within this development, to interrogate, question and re-examine the implications, potential and resistance of gesture driven, physicality based interaction.

The Kinect SDK uses a twenty point (or joint) skeletal tracking system, allowing the whole body to be digitally mapped. However, the data generated from this tracking is always an approximation, based on algorithmic assumptions, open to disturbance and noise (such as the effect of bright sunlight), it is variable and contingent.

In the *glitching* project, the Kinect was initially utilised as a motion capture device to digitise the physically enacted glitch choreography, performed by Tony Mills. Pre-existing hacks, plugins and commercially available Motion Capture software, developed specifically for the Kinect were trialled, evaluated and experimented with. This enormously rich, but immature technology has been radically exploited [3], with a multitude of uses, users and channels of distribution. Unfortunately, as a result, the reality of working with the Kinect presents an unstable development environment, rife with technical difficulties, inconsistencies, and frustration.

In light of the *glitching* project's conceptual embrace of interference, instability and malfunction, we attempted to harness the Kinect's disruptions and inconsistencies, as constructive matter to feed back into the project. For example, trialling the Kinect as a motion capture device with the freeware vocaloid animation software MikuMikuDance, (created by the Vocaloid Promotion Video Project) generated a fresh manifestation of the glitch choreography, re-configured amidst digital noise and skeletal misinterpretation. The resulting data, collated as digital video sequences, were subsequently used as reference material to modify the texture, countenance and characteristics of the physical choreography.

Ultimately, the conclusive glitch choreography sequence was captured using the iPi Desktop Motion Capture System, and applied to a computer generated 3D model of Tony Mills. The digital Tony was constructed by appropriating and adapting pre-existing character models, available within Autodesk MotionBuilder 2012's 'Content' libraries and Unity 3 Game Engine's 'Asset Store'.

Choreographing the interaction between audience, computer generated model and glitch choreography was the ensuing challenge. To bring computer generated movement i.e. glitches, into the real world and then playfully attempt to interweave this back and forth between the digital and real world environment, exploring overlaps, tensions and distortions evolved early on as an astute and pertinent tactic. Central to this approach was an inquiry into the possibilities of embedding physicality-based interaction. As a result, *glitching* appropriates the premise of current home entertainment dance and fitness training games (such as Just Dance, Dance Central and Your Shape:Fitness Evolved). Employing Microsoft's Xbox Kinect (in its original function as a motion-sensor controller), a pseudo gaming environment and large-screen display, *glitching* presents a full-body interaction, digital installation for the public to "play" (see Figure 4).

Figure 4: glitching 2012. Installation. Copyright: Beverley Hood

The *glitching* "game" was developed in C# using the Unity 3 Game Engine and the Microsoft Kinect SDK. Employing the expertise of experienced games developer, Hemal Bodasing, pre-existing Kinect plugins were evaluated and considered. Consequently, the Carnegie Mellon University's *Kinect Wrapper Package for Unity* was adopted, fulfilling fundamental functionality, and providing an initial technical development base. Hemal subsequently adapted and re-shaped the Kinect Wrapper/Kinect SDK relationship to suit the requirements of *glitching*. The development process was iterative and agile, happening in short, often weekly, cycles.

The result is a stand-alone Unity project, running on PC platform (Windows 7), installed with the Microsoft Kinect SDK drivers. Using skeletal tracking, the Kinect attempts to trace the entire viewer's body, transferring their movements onto the 'lead digital dancer'; the Tony Mills character, centrally positioned within the digital "game" interface (see Figure 5). Stepping into this full-body controlled mechanism, enables the viewer to be co-present "with that which is other to itself" [6], physically inhabiting the digital character. The co-present viewer is able to virtually trigger the glitch choreography, performed by the two digital backing dancers on-screen, and attempt to follow the awkward and intricate choreographic sequence in action.

Figure 5: glitching 2012. Interactive installation interface. Copyright: Beverley Hood

On the surface, the Microsoft Xbox Kinect appears to present an uncanny example of Donna Haraway's proposition that "The difference between machine and organism is thoroughly blurred; mind, body and tool are on very intimate terms" [8]. However, *glitching* reveals that this blurring is regularly brought sharply into focus, since an encounter with the Kinect is in itself rife with interference, resistance and glitches. As the participating viewer attempts to follow the glitch choreography onscreen, their movements are distorted, transformed and contingent, due to skeletal limitations, (mis)interpretation and unreliability of the data from the Kinect. Akin with Giannachi and Kaye's analysis of presence, where the 'I am' interacts with that which is before or in front "the environment generated by this process, is not neutral but rather charged, fraught with tension." [7]. This dynamic physical interface creates an additional layer of glitch within the live interactive experience; improvised, unpredictable and uncontrollable. The participating viewer is both an active and disruptive contributor.

5. PERFORMANCE DISRUPTION – INTERFERING WITH THE GLITCH

Presented in conjunction with the *glitching* installation, are a series of live *glitching* performances (see Figure 6). Utilising the digital installation as backdrop, source and reference, the performance is presented as a production in five parts, executed as a series of expanded glitch cycles, with a running time of approximately 30minutes. The performance was devised collectively through a series of development workshops with dancers Tony Mills, Hannah Seignior, Felicity Beveridge, and composer Martin Parker, over a four month period in 2012. To this, Tony and I brought the already existing glitch choreography and Kinect technology (from the digital installation), as source material to encompass and build upon. The performance concludes with an invitation for the audience to step on stage to 'play' and interact with the digital installation interface.

Throughout the development we presented "showings" (informal presentations of the performance in-progress), to a small invited audience, the feedback from which was built into subsequent project development. This iterative, collective and open development process, brought about technological adaptation, radical reconstruction of the original glitch choreography sequences, refinement of performance qualities and composition of an audio environment that included both a set soundtrack and improvised, performer controlled audio, enacted using a gaming controller on stage.

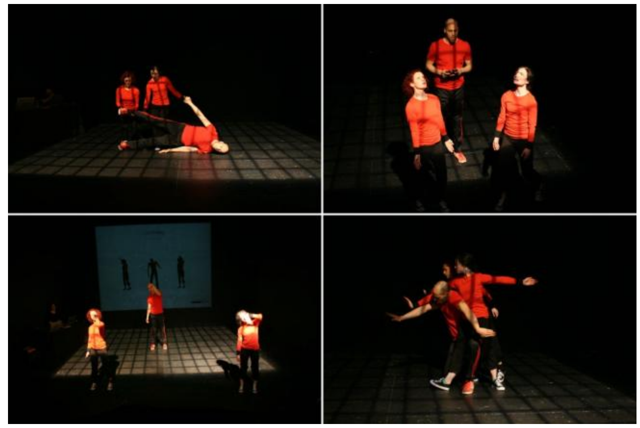

Figure 6: glitching 2012. Performance. Copyright: Kim Beveridge.

Embedded within the *glitching* project are multiple copies, versions, distortions and deviations: the physical movement "source" Tony Mills, the motion captured data, translated and re-interpreted by software, the re-enactment of this within the Unity game engine, and the distortion applied by the Kinect sensor in its translation of the participating viewer's movements. In the performance, this layering of copies and versions is taken to another level, with the source, Tony Mills, coming back on stage to dance with a distilled, re-interpreted, and disruptive, representational other of himself.

Real world echos, in the form of Hannah Seignior and Felicity Beveridge, become yet more copies, but in this case human embodiments, bringing their own personal, physiological and phenomenal interpretations. The choreographic material, appears in an array of divergent iterations, each imprinted with the qualities and effect of its processing whether physical enactment or data interpretation. *glitching* resonates, with Marcel Duchamp's thoroughly inconsistent (and mostly undefined), but potent concept of *infra-mince* as suggested by Gavin Parkinson, i.e. that it is concerned with "manifesting a sense of 'slippage' – of loss, lack or infinite multiplicity – threatening at once the unity of the self and the possibility of an absolute comprehension of the world." [14]. *glitching* absorbs and revels in the disintegration, misinterpretation and unreliability of the exchange of data from one source to another.

6. CONCLUSION

glitching sits within a diverse, rich body of creative projects, exploring the limitations, disruptions and malfunctions of technology, as potentially constructive attributes. It is also an attempt to investigate the potential of motion controlled, gesture driven technology as a tool to create physicality based interaction within installation and performance.

The project constructively assimilates Rinehart's adaption (motivated by the emergence of digital art) of Benjamin's assertion that "the work of art reproduced becomes the work of art designed for reproduction" [17]. This reproducibility is embedded within concept, development process and final artwork, which exists now, as multiple releases, adapting to its presentation environment whether installation or performance.

Michael Freid asserted that "art degenerates as it approaches the condition of theatre" [5]. If this is the case I would gladly argue that *glitching* is intentionally, highly degenerative.

7. ACKNOWLEDGMENTS

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NUI-based Floor Navigation — A Case Study

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ABSTRACT
In this paper, we describe a nui-based application using a Microsoft Kinect. The system displays a digital represen- tation of a university building, where users can navigate virtually through contact-less gestures. Users can step up and couple their hand with a virtual mouse cursor to navi- gate through the program such that hand movements to the right lead to cursor movements to the right for example. We present an evaluation of the system, which is based on a 100' day operation by logging 2.000 user sessions.

Categories and Subject Descriptors
H.5.m [**Information Interfaces and Presentation**]: Information Systems Applications Miscellaneous

General Terms
Design, Documentation, Experimentation, Human Factors

Keywords
User Experience, Inject,

1. INTRODUCTION
Natural user interfaces is a well researched topic over the past years. Gestures play a central role for contact and non-contact interfaces as well. In particular, the huge success of smart phones fosters a lot of innovative development. However, there is also the need for contact-less gestures, e.g. within an operating room or behind a shop front window. The number of smart ideas and applications of contact-less gestures have exploded since the availability of the Kinect [4]; a piece of hardware which is cheap, easy to program and easy to embed into complex systems.

We describe the design and evaluation of a system for NUI-based floor navigation within a campus building at the University of Koblenz. The system is part of a campus-wide information system, which is used to display various kind of information in buildings and within the university restaurants.[1]

There are three main challenges of this application:

- Users do not play a game. The user who stops in front of the door plan wants to solve a specific task, namely looking for a room or a person. They are generally not willing to spend time to learn or to experience something new.
- There is no chance to teach the user or to make them read a manual before using the device.
- There are no commonly accepted gestures for controlling a screen - we have to assume no prior user experience.

Figure 1: People using the gesture control

Specially the last point turned out to offer a real challenge for the design of the gesture interface. Many users find themselves rather helpless with regard to the system. During the design phase of the system we did some experiments in order to find the most appropriate gestures. After installing the system, we collected data about the usage in log files along with vid4eos of the users's behavior. We will offer an evaluation of the first few months of the application in a public building on campus.

2. RELATED WORK
The scene in Steven Spielberg's *Minority Report* science fiction movie is well-known where Tom Cruise uses gesture control to manipulate images. This was unimaginable in 2002, but now 10 years later it is a reality. Samsung has just released a new Smart TV with voice and gesture control. In the field of natural user interfaces a lot of research has been conducted not least since Microsoft released the Kinect: A cheap and robust sensor and a SDK for developing. More than 100.000 individuals downloaded the SDK in the first six weeks. Using a display with gesture control instead of a touchscreen offers the chance to install an interactive display behind a shop front window for presenting their goods or just analyzing the user behavior [6]. Besides doing research and using it within home entertainment, the usage of the Kinect can be useful in several scenarios where input with controller or touch are not useful. In the medical field it is used to manipulate medical images without having to touch a controller [2], reducing the chance of hand contamination in operating theatres [1]. For using it in such a critical environment it is important that the handling is as simple as possible. But finding simple and intuitive gestures is not trivial. "*Poke it or press it*, everybody had a very different idea of what that actually meant." [3]

3. THE APPLICATION
The system is located in the entrance area of a newly constructed university building. Users unfamiliar with the new building should find their way around quickly. Therefore, the goal was to develop an innovative interactive application, which empowers their users to acquire detailed information on floor levels and individual rooms, such as names of employees

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and contact data. The application allows users to navigate through the building with the help of gestures, moving a virtual hand over a floor map displayed on an up-right widescreen TV fixed to a wall. Using gestures instead of a touchscreen enables the usage of the entire display for everyone, also for small or handicapped people.

The floor plan of the entire building, including all rooms, was to be coherently displayed in an application and run permanently on a mini linux computer. The navigation through rooms and floors is enabled by gesture controls. The following gestures were to be implemented: Wave, push and swipe. Each of these are then associated with actions to enable navigation as shown in the following table.

Table 1: Defined gestures and their calling actions. *Push is realized by holding the hand 4 sec. above the clickable element. (cf. Figure 3)

gesture	action
Wave	*Activate*
Swipe_Left, Swipe_Right	*Switch_Person*
Swipe_Up	*Switch_Floor_Up*
Swipe_Down	*Switch_Floor_Down*
*Push**	*Entered_Room,Left_Room, Floorbox_Pushed, HelpButton_Pushed*

In order to allow the selection of certain rooms, the user's hand should be coupled to a virtual mouse cursor on the screen so that objects can be selected on the screen similarly to the way objects are selected with a normal mouse on a computer. An object should be selected by an appropriate gesture. Depending on the selected object, different information can be displayed. For lecture halls, this information contains the name of the current lecture being held, the person holding the lecture, and the subsequent lecture.

For offices, this information includes the employee's name, his/her contact information, an avatar or photograph, and a QR-Code with condensed information of that person. The necessary contact data for all employees and lectures can be updated every night and saved in a database.

3.1 Implementation

The system development was separated into two parts. The floor plan application and the development of the gesture recognition and control of the application. The entire program is written in C++ with the help of the OpenFrame-works toolkit. All necessary employee and lecture information for the floor plan part is retrieved from a database so that only up-to-date information is displayed.

For the gesture recognition, the SensorKinect driver by Primesensewas used in combination with OpenNI (Open Natural Interaction) [5], a framework which provides several different APIs for natural interaction devices. Additionally, NITE (Natural InTEration) was used. This framework also provides APIs for interaction between humans and machines. By combining these three technologies it is possible to read and analyze Kinect data. OpenNI provides functionality so that new data from the Kinect can be analyzed and gestures identified.

3.2 Gesture Design

As mentioned in the introduction, there are three main characteristics of this application. During the design of a prototype we had to address all three of them:

- Users do not play a game. A user stops in front of the screen in order to get information quickly. At this moment they do not know that the screen can be controlled by gestures. In order to clarify this, we run a movie in the lower part of the screen (cf. Figure 1), which shows a hand waving permanently together with the written info, that this is the way to activate mouse-control manually (cf. Figure 2). After the user's hand is recognized and tracked, the user can move the curser. This turns out to work nicely, however many users put down their hand after activation instead of controlling the curser. They simply expect another action from the system.

Figure 2: Video help for session activation. Translated into English: "Hand {control: Wave. Please two meters distance."

- No chance to teach the user. In a first approach during the development of the system we offered our test users wiping and pushing gestures. However, it turned out to be rather difficult to offer these gestures. We learned that users do not read any further help which is displayed on screen. Moreover, they immediately try to use individual gestures. Recognizing and scaling these gestures appears to be too difficult for a practical application. Therefore, we decided to use a rather traditional approach, clicking is implemented by mouse-hovering, depicted in Figure 3.
- No commonly accepted gestures. During the experimental phase of the system design we learned that an average user has a lot of problems in using gestures for navigation if there is no instruction. We will discuss this point in the following evaluation.

Figure 3: Mousehoover feedback for clicking actions.

4. EVALUATION

The Evaluation was done by analyzing the internal log files. In addition, we used videos, captured with the built-in camera.

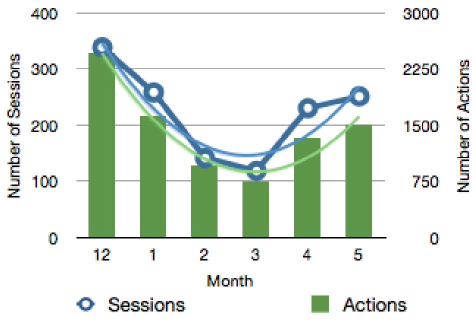

Figure 4: Usage during the time period: shows the number of sessions and the number of actions per month

4.1. Usage of the system

Figure 4 shows the distribution of the usage during the last months. The number of sessions and actions decreased during the semester and reached their minimum in the semester break. Afterwards, both figures started to increase again. The number of actions per session is nearly constant about 6 (see Figure 5). This development during the last 5 months proves the acceptance of the system as a daily routine. We will investigate this in more detail in the following.

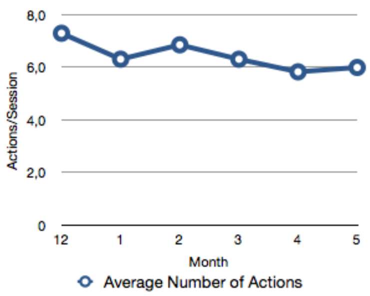

Figure 5: Average number of actions per session during the time period

4.2. Sessions, actions and events

Overall, since the rollout till now (14th of May) a total of 2.065 sessions have been started. On closer inspection, we have detected that 165 sessions have been opened unintentionally by people standing close to the system while talking to another person gesturing with their hands. Additional, 368 sessions have been recorded which contain no opening action. This means that during these sessions the person in front of the system tried to activate the control but did not succeed. Additional, 469 sessions have been successfully opened but the interacting person did not recognize the announcement on the display. If we adjust the logs and reduce these failure sessions we count 1.202 successfully opened sessions with 7.833 actions and 4.751 events. Unfortunately, we count 3.083 actions which did not lead to an event.

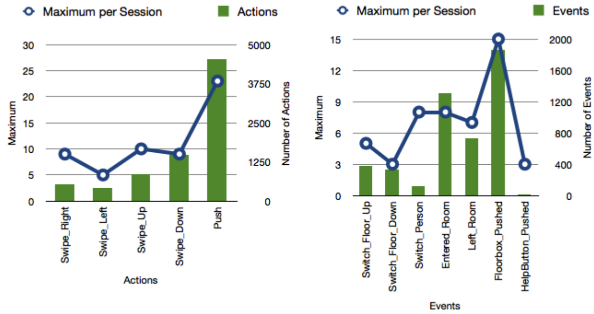

Figure 6: Total number of actions (left) and events (right) and the maximum number of each action/event performed per session

Figure 6 depicts the distribution of actions. The most performed action was Floorbox Pushed and, interestingly, the HelpButton was pushed only 19 times, even though it is placed very visibly.

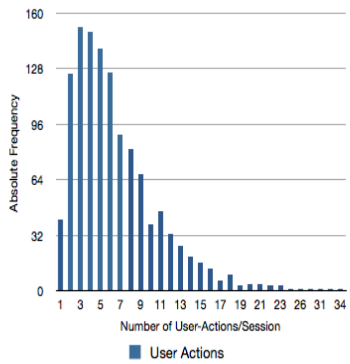

Figure 7: Distribution of number of actions per session

Figure 7 presents the distribution of the number of actions per session. 60% of all people performed more than 5 actions. At maximum, one person performed 34 interactions within 79 seconds another person spent 181 seconds while doing 18 interaction steps. In total, all users spent 36.380 seconds accordingly 10h 6min. The average usage time is 30.2 seconds per session and 4.6 seconds per action.

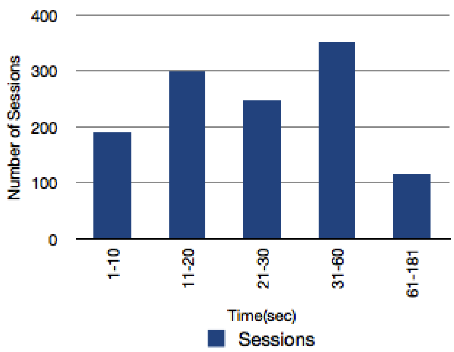

Figure 8: Duration time user spent

Figure 8 shows that most of the users spent more than 10 seconds within a session. This is not because of the unfamiliarity with the user interface, as shown in the following evaluation of the recorded videos.

