Physicality 2009

towards a less-GUI interface

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PREFACE

Physicality: Towards a Less-GUI Interface

http://physicality.org/physicality2009/

Physicality 2009 is the Third International Workshop following on from Physicality 2007 and Physicality 2006. These multi-disciplinary workshops have aimed to explore various issues surrounding physicality and have demonstrated both the timeliness and significance of this area of work.

As digital technology invades more and more of the devices and products that surround us, it is increasingly important that interaction designers and product designers are able to make sense of the subtle interactions between physical form and activity and the way these influence and are influenced by digital functionality and interaction.

In fact we never interact with computation, except through some form of physical interaction be it pressing a keyboard, gesturing with a hand, or creating pressure waves with our voices as we speak a command. In order to make sense of these physical interactions and produce better design for them, we need to take seriously the physical nature of the devices with which we interact and the nature of our own bodies and brains.

Towards a less-GUI interface

This year, we have adopted "towards a less-GUI interface" as a theme, inspired by the need to reduce the reliance on tiny screens through effective physical design. Despite the dramatic increase in power and functionality in contemporary information appliances, interaction methods continue to be heavily dependent on more and more overloaded small graphical user interfaces. Tiny screens are proliferating on appliances in the home, devices in cars and on the phones and media players we carry on our bodies. However, an aging population means that such screens may have increasingly limited utility, and even for those with full sight, staring at a tiny screen is not always optimal whether operating a remote whilst watch TV, or navigating down a busy street.

In 1991, Mark Weiser's Scientific American article introduced the concept of *ubiquitous computing* that has since become a major research area in itself. While computers were proliferating even then, Weiser foresaw a world where it was less about computers being the object of attention, and more about computation suffusing our day-to-day life. He wrote:

> "*The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it*." (Weiser, 1991)

However, the article went on to describe devices defined principally by *displays* of various sizes, which we can still see today: inch-scale *tabs* such as active badges and now mobile phones, foot-scale *pads* such as current tablet computers, and yard-scale *boards* such as Microsoft Surface. If computers were ubiquitous, the so were their displays.

Ten years later, Bill Buxton stated:

> "*In the early 1980s Xerox launched Star, the first commercial system with a Graphical User Interface (GUI) and the first to use the "desktop" metaphor to organise a user's interactions with the computer. Despite the perception of huge progress, from the perspective of design and usage models, there has been precious little progress in the intervening years. In the tradition of Rip van Winkle, a Macintosh user from 1984 who just awoke from a 17-year sleep would have no more trouble operating a "modern*" PC than operating a modern car" (Buxton, 2001).

Not only is the same true for desktop computers today, but the same basic argument can be applied to contemporary information appliances and mobile phones look more like mini-computers with mini-GUI-interfaces. While power and functionality have undoubtedly increased dramatically in the past decade or so, interaction methods have not kept pace and continue to be heavily dependent on increasingly overloaded and necessarily small graphic user interfaces.

This year's theme invites us to consider what the world would be like, if it were less reliant on the GUI or even with no screens at all – that is less-GUI or even GUI-less interaction.

Nearly half our brain is dedicated to vision, so there are good reasons for current display-bound systems, but equally there are times when that visual attention could be better used elsewhere, or when other more subtle cues to action may be appropriate. We are multi-sensory creatures and our non-computational existence makes use of all our exteroceptive and proprioceptive senses. Could physicality be better exploited in design through enabling technologies for haptic input and output and other non-traditional interfaces?

CONTENT

As the previous workshops in this series, this year's range of papers and participants is equally diverse and includes aspect of technology and interface design, philosophy and product design, ethnography and installation art.

The first invited keynote by Erik Geelhoed, from HP-Labs Bristol, explores the use of psycho-physics (psychology of the senses) in product design and speculates how recent research into mirror neurons might have a serious impact on physicality in design. The second invited keynote by Mark Evans, from Loughborough University, examines how a haptic feedback device can facilitate tactile cues when modelling products using computer-aided technologies.

The authors' contributions also cover a broad spectrum and, for inclusion here and presentation at the workshop, we have categorised them under the following interlinked threads:

Making Things. Two papers look at different aspects of the design of physical objects. Moussette's "Sketching and prototyping haptic interfaces: design challenges and insights" describes experience with very rapid prototyping of tangible interactions at different levels of fidelity, showing how physical interfaces can be developed even in a few minutes. In "The digitally 'hand made' object – the potential impact of new types of computer interfaces on the aesthetics of design artefacts", Jorgensen combines the aesthetics of human interaction with different digital capture devices and shows how digitally tracked free-hand lines can be used to automatically make moulds for beautiful glass and ceramics. While Moussette is physically prototyping digital devices, Jorgensen is using digital means to create non-digital final artefacts.

Bodily Interaction. We interact with physical objects using our own physical bodies. In "Good Vibrations: Guiding Body Movements with Vibrotactile Feedback" Linden, Schoonderwaldt and Bird consider the potential for using vibrotactile interactions to guide training for violin bowing and provide empirical evidence using psycho-physical laboratory experiments. England, Randles, and Taleb-Bendiab take a more technological focus; "An Advanced Framework for Whole Body Interaction" proposes an architectural framework for the software and hardware needed for body interaction.

The Body in Space. Three further papers look at the way we inhabit and interact in physical space. Cullen and McGee in "Vocate: Auditory Interfaces for Location-based Services" discuss the potential for sound in navigation. Tholander and Jaensson's "Bodily interaction and communication in an Art Exhibition hall" describes an ethnography of interactions in museum space; the way people use body positioning and expression in concert with spoken interactions. Also within the context of art "Physical contraptions as social interaction catalysts" describes Mitchell's installations which dynamically manipulate space in order to encourage social interactions.

Philosophy. Finally two papers take a more philosophical stance. Sorensen's "Making a Case for Biological and Tangible Interfaces" explores the relationship between user-centred design and activity-centred design in the context of emerging technologies, such as tangible-user interfaces, which enable more physical engagement with the user. In "Enacted experience and Interaction Design: New perspectives", Thompson and Vines analyse various radical philosophical positions of embodiment.

DEPtH AND TouchIT

This workshop is sponsored by *DEPtH: Designing for Physicality* (http://physicality.org/DEPtH), a 2-year joint project between Lancaster University and the University of Wales Institute, Cardiff, funded by AHRC/EPSRC as part of their Designing for the 21st Century Initiative.

As one of the outputs of this project we are producing a book entitled 'Touch IT', which aims to provide a comprehensive overview of this rich and cross-disciplinary area, and also expose the issues to a broader readership. Issues of interactive technology, product design and philosophy intertwine and the book draws extensively on the experiences form the physicality series workshops. More information on this can be found at the TouchIT website (http://physicality.org/ TouchIT).

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August 2009

KEYNOTE

Erik Geelhoed
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Designing for Physicality

In this talk I highlight "physicality" of two HP products: the Mini-Note, a net-book aimed at education and Halo's Telepresence. I will show how we use psycho-physics (psychology of the senses) in product design. In addition I speculate how recent research into mirror neurons might have a serious impact on physicality in design.

On the design research side, I will talk about Nexus, a multi-media running game, Vue, discovering possibilities in a pervasive computing world, and how wearable cameras take us down the dark underworld of the Strange Case of Jekyll and Hyde.

Mark Evans
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As industrial designers face increasing pressure to reduce lead times for new product development, the definition of three-dimensional (3D) form using computer aided design (CAD), computer aided industrial design (CAID) and rapid prototyping has become widespread. Whilst these technologies offer demonstrable benefits, their use can remove the potential for the designer to actively engage in the definition of form through tactile interaction with a physical material (as when working with foam or clay). In my talk, I shall discuss how the use of a haptic feedback device can facilitate interaction with virtual geometry and provide the designer with tactile cues during product modeling. The potential to model 3D form using the SensAble Phantom haptic feedback device and FreeForm software is explored through a product design case study. Outcomes indicate that whilst tactile sculpting operations can be emulated by the FreeForm/Phantom system, problems exist in the definition of the smooth surface continuity that is required by industrial designers.