4.3. Observing the users

The videos, we recorded for a more careful semantical evaluation, show that many users performed exaggerated motions in front of the system at the beginning of a session, but after a short while they learned how to control the system.

Indeed, learning-by-doing is the most important factor in the shift from novice to experienced user. We analyzed the videos of 188 sessions during a period of 17 days. In these sessions we counted 176 different people standing in front of our camera, 88 people interacted with the application (Figure 9). In 129 sessions the interacting person was accompanied by other people. The maximum was a group of 5.

The video analysis also showed some gender aspects. 33 of the interacting people were female and 55 male. Males performed more actions and harder than females. The maximum amount of actions was 16 performed by a male (11 female) and the average amount of actions per session was 7.7 by males (5.0 female).

Most of the interacting persons showed positive emotion. 85 percent of the females and 78 percent of the males left the place with a smile on their face.

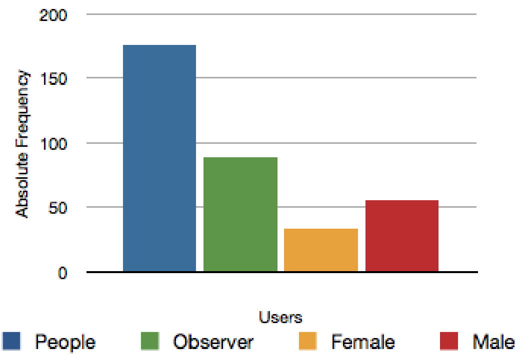

Figure 9: Distribution of interacting people

5. LESSONS LEARNT

The development and the evaluation of the system reported in this paper started as a student project. In the beginning a lot of experiments have been done in order to find easy and precise gestures for the specific task of a floor navigation system. During this initial phase it turned out that this is by far not trivial. For example, we thought that waving is a good and simple gesture to activate the application control. But we had to learn that people wave hands in their own way and a lot of them did not achieve to take control of the application. From this experience we came to the solution to show the activating waving-gesture in an introduction video, which is shown whenever the screen is not in use.

When we finally mounted the system on a wall in the entry area of the building, we learnt a lot about changing lighting in the building in the course of an entire day and about its influence on the performance of the system. Also, the area in which the Kinect should identify users and react to their actions has to be determined by numerous experiments. Then we started the evaluation phase in which we collected the data which was evaluated in the previous section.

The main points from this evaluation are

- Since there is no chance for such a system to train users, it is important that learning can be done during a single session. The number of actions necessary to perform an event is usually decreasing during a single session, which clearly indicates that the user learnt to control the system more efficiently.
- Our evaluation during several months proves that such NUI-based systems are ready to be used in real-life applications under realistic and natural conditions.
- The video analysis of a smaller sample gave us additional insight into the behavior of users. Although this analysis is of course rather limited, because it is based on interpretations of the assessor, it can be used very well as a kind of formative empirical evaluation.

For us it was fun to develop the application and for most of the people using it, it is was fun too. A more detailed description and evaluation we will give in an other paper.

6. ACKNOWLEDGMENTS

We thank the University of Koblenz for giving us the opportunity to install the system and thus having the chance to use thousands of users for this research.

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Towards a framework for the rapid prototyping of physical interaction

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ABSTRACT
Physical Interaction is based on sensors and emitters that convert real world data into digital data and viceversa. Accessing to these data in a meaningful manner can be a hard process that requires knowledge of the underneath physics and many hours of programming. Furthermore, data integration can be cumbersome, because any device vendor uses different programming interfaces and communication protocols. We introduce preliminary work for the design and implementation of a framework that abstracts low-level details of individual devices. We aim at providing access to sensors and emitters by means of a unified, high-level programming interface that can be used for the rapid prototyping of interactions that explore the boundaries between the physical and the digital world.

Categories and Subject Descriptors
D.2.2 [**Software Engineering**]: Design Tools and Techniques — software libraries; user interfaces . H.5.1 [**Information Interfaces**]: Multimedia Information Systems —artificial, augmented, and virtual realities . H.5.2 [**Information Interfaces**]: User Interfaces — input devices and strategies; interaction styles; prototyping; user-centered design .

General Terms
Design.

Keywords
Tangible interaction, ubiquitous interaction, programming toolkit.

1. INTRODUCTION
Human Computer Interaction is a multidisciplinary research area that embraces knowledge from computer science, psychology, sociology, cognitive science and design among others.

The profile of researchers in interaction and user experience design, who deal with new interactive technologies, found its archetype in the Renaissance man: a man with an insatiable curiosity, a great power of invention and a broad knowledge of different subject, from mathematics to architecture, engineer, anatomy and painting. Nevertheless, mastering different areas of knowledge can be difficult and time consuming and there are very few (if none) Leonardo da Vinci out there. In any case, researchers and designers who want to build prototypes of interactive systems need to have some basic knowledge of different related subjects. For example, interaction designers should have basic programming skills and know some basic electronics in order to develop prototypes for tangible and physical interaction. Programming environments such as Processing [1] and Wiring [2] are intended to facilitate the development of interactive artefacts by providing an Application Programming Interface (API) for handling visual and conceptual structures as well as the communication with physical components. However, although they provide a good level of abstraction, we noticed that they do not provide a general API to communicate with different hardware components. You can interface with a sensor and get data from it, but it will only provide raw data that you have to analyse and interpret to get some results. This is not a difficult task for a user with sufficient programming skills, but it could represent a serious obstacle for the end-user (e.g. an interaction designer or a digital artist) that simply want to use the sensor capabilities in her project. In this case, programming libraries written by expert users can be exploited to interface with hardware devices. For example, currently, there is a Processing library for interfacing with the Kinect [3] RGB and Depth (RGBD) cameras and there are also many code samples for getting data from other specific sensors (e.g accelerometers, gyroscopes and compasses). Nevertheless these are only examples of isolated efforts to provide final users with libraries for managing sensors data. These attempts do not follow the rationale of a reference architecture or framework and, for this reason, they cannot be structured in a functional API.

2. MOTIVATION
A Physical Interactive system communicates with the real world by means of sensors and emitters. Sensors convert real world inputs into digital data, while emitters are mostly used to provide digital or physical feedback (e.g. a speaker emitting sounds or a blinking LED). From the experience we gathered in implementing multi-modal interaction systems [4] and [5], employing such a variety of hardware devices in a real application can be difficult because their use requires knowledge of underneath physics and many hours of programming work. For example, a digital 3-axis accelerometer is a sensor that gives you acceleration on the three dimensions. Once you get these data, you should interpret them in order to extract some meanings. It is not so straightforward to get the rotation along the y-axis (pitch) from the raw gravity data provided. Furthermore, integrating data from different devices can be cumbersome because any device vendor uses different programming interfaces and communication protocols. This is true also for the same device from different vendors. Imagine that you spent many hours programming the behaviour of the accelerometer of a Nintendo Wiimote Controller [5] and want to use the same routines in a new project with the accelerometer of an Apple Ipad [7]. That is almost impossible, because of the different interfaces and protocols used by each sensor.

These examples illustrate that there is a need in the art of toolkits and frameworks that lighten the programming of physical interactive systems and that take into account different input modalities and interaction techniques, from tangible objects to TUI-VR interactions to full-body movement input. We introduce preliminary work for the design and implementation of a framework for physical interaction in ubiquitous environment. In this paper we focus on a toolkit that abstracts low-level details of individual devices. We aim at providing access to sensors and emitters by means of a comprehensive and unified, high-level programming interface to supporting the rapid prototyping of interactive systems and the reuse of software components in different applications.

3. RELATED WORK

To help designers and HCI researches to rapidly give life to physical-digital interaction prototypes, several projects have been created, following the End-User Development (EUD) and Do-It-Yourself (DIY) philosophy. Arduino [8] is a clear example: an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software, particularly intended for artists, designers, hobbyists, and anyone interested in creating interactive objects or environments. The programming language for Arduino is Wiring [2], especially designed to facilitate the creation of sophisticated physical interactive artefacts. Wiring is built on the top of Processing [1], an open source programming language and environment for people who want to create images, animations, and interactions. Today many users exploit Processing for designing, prototyping, and production.

Many frameworks and toolkits have been built in the last years, all of them trying to ease the development of interaction in ubiquitous systems. OpenNI [9] is a software framework that provides an API for writing touchless interaction applications using RGBD cameras. Its APIs cover communication with both low-level devices, as well as high-level middleware solutions (e.g. for visual tracking using computer vision). Microsoft provides a library with the same purpose, the Kinect SDK [3], which exploits the Kinect RGBD camera and a microphones array to programming gestural and voice interaction. These approaches are limited in scope, as they support only a particular class of devices (RGBD cameras).

Other frameworks and libraries do offer support to a wide range of devices, but focus only on a particular interaction modality. Examples are Mt4j [10], libTISCH [11] and CCV [12] for multi-touch interaction or Papier-Mache [13] and reacTivision [14] for tangible interaction. Another drawback we found in the state of the art is that all of these frameworks require a quite high user's programming expertise. Squidy [15] is an exception: its objective was mainly to provide a unique library that unifies different post-WIMP frameworks and tracking toolkits. Conversely from our approach, they offer a palette of ready-to-use devices and do not provide an abstraction level of devices into general classes. Squidy's most interesting feature is the visual programming approach they use, which hides/shows on-demand the technical implementation details to the final users. Unfortunately the project seems no longer active. Another framework that employs a visual dataflows programming and integrates several devices and toolkits is OpenInterface [16]. Again, they offers pre-defined device modules and do not provide devices abstraction as we do.

The need to provide unified access in environments where heterogeneous input devices coexist has been pointed out by Taylor et al. [17]. Specifically, the found that, in Virtual Reality systems "different devices may have radically different interfaces, yet perform essentially the same function; some require specialized connections (PC joysticks) or have drivers only for certain operating systems". Therefore they developed a software library that supports different devices by providing interfaces to a set of functions, instead of drivers for specific devices. There are other approaches that aim at providing comprehensive support to different technologies (devices and interaction techniques) in the same environment such as TUI-VR [18] for the use of tangibles in virtual reality systems and ROSS [19], which especially focus on ubiquitous interaction.

GISpL (Gestural Interface Specification Language) [20] also demonstrates research efforts towards the abstraction of input devices in the area of gestural interaction. It is a formal language that allows unifying different input modalities by the unambiguous description of gestural interfaces behaviours.

4. HAT: HARDWARE ABSTRACTION TOOLKIT

We aim at designing and developing a general framework for physical, tangible and, in general, ubiquitous interaction. To this end, we defined a set of APIs for interacting with hardware devices, which can be directly used by the final user (developer, researcher or designer) in her projects.

We view sensors and emitters as a bridge between the real world and the digital world. When a user is interacting with a computer system, she is really interacting by means of sensors, which capture data from the real world and convert these real data into digital information and emitters, which provides digital and physical feedbacks.

The Hardware Abstraction Toolkit (HAT) abstracts from the low-level details of specific devices. In this way it provides unified access to sensors and emitters, independently of their implementation or communication protocols. It defines a general and modular hierarchy where the top-level classes are all interfaces, which allows for flexible and generic access to device features.

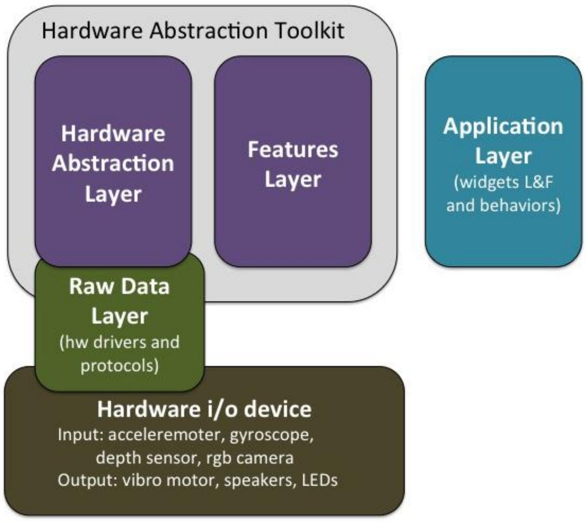

Figure 2. The general architecture of our framework.

Within the rationale of our framework, we can broadly define three components: Hardware, Abstraction and Application (see Figure 1). In the Hardware level there are physical devices: sensors, emitters, physical controls and actuators. As said, via sensors we can get data from the real world and many devices can also be viewed as a composition of sensors and emitters (e.g. the Kinect is composed by an RGB camera, a depth sensing camera and an array of microphone or the Nintendo Wiimote is composed by an acceleremoter, a gyroscope, several buttons, a vibro-motor and a speaker). This idea lead us to the definition of *Entity* in our environment as a physical, tangible object that may be composed by different devices. For example, a human hand is an input device that can be considered as a passive Entity, because it needs an external device to be tracked. A touch display surface is another example of Entity that provides both input (touch surface) and output (display screen) operations. Moreover, there are virtual Entities that can be digitally coupled representation of physical Entities or independent virtual objects that can interact with other physical or virtual Entities The capability to conceive and define objects in this way is the main purpose of the Abstraction layer. The Abstraction component represents the core library. Here we specify the interface through which we can elaborate the raw data from a sensor and so specify an API that abstracts from the specific device implementation. For example, in the case of an accelerometer, we defined methods like *getYAcceleration(): float*, in order to retrieve the acceleration in the y dimension from raw data. We can also define higher-level methods like *getRoll(): double* or *getPitch(): double* in order to retrieve rotations in the y and x dimensions. The implementation of these methods is completely transparent to the user, who does not need to know how the raw data are processed to get the final value. In this way we support devices interchangeability and code reuse, because the same code for, let's say, the accelerometer of the Nintendo Wiimote will work for the accelerometer of an iPad (and any device that is compliant with the HAT specification). The abstraction toolkit is powerful enough to allow the composition of devices. For example, an accelerometer can be combined with a gyroscope to create a general Inertial Measurement Unit (IMU) component. This level also Presently, the abstraction level supports a range of device types such as accelerometers, gyroscopes, LED, display screen, touch sensors, RGB cameras and Depth sensors among others.

On top of this API, different middlewares can be developed that, for example, implement gesture detection from sensors data (the Features Layer, which has not yet been developed). At the Application level, software applications can directly exploit functionalities provided by a specific middleware.

In our framework we will also consider output channels for feedbacks, while other similar frameworks do not [15]. For example, the speakers can be used as output for giving some audio feedback to the user. LEDs (Light Emitting Diodes) can be employed to create ambient displays giving visual feedback and small motors can provide haptic feedback (via a rumble feature). Therefore we will provide APIs also for defining and managing the output of the interactive system itself, in term of events perceived in the real world (e.g. an LED blinking) originated by some digital event (e.g. a control value exceeding a threshold) which was caused by a physical event (e.g. user's hand too close to a specific object: this event can be captured by means of a depth sensor).

4.1 Data types

Abstracting from heterogeneous devices implementations require the definition of a high-level data types that can describe raw data from hardware devices in a unified manner. To this end, we make use of Wallace's hierarchy of graphic input device semantics [21], in a similar way the Squidy [15] framework does. Nevertheless, we also needed to extend it, because Wallace's classification was not able to capture the semantics of all the devices we may encounter in ubiquitous interactive systems (see Table 1).

Table 1. Data types.

Data type		Example of device
Value		Potentiometer, depth sensor
Location	2D	Touch surface
	3D	3D pointer
	6D	Wiimote
Choice		Button, touch sensor
String	1D	Microphone
	2D	RGB camera
	3D	RGB camera + Depth
Pick		Mouse, light pen

Value are discrete, one-dimensional data. A potentiometer sends discrete values. Location are data related to information of a physical space: for example the position of a contact point in a 2D surface or orientation and acceleration with respect to the three dimensions. They are represented as a n-dimensional vector. Choice are boolean data: a touch sensor can be a prototype of this kind of devices for it sends *'yes'* or *'no'* data, depending on the contact. *String* data represents a stream of information like the one produced by microphones (one-dimensional audio data) or RGB cameras (two-dimensional video data) or RGB cameras plus Depth sensor (three-dimensional video data). The *Pick* data are a reference to an object being selected (e.g. through a 2D pointer) and it is mandatory to implement visual feedbacks of a selection. Although *Pick* data type can be implemented using *Location* data, we believe it is useful to have reference data to be logically separated from location data.

4.2 An example: the accelerometer

To better explain how our framework works, we present here a portion of its metamodel for a real sensor: an accelerometer (Figure 2).

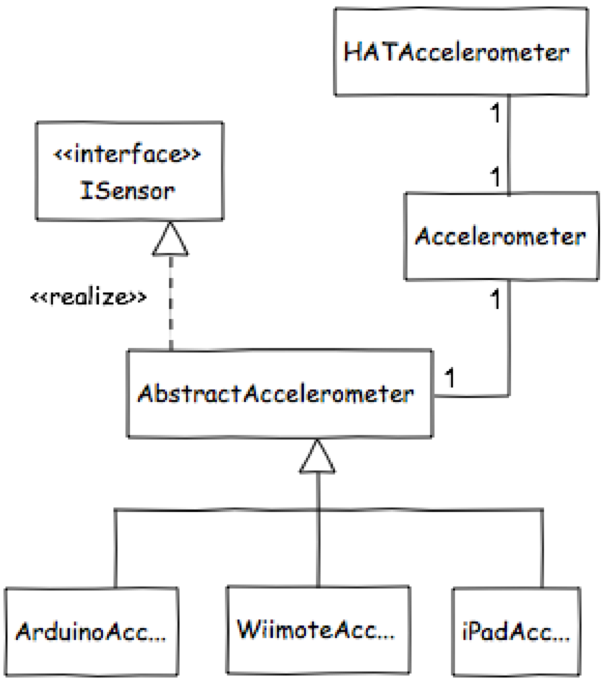

Figure 3. Metamodel for accelerometers.

AbstractAccelerometer implements the interface *ISensor* and provides method to connect with a specific accelerometer and get raw data. The *Acceleremoter* is an instantiation of an *AbstractAccelerometer* that make sense of the raw data (e.g. define the y-acceleration). Lastly, the *HATAccelerometer* uses 'primitive' data computed by the *Accelerometer* class in order to provide higher-level data (e.g pitch values). This information can be used to interact both with virtual and real entities. For example a system made of a microcontroller and an accelerometer can be used to rotate a virtual box (see Figure 3) or to tilt a physical board by means of a servo (watch the video at http://youtu.be/CsLeMpc_ykM?t=12s).

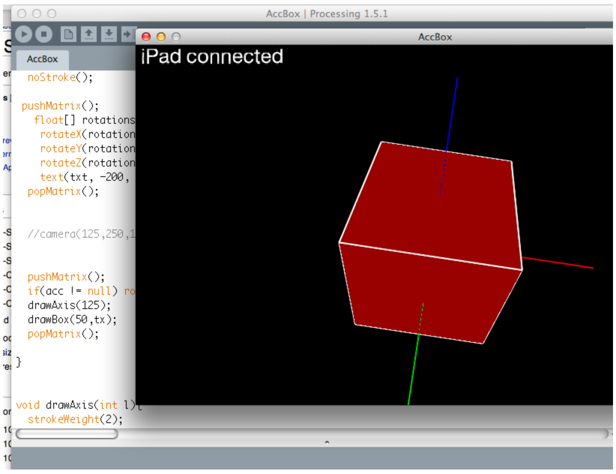

Figure 4. A virtual Entity

5. CONCLUSIONS AND FUTURE WORK

We presented a first step towards a framework that eases the prototyping of physical interaction by means of abstraction of hardware devices. Preliminary studies with HCI and Computer Science master students highlighted that the APIs do reduce the programming effort (measured in terms of number of errors per lines of code and time to completion). We are now implementing APIs for a wide range of different interaction devices that can be used to define interactive objects by composition. How to achieve consistent spatial integrity among objects is still an issue. Furthermore we are designing a visual environment for our framework. It could be possible to define visual elements corresponding to desired abstract devices and functionalities. In this way end-users, with no programming skills, can quickly develop their prototypes, as also proposed by [15] and [16].

6. ACKNOWLEDGMENTS

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Augmented Reality Centered Rapid Prototyping

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ABSTRACT
This paper discusses the potential of an updated version of IRIS, a rapid prototyping framework based on augmented reality technology. It extends a previous study conducted using a previous version of the system. Although the previous system performed as well as some other prototype methods, results gathered from the previous version led to the conclusion that the system suffered from key faults such as the insufficient resolution of the camera and the lack of connection between user and prototype device. Tests of the new version of the system showed that the increased resolution of the camera used in the new system gave a major benefit to the user interaction with overall increased performance ratings. The use of a blurry background also helped the users focus more on the prototype device and made them feel more connected during the tasks in comparison with the user experience of the previous study. The disadvantages of the new version were that users still claimed to feel distracted due to a minor lag on the video displayed on screen and the real movement of the hand. In addition, the representation of the prototype in 2D was a major factor for the users not to feel completely connected to it during testing.

Categories and Subject Descriptors
H.5.1 [**Multimedia Information Systems**]: *Artificial, augmented, and virtual realities*

H.5.2 [**User Interfaces**]: *Prototyping*

General Terms
Human Factors, Performance, Algorithms, Prototyping, User Centred Design, Augmented Reality, Reliability

Author Keywords
IRIS, augmented reality, rapid prototyping, IE units, study, physical model, information appliances, interface, physicality.

1. INTRODUCTION
Rapid prototyping typically falls in the range of a physical prototype and usually is fairly accurate and can be implemented on a component level or at a system level. [1] Rapid prototyping solutions help product designers to quickly generate physical objects and prototypes. Prototypes created with the rapid prototyping technique allow designers to swiftly evaluate and verify their product design at an early stage and to use three-dimensional representations of the design for sales, marketing and production purposes [2]. Companies that consistently "design it right the first time" and follow a path of continuous improvement in product and process development, have a formidable edge in the crucial race to market [3]. This highlights the significance of rapid prototyping in the product design cycle.

Prototyping is important as it helps verify product design at an early stage. However there are problems for computer embedded products. Gill et al. [4] highlighted one of the roots of these problems by using a prototyping method, the i.e Unit: The fact that the screen is separate than the prototype. In industry often a laptop is used and the interface is tested in a software form, by using the laptop's screen. During this testing a block model, i.e. a physical model that does nothing but key input, allows the users to interact with the software interface on computer screen. Gill et. al. demonstrated that this method was introducing major delay and usability problems. The reason of using this method to perform the study is that there is no straightforward procedure for integrating the software into the hardware at an early stage of the design process. Studies by Culverhouse et. al. and Wooley [5] et. al. have demonstrated that it is crucial for the companies to be able to easily change the size of the components on a prototype (especially the screen) during the rapid prototyping procedure.

Another major detriment is that prototypes created with the rapid prototyping technique, do not meet the requirements of functional prototypes, as neither the serial material nor the serial production processes are used. [6] In other words, the internal modification of the prototypes in order to utilize the prototyping stage electronics such as screens and buttons requires a different internal modification of the device than the one needed in the final product. Furthermore putting real screens of varying sizes into products at prototyping stage is expensive and very time consuming.

This paper examines a rapid prototyping technique based on the use of augmented reality. It eliminates the need for internal modification of a rapid prototype model for data output purposes by providing a virtual interactive screen layered on the prototype device. It extends a previous study on the same field, addressing some limitations found concerning the usability of the system.

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2. VIRTUAL REALITY AND PROTOTYPING

In recent years, increased computational power and technological advances in monitors and cameras, have allowed the use of Virtual Reality (VR) in the field of prototyping [7]. Such technologies can provide a deeper experience during the prototyping stage as they allow the users to experience prototype interaction and achieve a more intimate connection with the prototype device, providing physicality evaluation of the device and "on the device" interface emulation (including the screen). However, virtual prototyping methods and tools suffer from various fundamental issues when they are compared to physical prototyping. For example, errors such as the delay in image processing computations and the awkwardness of the users in the virtual environment [8]. Furthermore, by trying to apply VR techniques to consumer level products we encounter several restrictions, due to the current limitations in VR technology. For years now, the main restrictions that VR technology suffers are the low resolution of the screens currently used on VR glasses and the relatively small field of view [9]. Projection VR on the other hand, although it provides an increased field of view, requires more maintenance due to the significant installment requirements of the equipment needed for an adequate experience [7]. The significant installment requirements also render them inflexible for single person use. In such systems, during the design time, the prototype devices need to be created by making use of soft prototyping through 3D rendering programs - a lengthy procedure and an added prerequisite skill for the designer of the prototype device. The use of such programs also weakens the link between the user and the prototype device in terms of space and shape coherency, in comparison with direct manipulation of a real artifact by the human [10].

3. AUGMENTED REALITY

The use of augmented reality as a prototyping tool is gaining interest, as it provides a way of blending a prototype model in an early stage of implementation with virtual functionalities, creating an integrated prototype.

One of the most prominent augmented reality techniques, tested in the past on rapid prototyping is Spatial Augmented Reality (SAR). In SAR a virtual element is being projected on a real object from a projector. Studies on the use of SAR as a rapid prototyping technique from Itzstein SV [11] and Verlinden JC [12] have proven that prototyping is possible with SAR because this technique is solving various problems related to visual quality (e.g., resolution, field-of-view, focus, etc.). However, various issues render the whole technique as suboptimal for general rapid prototyping. Some of these issues include technical problems (e.g., tracking, lighting, etc.), and human factors (e.g., cumbersomeness, etc.) [13], issues like limitation to non-mobile applications and occlusion or shadows cast on the surface by the user or the other parts of the system.

4. THE IRIS SYSTEM

Our approach makes use of a screen-based video see-through display. This approach provides a window to the world solution [14]. The screen is placed in a fixed position and angle eliminating the need for head tracking. Technological problems that these devices were suffered for years, like lack of adequate resolution from the camera and from the monitor, are being gradually resolved. Such advances mean that screen-based, transparent AR use for rapid prototyping is becoming more and more viable.

The system in its current form is based on a modified version of ARToolKit, an open source augmented reality framework written in C++ that makes use of visual markers with the use of USB web cameras in order to overlay virtual elements on real devices [15]. The system was combined with FantastiqUI framework [16], a C++ implementation for low level access to Flash files in OpenGL environment. Integrating the system with a Flash interface allows designers to easily implement their software interface design (as Flash is a commonly used Graphical User Interface (GUI) design tool in industry).

The version of the IRIS system discussed in this paper is an improved approach on the version of the previous study. Based on feedback gathered from the previous study, we tried to identify usability problems connected to technological factors and we tried to address them in the hope of achieving an improved overall system performance. The main challenges addressed in the current version of the IRIS system are the low resolution of the image displayed on screen and the perceived lack of connection of the users to the represented on-screen prototype due to depth perceptional problems introduced by the monitor on which the prototype was presented.

4.1 Improvements on current IRIS system

The previous study highlighted various aspects that would benefit from further improvement. The previous implementation of the system highlighted two very significant technological problems:

The lack of adequate resolution on the screen. The prototype displayed on the screen was blurry and details such as button labels and shape was very difficult to identify.

Lack of connection with the device. The users were looking at the prototype through a monitor. This 2D representation of the prototype was blended with the background and users reported feeling that their hand holding the prototype displayed on the monitor did not belong to them.

In this paper we tried to solve the above barriers to the better use of AR for rapid prototyping by introducing the following:

1) To improve image resolution, a high definition (HD) web camera was used instead of a common low resolution web camera. The resolution used for this study was 800*600 in comparison with 640*480 in the previous one. We found that due to the better quality of the camera sensor, even at 640*480 there was significant difference in contrast and clarity between the two cameras, with the HD one having crisper contrast and smoother movement.

2) To tackle perception problems, the solutions were twofold: By putting a blurry background behind the participants' hand and by asking the participants at the beginning of each study to keep their hand in an optimal place, where the size of the hand on screen was the same as the size they would have perceived of their hand if there was no screen between it and their eyes.

5. EMPIRICAL TESTING

In a previous study, Gill et al. [4] conducted a series of tests comparing the performance of a real BT Equinox phone, an Equinox / IE Unit prototype and a screen based prototype using a methodology developed by Molich and Dumas [17].

16 members of administrative staff from the Cardiff Metropolitan University took part in the study. They ranged in age from 22 to 55 years. Experience of mobile phone interfaces was broadly similar to that described by Gill et al. [4] in their experiments and none of the participants who took part in these trials had participated in the earlier study.

In this study, we asked the participants to accomplish the same tasks as in our previous study. These tasks are linked with common functions (turning the phone on and off) and more complicated ones (dialing a number and changing the background wallpaper). The sequence in which the users were asked to accomplish the aforementioned tasks was based on the task difficulty, in order the users to feel gradually comfortable with the functions of the system. For this experiment we asked the participants to perform the same tasks as the previous study.

With the specific tasks we tried to identify the effectiveness of IRIS2 implementation on use on rapid prototyping. We also compared results with the previous implementation of the system, spotting usability improvements. Furthermore the same tasks were used in previous studies from Gill et. al. to evaluate the effectiveness of a prototyping tool called ie Unit [5]. Thus by using the same tasks was easier for us to evaluate and compare the usability effectiveness of the ie implementation and the IRIS2 one.

5.1 Procedure description

Each participant was given a questionnaire and instruction sheet. The info gathered from the questionnaire form, such as the experience of the user with the use of mobile phones, the age, etc. were analyzed for the qualitative analysis of the experiment. The users were provided with a basic description of the interface used for the study and they were allowed to do any questions they needed in order to feel more familiarized with it.

According to the feedback gathered from the previous study, there were two major changes in the new implementation of the device:

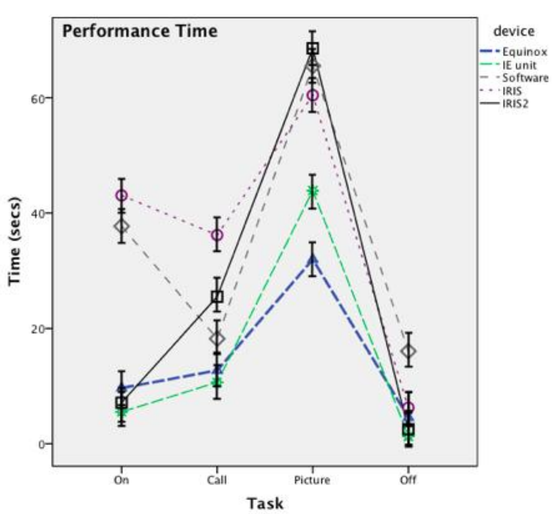

Figure 1: Mean time taken to complete each of the four phone tasks as a function of device type.

After experimentation an optimal distance was found between the system camera and the hand, so that the hand appeared the same size on-screen, as perceived by the user in real life.

The performance of participants was converted to four different interval data per task. These intervals included 0= success, 1= minor, 2 = serious, 3 = catastrophe. Analysis of performance outcome and performance time used a 5 (device type) x 4 (phone task) mixed analysis of variance (ANOVA).

Devices:

- Equinox: The real BT Equinox phone
- IE Unit: The prototype phone using the IE Unit and the GUI displayed on a separate PC monitor
- Software: The screen based prototype
- IRIS: The physical model using the augmented reality technology of the IRIS system
- IRIS2: The upgraded IRIS system.

Tasks:

- Turn the phone ON
- Dial a given number
- Change the background photo
- Turn the phone OFF

Figure 1 illustrates the mean time taken to complete each of the four phone tasks as a function of device type. There was a significant main effect of device, $F(4, 106) = 23.6$, $p < .001$, a significant main effect of task, $F(3, 318) = 159.75$ and an interaction between device and task, $F(12, 318) = 7.31$, $p < .001$. To explore the main effect of device, a series of pairwise post hoc tests (REGWQ) were performed. These showed that there were reliable ($p < .05$) differences between software/IRIS and IE unit/Equinox/IRIS2 and also a reliable ($p < .05$) difference

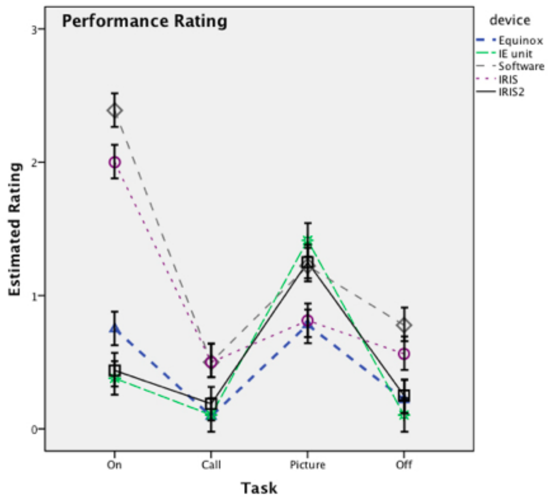

Figure 2: Success outcome (rating) with four phone tasks as a function of device type.

between IRIS2 and all the other devices. None of the other pairwise comparisons were significant (p > .05).

Figure 2 shows the success outcome (rating) in completing each of the four phone tasks as a function of device type. There was a significant main effect of device, $F (4, 106) = 10.24$, $p < .001$, a significant main effect of task, $F (3, 318) = 32.48$ and an interaction between device and task, $F (12, 318) = 5.81$, $p < .001$. To explore the main effect of device, a series of pairwise post hoc tests (REGWQ) were performed. These showed that there were reliable ($p < .05$) differences between software and IE unit/Equinox/IRIS 2.0 and also between IRIS 1.0 and IE unit/Equinox/IRIS 20. None of the other pairwise comparisons were significant ($p > .05$).

From the results it is evident that IRIS 2.0 outperformed IRIS 1.0 on the first, second and fourth task. The reason that it did not outperform IRIS 1.0 on the third task is linked to changes in user interface trends and is discussed hereafter. It should be noted that even though on the first study the performance of the system was lower than IE Unit and Equinox, the improved version of the second study placed them on similar usability levels. Nevertheless, it is clearly demonstrated that IRIS 2.0 performed remarkably well on the first task as the performance time/rating where in both cases high, outperformed only by the real Equinox device concerning the mean rating.

6. OBSERVATION

Task 1:

Users were asked to turn the phone on. There was no guidance on where the power button was located and thus from observing the time needed for the users to detect the power button, we were expecting to evaluate the effectiveness of the new high resolution camera used for the study. In the previous study the limited resolution prevented the users from identifying the button, spending a fair amount of time trying to switch on the device by pressing buttons on the keypad. With the use of a high definition camera, during the current study, we managed to improve to a greater extent the clarity of the image displayed on the screen. Users were able to spot the On/Off button almost instantly as the improved contrast and resolution made it almost look three dimensional.

Some of the users spent a bit more time trying to turn on the phone by continuously pressing the “end call” red button on the phone’s keypad. Comments like “I used to turn my phone on by pressing the power button” indicate that users were accustomed to turning the phone on and off this way from their personal mobile phones.

Task 2:

During the second task, users were asked to dial a specific telephone number provided to them. When the users started the task, the phone was displaying the main UI screen. The users would need at that point to start typing the number and when they finished they were asked to press the green button to perform the call.

In our first experiment, the represented numbers of the keyboard on the screen, lacked the high resolution the camera we used on our current study provided (Figure 4). Participants were able to distinguish easier the numbers on the keyboard. This was reflected on the better timings we recorded during this task. Also the number of mistakes the users did during the typing of the numbers was minimal. Between them the 16 participants made four mistakes entering the numbers, in comparison with nine mistakes in the previous study.

Task 3:

During the third task, users were asked to change the background photo of the phone. The results in this task are quite interesting and highlight UI usability problems beyond the scope of our study, which is mainly concerning IRIS System.

The users were asked to navigate through the phone’s menu until they find the option corresponding to “background customization” and then change the photo. Even though the users were able to quickly navigate through the menus of the phone, the way the menus were represented on screen confused most of the users, forcing a considerable number of the participants to abandon this task before completion. The main problem was that the customization section of the phone was represented with a music note icon (Figure 3). As the device that the prototype was representing was quite old, mobile phones did not used to be used as music players. With the intuitive new generation of smart phones, like Apple’s iPhone, Research in Motion’s Blackberry, the Sony Ericsson Xperia, Nokia Lumia and Samsung Galaxy, people are becoming more familiar with multimedia devices and the idea that a music icon represents a music player rather a customization section for wallpapers and ringtones.

It is interesting to check the results from the previous study. We will find out that during the same task in the previous study, users did better on finding the background customization section. In this study almost half of the users completely failed to find it. This fact reimburses our opinion of people getting used with different representation of the same functions as they are using devices of different technology.

Task 4:

During the fourth task the users were asked to turn the phone off by pressing the same button they pressed to turn the phone on the first task. We were expecting the timings to be better than the ones of the previous study because of the introduction of the high resolution camera. Our expectations were right as the timings indeed were better than the first study. The users were able to almost instantly turn the phone off.

7. DISCUSSION

From the results we can clearly see a vast improvement in the timings of turning the phone on and off and also on the calling a number task. It is evident the introduction of a higher resolution camera helped the users quickly identify interactive elements on the surface of the prototype.

Figure 3: Differences between the current representation of the settings icon in modern devices in comparison to the one of the Equinoxe

Although the system outperformed the previous version, users still felt that using it was not the best experience for them. The system seems that has a learning curve, as judging by the comments of the users, they initially tended to feel uncomfortable and nervous when they started the study before the first task but their comments after the fourth task showed enthusiasm and satisfaction from the overall experience.

Users felt much more connected with the representation of their hands on the screen while using the IRIS 2 in comparison to the experience they had with IRIS 1. The minor, milliseconds lag between the movement of their hand and the represented one on the screen in combination with the lag of depth perception due to the 2D monitor representation of their hands on IRIS 1 made the users feel quite disconnected concerning the representation of their hands on screen. This is highlighted by comments like: "There seems to be a lag between my real fingers and the ones on the screen", "I am not completely sure for the distance between my finger and the phone keys". In IRIS 2 users were asked to use the devices in a fixed position behind the screen where the representation of their hand was approximately the same size of their hand. We also placed a blurry background behind their hand of random colors which improved even more their experience. In sum, according to their comments and reactions the connection they felt with the system was much better than the experience of the users to the previous implementation of the system. Some users were even excited as they found the experience unique and appealing.

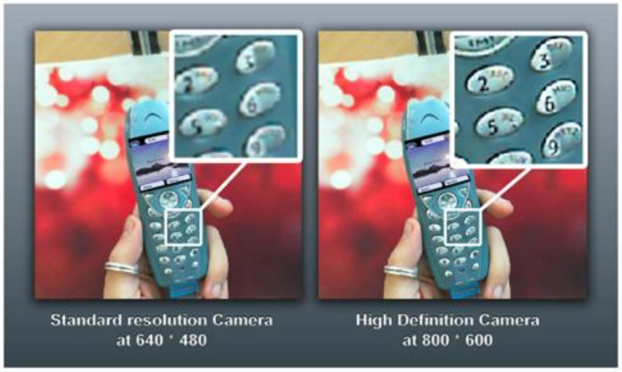

Figure 4: Detail of the prototype keyboard as displayed on the screen using a regular and HD camera.