Sketching and prototyping haptic interfaces: design challenges and insights

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ABSTRACT
This article explores and discusses some challenges of prototyping haptic (touch) interfaces early on in the design process. Using examples of prototyping activities for haptic interfaces that have strong 'sketching qualities', this paper elaborates on different prototyping levels and the consequences on fidelity, construction requirements and technical skills. It concludes by proposing various guidelines or insights relevant to the design of haptic interfaces by designers.

Categories and Subject Descriptors
H.5.2 [**User Interfaces**]: User Interfaces - *Haptic I/O, Prototyping, Interaction techniques.*

General Terms
Documentation, Design, Reliability, Experimentation, Human Factors.

Keywords
Interaction Design, Interface, Haptic, Touch sense, Sketching in Hardware, Prototypes.

1. INTRODUCTION
The benefits of prototyping activities are generally well accepted in the Design community [2][3]. Prototypes can be used to test and evaluate possible solutions (usability and requirement-oriented approaches), but they can also be seen as tools to stimulate reflections, objects to frame, refine, and discover possibilities [6].

Over the last decades designers have developed their skills, tools and methods to build prototypes. Numerous tools and systems are currently available to aid, support and ease the prototyping of graphical user interfaces or 'GUIs' (paper prototyping, screen mock-up, Flash simulator, etc).

Outside the realm of the visual and auditory domains, there is limited knowledge and literature how to go about prototyping for the other senses (touch, smell and taste). Recent advances in tools and applications [4][8] have made it more accessible to build tangible and interactive systems that interact with the physical world. Can these tools help prototype and sketch non-traditional interfaces quickly and efficiently?

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2. SKETCHING HAPTIC INTERFACES
The skin is a very complex, resilient and refined organ. It offers extreme sensitivity and tremendous capabilities as a medium between the external world (objects and environment) and us. The sense of touch is relatively well understood and documented medically, but designing directly for it (or around it) is very uncommon. Braille and other assistive devices for visually impaired persons have been developed for some time now, but they usually address very specific needs and situations.

Haptic interfaces are most commonly found today in game controllers (force feedback), training simulators and mobile devices (vibrotactile). These systems tend to be either very complex and expensive (medical and flight simulators), or extremely trivial (simple vibration). Can designers dive into the subject of haptic and fully explore its capabilities and limits throughout the design process? Is there room for rich, humane and natural-like sensorial experiences using the touch sense?

The sketching or prototyping of haptic interfaces brings interesting challenges for designers:

-How do you create touch stimuli with simple and cheap hardware?

-How do you communicate and document the perception of touch without building the whole system/apparatus? What kind of language or lexicon you need to use?

-How do you account for personal differences/vartiations in the human haptic perception, and considering that haptic is a dynamic process?

-What is sufficiently good or acceptable for haptic feedback?

-What is 'low-fi' for haptic interfaces?

These points demonstrate the great difficulties that one has to address in order to prototype haptic and generally other non-traditional interfaces.

3. HAPTIC SKETCHES
The following examples showcase results of recent design activities related to the prototyping of haptic interfaces. They were selected mostly for their 'sketching qualities', meaning that they are manifestation of early ideas, were quickly put together and have no clear intention of producing 'final quality' haptic feedback. They are *haptic sketches* with just enough information or function to inform the current questions at hand.

As a starting point, the prototypes are differentiated in relation to the time required for the construction or completion. It was purposely decided to discard works with long development time (many weeks) as these activities are often technically demanding and/or require considerable engineering work (where design activity is limited).

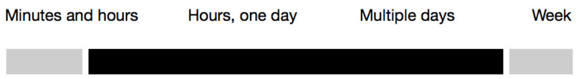

Figure 1. Spectrum of prototyping levels.

3.1 Minutes and hours

When time is scarce, human actuated systems are often the fastest and most flexible way for ideation and quick evaluation of design concepts. The haptic qualities tend to be rough, crude and difficult to repeat consistently, but quick and dirty tests like "how does this feel" and Participatory Design techniques to familiarize users/designers to the domain still can provide good and valuable insights.

3.1.1 A group exercise to brainstorm and prototype a haptic mp3 player (2 hours)

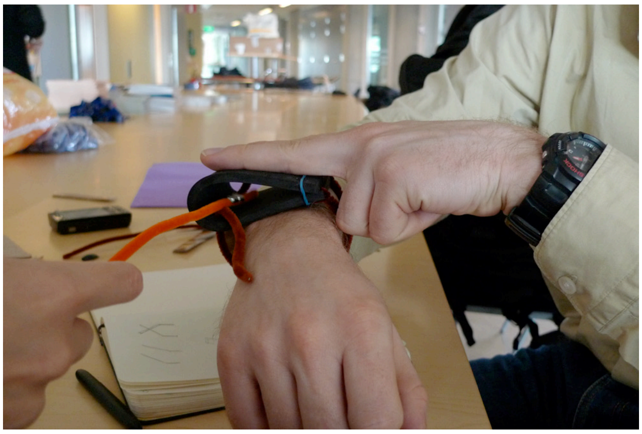

Figure 2: manual testing and brainstorming of haptic features.

The haptic features (various sequences or stroking gestures) were implemented using common-day items and the Wizard of Oz technique. One of the participants would actuate a miniature hammer (pipe cleaner and magnet) on the extension of the armband, creating tactile stimulation on the user's arm. Other alternatives were explored using small cases fitted with "ribs" and small rocks, that would generate, when tilted steps and notches stimuli in the user's hand. The quality of the haptic feedback was low, rough and not easily reproducible, but the prototypes and the process of building them led to unexpected explorations and discussions among the group's members.

A prototype of a cylindrical grip fitted with seven vibrators around its perimeter. The knob at the top controls the direction of the stimulus. The manual operation (via the knob) acts as replacement for an eventual electronic compass that triggers the right vibrator to maintain a specific heading. The prototype showed that the vibration propagates very easily throughout the grip. A decoupling (soft) material or suspension mechanism should be added to properly isolate the source of vibration from the main body of the grip.

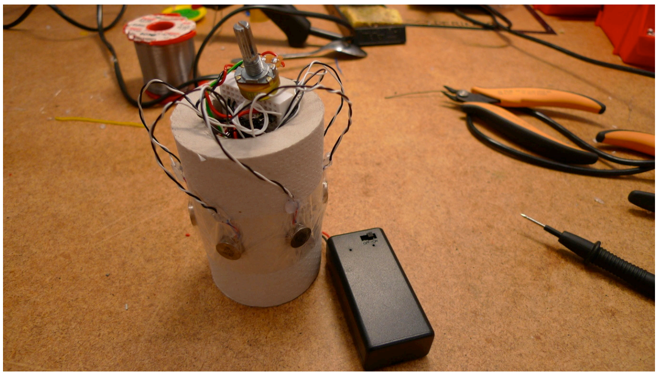

Figure 3: a grip with 7 vibrators, with manual control.

3.2 Hours, one day

In this timespan, prototyping activities will usually provide more time for variations and some opportunities for bypassing the experimenter's involvement and manual control. Access to basic construction elements and tools allow for simple mechanisms and assemblies. While human operation will still prevail, trigger or control system can be put in place relatively quickly. This provides a greater reliability and fidelity in the haptic stimuli.