Another problem with the IRIS system was the covering of the augmented reality sticker (bar code) with the user's hand (when switching the device on and off), which resulted in the GUI not being transposed onto the physical model. An alternative solution to putting the interface over the sticker, could be to place more than one sticker in random places on the surface of the prototype, and thus decreasing the chance all the stickers to be overlapped by the fingers at the same time. That could allow a better visual tracking of the markers and a more effective translation of the position of the prototype device on space. Furthermore. use of chroma keying techniques could solve the problem of displaying the fingers in front of the screen. Something that could potentially lead to extend the prototyping capabilities of the system for testing touch screen devices.

8. ACKNOWLEDGMENTS

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ting of the system, for their time, comments and patience. We would also like to thank Steffan Daniel for designing the stand to supporting the screen.

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Designing and Studying a Multimodal Painting Installation in a Cultural Centre for Children

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ABSTRACT
We here discuss a research project involving the design of a multimodal painting museum installation for children and study this relating to experience and engagement. During an ongoing PhD research examining multimodal interaction with museum installations, an opportunity arose to develop an installation and study the interaction with it. The installation was developed with a focus on tangible media combined with a GUI, spurred by a key interest to examine the interaction, experience and engagement outcomes of tangible media combined with other modalities, in the context of physical interaction with digital information. An overview of the study carried out is presented as well as a number of questions the study explored and initial observations.

Categories and Subject Descriptors
H5.2. User Interfaces: Input devices and strategies

General Terms
Design, Human Factors

Keywords
Museum installation, exhibition design, observational study, children, engagement, digital physical painting, TUI, tangibles, multimodal.

1. INTRODUCTION
Typically, science museums adopt a strong hands-on interaction approach, while traditional museums assign a more passive, observatory role to visitors. However, this is shifting as traditional museums strive to incorporate technology and allow for a more active role for visitors. But a lot of the technology that has been implemented in museums only results in frantic button pushing, or provides visitors with the equivalent of a multimedia CD-booklet, with a lack of engagement with the actual topic and/or confusion (c.f. [6,7]). This PhD project aims to examine installations considering their modalities, particularly tangible media and its inappropriate or appropriate integration with other modalities, the context/topic and target audience. The research focuses on how the use of particular modalities or combination of modalities relating to the topic and target audience, influence engagement and experience.

A call for submissions for installations to the ARK, a cultural centre for children in Dublin provided a vehicle to move our research forward. It presented the opportunity to build an installation with a range of multimodal elements building on the principles of physical interaction and to examine the resulting interactions. Key issues for the study are to understand how physical interaction can contribute towards a better experience, engagement with the content for visitors, and to social engagement with peers and other visitors. This has us take both the perspective of the designer and the evaluator. We have the inside view of why specific layouts, shapes, sequence of events, colours, materials, etc. were chosen, and whether these were hoped to encourage particular behaviours, interaction and engagement. Studying the interaction of visitors can then reveal how effective these design decisions were for the desired outcome.

The study examined how visitors interact with the installation as a whole as well as regarding its individual elements. We consider how the interaction modalities exploit different sets of skills and capabilities (i.e. manual dexterity) [2] and what this means for the users' experience and engagement. Comparing the visitor/user interaction with the designer's perspective of intended interaction, we might be able to identify where the installation has intentionally and unintentionally encouraged certain interaction, understanding and engagement. The design of this installation creates a physical interaction that mimics the real life action of painting. On the other hand, the installation also explores tangibles and actions that are not totally familiar to the audience, such as using wooden cards and a slot for them to be placed in as key activation and selection tools.

2. CONCEPT AND INTERACTION OVERVIEW
The concept was generated around the exhibition theme of 'Awakening Curiosity, exploring nature, biodiversity and the world around us'. The target audience for the installation was children approximately aged 5. A key aspect of our installation design was to support multimodal interaction. Thus, physical and visual communication were included in the design specification. The basic concept is that children pick an animal/organism to paint by choosing from a selection of wooden tokens, shown in part A of figure 1. Inserting this into a slot in the table, the image chosen appears on the table and projected screen to colour in (part B and C of figure 1). The children paint the image using a physical paintbrush and paint pots (parts D, E and F of figure 1). When the child has finished painting, they remove the wooden token from the slot (part G). Their individual painting is added to a collection of visitors paintings brought together to make up the wing patterns of a butterfly on the projected and screen image (part H of figure 1).

The installation design adapted the idea of selecting a page in a colouring book to select a drawing to colour in, by selecting a wooden card with a drawing on it. The concept was developed to collectively involve visitors in the creation of a new species of butterfly from smaller user-generated paintings. This concept was chosen to highlight how our actions affect other living organisms and portray the relationship of how different organisms affect other living organisms. By involving users in

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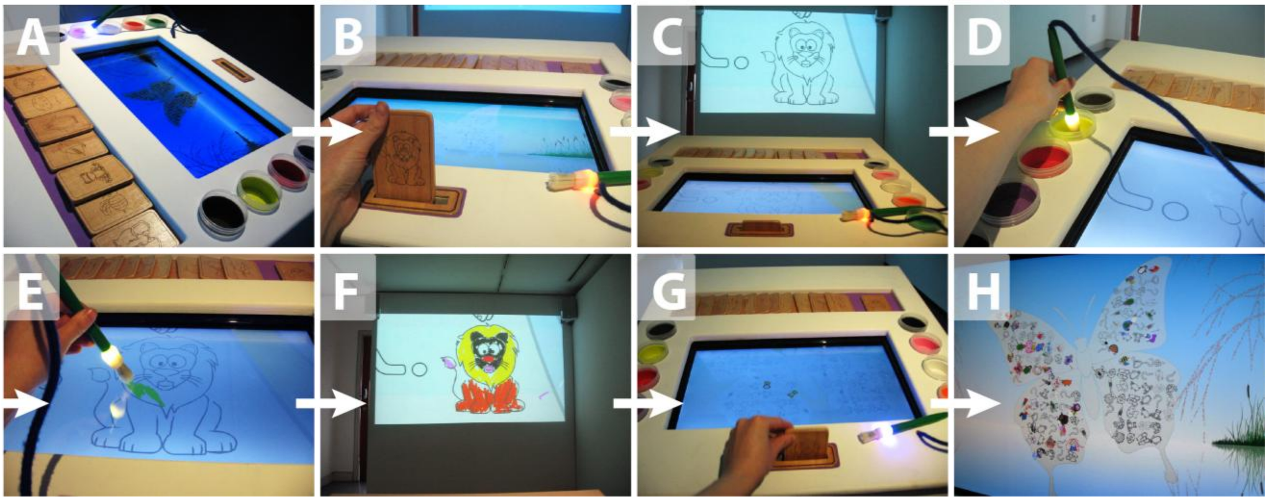

Figure 1. Interaction Flow

the creation of content it was hoped that visitors develop a feeling of ownership. This was anticipated to create an engaging experience where visitors are involved in creating the content rather than taking only a passive role regarding content, as is the case with standard information access points or databases of images or information.

a. DESIGN APPROACH

Throughout the process an iterative design process was adopted. After generating initial concepts based on the exhibition theme and a multimodal interaction, a concept was selected to develop and run an explorative session with adult participants using paper prototypes. Then, a medium fidelity prototype, shown in figure 2, was developed which was evaluated with 16 adult participants, in 3 groups. The prototype evaluation was carried out using a partial Wizard of Oz technique, meaning the touch screen reacted to a real paint brush, but colour selection and token selection were simulated by a facilitator changing the screen and projection output, manually. While adults are not the target audience, this provided insights into usability issues, potential social interaction patterns, and suggested necessary concept changes. A second medium fidelity prototype was developed taking into account findings from the first evaluation. This was evaluated with 2 siblings aged 6 and 9 in a lab setting, before building the final installation for the exhibition.

Figure 2. Medium Fidelity Prototype

3. SYSTEM DESCRIPTION

The installation (see figure 3), consists of a screen projection, an interactive touch screen which is synched to show the same visuals, a physical paintbrush, 10 physical paint pots, a tangible token slot, tangible wooden cards and an ambient audio track of wildlife sounds.

Physical wooden cards with laser inscribed drawings representing animals/organisms to colour in are used in the installation. The slot and cards are designed to have a similar appearance by using the same materials, colours and laser etching, thus implying a connection between the two. Inside each card is a RFID tag. A RFID reader is placed inside the table slot that the cards go into. Once a new tag is recognized, a new image of an organism shows on the projection and table screens for children to paint.

Initially, we intended to utilize video camera tracking of two paintbrushes, using IR LEDs on the tip of each paint brush. While this worked in principle, due to software constraints and available resources we reverted to using one paintbrush on a HP touchsmart screen. We knew from early testing that this works quite well, although it has the disadvantage that the screen cannot differentiate different brushes and the screen would pick up any object touching it, not just the paintbrush. The paint pots are fitted with pulsating IR LEDs, which are detected by an IR sensor in the tip of the paintbrush. Once the IR sensor detects

which paint pot the brush has been placed in, it feeds this

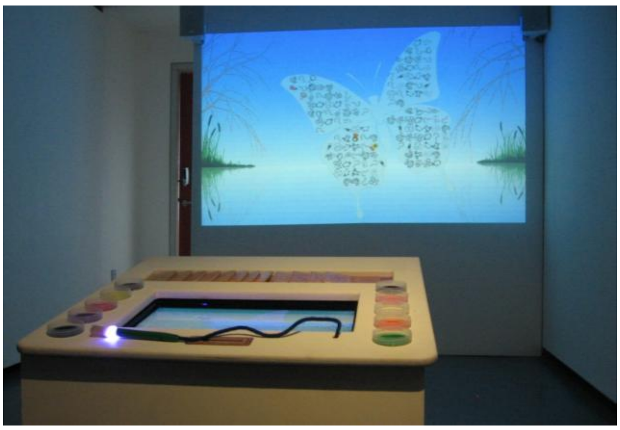

Figure 3. The final installation in the Ark

information to Java and then to Flash, which changes the painting strokes' colour. Furthermore, the colour of an LED on the paintbrush changes to the chosen colour. This hardware and software communication set up can be seen in figure 4. The LED on the paintbrush indicates the paint pot colour and is essential to provide feedback to the user while simulating the paint on a real paintbrush.

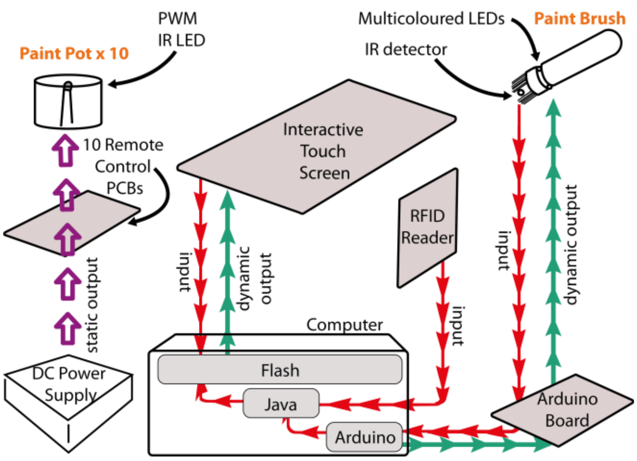

Figure 4. Communication diagram

4. RESEARCH QUESTIONS AND INITIAL FINDINGS

Meanwhile, the installation has been exhibited at the Cultural Centre for Children for 3 months during schools tours and public opening periods over the summer. We have carried out observational work and some video recording during both school tours and public opening times. A small number of school groups were observed at the exhibit (given their time limitations and low numbers per day) thus the main discussion will be based on the observations of the general public.

An element we chose to investigate was whether visitors immediately understand how to use the installation (i.e. 'immediate apprehendability' [1]) Will people understand what to do with these physical objects (1) paintbrush and paint pots and (2) wooden cards and card slot in the table's surface? What will they do with them? Are there unexpected behaviours in using these physical tokens? Immediate apprehendability was present for interaction with the paintbrush as children were continually observed instantly picking up the brush and then trying to start painting. Upon doing so a prompt animation would appear on the screen showing an outline drawing of a person picking up a wooden card and putting it in the slot. A number of different actions occurred at this stage. (1) Many children understood the prompt and chose a card, then inserted in it the slot, (2) children would keep trying to paint while siblings or parents understood what to do and communicated to choose a card or they would choose a card together, (3) a parent or sibling/friend would read out written instructions placed at the top of the table, (4) if floor staff were present they would talk them through what to do. From the observations, it was evident that selecting a card to insert was not an obvious connection for visitors when they first approached the exhibit. The cards also are not the most enticing familiar objects of the exhibit, as children are initially drawn to the paintbrush. When children notice the paintbrush and pots it is apparent they understand the exhibit will involve painting and are motivated by this. The exhibit thus supports visitors in understanding what the exhibit may involve and it's subject matter before interacting with it. However, this pattern of events provided an opportunity for children to embark on experimental learning, for social interaction and inclusion of others in the experience.

Upon inserting the card initially, many would remove the card from the slot immediately and repeat this a couple of times, testing the reactions and learning what it does. Following initial exploration, children's behaviours' illustrated they understood what the cards did and how to use them. While painting, if they wished to paint a different image or made a mistake they did not hesitate to remove the card and replace it again or to choose another card to insert.

The majority of children completely took the illusion of the paintbrush being the sole control to enable painting. Even if they knew something else touching the screen would paint they continued using the brush, possibly, because they could only choose colours with the brush. They used the brush as an object and explicit mediator of control, handing it over to another person, or when other children were at the table waiting for a go, or siblings directly handed the brush to their sibling. Also, the key position of power/control is at the seat, children moved into this position while painting and others moved closer to it to as they waited for their turn.

Furthermore we are interested to see what social acts or communication emerge around these physical tokens. This is important because museums are a place of social interaction – museum visits often are done in groups, either by families or as a school field trip [4]. We thus want to know what aspects of the installation encourage social interactions among individual visitors and groups or discourage it and how? As a generalization, the exhibit highly promoted social interaction and included individuals who were not directly painting. In particular the use of wooden cards and the projected image showing the current painting encouraged interaction and included others in the experience. Parents, siblings and friends would verbally communicate with the child painting from observing at a distance the projected image or staying beside the table to help select colours, paint white over mistakes or praise the painting verbally. Occasionally, the painter would initiate conversation for example, asking what colour to choose or prompting others to observe their painting.

The wooden cards provided a reference for visitors to communicate around [8], children would take a card while not using the exhibit. They would bring the card over to the bench, show others what they intent to paint, hold it until they had their go using it as an expression of their intent, moving it in front of the projected image or staying at the side of the table with it in hand. The exhibit allowed others to choose what they would like to do and plan by browsing through the wooden cards while another child painted. The painter rarely showed any signs of disruption during this. Fernaeus and Tholander identify the ability to work offline and parallel as important qualities for users' interaction with technology [3]. Similar as observed in [3], we saw how the wooden cards provide children with the ability to re-arrange these, draw one's attention to something using a physical reference while physically relocating oneself and plan ahead individually and together in parallel to the action of painting. Fernaeus and Tholander argue these elements contribute to increased social interactions and allow children to "act individually as well as collectively" [3].

Furthermore, we want to know how the physical set up of the installation supports the visitors experience and social interaction. Are other visitors included, even if they are not painting? The table layout, size and height was designed considering the social interaction, target age groups ergonomics and anthropometric data and the physical limitations of the hardware. [9,10 Paint pots were dispersed on either side of the table so as not to exclude one side from being closer to the interactive screen. The tabletop is tilted slightly to allow visitors from all sides of the table to approach it and observe the interaction, while still implying a key position at the table for interaction. It can be assumed that children identified a clear control position at the installation as all but two children were observed locating themselves at the table where the slot was, in front of the chair placed at the installation. The layout of objects on the table allowed others that were not painting to explore the paint pots and cards without interfering with the painter. The painter was able to protect their card from being removed from the slot by others. We noticed younger siblings trying to remove it while others were painting and either the older sibling or parent holding it in place.

From an initial brief observational study with school groups that were led around by a tour guide we could see that visitor interaction is influenced by the directions and interpretations provided by the tour guide and teachers. Similar effects were found by a study carried out by Katriel looking at guided tours. [5] School groups were shown what to do with the installation. The observational study of school groups revealed positive social interaction among the students, encouraging the painter while they are not painting. However, teachers and guides occasionally need to ask children to wait for their turn. This indicates that without any supervision possible confrontations may emerge along with less outgoing students being somewhat excluded. As similarly observed with public groups, children picked up the cards and said to the guides and teachers "I want to put this one in next." They seem to be using the cards to indicate their intended actions.

Approximately only a third of visitors observed realized that the image was added to the overall butterfly and showed an interest in this. After a child finished painting and removed the card from the slot there was little to no time for them to reflect on the overall butterfly pattern and their painting. Typically, another card was inserted immediately, thus zooming in on one image to paint, or somebody touched the screen, stimulating the prompt animation to appear which covered the overall butterfly pattern. This affected people's understanding of the individual paintings relation to the overall butterfly. It also prohibited people from reflecting on their input. Many would realise their image was up on the butterfly, but once another person started to paint they were not able to view the overall butterfly. An integral element to exhibits is to support further interest and reflection. However, the installation hinders this by not providing an overview of the final butterfly pattern while somebody is painting.

Children commented that they liked to see what they were painting up on the main projected image as well as the table screen. They also pointed at the main projection showing it to others. During painting children used the projection for an overview when they were choosing a new colour or finished painting a section they would look up at the overall projection. On rare occasions painters would watch the projected image while painting.

From initial findings it is clear children are highly engaged with the exhibit. But what exactly they are engaging with in terms of their understanding of what the exhibit is about is to be further explored using video analysis. At this stage it appears the exhibit is about painting for visitors and less about creating a butterfly pattern collectively. It was rare to see visitors reflecting on where their image was on the butterfly or expressing they were adding to the pattern without floor staff prompting such thoughts.

5. FUTURE WORK

As the analysis of data is at the initial stages any questions brought up need to be further explored by analysing the observational notes in greater detail along with the video data captured.

It was hoped that a comparative study with an altered installation based solely on touchscreen interaction could be carried out during the exhibition. However, this was not feasible for organizational reasons. We hope to be able to conduct a brief comparative study in the future to investigate how the tangible objects affect the interaction with this exhibit in comparison to a solely screen based interaction.

6. ACKNOWLEDGMENTS

Our thanks to The Ark, Cultural Centre for children for supporting us throughout the development and research of this project.

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Thawing colours: dangling from the fuzzy end of interfaces

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ABSTRACT
In this paper we present *Thawing Colours*, a tactile, visual and sonic installation, which uses suspended spheres of melting ice to paint on surfaces, woollen strings to provide a means of interaction, and concatenative synthesis–the stitching together of many small fragments of sound–to provide a digitally mediated response to motion and vibration by resynthesizing the input sound using a corpus of pre-prepared sounds. In one sense, it is an evolving, site-specific physical installation, a painter or designer that produces images over the course of several days. With some intellectual license, it can be taken as a naturalistic interface for querying a database of sounds, or as a particularly large and unwieldy musical instrument. It is literally a fuzzy interface, with boundaries extending out through the fibres of the woollen strands used to attach coloured balls of ice, and through the supporting cables into the foundations of the building, and through the fingers, palms, and bodies of the participants. We argue that there is a niche for interfaces that are whimsical, ludic and exploratory, and that as part of exploring this niche, we can take an ecosystemic view on interfaces: embracing their physical properties, their situation in an environment, and the byproducts and feedbacks therein.

Categories and Subject Descriptors
J.5 [**Arts and Humanities**]: Arts, fine and performing. H.5.5 [**Sound and Music Computing**]: Signal analysis, synthesis and processing.

General Terms
Experimentation, Human Factors.

Keywords
Interactive installation, embodied interaction, concatenative synthesis, signal processing.