3.2.1 Poking grip (1 day)

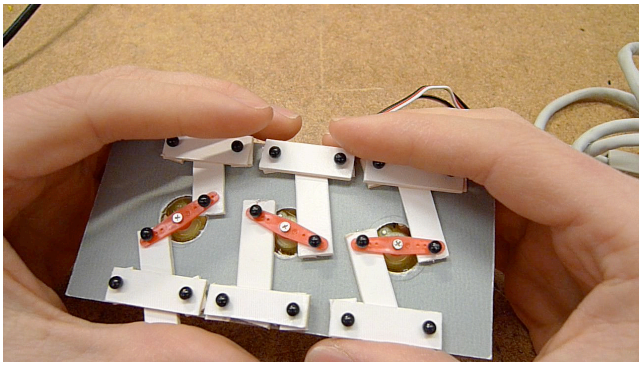

Figure 4: servo motors to poke the user's hands.

The prototype was built to test how it would feel if one part of a handheld device would stick out and poke your palm. The interface was built quickly with servo motors, cardboard and pins, controlled with an Arduino board (basic sequences only). The poking action was perceived adequately by users and the prototype was used as a proof of concept to continue further the development of this genre of haptic interface.

3.3 Multiple days

Working multiple days on a project opens up many possibilities. Fancier mechanisms or actuation systems can be explored. Partial or full machine control results in greater adjustability, repeatability and control over the feedback system. Designers can build electro-mechanicals apparatus and add electronics into the mix. Basic measurements of the haptic stimuli (time, amplitude, frequency) are also within reach.

3.3.1 Penta-grip, manual control (3 days)

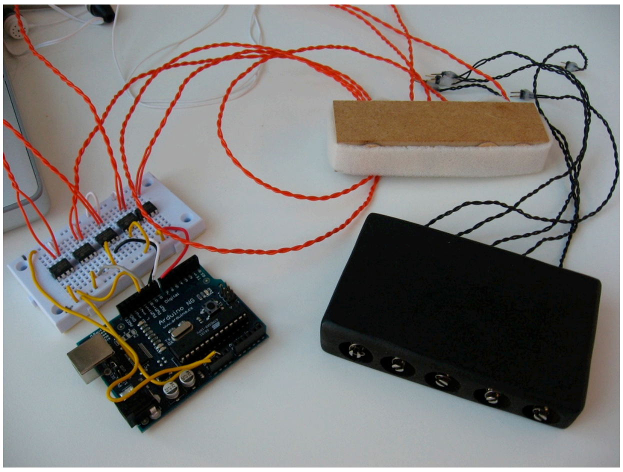

Figure 5: poking and vibration grips actuated via embedded electronics, no computer needed.

A modular handheld interface using vibration or poking movement as stimulus. Five nodes can be triggered via a matching controller. No computer or software was needed to activate this prototype. The natural interaction technique, like a puppeteer, allowed free exploration of interesting sequences by many users.

3.4 One week

With about 40-50 hours available, designers can refine the control mechanisms, actuation parameters and optimize various configurations. The fidelity can be quite high depending on the project and the available resources. Projects spanning many days tend to result in a mix of hardware, software and 'humanware'. Software can be helpful to store different configurations or change settings on the fly during evaluation. Human intervention is often inevitable as models are not fully functional and robust enough.

Figure 6: full prototype with advanced features and controlled via software.

3.4.1 Penta-grip, manual control (3 days)

This prototype adds computer control capabilities to the penta-grip (described previously) and doubles the number of vibrator to allow left-right stimulation of the interface. The level of development is higher in this prototype but it proved necessary to obtain proper replicable sequences of vibration. The software controls offer recording and playback functions of the sequences. This implementation was useful to establish and determine valid timing values for sweeping and rolling stimulus [10].

4. CHALLENGES AND DIFFICULTIES

Building interfaces offering proper haptic feedback is generally technically demanding. As haptic feedback has its roots in disciplines like automation, robotics and tele-operation, it is to be expected that researchers and authors typically present highly technical work and results in this area.

On the other side, today's interaction designers excel mostly in designing and developing traditional interfaces based on vision and audition. Touch (sensing) technology is rapidly reaching mass-market, but only as input mechanisms. Haptics with its active and actuated feedback is still unfamiliar to most designers. This new design space can be daunting as very few tools and methods are available to tackle the numerous challenges surrounding the topic. Humans are very skilled at 'handling' interactions and sensations with the real world: playing a musical instrument, medical surgery, peeling a potato, riding a mountain bike. We (human beings) have developed our nervous and motor systems in tune with the natural stimuli surrounding us. Recreating such stimulations successfully, and on-demand, on the touch sense is absolutely not trivial.

4.1.1 Synthesizing movement and forces

Generating haptic feedback is not trivial. Most of our haptic perception comes from applied forces on our skin and body. Moving, actuating and influencing the world and its atoms require its load of energy and some level of control. Human action or human-operated mechanisms are probably the simplest way to provide haptic feedback (like poking someone to wake him up). The level of precision and repeatability is dependent on the skills of the operator/experimenter.

At the other end of the spectrum, devices like haptic arms are commercially available to programmatically deliver force feedback to user through their interface. Such machines offer full control, precise measurements and multimodal synchronicity. The general consensus is that this type of apparatus delivers low quality stimuli compared to real physical interaction with the world.

In the middle lies a design space totally open to designers and creative professionals. It is the author's opinion that sketching and prototyping activities in this realm are possible and essential if products or systems with meaningful haptic qualities are to be seen more commonly.

4.1.2 Documenting and describing haptics

Haptic stimulations are often described by their mechanical characteristic (force, amplitude, oscillation speed, area of contact, space resolution, successive limen, etc) [11]. This way of describing stimuli is convenient technically, but can fall short once we dive into human haptic perception. Sensory receptors related to touch are varied and all have their own characteristics and behaviors. Medicine and other fields like dance and gestural interaction have established high-level lexicon to describe movement and touch-related attributes. As a designer, how should one deal with the situation? Should designers aim at high-level description, independent of the hardware implementation, or should we specify forces in relation to specific devices? How does a bump or a poke translate in Newton and square millimeters, and how long it last at a minimum? Does it compare across users or devices? It is far from obvious and the author certainly doesn't have a clear answer for now.

MacLean and Roderick [15] have explored what a haptic language or grammar could be. It provides high-level directions for differencing and organizing movement, forces and skin sensations. The implementation of these haptic features or qualities is still blurry and difficult somehow, as the interpretation and translation of psychophysical perspectives have to relate to mechanical movements in the end.

Hayward [4] recently introduced a brief taxonomy of tactile illusions that put forward terms and notions like disjunction-conjunction, change numbness, distal attribution and more. These terms are very useful to summary and communicate often very complex sensations and illusions. As researchers and designers understand more how these tactile illusions work, they can possibly develop a better mastery of haptic notions and concepts.

5. SUGGESTIONS AND GUIDELINES FOR SKETCHING HAPTIC

Based on the limited research and observations, the author can offer some suggestions and guidelines for designers who would like to approach haptics. These recommendations should not be followed blindly, but should be considered as inspirations or directions to get started.

5.1.1 Ignore technology constraints

Don't try to build a perfect system initially. Concentrate of one aspect or characteristic first. Scale up or simplify models if necessary to ease prototyping activities.

5.1.2 Fake as much as possible

Designers should exploit fully the fact that the touch sense can be tricked or fooled to some extent, like any other sense. Faking, taking shortcuts or using other representations are all parts of the toolbox to obtain interesting results in a timely manner [2,3].

5.1.3 Use the world to control the world

Synthesizing movement and forces is not trivial and can require complex mechanisms to avoid robot-like actuation. Use or record analog sources as input/control data. It naturally contains noise, acceleration/deceleration, physical constrains and such.