1. INTRODUCTION
The piece, *Thawing Colours* (*TC*), created by the authors is an interactive installation piece that unfolds over time; each day, spheres of ice, pebbles and pigment are suspended over a large sheet of paper. Sensitive contact microphones capture vibrations within the physical structure, which are then amplified, and sent to a concatenative synthesis system for digital interpretation. The audience is invited to interfere with the piece, which creates a soundscape of live and resynthesized noises, as well as affecting the mark-making carried out by the dripping water and pigment. The piece was conceived as an experiential artwork, to engage the audience in playful interaction. During the piece's development, a number of points of engagement with physicality and interfaces arose. In this paper we describe the piece in more detail, and then discuss its qualities as an interface[2]. We see this as related to Bill Gaver's ludic design work [5], Rudolf Frieling's art of participation [3], Simon Waters' performance ecosystems [13] and Tim Ingold's lines of interaction and experience [7]. We also find resonance with a call for interfaces with 'a low entry fee, with no limit on virtuosity' [4, 14]. Finally, this relates to the author's other works: *ChaoDependant* [9] an interactive installation based on a physical system sonified through sensors and synthesis, and *Truth Table*[3] which is a ludic interface to multi-source internet searches, and to the other author's work: *Like Fish in Sand*[4] an audiovisual physical interactive installation which uses water and sand as playful and distortive projection surfaces, and *The Surface Inside*[5] an audiovisual piece to perform ecosystems on surfaces while moving along paths.

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2. DESCRIPTION
2.1. Physical Presence
Physically, the piece consists of a grid of wires, suspended above the audience (Figure 5, left). Ephemeral ice shapes are added to this base: spheres of ice, containing pigment and pebbles are hung from the grid, using woollen strands attached to metal hooks. The metal hangings are designed to allow rotation and movement, and to interfere with each other, the wool, and the metal grid. Sheets of thick, absorbent paper are suspended below the ice, to catch the water and pigment that drips down, with a pool beneath to catch any possible overflow not absorbed by the paper. Over the course of the exhibition, new ice is added every day, in different colours and configurations; each batch of ice has a particular effect on the paper surface, and constructs its identity based on the colours used and those already present. As the paper becomes saturated, it warps, creating an organic terrain onto which new drops fall; this lends the piece a geological and hydrological feel, as mounds, rivers and lakes emerge, complete with sediment deposition and concentration of colour through evaporation.

[2] A video showing *Thawing Colours* in action is available at http://vimeo.com/davemurrayrust/thawingcolours. More images and construction details can be found at http://mo-seph.com/projects/thawingcolours

[3] *Truth Table*: http://mo-seph.com/projects/interactable

[4] *Like Fish in Sand*: https://vimeo.com/30694250

[5] *The Surface Inside*: https://vimeo.com/33247804

2.2. Analogue and digital electronics

To begin the transition into the digital realm, a hypersensitive array of contact microphones is glued to the metal grid, sent to a custom preamplifier (http://www.zachpoff.com/diy-resources/alex-rice-piezo-preamplifier/), and input to a computer. Some minimal processing is carried out to reduce feedback and tame some troublesome frequencies; this live signal is sent directly to the speakers, and used as the input for further processing (see **Error! Reference source not found.**). CataRT [10, 11] is a library for the Max/MSP programming language, which supports *concatenative synthesis*: creating output by concatenating many tiny fragments of audio from a corpus. Here, *descriptors* are calculated from the incoming audio – such as pitch, periodicity, spectral centroid – and then matched to descriptors of sound fragments in a database. In this manner, the incoming sound is re-interpreted, using a corpus of sounds obtained from ice melting and shattering. This re-interpretation is delayed from the live sound, to allow it to be experienced as a discrete voice.

2.3. Interaction and conceptualisation

In a soundless room, the piece is silent. The main participant interaction with the piece is through physically manipulating the balls of ice, interfering with the woollen strands and ultimately, activating the movement of the metal hooks from which they depend. To encourage the visitors to begin the exploration of the “thread that will become an audible trace” [7], extra pieces of wool with the tag “Pull Me Gently” are suspended which can be stroked, plucked and tugged, and cause the piece to move in sympathy, building up rhythmic oscillations which are converted into audible sound. Many of the sounds produced this way are not directly audible – thin wires brushing against each other and wool or metal rocking on metal produce incredibly quiet sound, while plucking the woollen strands creates a low frequency vibration without sufficient power to move enough air to be heard. It is only the use of sensitive microphones, which respond to vibrations within the structure that elucidate this microcosm of hidden sound. At the same time, the sensitivity of the microphones used means that the piece is sensitive to its environment, becoming part of a performance ecosystem [13]; it is not isolated, but the interface extends out to include the acoustic environment, picking up feedback and speech, and the infra-acoustic world vibrations of the building: rumblings from the foundations, footsteps, shifting floors. All of these vibrations are re-interpreted into the vocabulary of ice and water: sounds are matched to similar fragments; the creaking of the building becomes squeaking of outgassing ice, plucked strings become drops of water and metallic impacts are replaced with the shattering from heat-stressed ice blocks.

Figure 5: Thawing colours. Left: at the start of the exhibition, showing the wooden frame and wire grid, the paper and collection pool. Right: partway through, showing the growing collection of pigment-covered suspended stones, some melting ice and the additional wool added to encourage audience interaction.

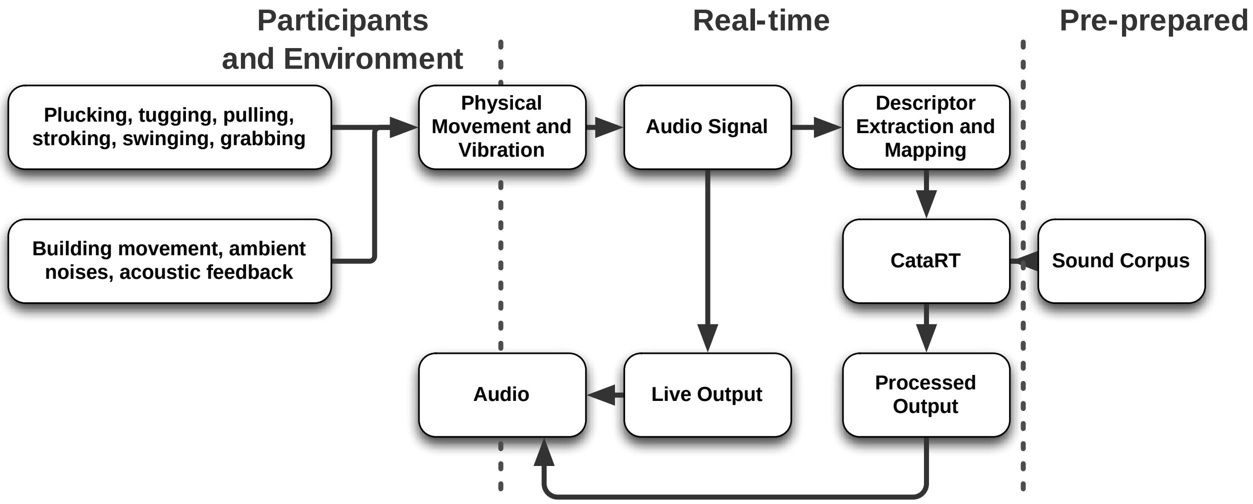

Figure 6: System diagram – flow of information between participants and the real-time synthesis engine

3. FUZZY INTERFACES: REFLECTIONS AND CONNECTIONS

Thawing Colours is an open-ended piece, a facilitator of interaction that works with processes, presence and materiality. There is no particular form of interaction desired, no goal to be achieved. Like the Drift Table [5], it encourages exploration and investigation, a *ludic* approach to joining in. In the absence of a formal evaluation, here we attempt to connect the piece to some broader concepts, and reflect on which parts were successful.

A simple interface can hide a depth of interaction: on a first pass, one discovers that tugging a string brings a cascade of sound; later, the live sound can be heard as distinct from the processed; then, the effect of different types of plucking and pulling on the timbre of processed sound emerges; eventually movements involving the whole structure allow for different areas of the sound-world to be accessed. This journey can be seen through the lens of *engagement*, as participants–the *parts* that *take* part [3]–discover a gradually unfolding set of possibilities inherent in their interactions with the piece. It can also be seen a development of *virtuosity*. In particular, as creators of the piece, we developed our own virtuosity in playing it, as an instrument – or *infra-instrument* [1]. Through the process of constructing and improving the piece, we were also encouraging and developing its virtuosity as an improvisational partner, and in interpreting and responding to *our* desires and nuances: ‘we encounter ourselves in the work’ [8]. From talking with and observing participants, it was clear that there were very different levels of understanding of the piece. Many, especially in a crowded gallery context understood that some kind of response was taking place, but were not aware of the mechanism, or relationships between the live sound and the re-synthesis. Many visitors would hesitate to touch the piece, or briefly pull a string to verify that something happens and then return to observing. We feel that without the possibility for *tranquil interaction* [6], for example at the opening with many people and a high level of background noise, many visitors are unable to explore the interaction possibilities the piece offers. There is a tension here, between providing open-ended, multi-layered experiences, and guiding or prompting visitors to explore the depth of possibilities. With more analysis and refinement, it would be possible to provide clearer jumping-off points to help initiate development of understanding and technique, without losing the exploratory feel of the piece. It would also be possible to create an environment around the piece which encouraged a slower, considered interaction.

Interface design is often discussed in terms of “interface to…”, which brings with it conceptions of control and intention, and the implication that there is a thing which is being interfaced. In this case, a formulation of “interface between…” is more appropriate–the piece is the interface, and comes into being through the interaction between different worlds, rather than the harnessing of one to another. The simple act of adding a hypersensitive microphone creates an interface between the separate domains of the physical environment and the digital system. The boundaries of the interface are blurred, as they extend through the smallest threads of woollen strands, along the suspending cables into the foundations of the building, and of course through the fingers, skin and embodied presence of participants. Nic Collins suggestion of “laying on hands” [2] is apposite here: although the participants hands do not directly touch the circuitry involved, there is a sense of intimate connection with the electronics, as minute movements are captured and amplified. In the action of drawing sounds with wool threads, the body slips into the virtual realm of processed sounds while simultaneously being present in the interaction of ice, colour and paper.

With a small amount of academic license, *TC* can be interpreted as a whimsical approach to database querying [12]. There is a mapping between input sounds and those in a corpus. By modulating the sounds of the piece, a skilful performer can select regions within sound space from which output sound can be constructed. This is unlikely to replace MySQL or NoSQL as a database query language. However, there are useful points here for interface design. In many cases, accuracy, power and reproducibility are the primary concerns. Here, it was more imperative to be engaging, to be suggestive, to be accessible. With practise, it is possible to cause individual samples from a corpus of several thousand to be played. At the same time, with no questions of syntax or screen-based literacy to contend with: complete novices can elicit some kind of understandable response. Many systems require an up-front learning of structure and control, and discrete bits of functionality must be explicitly discovered and learnt to progress (e.g. adding clauses to query statements). Here we have a query system that can be used immediately, but allows a gradual refinement of precision, through a physical, tactile interface. From a methodological point of view, the mapping between input sounds and those in the database is a slightly opaque process. Querying the database using features directly extracted from the input results in an unsatisfying experience, as the signals occupy different areas of parameter space, and a very limited subset of the corpus is used. The mapping of input parameters to corpus parameters was carried out in an ad-hoc fashion, roughly matching ranges of each descriptor. While workable, this is cumbersome, and unsatisfactory, and is a part of the work where stronger methodological or technical approaches could be brought to bear.

Much of the impact and richness of the piece comes from its physicality. Using vibration as the connective tissue articulates an interface built on an “organic” skeleton. “Natural” materials – wood, wool, stone – are the main points of contact; they are not *sensors* or knobs wired up to control something else. These components *are* the interface connecting the digital and corporeal. This means that it is not only the behaviours envisaged by the creator that are available – the full range of physical reactions are potential means of engagement. This leads to the interface being more intuitive, more open ended, and more *comprehensible* – it does not need to be designed with a particular conception of a *user* in mind, but can be receptive to the inventive ways people find to interact. At the same time, the richness of the piece can be an issue; by combining several processes together, there is no clear statement or story that can be extracted. In particular, although the painting produced by the piece and the sounds produced have their origins in the same phenomenon, there is no direct relationship between the drips of water and the sound made; there are no parallels in the patterns of paint and of audio. It could be argued that there are two separate pieces, one which paints and one which makes sound, which happen to be physically super-imposed, or share some elements. However, when physically present and interacting with the piec, the individual tends to bring these two elements together: sounds, images, and space are combined and processed simultaneously. This is an area that could be strengthened significantly, to create a more substantial relation between the physical traces and the ephemeral interactions.

With this in mind, the auditory and semantic coherence of *TC* is important. The sounds of metal and wool provide the first voice of the *TC*, which is immediate, responsive and surprising in its range: much of the acoustic activity occurs in the low frequency spectrum, going down to ~25Hz. This voice has a very different feeling to the dripping and splashing of water droplets that constitutes the painterly activity of the piece. Using a corpus of water-derived sounds adds a second voice to the piece, creating a three way conversation when participants+environment are included. This third voice relates to the water and ice used to carry out the mark making, the physical traces that reveal the developing and transitory nature of the piece components; the sounds are not just used formally, but for their semantic relation to the other elements. There is a similar feeling to both voices through their exposure of otherwise inaccessible soundworlds – both involve presenting very “small” sounds: through hypersensitive microphones and through “close miked” recordings of the microsounds of ice melting respectively.

Another aspect of interface design to consider is statefulness. Does the same action produce the same result each time? In this case, there is very little modifiable state stored in the physical system: a delay on the descriptors sent to the concatenative synthesis engine is the only digital memory used (apart from a fixed corpus of sound). However, there are several layers of physical state, working at several timescales. At the coarsest scale, physical elements are added to the piece, which interfere with each other, and modulate the sensitivity. Over the course of an exhibition, the piece becomes more physically cluttered, and more acoustically sensitive as there are more pieces of wire, wool, melting ice, and pebbles ready to swing, tangle, brush and bounce off each other. There is the state inherent in the melting of ice; a daily rhythm of decreasing mass, affecting the swing of the elements, allowing for different tanglings and fusings. There is the state created through the flowing of water and pigment, which has no *direct* bearing on the sound created, but results from, and records, the splashing and movement created through interaction, it is ultimately the physical trace of the intertwining of the elements that constitute the piece and the action of participants. And finally, there is the physical energy contained in the piece at a given moment in time: displacement, oscillation, the varied rhythms and resonances of the grid, the hooks and armatures, and the suspended weights. It is this final state which is most directly accessible to a participant: while on a base level, the more energy that goes in the louder it gets, different modes of vibration can be encouraged, between frantic shakings of the grid and slow pendulumic sweeps of the balls of ice.

The point we would like to make here is the balance between digital and physical state. Digital state is often seen as more manageable: memory is cheap, storage can be used long- or short-term, it is invisible, commodified, tractable. While these are generally useful qualities, in this case, rejecting them provides something richer. The physical state of the piece is directly observable – there are correlates between motion and sound, and participants can affect these in an intimate, relatively unmediated manner.

4. CONCLUSIONS

We have presented *Thawing Colours*, an installation piece which uses concatenative synthesis and hypersensitive microphones to create a responsive partner in open ended interaction. We have discussed the area between engagement and virtuosity, and how the creators of a piece can look to imbue the work with virtuosity as well as allowing it for participants. We have argued that using a naturalistic interface allows for a different way of interacting with databases, a gentle, ludic approach to querying, which can be backed up by a rich physical system, creating a *fuzzy interface*, with no clear boundaries, no clear goals, yet semantic coherence, richness and depth.

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Interactive Sensory Objects Developed for and by People with Learning Disabilities

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ABSTRACT
This paper describes a project that aims to help improve the accessibility of museums and heritage sites by creating a series of interactive, multisensory objects. The objects will be developed collaboratively by artists, technologists, people with an interest in heritage sites, and people with disabilities and their carers in a series of sensory art and electronics workshops. The workshops and the sensory objects will explore aspects of physicality and how to appeal to the entire range of senses for both control and feedback. In addition to creating new interactive objects, the project aims to learn more about how to engage people with disabilities as participant researchers in designing art objects, and how to make heritage sites more accessible generally.

Categories and Subject Descriptors
H.5.2 User Interfaces – Interaction Styles. J.5 Arts and Humanities – Fine Arts.

General Terms
Design, Human Factors.

Keywords
Interactive art sensory objects, learning disabilities, museums, heritage sites, participant researchers.

1. INTRODUCTION
"Hands-on exhibits bring a space to life, giving a greater understanding and meaning to cultural heritage. This is especially important for people with learning disabilities"

Lord Rix, 2005, President of Mencap

The experience of handling artworks, as Lord Rix makes clear, enormously enhances our understanding of cultural heritage, and this is especially so for those with learning disabilities. For this social group, hands-on experience of cultural objects has in recent years become an important approach in promoting an understanding of cultural heritage as highlighted by the Access to Heritage Forum [1], and in response many museums and heritage sites have established 'handling collections'. Yet there are many drawbacks. The materials made accessible to those with learning disabilities as substitutes for the originals are usually chosen by the curators rather than determined by the user-group, and are often of lesser quality that the main museum exhibits [2]. Furthermore, many materials are deemed by curators too delicate to be handled by the user group, and in some heritage sites access to the objects is limited because of the complex nature of the site's environment, and so their character is sometimes limited to pictures in books.

This project aims to address this problem in three ways:

1. Create a series of interactive, multisensory objects that replicate or respond to artworks or other objects of cultural significance in our national collections. The artworks and cultural objects of interest will vary with the heritage sites - for example, Victorian cooking implements in a National Trust house or a farmer's plough in a Museum of English Rural Life. Artistic responses to the existing artworks might include, for example, a replica that has a screen or speaker embedded in it which responds to light or movement. This could trigger a recording of an oral history or a series of photos from the archives to appear on the screen, or perhaps a recreation of a physical experience such as the vibration felt when ploughing a field or even the smell of wet straw.
2. Employ people with learning disabilities as participant researchers in generating and designing these art objects, so that they cater for a wide and yet targeted range of needs.
3. Explore techniques for developing interactive sensory objects, focusing on iterative design through participant workshops, with a view to developing best practice guidelines which can provide a basis for future development and provide a lasting resource for museums and heritage sites to support them in engaging with user groups.

The project potentially benefits heritage sites and their visitors, and helps to promote greater access to museum and heritage collections for people with learning disabilities.

2. BACKGROUND
“We experience reality with all our senses. We should experience our heritage the same way.”

Richard Crowest, 1999

For people with learning disabilities, there are many challenges in accessing museum collections, as recognised in Touch in Museums: Policy and Practice in Object Handling [3]. This book was developed from a series of workshops funded by the AHRC at University College London. It identifies the need for further

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research to improve accessibility of museums, particularly the role of touch in knowledge transfer, and recognises the huge potential museums can play in learning, enjoyment, health and social care, centred around a multisensory approach to tactile provision. In particular, Chatterjee refers to the chapter by Marcus Weisen [7] 'How Accessible Are Museums Today?' which notes the significant barriers that many disabled people face in the enjoyment of museum collections and the size of the challenge remaining in order for the cultural rights of disabled and visually impaired people to be recognised.

The importance of widening participation is also recognized by The Museums, Libraries and Archive Council's 'Outcomes Framework' 2010 [6], which stresses the role Museums, Libraries and Archives play in cultural participation. This framework document states that widening cultural participation "creates and maintains social capital helping individuals participate in society and the economy," and it makes the case for delivery of outcomes at a local and regional level, noting that adult health, a sense of wellbeing, and the perception of equality are key indicators. While museums have focused on enhancing physical access to museums, " the absence of disabled people as creators of arts images and artefacts and their presence in works reinforcing cultural stereotypes conspire to present a narrow perspective of the existence of disability in history" [5].