5.1.4 Modular approach for mixing and mashup

While developing systems and parts, consider a modular approach for connectors, protocols, input/output mechanisms. Mixing and matching sub-systems can lead to interesting and unexpected results. It also allows to repurpose and reuse previous work.

5.1.5 Prototyping skills and attitude, with a human centric approach

What technology to use and how to design the haptic characteristics/qualities are totally up to the designer in the end. As with any technical systems, it can be temping to push back design activities until the technical details are solved or limit explorations to the tools available at hand. In our opinion, designing haptics should be a journey that starts with human-centered considerations.

6. CONCLUSION

Prototyping and sketching of non-traditional interfaces pose new challenges for designers. Very few reference points (and guidelines) exist for exploring and working in these new areas like haptic interfaces. It demands a good reflection about the nature of prototyping itself: how simple or low fidelity is appropriate, desirable and/or justifiable while developing for new (uncommon) senses. The difficulties arise mostly from finding the right balance between complex technical development and sufficient outcomes/results to inform or ground design decisions [3][20].

This article presents clues and evidences that haptic design can be developed very early on in the design process, with basic items like magnets, plastic cups and rubber bands. More and more tools are becoming available to support prototyping tangibles and actuation when time is a major constraint.

The work presented in this research consists of various prototypes or sketches of haptic interfaces based on the amount time they required to come to fruition. These *haptic sketches* were selected to show that quick hardware sketching and prototyping activities are still possible and have their place, despite the unfamiliarity and complexity of projects involving the touch sense.

The paper concludes by proposing general suggestions and guidelines to support design activities in haptics. The hope is to expose the many questions and issues in this nascent design activity to eventually expand our collective haptic design toolbox and library, and bring consistency and rigor within the field.

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The digitally 'hand made' object - the potential impact of new types of computer interfaces on the aesthetics of design artefacts

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ABSTRACT

This article will outline the author's investigations of types of computer interfaces in practical three-dimensional design practice. The paper contains a description of two main projects in glass and ceramic tableware design, using a Microscribe G2L digitising arm as an interface to record three-dimensional spatial design input.

The article will provide critical reflections on the results of the investigations and will argue that new approaches in digital design

interfaces could have relevance in developing design methods which incorporate more physical 'human' expressions in a three-dimensional design practice.

The research builds on concepts indentified in traditional craft practice as foundations for constructing new types of creative practices based on the use of digital technologies, as outlined by McCullough (1996).

General Terms
Performance, Design, Experimentation, Human Factors.

Keywords
HCI, Interface Devices, 3D sketching, Hand Movement, Digital Design Tools, 3D drawings, CAD, 3D Modelling.

1. INTRODUCTION

Throughout the last decades there has been a steady growth in use of Computer Aided Design (CAD) systems in three-dimensional design practice. The range of programs available for this use is now very extensive with long standing applications such as Rhino 3D (2009) and Form Z (2009) having been developed and refined over many years. Equally the range of methods and technologies for prototyping and physical realisation of designs directly from CAD drawing data have also expanded rapidly. A wide range of methods is now available, both in terms of additive, via layer manufacture, and reductive via Computer Numerically Controlled (CNC) cutting.

However, throughout this period of development in the digital design tools there has been little change in basic way most designers interact with these tools. Apart from a few exceptions, the interfaces used in this field have overwhelmingly been based on the Window/Icon/Menus/Pointer (WIMP) and keyboard interface.

Equally there has yet been relatively little development in exploration of the aesthetic possibilities more intuitive interfaces presents to three-dimensional design practice. This paper will ask if more intuitive interfaces could help to facilitate the creation of new types of aesthetics in design artefacts - ones that more clearly reflect the personal expression of designer or the artist behind the creation. This research is focussed on the practical application of new interfaces in 3D design practice and the challenges faced in terms of the production of artefacts which have been designed via these new types of interfaces.

2. Investigating the ShapeHandPlus data-glove as a human computer design interface

This research builds on the finding presented by Jorgensen (2005, 2007), these papers describe research investigating the commercially available ShapeHandPlus data glove from Measurand Inc (2009). This data-glove is explored for its potential as an interface for practical three-dimensional design applications. Although this equipment proved largely unsuccessful in this context (largely due to low accuracy), surface generating methods established in this project provided useful knowledge that was utilized in the investigations with the Microscribe, which constitutes the core of the research described in this paper.

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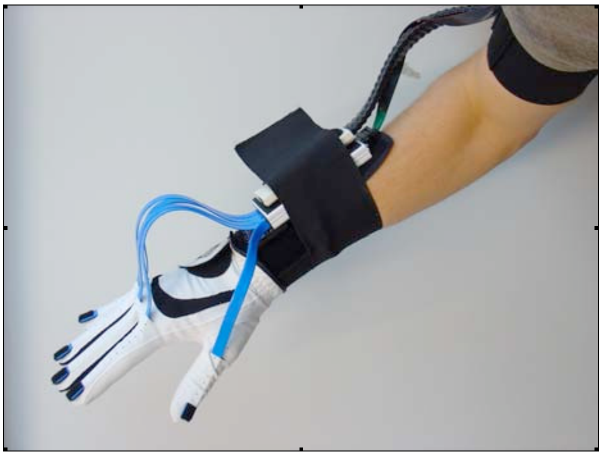

Fig 1. The ShapeHandPlus Motion Capture data glove from Measurand Inc.

2.1 Observations on surface generation

When using a typical motion capture system (such as the ShapeHandPlus system), it is not possible to make direct descriptions of surfaces during the recording stage. Skeletal joint location (and movement data) can only be recorded as a series of Cartesian co-ordinates. A series of these co-ordinates can then be used to generate trajectories of the hand and finger movements and thereby facilitate the creation of three-dimensional splines. To achieve a surface or solid form, planes have to be generated between these splines in a subsequent 3D modelling operation using commands such as 'lofting' or 'skinning'. However, when created, these surfaces have the capacity of clearly displaying the visual evidence of the movements of the designer's gestural hand movements during the recording, with even the smallest trembling of the hands and fingers contributing to create a very distinctive aesthetic.

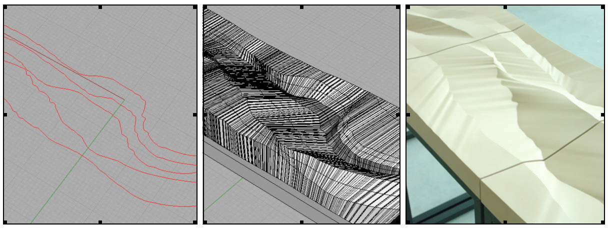

Fig. 2 Surface generation from recordings using the ShapeHandPlus data glove, illustrating the resulting aesthetic reflecting the movement of the designer's hand and fingers.

3. Using the G2 Digitizing Arm as a human computer design interface

This investigation is related to research by Sener (2003) and Shillito (2004), who both have published papers investigating the use of haptic arms as design interfaces.

The intended application for the G2 Microscribe is not as an interface device rather than as a digitiser for recording co-ordinates of physical objects into CAD programs. The arm has no haptic capability, and there is no standard facility for employing the arm in a virtual reality environment. However the Microscribe dose have several advantages compared to other dedicated interface arms. Due to its intended application as digitiser, it is a very precise piece of equipment, facilitating both dimensional and spatial data sampling with an accuracy of 0.4mm. In contrast haptic arms such as the Phantom from Sensable Technologies (2009) generally suffer from low levels of precision, an issue that has been raised by Sener (2003) as a potential problematic element in the context of industrial design.

Setting up and calibrating the Microscribe is a very quick and straightforward process. The functionality of the scribe is somewhat dependent on which 3D modelling package is used as the equipment connects via plug-ins and is therefore somewhat dependent on the individual program's capability. A foot pedal connected to the device provide hands-free activation of modelling tools and data sampling, which enables the user to concentrate the use of the hands to interact with the Microscribe. As rotation is limited in some the arm's axes, the equipment dose not provide the user with full six Degrees of Freedom (DOF). However the Microscribe's 4/5 DOF is sufficient for the majority of practical design and data sampling tasks.

Fig 3. The G2 Microscribe digitising arm from Immersion Inc.

3.1 Comparing the Microscribe G2 and the ShapeHandPlus as design interfaces

There are some key differences between using the Microscribe and the ShapeHandPlus as design interfaces. Most significantly the Microscribe provides only a single point input, whereas the ShapeHandPlus has the facility of tracking all the human skeletal joints in the arm and the hand. This enables a multiple point input and therefore the opportunity for much more dynamic 'design expressions'. However, this capability is hampered by the ShapeHandPlus' very poor dimensional and spatial accuracy. Another problematic element with this equipment is that unlike the Microscribe, the ShapeHandPlus system dose not provide plug-inns for direct input into general CAD programs. Instead the gestural expressions have to be recorded via specific motion capture software, with the raw data having subsequently to be developed into three-dimensional paths to facilitate the creation of designs via CAD programs. This sequence results in a very disjointed creative workflow.

The Microscribe connects to most common 3D CAD packages, consequently the device can be used along side standard modelling commands facilitate by WIMP/keyboard input, thereby potentially enabling the user's existing 3D modelling skills and knowledge to be utilized. This facility combined with its high level of accuracy means that despite its single point input capability, limitation on reach and restrains on DOF, the Microscribe has to be considered a fairly capable design interface. In contrast the ShapeHandPlus is severely compromised by its poor accuracy and the lack of direct software support within general 3D CAD programs, therefore it cannot currently be considered a usable design interface. However, this position could change if these issues could be resolved, and promising prospects remain for adapting Motion Capture technology to be used as design interfaces to explore new types of aesthetic expressions, as some of the results of the ShapeHandPlus investigation indicate.

3.2 Investigations using the Microscribe G2 to design glass artefacts

This research utilised previously established spatial design drawing methods, using the Microscribe in combination with the Rhino 3D software as describe by Jorgensen (2005, 2007)

Experiments were undertaken to further explore a range of different design input approaches. The various factors explored for their potential impact included:

- Speed of drawing.
- Direction of drawing
- Recording tool selection (curve type and frequency of point sampling).
- Geometric and non-geometric shape interpretations (describing circles, ovals, squares and irregular/organic)
- The use of templates and physical props to guide the drawing and design process.

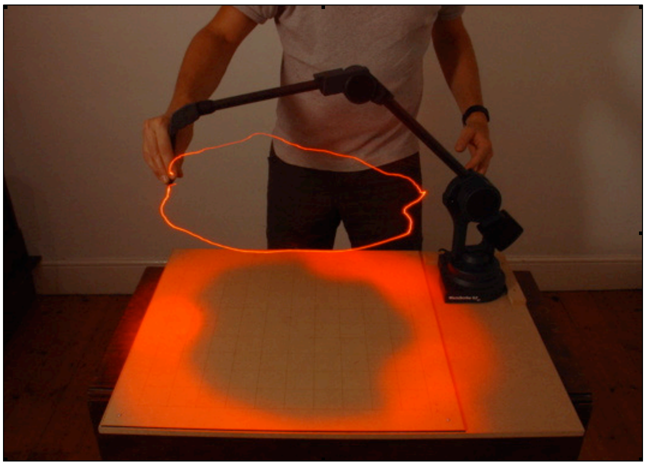

Fig. 4 Drawing/designing with the Microscribe G2

The findings from this investigation indicates a good potential for using the Microscribe to facilitate a much more expressive design input than with a conventional WIMP and keyboard interface.

Included in the aims and objectives of this project was the creation of finished artefacts to enable a more accurate evaluation of the potential for the Microscribe to used as an interface in the context of 'real life' design practice. Glass was chosen as the initial medium for these artefacts. However early investigations using CNC milling to create models to create conventional refractory glass moulds proved relatively unsuccessful, both in terms of the aesthetic qualities and production feasibility. In response an investigation was undertaken to establish an alternative method of producing glass artefacts. This research resulted in the creation of a method which combines a specialist glass forming method called 'free fall slumping', described by Cummings (1997) with a new way of creating refractory moulds specifically developed to facilitate a highly gestural design input.

The mould making process developed (which is illustrated in Fig.5) relies on combining two-dimensional laser cut stainless steel profiles to create a physical model of the three-dimensional spatial input.

Fig. 5 The development of glass moulds from spatial data via laser cut profiles.

Glass bowls manufactured by this process will all feature an edge which is a relatively accurate reflection of the spatial hand drawn design input. This feature is particularly visually evident when the overhanging surplus glass is trimmed away, leaving the optical qualities of the glass to create a dark rim, clearly illustrating the three-dimensional line recorded with the Microscribe.

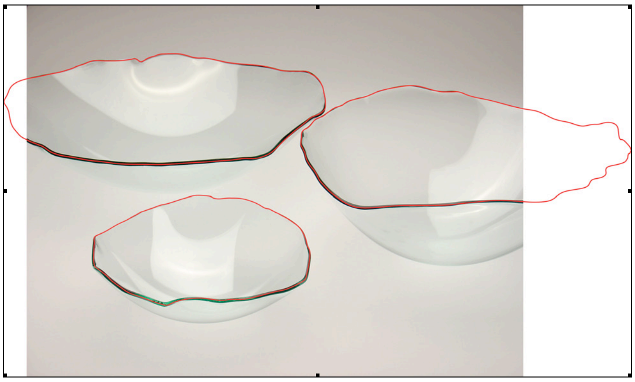

Fig. 6 Examples of glass bowls designed with the Microscribe - the linear design input is superimposed in red on the image.

3.3 Investigating the Microscribe G2 for Ceramic tableware design

In contrast to the glass design investigation this project explored the use of the Microscribe in the context of conventional industrial manufacturing processes, rather than establishing a completely new production method.

This particular context presents challenges in terms of achieving aesthetics which reflects the expressive gestural design input without compromising the manufacturability of the artefacts.

This investigation had the same starting point as the glass design investigation, using the Microscribe to draw spatial 'perimeters' of vessel forms. The project was developed in collaboration with two commercial bone china tableware manufacturers (Topaz China, UK and AsianEra, China). The companies provided feedback on the designs in terms of manufacturability and also in regard to how the distinctive aesthetic of the shapes might impact on the saleability of the artefacts.

Investigations in terms of modelling surfaces from the single line input recorded via the Microscribe, so these forms contained a high level of visual evidence of the gestural movement, was facilitated by critical reflections of the results from the projects with the ShapeHandPlus. Surfaces generated with this equipment were indentified as having a very high level of evidence from the expressive hand movement input. A factor in achieving this evidence was identified in the way the surfaces were created by the trajectories of the individual movement of multiple tracking points (one on the end of each digit). In order to transfer these findings to Microscribe investigation a software modelling method that replicated this approach to surface generation was sought. This was achieved by establishing a simple sequence of modelling commands. This sequence starts by generating a copy of the recorded path, this path is then rotated and moved in the Z-axis to the desired height of the bowl design. From these two paths a slanted and rippled surface can be achieved by using the 'lofting' command. The resulting aesthetic closely resembles those achieved with the ShapeHandPlus equipment with a high degree of visual evidence of gestural design input, as the twisted and rippled surface reflects the direction and movement of the designer's hand when describing the perimeter of the bowl. The data can then used to create physical prototypes and production models via Rapid Prototyping and CNC milling.