3. WORKSHOPS

At the centre of this project is a series of workshops that are fundamentally experimental and exploratory in character. In each, the academic research team works together with the participant researchers with learning disabilities to develop interactive art objects, and in so doing record their successes and failures. Participants take part in the design prototyping of the sensory interface objects, acting as experts and consultants in their disability. Through the inclusive design methodology of the workshops, the groups are encouraged to experiment, tryout and feedback their own opinions, rather than passively receiving what researchers think they need to access heritage. This opportunity to be a researcher for accessibility provision can be an empowering experience for a group whose opinion can often be overlooked or misrepresented.

Participants' ideas, views and activities during the participatory investigations are captured through methods such as photographic note-taking, video ethnography and questionnaires, and the progress is made available online via a blog. The academic researchers use their own expertise as artists and technologists in guiding the exploration, and in particular, exploring the role of newly developed easy-to-use electronics (e.g. Arduino). In the process, we expect to explore and learn much about what is meant by meaningful and creative engagement, and the potential and means for achieving this.

In year one, participants will be engaged as researchers through collaboration with the Access to Heritage Forum, Liverpool, and will use the collections at Speke Hall (National Trust) as the basis for developing the interactive objects. In year two, participants will be recruited through the Tower Group, Limehouse, London, and will use the collections at The British Museum. Year three will involve participants from local special schools in Reading and use the collections at the Museum of English Rural Life (MERL) at the University of Reading.

4. EARLY WORK IN PROGRESS

The project started in April 2012. Since then we have held the first workshop where the project team met the participant researchers, looked at some everyday objects (e.g. a fan, a pair of woolly gloves, a feather boa and various other tactile objects) and explored how we use them and what was the effect of using them. The group explored each object, what associations they made from the various textures, smells and sounds, and thought about how all these objects are in some way interactive and physical. Some electronic objects were also explored by the participants, including a touch sensor which produced music through a computer, and a bend sensor that manipulated a face on the computer screen.

The participants were introduced to the idea of documenting research through the use of photographs and video, and tested out a selection of different cameras to discover which one(s) were the easiest for them to use, and the most accessible. For instance, some cameras were considered too bulky, had too many buttons or buttons in the wrong place. We rounded up the session with some discussion on which camera was the most popular, by giving 'star' ratings to each, voted for by the participants.

5. BENEFITS TO MUSEUMS AND HERITAGE SITES

Museums and heritage sites both nationally and internationally can potentially benefit from the research, through guidelines to help improve the visitor experience. For instance, the project will explore ideas for displays with heightened sensory interaction and improved accessibility. Educators and designers of museums and heritage sites will be able to consult case studies from each museum to support them in adopting good practice in running inclusive workshops and providing accessible heritage displays in their own sites.

The ability to experience objects physically triggering media in museums and heritage sites, where you are often not allowed to touch the objects in the collection, presents new opportunities for visitors. People with disabilities could also benefit too: for example, wheelchair users could be provided with new techniques to access and experience objects that are currently inaccessible to them. This is the case with some heritage sites which cannot provide lifts due to listed building regulations.

Heritage sites can also benefit from guidance on alternative ways to engage people with learning disabilities acting as consultants, which will help them gain a real understanding of the needs of this group of visitors. This should help museums and heritage sites improve their service provision for people with learning disabilities, with the potential to influence policies on widening participation, for example in documents such as The Museums, Libraries and Archive Council's 'Outcomes Framework'.

The three sites that are directly involved in this project will benefit from the new handling collections developed during the project, which will be left at the sites so that they are available to museum visitors after the project has ended. The Museums and Heritage site will keep the interactive objects as part of their collection for public engagement. The British Museum is keen to involve their curators and outreach staff in the workshops. MERL will highlight the project as a case study that other museums might use in creating inclusive workshops, and in encouraging volunteering for people with Learning Disabilities.

6. ACKNOWLEDGMENTS

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In Control – Hear Rate-driven Architecture

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ABSTRACT

We describe the design process of a formal study that investigates the potential of adaptive architecture to directly influence or control the physiology of its inhabitants. We depict two pilot studies that inform the design process of the formal study. These studies raise questions regarding the effects of such environments, including the benefits and potential dangers. The formal study will also be an initial step towards introducing the built environment as an active agent in environmental (architectural) interactions.

Categories and Subject Descriptors

J.5 [COMPUTER APPLICATIONS]: Arts and Humanities, Architecture

General Terms

Design, Experimentation, Human Factors

Keywords

ExoBuilding, adaptive architecture, biofeedback, control, experimental study, physiological data, heart rate variability.

1. INTRODUCTION

This paper introduces two pilot studies situated in the context of adaptive architecture, responsive and biofeedback environments. We use specific, well-studied physiological phenomena to focus on the question whether it is possible under certain conditions to control an inhabitant's physiological processes through interventions of the built environment. Possible scenarios of participant behaviour, implications for computing and architectural research and design, as well as benefits and dangers of environments with such capabilities will be briefly discussed.

1.1 Developing the formal study

The environment used for this study is called ExoBuilding [12] (shown in Figure 1), which is a single-person, tent-like structure that changes its height, volume, and shape based on its inhabitant's real-time physiological data. Schnädelbach, Glover and Irune [12] describe the rationale, design process and finished result in detail. For the purposes of this paper, a brief description of the environment follows below.

ExoBuilding is driven by servomotors that receive signals through a middleware platform called ECT [3]. ECT allows data processing and manipulation as well as communication with physical actuators. It is the combination of physical structure, sensing technology and middleware platform(s) that allows direct physiological interaction between inhabitant and environment. More specifically, white jersey fabric is stretched over a central spine made from thin aluminium tubing. This spine is suspended from two servomotors mounted to a wooden ceiling structure. The servomotors allow for a motion range (up and down) of about 30 centimetres (Figures 1 and 2).

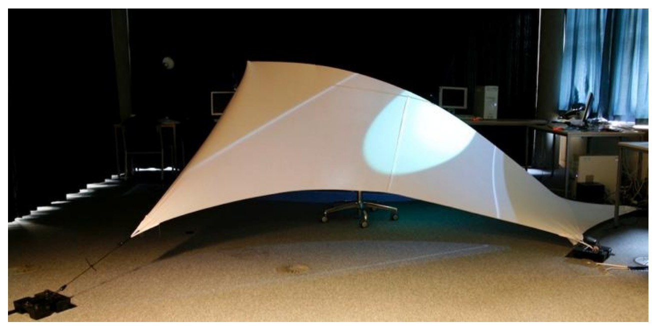

Figure 7: ExoBuilding in "down" state

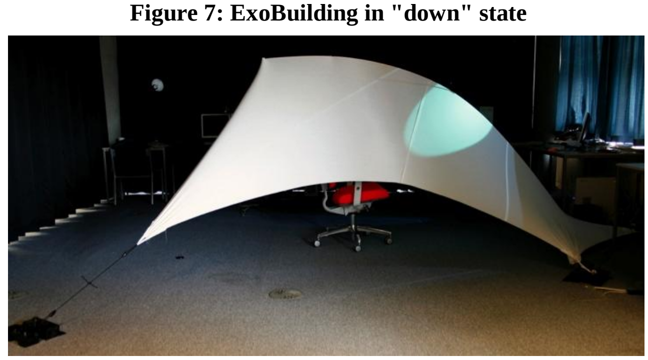

Figure 8: ExoBuilding in "up" state

The structure is ca. 1.3-1.6 metres high, about 3.5 metres long, and about 3.5 metres wide. The single inhabitant of ExoBuilding first sits down on a reclining chair, which itself is mounted to a wooden platform equipped with coasters. The inhabitant is then rolled into ExoBuilding by the experimenter, entering the structure from the back (Figure 3). The inhabitant or participant

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then sits underneath the stretchable jersey fabric onto which a circle of blue light is projected for the duration of the experiment (Figure 4). Fur the duration of each trial, the lights are extinct and only residual light coming through the window curtains and the light of the projection illuminates the environment (Figures 3 and 4).

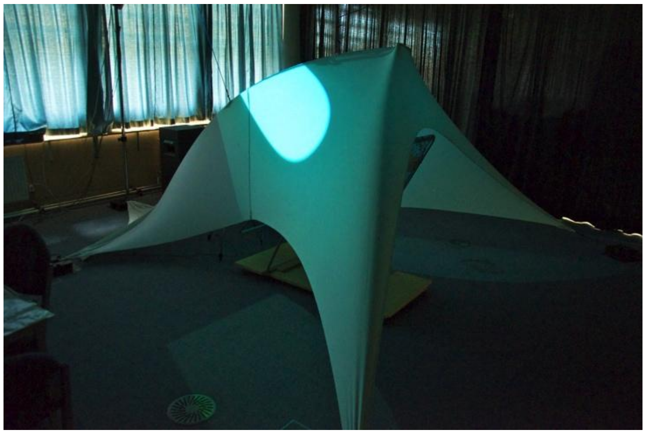

Figure 9: ExoBuilding side and back

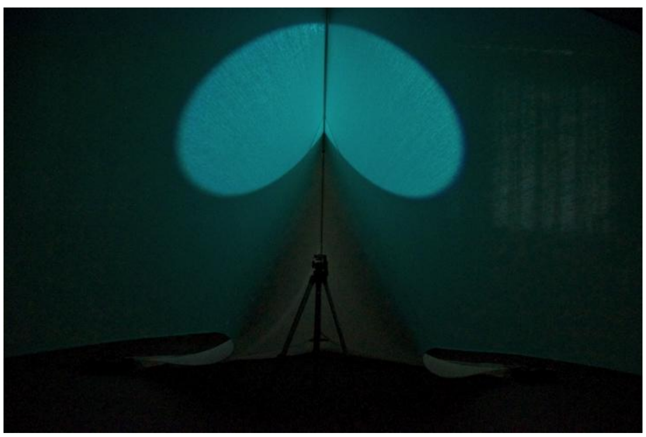

Figure 10: Inhabitant's view during experimental trial

An initial pilot study by Schnädelbach, Glover, and Irune [12] explored the potentials of ExoBuilding as a biofeedback environment and as proof-of-concept regarding the feasibility of using live physiological data to influence an architectural structure. Schnädelbach et al.'s based their exploration on two biofeedback conditions (respiration, heartbeat, and electrodermal activity): (1) sitting in a fully reclined office chair inside ExoBuilding, (2) lying on the floor inside ExoBuilding. Three participants experienced both conditions without instructions regarding their behaviour and reported that the experience felt relaxing, "womb-like" and extending their body "as if the tent were controlling my chest".

An as yet unpublished formal and controlled study by Schnädelbach probed into physiological effects of immersive biofeedback. Twelve participants experienced three counter-balanced conditions. They were (1) no biofeedback and no motion of ExoBuilding, (2) no biofeedback but regular motion of ExoBuilding, (3) biofeedback of heart beat, electrodermal activity alongside biofeedback motion of ExoBuilding controlled through the participant's respiration. The study revealed that on average, participants reduced their respiration rate during the biofeedback condition, while only a few participants reported this to be comfortable. Both other conditions, the no-movement and the regular movement condition, did not produce any significant effects in participants.

Based on the findings of the first pilot study, the formal and controlled study, as well as subsequent tests, we were intrigued to investigate other biofeedback conditions in the ExoBuilding environment as well as to explore whether biofeedback environments could be used to actively control inhabitant behaviour.

The interest in controlling a person's (physiological) behaviour through the environment arose primarily out of participant feedback of the first pilot study. As mentioned above, a participant had expressed a strong post-condition reaction to ExoBuilding. The participant described a sympathetic chest movement when biofeedback was disabled and ExoBuilding merely returned to its default position. That is when ExoBuilding was moving up, the participant felt the chest rise simultaneously. Subsequently, we discussed ways to replicate such a strong connection between the environment and a person as well as the architectural relevance of and interest in controlling human physiology directly through real-time architectural interventions.

1.2 Control in architectural research

Controlling people through an architectural environment has been studied in architectural research. However, research regarding control and power in the built environment does not usually involve directly controlling a person's physiology. Instead, architectural researchers describe control mainly as a top-down power structure, which has been and is being used to express governmental authority and omnipotence or to express governmental structure or political systems. This has, for example, been analysed by Kim Dovey [2] with regard to the imposing scale of Hitler's plans for Berlin, the exclusion of imperial Beijing's forbidden city and the all-inclusive nature of communist Beijing's Tiananmen Square. Dovey identifies additional expressions of power or economic and political systems in the ubiquitous office tower and modern governmental buildings (using Canberra, Australia as example).

Control has also been discussed in terms of neighbourhood and building safety. Oscar Newman [8] has argued for specific neighbourhood and urban designs to enhance, for example, visibility of entrances in order to enable increased social control and the ability to defend space against unauthorised or unwelcome visitors. Such designs would allow inhabitants to better visually and physically control their immediate urban environment.

As Schnädelbach has described in "Physiological Data in Adaptive Architecture" [11], there are architectural projects utilising the human body to create interest (e.g., varying degrees of façade transparency of the Laban Dance Centre revealing dancers' movements to the outside world) or technical adaptations to react to external data sources (e.g., the shutter mechanism of the Institut du Monde Arabe reacting to increasing or decreasing daylight levels). But we are not aware of projects were real-time physiological data is being used to actively change the building fabric or parts thereof. Our research in this area is on-going and therefore currently incomplete.

1.3 Physiological background

In order to study control between participant and the environment, we utilise the physiological phenomena of heart rate variability (HRV) and respiratory sinus arrhythmia (RSA).

Heart rate variability (HRV) describes the phenomenon of varying time intervals between heart beats. Respiratory Sinus Arrhythmia (RSA) links heart rate and respiration. On inhalation, heart rate rises, on exhalation heart rate slows down [4]. This effect is strongest at low respiratory frequencies as shown by Song and Lehrer [14] who indicated that HRV amplitude is highest at 4 breaths per minute. Figure 5 shows how the (stepped) curve of heart rate and respiration (raw data measured by respiration belt) align. Thus, it is possible to indirectly influence or control the variability of heart rate through one's respiration.

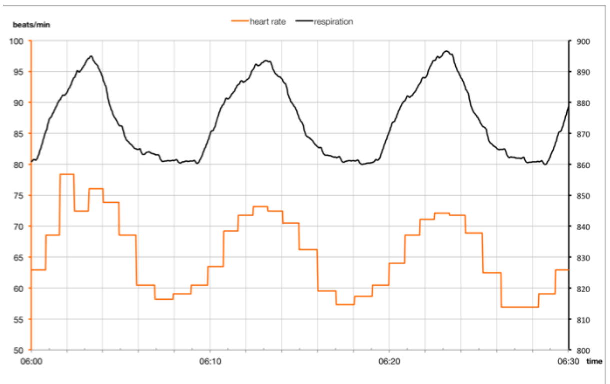

Figure 11: HRV and RSA - heart rate data (bottom) in relation to raw respiration data (top)

RSA biofeedback has physiological benefits. It helps to increase heart rate variability amplitude [5], which, for example, has been used to treat post-traumatic stress disorder [15]. It has also been suggested that RSA biofeedback training can have positive influences on state anxiety and stress reactivity of heart rate [13]. Any health benefits are welcome, yet not central to our study. However, we use the physiological phenomena of HRV and RSA and the indirect control mechanism for the purpose of this study.

2. THE PLANNED FORMAL STUDY

Here we describe the goals and setup behind the planned formal study, with which we intend to investigate control in and over adaptive architecture.

2.1 Study goal

We aim to effectively control a participant's respiratory rhythm through the ExoBuilding environment under the condition that the participant is unaware of losing biofeedback control over said environment.

In order to control a participant's physiology, the participant must be unaware of being controlled. As Schnädelbach's formal study has shown, regular motion of ExoBuilding without discernable relation to participant physiology did not cause physiological effects in participants. Hence, we do not reveal the true purpose of the study at first. In addition to being unaware of the real purpose of the study, participants must not be able to perceive any difference between biofeedback control over the environment and being controlled by the environment.

2.2 Taking control

Since the participant is controlling ExoBuilding indirectly, as described above, we expect that this abstraction of control will allow us to more easily and less obviously reverse the power relationship between participant and ExoBuilding. Still, several conditions must be met before control can be transferred unnoticeably.

First, the participant must establish a trusting relationship with the environment. That is, the participant needs to experience control over the environment. Therefore, we allow participants to experience biofeedback control over ExoBuilding. We also (seemingly) duplicate this first biofeedback session, for the participant is likely to feel familiar with the environment and procedure at this stage and will expect ExoBuilding to behave as it did during the first session.

Secondly, the transition between biofeedback control over the environment and being controlled by ExoBuilding must be seamless to the participant. Hence, the second session is split into an initial biofeedback phase and a subsequent phase during which ExoBuilding imperceptibly assumes control and attempts to alter the participant's physiology. During the first phase of this second session, the biofeedback phase, our software tracks the fluctuation of participant heart rate (HRV) and calculates its frequency. The software then uses this information to mimic the participant's HRV in order to disguise the switch in control.

2.3 Driving a participant

With the previously mentioned tactics of switching control in place, we require a measure of success enabling us to tell if ExoBuilding is indeed controlling the participant's respiration frequency. Changing the motion frequency of ExoBuilding was selected to measure whether the participant would follow this frequency and adjust his or her respiration rate accordingly.

We decided that once the transition to ExoBuilding control has occurred, our software would reduce the motion frequency of ExoBuilding by 20 per cent over a predefined period of time. We chose a reduction of the frequency because of the previously explained health benefits of RSA biofeedback. It seemed logical to reduce the frequency rather than to create an environment that attempts to induce stress (i.e. increased respiration rate).

2.4 Anticipated participant behaviour

As explained above, participants indirectly control ExoBuilding's motion through their respiration. We have seen in a previously conducted pilot study that not all participants might be able to make ExoBuilding move regularly and smoothly. Based on this experience and extensive testing of the technical setup with various data sets, we can expect three main participant behaviours or reactions to this kind of environment and experimental design.

First, the participant is able to quickly get into a regular breathing pattern and maintains this pattern throughout the sessions. After the transition to artificial data has happened in the second session, the participant closely follows the decreased motion frequency of ExoBuilding.

The second plausible course of participant behaviour is that the participant is able to get into a regular breathing pattern, causing ExoBuilding to move regularly. But just before the transition to CG data, either the participant momentarily loses respiratory regularity or the software produces inaccurate data (frequency too high or low). This would create a motion frequency of ExoBuilding that is unrelated to the participant's prior performance and experience. It is likely that this would prevent the participant from following the decreasing motion frequency of ExoBuilding.

The third expected scenario consists of a participant who is unable to produce regular heart rate variability curves resulting in seemingly erratic ExoBuilding motion. To the participant ExoBuilding will appear to be moving independently from the participant's breathing pattern. Such a scenario will make it difficult to control the participant's respiration frequency through ExoBuilding, as the participant might not have been able to establish a 'trusting' biofeedback relationship with the environment. Accordingly, any expectations of the environment's reactions and how to influence these reactions will differ significantly from participants in the previous scenarios.

3. PILOT STUDY NO. 1

3.1 Aims

This pilot study was conducted to test the main procedure for the formal study, as well as participant behaviour, measurements and analysis of the data.

3.2 Participants

The first pilot study consisted of three participants, one female and two male in the age range of 25-35. All three participants were recruited from within the lab but had neither prior experience with ExoBuilding nor exposure to the study procedure.

3.3 Methods and Measurements

3.3.1 Methods

We did not initially reveal the true nature of the study in order to avoid participant expectations or suspicions. We told participants that we were interested in observing differences between first- and second-time exposures to HRV biofeedback through an environment.

The experiment was designed with two experimental sessions of 12 minutes each, occurring consecutively on the same day. To a participant both sessions would appear to consist of biofeedback. The second session, however, was split into two parts: (1) participant control (biofeedback) and (2) computer control.