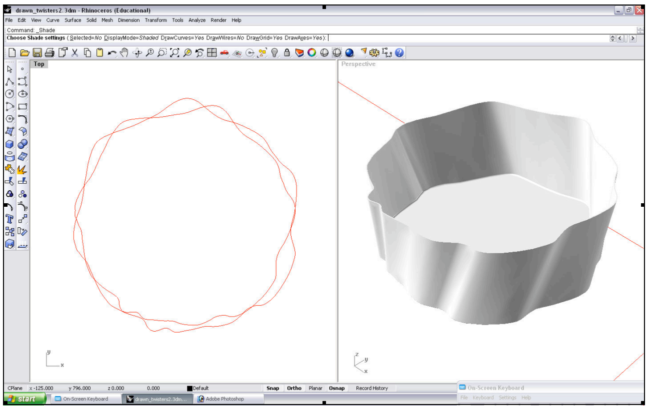

Fig. 7 The Perimeter path copied and twisted to generate a surface aesthetic indicating movement and direction of spatial sketching.

Considerations in terms of manufacturability were also key concerns with this project and this aspect normally impacts with considerable limitations on the use of expressive aesthetics. Using the surface generating method just described, the resulting twisted and ripped shape will inevitably have 'undercuts', which in theory would prevent the use of cost effective single piece production moulds. But using a central datum for the rotation of the copied path enables the shapes to be released from the moulds by twisting (like a screw thread), thereby facilitating the production via single piece mould manufacturing methods, despite the undercuts and expressive aesthetic.

4. Discussion

The investigations with the Microscribe illustrate two different approaches of integrating a new type of interface devise in design and artefact development processes. Unlike other projects (Sener 2003) (Shillito 2004) the core intention of this research is not to investigate new types of interfaces aimed towards improving existing design product development processes, instead the aim is to explore new creative possibilities and aesthetics, which can be facilitated by the use of digital tools and new types of interfaces. The central ambition is to establish systems that can facilitate free intuitive interaction for the designer or artists to create artefacts which in their aesthetics reflect a more 'personal' and 'human' expression. In this approach digital technology is not seen as an 'active tool' rather than a facilitator or conduit for human gesture as the central creative input in the design process.

The projects illustrate two different solutions to the challenge of implementing highly expressive design input via new types of interfaces in practical design and artefact production. The glass bowl design investigation illustrate how production techniques can be adapted and developed to cope with the challenges expressive design input presents, while the bone china tableware design project demonstrate how methods of interpreting a similar expressive design input can be developed and achieved via software tools to fit within existing production capabilities and constrains.

Fig. 8 Examples of the final Bone China tableware designs.

Developments in the fields of Rapid Prototyping and Rapid Manufacturing are likely to provide further opportunities for designing and producing artefacts beyond the constrains of traditional manufacturing techniques. However, despite these developments it is unlikely that these production processes will be able to compete with the majority of conventional industrial manufacturing techniques in terms of speed and costs in higher volume production. Therefore the issue of how to practically adapt expressive designs to be produced with conventional production methods will continue to be an issue when exploring the use of new types of interfaces in the context of three-dimensional design practice.

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Good Vibrations: Guiding Body Movements with Vibrotactile Feedback

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ABSTRACT
We describe the ongoing development of a system to support the teaching of good posture and bowing technique to novice violin players. Using an inertial motion capture system we can track in real-time a player's bowing action and how it deviates from a target trajectory set by their music teacher. The system provides real-time vibrotactile feedback on the correctness of the student's posture and bowing action. We present the findings of an initial study that shows that vibrotactile feedback can guide arm movements in one and two dimension pointing tasks. The advantages of vibrotactile feedback for teaching basic bowing technique to novice violin players are that it does not place demands on the students' visual and auditory systems which are already heavily involved in the activity of music making, and is understood with little training.

Categories and Subject Descriptors
H.4 [**Information Systems Applications**]: Miscellaneous.

General Terms
Experimentation.

Keywords
Violin bowing; motion capture; vibrotactile feedback; teaching system

1. INTRODUCTION
As part of the e-sense project (http://www.esenseproject.org) we are building novel augmentation devices to explore sensory, bodily and cognitive extension [3]. Our research breaks away from desktop- and GUI-based styles of interacting with technologies, and focuses on the development of devices that facilitate more physical forms of interaction. We have developed a wearable vibrotactile array and initial experiments have demonstrated that vibrations generated by this device can guide behaviour. For example, the system has been used as part of a minimal tactile vision sensory substitution (TVSS) system that maps an image captured by a webcam (either fixed or head-mounted) into vibrotactile stimulation. When blindfolded participants wear the array on their abdomen, they quickly learn how to track and bat balls rolled towards them along a table (see [4] for more details).

In this paper we describe the ongoing development of a system to support the teaching of good posture and bowing technique to novice violin players. We use an inertial motion capture system to track the bowing action of the musicians and use vibrotactile feedback to guide their movement along the correct trajectory.

In Section 2 we discuss our motivation for the development of a system to support violin teachers and students, using novel technologies that are physically engaging. In Sections 3 and 4 we highlight the challenges involved in learning and teaching good violin bowing technique, and discuss how we seek to develop a form of embodied learning in which the pupil actually experiences the complex dynamic arm movement that is required for bowing. Section 5 focuses on the motion capture component of our system, and we explain our method for recording a desired bowing trajectory which can then be used as a reference for feedback. We give details of an initial user study with young violinists and their teachers and show an example of actual bowing and how this can be compared to the desired bowing trajectory as set by the teacher. Section 6 describes the development of the feedback component of our system. During training, we will inform the musicians about how their bowing arm movement deviates from the target trajectory using vibrotactile feedback. We present some initial studies that show how vibrotactile feedback can effectively guide arm movements in one and two dimensions and outline how we plan to extend this technique to guide three dimensional bowing movements. Finally, we describe the challenges involved in integrating the existing motion capture and feedback components into a real-time training system.

2. MOTIVATION
A general motivation for our research is that health benefits and a sense of well being result from an increased awareness of body posture and movement. In this study we focus on children learning to play the violin: an activity during which they need to become aware of their precise physical movements and posture in order to learn how to play the instrument.

Advances in technologies for analyzing movement and performance are increasingly applied in sports training, for example, golf, snowboarding and swimming [5, 6, 16, 17]. These technologies have, to a lesser degree, also been used in dance and music science [7] and where used they have tended to focus on expert rather than novice players.

Learning to play the violin requires the development of a range of different skills. Good posture and correctly holding the violin form a fundamental basis of playing technique. Furthermore, the production of a good tone requires a high degree of control of the movements of the bow. During music lessons, teachers demonstrate the correct posture and bowing. However, most

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novice players will have less than one hour contact time per week with their teacher – the majority of their learning time consists of practicing alone. In the absence of a teacher to guide them, there is a potential danger that novice students play with an inferior technique which is then reinforced through repetition: the more they practice, the more difficult it is for their teacher to correct their playing at the next lesson.

Our goal is therefore to develop technology-based methods to assist novice violin players during their practicing, with the aim of making it more effective and rewarding. Our methods should be considered as complementary to their regular music lessons.

In particular, we are exploring the combination of motion capture technologies and vibrotactile feedback. Motion capture is suitable for measuring instrumental gestures in violin performance. Vibrotactile feedback has some clear advantages over visual and auditory feedback in the context of music performance. Auditory feedback is likely to interfere with the sound produced by the instrument, whereas visual feedback might disrupt other visual tasks, such as reading the score.

3. THE CHALLENGE OF LEARNING BOWING

Bowing action is a complex motor skill that requires the coordination of a number of degrees of freedom in the shoulder, elbow, wrist and hand. A particular difficulty of playing string instruments lies in the sound generation process, which takes place due to the frictional interaction between the bow and the string. A good, regular string vibration (Helmholtz motion) requires a refined coordination of bow velocity, bow force (normal force exerted by the bow on the string) and bow-bridge distance [13]. The player has many degrees of freedom at hand to control the course of the bow and to influence the contact mechanics between the bow and the string. The angle of the bow with the string forms an important factor therein and should therefore be under the control of the player [14]. Research by Konczak and colleagues has shown that novice players require in excess of 700 practice hours in order to master the basic motor skills for bowing [8].