3.3.2 Measurements

We measured primarily the participant's physiology (i.e. heart rate respiration rate and skin conductance). We also measured the motion of ExoBuilding itself with an accelerometer. This allows us to measure whether participant and ExoBuilding are behaving/moving synchronously. All the mentioned sensors are part of the MindMedia biofeedback sensor kit called NeXus-10.[7]

A demographic survey and multiple pre- and post-session questionnaires were used as statistical covariates.

We also assessed the participant's experience through an open-question questionnaire as well as a semi-structured interview at the end of the experiment.

A video camera in front of the participant recorded the participant's behaviour during each trial.

3.4 Procedure

Initially, each participant was fitted with electrodes (electrocardiogram, galvanic skin response, and a respiration belt) and experiences two experimental sessions. Prior to the first experimental session, the participant received a short explanation of heart rate variability, its link to respiration, and its mapping to ExoBuilding's motion. Before each session, the participant received minimal instructions to "breathe slowly and regularly and focus on your breathing." The participant filled out pre- and post-session questionnaires for each session. Each participant was also fitted with noise cancelling headphones to prevent the participant from focusing on external sounds, especially from the servomotors, and to help with focusing on breathing.

After the second session, the participant executed a short drawing task of the experience, which is intended to help the participant think about his or her relationship to ExoBuilding. The drawing was then used as an entry topic to a short, semi-structured interview.

3.5 Results

3.5.1 Physiological Data

Pilot study no.1's most intriguing result indicates a change in the participants' breathing behaviour after the transition to artificial data in the second trial. As opposed to our expectation that participants would follow the decreased motion frequency of ExoBuilding with their respiration (i.e. participants would breath more slowly), all three participants' respiration rate increased on average after the transition. It is unclear if this effect is caused by the sequence of trials (the manipulation being always in the second trial) or the duration of exposure to biofeedback through the environment (the manipulation happening after a total of 15 minutes of biofeedback).

3.5.2 Self-report

All three participants reported the experience to be relaxing and overall pleasant. In addition, all three participants independently reported sleepiness after the first trial. None of the participants noticed or suspected a manipulation. However, they did report that the mechanism was not working as well as before. One participant assumed that the environment (after the transition to automated data) was attempting to help to achieve a more regular respiration.

3.5.3 Technical aspects

Pilot study no. 1 revealed a delay in the responsiveness of ExoBuilding to physiological data that was not previously detected. For all three data sets, the delay seemed to vary, with one data set being significantly different (longer delay) from the other two. This phenomenon is currently under investigation. We intend to remove delay of responsiveness as much as possible while simultaneously maintaining the ability of transitioning between physiological and artificial data unnoticeably.

3.6 Reflection

The results of this first pilot study prompt questions regarding potential order effects, experimental procedure, and trial length, which need to be addressed before proceeding with the formal study.

We currently investigate two options regarding order effects: one option is to incorporate counter-balancing in the formal study, while another option is to run a subsequent study to confirm the manipulation's effect independent of its timing.

Regarding experimental procedure, the formal study will include tasks before each trial designed to raise participant alertness. Such tasks might consist of physical or cognitive exercises. The issues of order effects and trial length seem to overlap and are partially being addressed in an additional (already conducted) pilot study (no. 2), which is described in the section “Pilot Study No. 2”.

It is unclear if the effect of changed respiration behaviour in participants is caused by the experimental manipulation (switching control) or due to the length of exposure to a biofeedback environment. We, hence, designed a second pilot study to investigate the effects of extended exposure to a biofeedback environment on inhabitants.

4. PILOT STUDY NO.2

4.1 Aims

In response to pilot study no. 1, the goal of this study was to investigate how extended exposure to a biofeedback environment affects participants. The findings should help establishing parameters for optimal trial length in the formal study.

4.2 Participants

We recruited eight participants from within the lab, of whom three were female and five male. The age distribution was as follows: 18-21 (1), 22-25 (1), 26-30 (3), 31:40 (1), 41-50 (2).

4.3 Methods and Measurements

4.3.1 Methods

The experiment was designed with one experimental trial of 30 minutes HRV biofeedback inside ExoBuilding.

4.3.2 Measurements

The measurements were identical to pilot study no.1.

4.4 Procedure

The procedure was very similar to the procedure of pilot study no. 1. The main difference is that there was only one trial of 30 minutes. Fitting of electrodes, explanation of heart rate variability, surveys and questionnaires, breathing instructions, use of headphones, drawing task and interview were identical to the first pilot study.

4.5 Results

We visually analysed respiratory behaviour regarding regular respiration and respiration rates. Resting respiration frequencies range between 12 and 15 cycles per minute (cpm). [1] The ability to stay below 12cpm for an extended period of time indicates both the understanding and following of the instructions given and the understanding of how to manipulate the mechanism. The video recordings were analysed for first signs of discomfort (shifting of the torso). Preliminary visual analysis of the physiological data was done to observe the participant’s ability or failure to maintain regular respiration and consistent respiration rates below 12 breaths per minute.

4.5.1 Physiological data

Early visual analysis of the physiological data of this study suggests that the eight participants fall into three groups of respiratory behaviour. Two participants were able to breath consistently at low frequencies (repeated periods of several minutes below 12 breaths per minute) with few deviations (faster respiration) from this pattern. Four participants seem to have been able to maintain respiration rates regularly below 12cpm in the beginning of the experiment ranging from about 2.5 to about 7 minutes. However, they subsequently started to deviate from a regular and slow breathing pattern. The third group consists of two participants who seem to have been generally unable to fall into regular and slow breathing patterns. This will need further analysis to substantiate these preliminary results.

4.5.2 Video data

Preliminary analysis of the first 15 minutes of video data (frontal view of the participant during the trial) indicates that participants start to move their torso (indicating discomfort with their seating position) for the first time on average after about eight and a half minutes (8m27s). However, the times vary between not moving within the first 15 minutes and moving after only 2 minutes and 13 seconds. However, six participants moved after seven minutes.

4.5.3 Self-report

Seven participants reported the experience to be generally relaxing. One participant said that the experience would be relaxing under certain circumstances, such as not being overly stressed, which this participant reported to have been at the time of the experiment.

Two participants reported that they felt to have lost control over ExoBuilding during the trial. Both these participants were aware of our research in the previous pilot (but were not participants of pilot no. 1) and had apparently projected this knowledge onto pilot no.2.

4.6 Reflection

The preliminary results of pilot study no. 2 suggest that participants on average remain comfortable for about 8.5 minutes. Additionally, a majority of participants seems capable of achieving and maintaining regular respiratory patterns for several minutes. More detailed analysis of the data will be necessary to establish the optimal timing for experimental manipulation, in this case the transitioning from participant control to computer control.

Although most participants reported a relaxed experience, analysis of the video data revealed that some of these participants started to move their torso (shifting weight and making posture adjustments) after only a few minutes inside the structure. We interpret this behaviour as restlessness or discomfort. Accordingly, a contradiction between self-report and behavioural observation seems to exist, which will need to be investigated further.

The results also suggest ensuring careful recruitment of participants for the formal study to avoid biased data.

5. FORMAL STUDY

Results of both pilot studies appear to suggest that the formal study can be undertaken once all previously raised issues have been addressed. We describe the adjustments for the formal study in the following.

5.1 Participants

Most participants of pilot study no. 2 had knowledge of our general research interest in adaptive architecture and responsive environments. In particular, the finding that participants might enter experiments with specific expectations, such as being manipulated, shows the importance of, recruiting from outside of the lab. This will help to avoid expectations or anticipation of any manipulation. Therefore, participants will be recruited campus-wide through email distribution and posters. Participants will be screened for severe heart or respiratory conditions, as well as claustrophobia. All participants will receive financial compensation. We anticipate recruiting twenty or more participants.

5.2 Methods and Measurements

5.2.1 Methods

The methods remain the same as described for pilot no. 1.

5.2.2 Measurements

Measurements also remain the same as described for pilot no.1 To measure physiological effects and alignment between participants ExoBuilding, we will compare correlation coefficients between accelerometer data (movement of ExoBuilding) and participant heart rate (variability) data and respiration data (raw). We will analyse two time windows per session, before and after the point of transitioning from 100 per cent to 80 per cent of the participant's respiration rate.

We will analyse questionnaires and demographic survey as covariates.

Video analysis seems capable of revealing possible contradictions between self-report and behavioural observations and will again be part of our measurements.

5.3 Procedure

The procedure of pilot no. 1 will remain generally intact with two trials, one of which will contain the manipulation. A decision on counter-balancing within this study will be made after careful consideration.

We will add a task before each trial. As mentioned above, such a task might be physical or cognitive but will be intense enough to ensure the same baseline of alertness for both trials.

Based on the results from pilot study no.2, it seems feasible to reduce the time for both trials to about 9 minutes, as participants seem comfortable for roughly 8.5 minutes on average. The best possible timing of the transitioning of control still requires further analysis of the physiological data of both pilot studies.

5.3.1 Anticipated results

Based on the results of the two pilot studies, we expect a majority of participants to be able to sustain regular and slow respiration for several minutes. Hence, we anticipate that the manipulation of transitioning control from participant to ExoBuilding and the simultaneous deceleration of motion frequency will have an effect on most participants. The pilot study seems to suggest that at least some participants will increase their respiration rate instead of decreasing it. This phenomenon still requires investigation but might be related to physiological, demographic, or personality reasons.

Should a significant number of participants indeed reduce their respiration in correlation to ExoBuilding's motion frequency, this would support the argument that environments, under specific conditions, might be able to control parts of the human physiology. The implications both for research in computer-human interaction as well as architectural research and design applications would be significant.

6. DISCUSSION

As Ratti and Haw have pointed out buildings are increasingly becoming sentient and active in their participation in daily life. They argue similar to Merleau-Ponty [6] (although not directly involving the human body) that architecture is becoming "self-aware digital systems inseparable from the flesh of life itself." [9] In the case of the introduced study, the level of embedded computing in the case of ExoBuilding goes beyond Ratti and Haw's description of the built environment. Not only does the digital system become part of the physical structure but it also becomes part of human physiology. In turn, human physiology becomes an integral part of the software by providing the data that is used to actuate the environment.

The ability to control a person's physiology through an environment, however, raises ethical questions as well as initiating a discussion about agency in the environment.

The ethical issues are manifold. As mentioned by Schnädelbach [10-12] the use and storage of personal data and its public availability needs to be carefully considered. Additionally, there are personal preferences regarding potential physiological integration with the built environment. Some participants have reported that the intimate physiological linkage to an environment is not pleasant.

Also, the duration of such environmental interactions and interventions can become challenging. As was revealed in the unpublished study by Schnädelbach, the effect of respiratory biofeedback on respiration rate decreased significantly after about 6 minutes. Consonantly, one of the participants in the recently conducted pilot study of HRV biofeedback liked the experience in general but suggested that this might be best used as an "after work" relaxation rather than inhabiting a constantly moving structure. This suggests biofeedback environments or controlling environments to be temporally visited or temporarily enabled rather than persistent features of the built environment.

Accordingly, similar to a sauna or floatation tank, one can easily imagine a temporarily visited environment that supports relaxation, healthier sleep patterns, or recovery from illness through specific actuations. On the other hand, it seems not implausible to imagine misappropriation of such technology. Examples of which might be to never let people fully rest as part of torture or simply to have employees constantly engaged or "on edge" as opposed to letting them fall into afternoon sleepiness.

Another set of questions involves the notion of agency in the environment. Here, one of the interests lies in the distinction between using the environment as a tool in influencing human behaviour and affording the environment with agency of its own. Particularly intriguing seems to be the case of an environment actively intervening in a person's health through actuations. It seems reasonable to assume that this kind of "enmeshedness" and embeddedness with the environment and subsequent embodiment of the environment would fundamentally challenge our attitudes towards both the built and natural environments. It is at this intersection between physical and digital world where the contribution of our research lies. As part of the formal study's data analysis and discussion, we intend to engage with actor-network-theory as well as further investigations of embodiment theories.

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Collaborative Communication Tools for Designing: Physical-Cyber Environments

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ABSTRACT

Designing for Physical-Cyber Environments (P-C E) will require a collaborative interdisciplinary approach. A Physical-Cyber Environment is my interpretation of an emergent hybrid, physical, digital mix, firmly grounded in physicality, which is technologically, digitally enabled and augmented. This landscape (P-C E) is an emerging possibility space where all types of products, services and environment will be possible. Designing for such complex environments will require the involvement of various disciplines, stakeholders and end end-users when appropriate. Each of these bringing with them their own internalized assumptions and thought processes, making understanding and discussion between the various parties potentially problematic. Tools are needed to aid productive dialogue between those involved. In this paper a selection of technologies in varying stages of development and concepts from science fiction are introduced to help describe the Physical-Cyber Environment. A discussion regarding difficulties in interdisciplinary collaboration and a description of a workshop called the "Alien Technology Workshop" designed to explore tools to aid productive collaborative discussions is also introduced.

Categories and Subject Descriptors

A.m [Miscellaneous]

General Terms
Design

Keywords
Hybrid, Physical-digital, physicality, design-tools-methods, interdisciplinary collaborative, Alien Technology, communication tools, design process.

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1. INTRODUCTION

Imagine a future where the physical and digital become seamlessly intertwined producing a strange new hybrid landscape. Where technologies have the potential for virtually unbounded possibilities. In this paper the author introduces the idea of an emergent physical, digital hybrid space called a "Physical-Cyber Environment" (P-C E) and an interdisciplinary workshop called the "Alien Technology Workshop".

This Physical-Cyber environment, although not a reality at present in its full manifestation, is in the context of this paper a possibility spaced and proposed as emerging. Currently things physical and things digital are already converging into hybrid objects and environments and the world of ubiquitous embedded computation continues to grows rapidly. [24][32] The realm of the Physical-Cyber Environments is an umbrella term to help describe a landscape, forming from an aggregation of many technologies, materials, systems and innovations. These may include: ubiquitous computing,[17] Cyber-Physical systems, ambient intelligence [1], physical digital hybrids,[22] smart materials,[6] augmented reality, [2] mixed reality [13] [20], cross reality, [18] and embodied virtuality. [32] Figure 1. depicts physical and digital merging into the hybrid Physical-Cyber Environment. Whilst looking at this landscape, a selection of research projects and concepts are presented to help describe the idea of Physical-Cyber Environments. These include: Lightspace, Home of The Future, Mirage and science fiction based concepts.

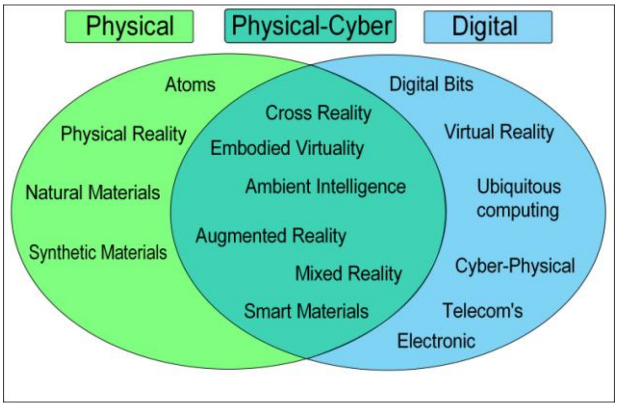

Figure 1. Emergent Hybrid Space: P-C-E

The concept of the emerging hybrid space (P-C E) builds upon and expands ideas and concepts discussed by other researchers into hybrid spaces. For example the latest Blast Theory game "I'd Hide You" [3] which combines the physical reality of an urban space (Manchester city centre) where 'performers' wearing cameras are tracked and interacted with via GPS and live video streaming by online game players, mixing virtual and physical elements. Steve Benford and Gabriella Giannachi [12] collaborative project 'Day of The Figurines' which likewise mixed the physical elements with virtual element to create a gaming experience. In this game the players can interact via text messaging with a game operator to effect and move physical game figurines from one position to another on the game board. Players can also interact with one another electronically to share knowledge and objects within the game.

Adriana de Souza e Silva in her article 'From Cyber to Hybrid' [8] discusses the blurring of borders between physical and digital spaces via the mobility of users and their mobile devises. She explains her definition of a hybrid space as one that occurs *"when one no longer needs to go out of physical space to get in touch with digital environments".*

Paul Dourish discusses [10] 'place and space' in light of mobile technology and how one is affected by the other. Having defined space as that which is the geometric configuration and place being that of the the social meaning and 'understood reality' he explains how the introduction of 'locative media' via technology into a space can change its meaning. He argues that the overlaying of "real" spaces with "virtual spaces" in a physical world embedded with technology provides new meaning and new ways in which that world is understood. He puts forward a different interpretation of space and place where the physical world is not separate from the technologically mediated world from which *"new cultural practices"* and *"new forms of environmental knowing"* emerge.

These interpretations and discussions of hybrid spaces, helps to describe the genesis of hybrid spaces. However for the purposes of this paper the Physical-Cyber Environment hybrid space is that of an evolution into a broader perspective of the hybridisation of the physical world. The term Physical-Cyber Environment describes the gradual aggregation of many different technologies and systems including digital mixed with the physical.

It is this author's contention that designing for such complex hybrid landscapes will require interdisciplinary collaboration, which may include stakeholders and end users participation. It is recognised that currently the design of complex systems often involve interdisciplinary collaboration and many design houses utilise participatory design methods. These strategies can be problematic concerning issues regarding, time, cost and communication difficulties encountered in involving other disciplines, stakeholders and end users [26]. However in this paper the author is concerned with one problematic aspect of those strategies, that being interdisciplinary communication difficulties. This paper introduces the 'Alien Technology Workshop' set within an imaginary scenario, where tools to aid facilitation of productive interdisciplinary discussions are explored. This particular technique "Alien Technology" aims to help participants be more at ease and open to collaborative discussion, where participants are equally inexpert and are encouraged to postpone judgement. The aim is to aid participants in externalising, recognising and valuing differences in disciplinary cultures.

The following sections contains a selection of technologies which help describe Physical-Cyber environments, followed by a discussion of interdisciplinary collaboration in design, then followed by a description of the Alien Technology workshop.

2. TECHNOLOGIES

2.1 Lightspace

Lightspace [19] is a project which draws together aspects of augmented reality and surface computing producing in combination a deeply interactive environment. The system enables the environment so that any physical surface can become interactive and also the actual space between surfaces all become *'fully interactive'*. The Lightspace system is a combination of different technological artefacts including several depth cameras and video projectors to produce an interactive spatial computing environment. Within this environment it is possible to move data, represented visually, from one place to another, for example from a wall to a table. The system also facilitates the shifting of data from one person to another as they interact with projected images passing them from one person to another. The Lightspace environment is calibrated so that projected elements are mapped to real world coordinates. This in turn means that any surface set within the Lightspace environment can potentially become an interactive artefact, including the open space. People are able to interact with the environment by way of gestures and multi-touch interactions with surfaces. In one example a person was able to hold out their hand (palm facing up) into a projected beam, which in-turn acted as a sort of menu, at which point raising or lowering the hand induced different options to appear in the palm of the hand.

2.2 Ambient Intelligence / intelligent environments

The UK's Channel 4 documentary series "Home of the Future" [7] explored a variety of technologies which created an intelligent environment for the inhabitants. The house had been fitted with new and experimental technologies to investigate how the family living there would respond to such an environment. This is a form of possible end user showroom / prototype testing. [14] Some of the technologies included: Eco-power systems to help control power consumption and explore new domestic power systems, various sensors to tailor temperature and lighting to the individuals, entertainment and leisure systems, Smart materials for example clothing which responded to music, an intelligent bathroom mirror connected with health and fitness and devises which monitored brain activity. In this experiment the family on the whole were positive and receptive to the technologies they had to live with. However some difficulties were experienced for example: personalised automated temperature regulation of bath water, appears to have not always delivered desired results which affected user confidence in the technology. Another example was end user habits in contrast to automated systems, in one case the father habitually switched power off to save electricity, which clashed with the automated systems needed to regulate power usage.