In our study we focus on the particular issue of *straight bowing* in long bow strokes, where the bow remains perpendicular to the strings. Straight bowing is a basic skill that novice players need to accomplish, and forms an important component in learning how to *control* the bow. It should, however, be noted that expert players often exhibit subtle and systematic deviations from straight bowing during expressive performance, and it has been shown that skewness of the bow has an important control function [14].

4. THE CHALLENGE OF TEACHING BOWING

Novice violin players traditionally learn how to hold their violin and bow correctly by: i) observing and imitating their teacher's actions; and ii) listening to verbal feedback from their teacher. Sometimes a mirror is used so that students can watch their own bowing action and posture.

Learning by observation and imitation is challenging for novice players for a number of reasons: i) they often do not know what it is they are looking for; ii) they don't know how to translate what they see into their own body movements. It is very difficult for the teacher to give verbal feedback in the midst of a dynamic bowing action and so generally comments are made after the movement is completed.

In discussions with violin teachers we became aware of a number of additional strategies that are used to teach straight bowing:

i) Bowing through a cardboard tube, such as found in the middle of a roll of kitchen paper. The teacher holds this tube at a straight angle to the strings. The challenge for the pupil is then to bow through this tube without touching its sides. The tube helps to focus the pupil's awareness of the straight path of the bow, and allows them to experience the complex physical movement of the arm.

ii) Passive bowing, where the pupil holds the bow keeping the right arm relaxed, while the teacher guides the bowing movement.

iii) Following the bow with the right hand. In this exercise the teacher places the tip of the bow on the string, keeping it at a straight angle. The bow itself remains stationary during this exercise, and the pupil moves the right hand along the bow, thus performing the type of arm movement required for proper bowing.

Figure 1. Tracking the bowing action of a young violin player who is wearing the Animazoo IGS-90-M motion tracking system. The movement of her bowing arm and the position of the violin are tracked using 6 inertial measurement units. The motion capture data are transmitted wirelessly to a laptop.

These exercises provide the pupil with physical experiences of the correct bowing movement required for straight bowing, even if only briefly or passively (as in the second example, where the teacher guides the movement). It is these moments of embodied learning that we aim to emulate and automate in our system, with the added benefit that it will provide real-time feedback to a student while they are actively performing their actual bowing action.

5. MOTION CAPTURE SYSTEMS

The development of motion capture techniques in the last decade offer new possibilities for the study of bowed-string instrument performance. A variety of systems have been successfully used to measure bowing gestures, using sensors, motion capture systems (optical, as well as magnetic field tracking) or combinations of the two [2, 10, 15, 18].

For our system we used an IGS-190-M mobile motion capture system from Animazoo [1] (Figure 1). This system consists of small inertial measurement units (a combination of three-axis accelerometers, gyroscopes and a magnetometer), suitable for measuring 3D orientation. The sensors are attached to a lycra body suit and the data are transmitted by a wireless processing unit to a receiver connected to a computer.

The advantage of this system is that it is highly mobile and convenient to carry around, and it can therefore be used in settings familiar to the novice players we are working with. The system requires only a few minutes to set up, and provides data that is sufficiently accurate for our purposes.

5.1 Pilot Studies and Findings

We performed a pilot study with three young violin pupils in the presence of their violin teachers, using the motion capture system. For each student we determined the reference bowing trajectory for each string, using the passive bowing and the "follow the bow" exercises as described above under assistance of the teachers. Also the pose of the violin during the exercises was recorded as a reference for the hold of the violin. It should

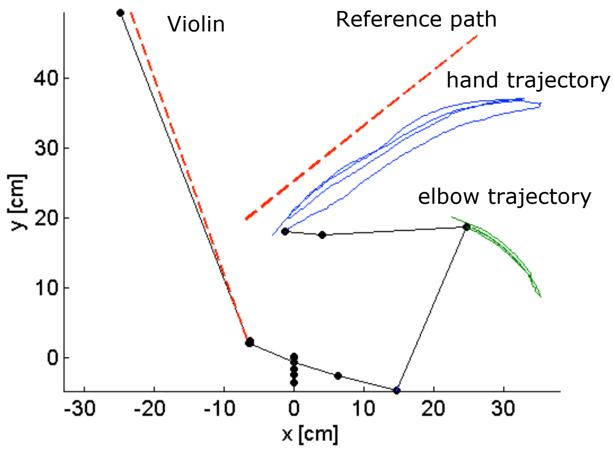

Figure 2: Illustration of bow strokes performed by a novice, showing the bowing trajectory as seen from above. The reference bowing path and the reference position of the violin are indicated by dotted lines.

be noted that the reference bowing trajectories are individual, depending on the build of the player and the way she/he holds the violin. The recorded data were used to construct a line, which can then be used as a reference for the pupils' actual bowing without the assistance of the teacher.

The principle of the bowing assessment method is illustrated in Figures 2 and 3, which show a typical example of the bowing movement of a pupil. The reference path obtained in the calibration trial is indicated by a dotted line. It can be seen from the top view (Figure 2) that the bow stroke is reasonably straight, but shows a stronger deviation when approaching the tip. Furthermore, the bowing trajectory shows a persistent offset, which might indicate that she was bowing too close to the bridge.

The side view (Figure 3) reveals that the violin had dropped

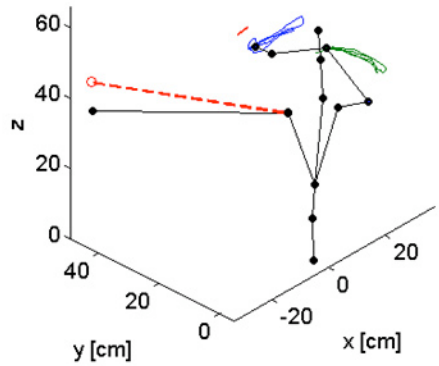

Figure 3. Illustration of bow strokes performed by a novice. The side view clearly shows that the violin position was lowered compared to the reference position.

compared to the reference position (indicated by a dotted line). This might also have confounded the bowing path, which was in this case not adapted to the orientation of the violin. The appropriate feedback would in this case be to raise the violin and correct the bow movement when approaching the tip.

6. VIBROTACTILE FEEDBACK TO GUIDE MOVEMENT

Our work is related to that of Förster [6], Spelmezan [16], and their colleagues, who explored the use of tactile motion instructions for guiding physical activities, respectively swimming and snowboarding. In these activities auditory feedback is usually not an option: the environment is either too noisy (the presence of water combined with the physical activity of swimming [6]); or the subject's auditory channel is already occupied by listening out for fellow snowboarders approaching from behind or to judge the performance (by the sound of the board on the snow) [16]. Under these circumstances vibrotactile provides a good alternative.

Spelmezan and colleagues [16] conducted a series of experiments to test whether vibrotactile instructions could be used to give real-time feedback to snowboarders.

In the first experiment, vibrating motors were placed on various parts of the body (knees, thighs, arms, chest), and participants were asked to assign meaning to a series of tactile instructions. Some instructions consisted of several vibrations from one motor, while there were also instructions with directional patterns, where three motors are placed in a line, and pulsate one after the other. They reported a 'push-pull' division among the respondents - some respondents interpreted a vibration as a warning signal, and intuitively moved away from the vibration; others felt that they should seek to intensify the vibration.