2.3 Mirage

Mirage [31] is being developed at the Virtual Reality Applications Centre, Iowa State University, this is a three dimensional, fully immersive, synthetic environment. This environment contains back projected images on the walls ceiling and floor, eight channel surround sound, haptic force feedback, physical objects, virtual and augmented reality and tracking systems. Mirage and the various other projects in development at the centre are interdisciplinary collaborations between the research lab, government and industry. The centre is researching and developing a variety of these environments aimed at leisure, education, business and military uses.

2.4 Science Fiction

Increasingly science fiction presents ideas of interactive, immersive, augmented environments. Notably is the fictitious *Holodeck* set within the Starship Enterprise featured in the *Next Generation Star Trek series.* This example pushes the imaginary boundaries to the limits as the Holodeck is not only able to produce a visual environment but also touchable physical interactive objects of just about any kind, which can be manipulated, felt and even sat on. It can even simulate corporeal entities such as people who are fully interactive. Nevertheless a holodeck environment, like the one featured in Star Trek appears to be a sort of holy grail for some in pursuit of augmented reality.

Most recently the film Prometheus, the 2012 prequel to the Alien films depicted a spatially interactive navigation system which surrounded the pilot. Not only did this system appear as visual augmented reality but the planets could be manipulated physically, a sort of hybrid tangible user interface. Nathan Shedroff and Chris Noessel [27] offer the suggestion that lessons can be learned from science fiction interfaces in the development of real world interfaces. They speak of a two way influence on design, one being real world design influencing hybrid science fiction interfaces. The other being science fiction influencing real world interface design by inspiration, expectation, social context and the innovation of new paradigms. For example the Motorola Star-TAC flip phone bears similarity to the flip communicator from the Star Trek original television series. Lab research of gesture interfaces like g-speak platform of oblong industries inspiring gestural interfaces of films like The Minority Report.

These examples demonstrate that the designing of complex hybrid environments involve the collaboration and expertise of various disciplines and stakeholders. Collaboration can however bring with it some communication challenges between those parties involved where difficulties making their ideas explicit can arise. [21]

To explore some of these challenges a discussion about interdisciplinary communication difficulties is put forward, a workshop technique “Alien Technology” and a collaborative “Communication Tool-kit” is introduced as an aid to encourage productive communication.

3. INTERDISCIPLINARY COLLABORATION IN DESIGN

To produce valued solutions in design, there is a need for frameworks and tools which take into consideration and can help to bring together multidisciplinary groups from within specialized areas of expertise.[15] Cross discipline collaboration can improve the possibility of innovative and effective solutions. [28]

A growing challenge to design practice is the need to bridge the communication gap between various professions, designers, other stakeholders and end user groups involved in the design process.[26] Even within sub departments of organisations people have “unique perspectives”of aims and tasks causing conflict. The “sharing of perspectives” is seen as helpful in this conflict and that becoming aware of conflicting ideas and discussions about them can be useful. [4]

Ethnography suggests that collaboration can be enabled by shared representation, these externalized representations add to cognitive processing. Externalization of individuals thoughts and ideas via representation in artefacts can aid communication of those thoughts and ideas. [9]

Myra Strober's studies into interdisciplinary conversations [28] have shown some of the difficulties faced by interdisciplinary teams which include differences in: language, ways of thinking, assumptions, ideas, ways of presenting, discerning and evaluating. These are described by Myra as “discipline cultures” and “habits of mind”. Myra Strober's study over several years makes some suggestions concerning the barriers between the disciplines and strategies which could help to make the conversations more productive. These suggestions are: Start by introducing the idea of disciplinary cultures to tightly structure sessions, making apparent the purpose of the session, selecting participants who are interested in syntheses between disciplines, establishing trust between the participants by being selective of participants with good interpersonal skills and distribution of conversation among the participants avoiding monopolization, introduce the participants to the idea of differences in disciplinary “cultures”, agreement on some base rules for the session by the participants. Liora Salter and Alison Hearn in their book on issues in interdisciplinary research [25] they note that it took two years to be effectively submerged in a new culture. Myra Strober similarly emplanes that at Bio X an interdisciplinary science centre at Stanford, it took two years of weekly meetings to learn the culture and habits of mind of each others disciplines.

Such a time-scale poses a problem for interdisciplinary / collaborative design teams as they may not have the luxury of two years to learn multiple discipline cultures and habits of mind. Therefore time effective solutions need to be explored to begin to address some aspects of developing productive communication between various and diverse collaborators. Some of these issues and suggestion are explored in the context of the Alien Technology workshops. The workshops overall aims are to help collaborators recognise and value differences equally in disciplinary cultures through the externalisation of differences.

4. THE ALIEN TECHNOLOGY WORKSHOPS

The Alien Technology workshops are a series of workshops investigating the development of a tool-kit to aid productive interdisciplinary communications in a collaborative design process set within a landscape of Physical-Cyber Environments. Each workshop focuses on different elements in the development of productive communication. The first workshop being a pilot study exploring the externalisation of the participants design process, as process is mostly hidden within a designers mind. [16] The second workshop (ATW 1.0) investigating the externalisation of disciplinary differences in assumptions, interpretations, representations and modes of presentation. A third workshop (ATW 2.0) exploring the recognition, valuing and synthesis of ideas. A fourth workshop (ATW 3.0) exploring collaborative design for the application of technology. The Alien Technology technique is used as a method to explore the design and development of such emergent hybrid spaces. The Alien Technology technique includes a fictitious scenario including roles, props and objectives.

The scenario includes the participants taking on the role of an alien with access to advanced technology, this technology is called “Alien Putty”. While in this role they are expected to consider an alternative alien culture and their environment which they have limited information about and at some stage they consider the application of "Alien Putty" to that environment. Giving participants a scenario provides context to the task in which to frame ideas and thinking about an unknown environment, technology and end user groups. The fictitious nature of the scenario enables some ambiguity [11] and freedom of imagination on the part of the participants in the design process. In this scenario there are no experts within the group and therefore the participants are equally inexpert. All participants should be viewed as equally valuable in the creative process. There is no right or wrong, all participants can create and contribute in a safe non threatening environment. A role to play in the scenario helps to immerse the participant into the scenario enabling them to engage and participate in the task given. In this scenario the role is fictitious to add a fun element and put participants at ease allowing them to be more open towards collaborative discussions.

The alien environment represents a Physical-Cyber Environment. The participant aliens represent a collaboration of disciplines and stakeholders. The alternative alien culture represent the end users of an environment. The Alien Putty represents technology with virtually no constraints and seemingly limitless uses. It is a metaphor for known and unknown abilities and possibilities that technologies may bring in the future. The 'Alien Putty' it is used in a conceptually similar way to *'dream tools'* [5]

4.1 Alien Technology Pilot Study

A pilot study was undertaken to explore the concept of the Alien Technology scenario and the externalisation of the participants design process, as process is mostly hidden within a designers mind. [16] The pilot study focused on individuals from different disciplines. The participants were given the role of being an alien and a scenario where their mission was to plan, how they might undertake the application of their own "Alien Technology" to enhance another alien culture's environment.

Figure 2 Pilot Study Mission Card and Badges

A prop was introduced to them representing the alien technology, in the form of "Alien Putty" figure 3. and is represented by soft modelling clay. In the context of the workshop the Alien Putty is a technology which can do virtually anything the participants can imagine. This provided a physical focal point to interact with which aided them in expressing their process, thoughts and ideas verbally and on paper. The participants were asked to use verbal protocols to externalise their thinking.

The participants of the pilot study were drawn from a mixture of artists, software engineers, HCI, product designers and business management. In this mix were Practitioners, Professors and Ph.D students, see table 1.

Findings showed that the alien technology scenario and roles where adopted readily by the participants and they were at ease with their roles. This workshop demonstrated that the introduction of the fictitious alien scenario gave participants a context on which they were able to comment and verbally externalise their process.

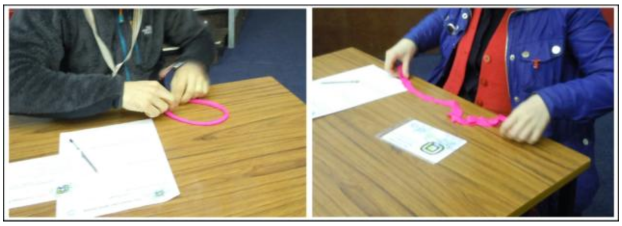

Figure 3. Interacting with the "Alien Putty"

Additional findings of the study emphasized some differences in the assumptions made by professionals from different disciplines. It was also observed that the participants tended towards two distinct approaches to their process with regards to consideration of the end users. These were, those who would take an ethnographic approach and those who would build it and see what happens approach. During the session there was opportunity for the participants to make notes, some of the participants did make notes whilst other preferred not to, demonstrating some differences in preferred modes of communication. The aims and findings of the pilot study were successful in helping to frame the first Alien Technology workshop 1.0.

Participant Code	Date	Profession /Discipline	Location
A1	15/3/ 2012	Artist	LICA
A2	15/3/ 2012	Software Engineer	LICA
A3	15/3/ 2012	Business	LICA
A4	15/3/ 2012	Software Engineer	LICA
A5	15/3/ 2012	Product Designer	LICA
A6	23/3/2012	Software Engineer	TTW3
A7	23/3/2012	Product Designer HCI	TTW3
A8	24/3/2012	Artist	TTW3
A9	24/3/2012	Software Engineer	TTW3
A10	24/3/2012	Software / HCI	TTW3
A11	24/3/2012	Software Engineer	TTW3

Table 1. Pilot Study Participants

4.2 Alien Technology Workshop 1.0

The aim of the Alien Technology workshop 1.0, was to investigate tools to aid the externalization of disciplinary assumptions and differences between participants in an interdisciplinary team within a landscape of seemingly unbounded technology.

The workshop attempts to do this in a number of ways:The introduction of the Alien Technology scenario. To introduce the idea of differences in disciplinary assumptions, thought processes and modes of representation and presentation. The introduction of a communication kit figure 6. to aid productive communication. In the context of these workshops the communication tool kit is used in a face to face setting and at this stage virtual participants are currently not involved. ATW 1.0 had a duration of one hour. The elements of the workshop are as follows:

Warm-up

A warm up activity to externalise some differences in assumptions based on the phrase 'space alien' where the participants create their own model of a space alien and give it a name. This helps participant 'postpone judgement' and give permission to push the boundaries to the nonsensical in a non threatening way. [29] Each participant then briefly introduces themselves and the space alien they have made to their group.

Figure 4. Space Aliens

Main Task

The introduction of vignettes, artefacts that aims to ensure all the participants are responding to the same materials, these also act as controls for the research. In this workshop the artefacts are reconnaissance pictures figure 5. from the alien environment, which the participants are encouraged to interpret and then are asked to present their interpretations to the group. This task reinforces some of the differences in thoughts and ideas of the participants. The reconnaissance images are purposely ambiguous however suggest some form of intelligently constructed environment.

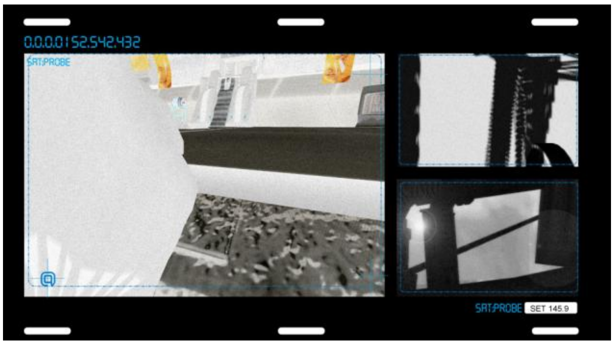

Figure 5. Main Task Reconnaissance Images

A communication kit figure 6. containing a considered selection of materials to aid articulation of ideas and thinking between the different disciplines. These materials are intended to allow for different modes and styles of representation of ideas, thinking and presentation, making them accessible to different participants preferences and require no specialised skills to use. [23] The communication kit comprises of 3D and 2D materials and a variety fixing / fastening and mark-making items. The 3D items included: Lego, K'nex, Construction Shapes and Modelling Clay.

Figure 6. Communication Kit

The 2D items included: Sticky-notes, various sized notepads, a selection of A4 paper / card and an A2 sketch / flip pad. These resources are included to facilitate low-fidelity 3D models, sketches and notation. The participants make their own selection of materials from the communication kit to create their individual interpretation and representation of the environment. The participants were instructed to use the items in any way they chose to represent their individual interpretations.

Presentations

Presentations, the participants present their individual representations, interpretations, ideas figure 7. and key characteristics to their group, allowing other participants to view and discuss the different interpretations and modes of representation and presentations.

Figure 7. Different Presentations Modes

The participants are reunited with their space aliens (made earlier) and then asked to introduce their space alien to their environment figure 8. This gives the opportunity for participants to interact with their space alien and environment as a fun element if they chose to. This also serves to link the space alien with its name tag to the interpretation work on the table for reference.

Figure 8. Reunited Aliens

The facilitator rounds up by emphasising some of the benefits of externalising assumptions and differences in disciplinary cultures, in aiding productive communication between disciplines. It is hoped that the participants can take away with them the idea of looking for and recognising disciplinary differences with a view to valuing those differences equally in a interdisciplinary collaborative setting.

The participants of workshop 1.0 were drawn from a mixture of artists, computer sciences, business management and organisational science. In this mix were Practitioners, Professors and Ph.D. students, see table 2 & 3.

Table 2. Group B: Presentation Modes

Participant Code	Group B, Mode of Interpretation / Presentation	Profession / Discipline
B1	Clay, K'nex, Other & Smart-Phone	Project Management
B2	Notes, Drawing on card & Smart-Phone	Management
B3	Notes	Management
B4	Notes + drawing, Lego & Smart-Phone	Computing Science
B5	Clay, K'nex, Paper	Management
B6	Clay, K'nex, Lego, Paper & Smart-Phone	Computing Science
B7	Notes with red and blue ink & Smart-Phone	Software / Art

***Table 3.* Group C: Presentation Modes**

Participant Code	Group C, Mode of Interpretation / Presentation	Profession / Discipline
C1	Clay, K'nex,	Business
C2	Clay, K'nex, Lego, Pipe Cleaners, Shapes,Notes, Other	Management
C3	Clay, Card, Pipe Cleaner, Pencil markings,Notes	HCI / Interact Art
C4	Clay, K'nex, Shapes,	Computing Science
C5	Clay, K'nex, Lego, Pipe Cleaners, Shapes, Rubber Bands, Other	Organisational Science
C6	Clay, K'nex, Shapes	Computing Science

4.3 Findings

The overall findings of ATW 1.0 generally supported the aims of the workshop in that the communication kit appeared to aid the externalisation of the participants assumptions, ideas and interpretations. The selection of resources provided in the communication kit did allow for some differences in modes of representation and presentation to be observed and recognised by other group participants. The selection of resources in the communication kit appeared to be accessible to all participants. The participant demonstrated a wide variety of differences in their assumptions and interpretations derived from the phase "space alien". Some created space aliens with humanoid features, some were creature like and others were abstract, figure 5. some gave their space aliens special attributes .

Throughout the main task it was observed that all participants externalised their thinking in some way, verbally, visually, through gestures, note form, 2D sketches or 3D models. The individual interpretations of the reconnaissance image varied widely creating some discussion within each group see figure 9.

There were distinct differences between the two groups. In Group B individual and disciplinary differences were easier to observe than in Group C. During the workshop the two groups appeared to approach the main task somewhat differently. Group B appeared to approach the task in a *more* cautious and systematic manner with a playful aspect. It was observed that Group B began the main task by predominantly spending some time contemplating the reconnaissance images before shifting into the representative phase. Whereas some participants in Group C seemed to approached the task *more* impulsively seemingly playing rather than being playful. In Group C most participants appeared to go directly into the representative phase after viewing the image briefly, predominately building and making utilising the communication kit.

Group B carried out their task mostly in silence in an insular manner and appeared very focussed on producing their own interpretations. Group C carried out their task in a seemingly more sociable manner. In group C there was more discussion during the task, some social and some related to the task, discussing ideas about the interpretations. The representations produced by Group B were more varied in mode than those of Group C. Group B members appeared to adhere to their own discipline modes of representation, some externalised their thinking in note form figure 9.4, 9.9 some through sketches, figure 9.6 others through model making figure 9.3. In Group C most members used similar modes to one another in their representations, externalised through model making, figures 9.1, 9.2, 9.7. However in Group C there appeared to be some recognisable disciplinary influences in their interpretations, use of materials and attitude towards the materials provided. In Group C one member used card figure 9.8 to form and build their representation whilst the rest of Group C used the preformed materials such as Lego. In Group B paper and card where used as predominantly as materials for writing and drawing on figure 9.5. A few members of Group C seemed to view some of the materials provided as merely play things.

Figure 9. Different Interpretation Representations

During presentations the participants demonstrated a variety of differing modes. One stood and read from notes some used the reconnaissance image as a visual aid. Some used their models as aids, others used a combination of the reconnaissance image and their models / sketches as visual aids figure 7.

Following the individual presentations, some of the participants held a discussion concerning differences they had noticed during the tasks. Others commented that they would have liked more time to reflect and discuss disciplinary differences. Some participants expressed how they would have liked to continue on into a group phase to synthesise their ideas about their interpretations of the environment. One participant commented that the workshop had been "a revelation" regarding observation of process.

Further workshops are planned (WT 2.0 & WT 3.0) to continue this line of inquiry, where the collaborative design elements of the workshop will be introduced while implementing the communication kit to aid productive dialogue, for the exploration of creative interdisciplinary collaboration within a landscape of seemingly unbounded technology. Further workshops are currently in the design and development stage.

5. CONCLUSIONS

In the future design of Physical-Cyber Environments (P-C Es), where the physical and digital become seamlessly intertwined, incorporating technologies of seemingly unbounded possibilities an interdisciplinary collaboration of professionals, stakeholders and end users (when appropriate) will be needed. This paper has put forward some of the difficulties faced by interdisciplinary collaborative teams and some of the suggestions made by others who have researched into this area and a workshop based communication kit to aid productive communications. It is recognised that there is no one panacea to address these difficulties and that more tools are needed to aid these interdisciplinary discussions in the design process. The workshop tools put forward in this research, although in the early stages, preliminary findings have demonstrated that externalisation of differences in assumptions, modes of representation and presentation can be helpful in developing some recognition of these differences which may lead to valuing equally differences in disciplinary cultures. This recognition and valuing of disciplinary cultural differences are necessary steps towards productive communication in interdisciplinary groups. The communication kit used in the Alien Technology workshop contains a variety of materials and artefacts to encourage externalisation of ideas and thoughts which consider differing modes of communication. This communication kit could be a useful resource for design teams in the early stages of a interdisciplinary collaborative project, where externalisation of assumptions, thoughts, ideas, differing representation and presentation modes could be beneficial in aiding productive dialogue.

The Alien Technology technique used in the workshops essentially comprises of a series of stages, incorporating the interdisciplinary communication kit and a fictitious scenario as part of a design process. The stages form a framework to aid productive communications alongside the communication kit. The stages are as follows:

1.Externalising assumptions about the end user.

2.Externalising differences in ideas, thinking, modes of representation and presentation.

3.Reflection and discussion, to aid recognition and valuing of differences.

4.Synthesis of ideas.

5.Ideation and application of technology.

The "Alien Technology workshop" using the Alien Technology technique is seen as a workshop that could be implemented at the start or early stages of a real world interdisciplinary project, or as an introduction to disciplinary cultures in business and academia seeking interdisciplinary approaches during the development of design ideas for emergent hybrid technologies and environments (P-C Es).

The Alien Technology technique incorporating a real world scenario could also provide a useful framework to follow as a method to continue productive communications throughout the design process of a real world project.

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