In the second experiment, meaning was already ascribed to the tactile instructions, and participants were asked to react to the instructions using a Nintendo Wii-Fit balance board for slalom snowboarding. Instructions were set up using the push metaphor, meaning that a vibration on the right side should be interpreted as an instruction to lean to the left. Participants were asked to say aloud which instruction they felt they received, and then to perform the action. This experiment was about testing whether participants could learn the instructions, and could interpret them accurately during physical activity. The experiment confirmed both, and in particular that even though participants experienced physical and cognitive load while using the balance board, they were still able to correctly identify the instructions. The only thing that participants seemed to struggle with was translating the experienced tactile instructions into speech before performing the movements.

In the third experiment snowboarders (with varying degrees of expertise) were asked to board down an actual slope, while responding to instructions coming from the instructor standing at the bottom of the slope. The instructor could communicate to the boarders by sending signals. For example, an instructor could press the 'lean left' button on her mobile phone if she noticed that the boarder was leaning too much towards the right. Pressing this button would cause a vibration on the right side of the boarder's upper body, which would be interpreted as 'being pushed' towards the left, and thus making the boarder lean to left. Boarders had to say out aloud the perceived instruction (whether the instruction was given in auditory or tactile form), and the response time to tactile instructions was compared with response time to auditory commands. The finding was that the response time to tactile instructions was faster than to auditory instructions.

For musicians, listening forms an integral part of music making and interference in that listening process is likely to be distracting. However, in their study of the augmented mirror for violinists Larkin and colleagues [9] provide auditory feedback on bowing techniques in the form of short 'beeping sounds' in preference to visual feedback. They found there was considerable cognitive overload for processing complex visual feedback, particularly since players were already occupied with reading musical scores.

7. INITIAL STUDIES – GUIDING MOVEMENTS IN 1 AND 2 DIMENSIONS

In order to obtain a first indication of the usefulness of vibrotactile feedback for the guidance of bowing trajectories in 3D, we carried out two exploratory studies to see how effectively vibrotactile feedback could guide subjects' arm movements in one and two dimensions. The first task involved moving to a target on a line and the second to a target on the plane. We also wanted to investigate whether our target group (8-12 year olds) finds vibrotactile feedback disruptive or uncomfortable.

We used 10 mm shaftless DC motor [11], commonly used in mobile phones, to provide vibrotactile feedback during these studies. Each motor was driven by an Arduino microcontroller pulse width modulation (PWM) channel. By varying the PWM signal it was possible to control the intensity of vibration, although frequency and amplitude cannot be separately adjusted. We chose these motors as they had been successfully as part of the TVSS system described above [4]. These motors can be updated at least 10 times per second.

Earlier pilot studies had indicated that two vibration motors, located on opposite sides of the wrist, could effectively guide hand movements in one dimension if the feedback intensity was directly proportional to the distance of the hand from the target. The feedback decreased to zero when the hand was over the target, giving users a clear cue that their hand was in the correct location. It did not matter whether the feedback 'pushed' the hand (that is, the motor farthest from the target was activated and the other was switched off) or 'pulled' the hand (that is, the motor closest to the target was active and the other was off). The participants showed a clear preference for a decreasing vibration intensity when approaching the target, as opposed to an increasing intensity when approaching the target.

In the current study we used this 'opposing motor pair' set up to provide 'pushing' vibrotactile feedback in the one dimensional task. In the two dimensional task one of the motors indicated the left/right (x coordinate) distance from the target, and the other the up/down (y coordinate) distance. In this set up, in contrast to the one dimensional task, both motors could be active at the same time.

7.1 Experimental Setup

The experimental set up was the same for both studies (Fig. 4). Subjects stand in front of a computer display where they see a mirror image of themselves captured by a webcam. In the centre of the display is a circle which indicates the starting point of all movements. The subject's hand is covered by a coloured glove allowing the hand to be easily tracked with the webcam and computer vision software. A laptop runs the software and communicates via a USB connection with the Arduino microcontroller to drive the motors on the subject's wrist.

Figure 4. The experimental set up for testing whether two vibration motors could guide arm movements in one and two dimensions. The subjects wear a coloured glove on their moving hand that is tracked using a webcam and computer vision software. Subjects position their hand at a central starting point on the display area and then have to move their hand as quickly as possible to a target location. In some conditions the target position is shown with a brief visual cue. Vibrotactile feedback from two vibration motors provides information about the hand's proximity to the target in some of the test conditions.

In an initial calibration phase, the subject moves the gloved hand to different locations, and the system stores these as target positions. In the one dimensional task the targets only vary in height (y coordinate); in the two dimensional task the targets vary in both their x and y coordinates. In each task subjects stores 4 targets in the calibration phase.

During the testing phase, each target is presented once under different conditions and the system measures the accuracy of the subject's movement and how long the movement takes. There are three different conditions:

i) Visual-only - the target appears on the display as a green circle for 1 second and then disappears. The subjects then have to move their hand as quickly as possible to the target location and indicate vocally when they think they have reached it.

ii) Visual + vibrotactile - subjects position their hand at the starting position and see the location of the target for 1 second on the display. When the visual cue disappears they move as quickly as possible towards the target while also receiving vibrotactile feedback that indicates how far they are from the target position.

iii) Vibrotactile-only - subjects position their hand at the starting circle but do not see the visual location of the target, having to rely entirely on vibrotactile feedback to move to the target.

8. DISCUSSION

The analyses showed that in the one-dimensional task, there was no significant difference between the three conditions in accuracy. It was, however, found that in the vibrotactile-only condition it took a longer time to reach the target. This is explained by the fact that in the visual-only and visual + vibrotactile conditions, subjects are able to perform an initial ballistic action followed by a corrective phase (Fitts' law), whereas the tactile-only condition is entirely characterised by closed-loop behaviour, where subjects continuously adjust their movement on the basis of the vibrotactile feedback. A similar time effect was found in the two-dimensional task. Furthermore, the vibrotactile-only condition showed a lower accuracy compared to the other conditions.

None of the subjects reported discomfort and our target group (8-12 year olds) actually found the tasks engaging and 'game-like'. The subjects generally found the 'pushing' vibrotactile feedback intuitive in the one dimensional task and were able to use it straight away to guide their movements. Most subjects needed a few trials to learn how to interpret the feedback in the two dimensional task.

The accuracy results from the one dimensional task show that vibrotactile feedback, presented using an opposing pair of motors that 'push' the hand, is as effective at guiding arm movement to a location as a visual cue that is held in short term memory. The results from the two dimensional task show that if two closely located motors provide distance signals at the same time, then the vibrotactile feedback is not as effective at guiding movement as a visual cue in short term memory. The simultaneous feedback appears to confuse the subjects, but with more training they may learn how to use this type of feedback effectively. Both tasks show that closed-loop movements towards a target are slower than ballistic movements.

9. FUTURE WORK

Building on the initial studies reported in this paper, we will continue and put together the two components of our system in order to have an integrated teaching system delivering real time vibrotactile feedback based on players' bowing actions tracked through the motion capture component. In doing so we will explore the following issues:

1) Collision versus Pushing

In our current study we used the concept of 'feeling no feedback means good', which is closely related to the idea of 'pushing to get the body moving'. However, if we work with the metaphor of 'bowing through a tube', then feedback will be given when the bow approaches the sides of the tube in order to prevent a 'collision'. We will investigate whether users prefer one form of feedback over the other and whether there is a difference in its utility for teaching correct bowing technique.

Another feedback metaphor that we would like to explore is 'hot and cold' and the idea of 'getting warm'. It may be that this metaphor is too closely connected with the idea of finding an object, or a particular point in space, rather than guiding a continuous movement. However, it is also possible that it is easy to interpret and therefore may prove particularly effective as a guide when the pupil explores the bowing movement in real-time.

2) Signalling Low Bow Speed

There is the potential danger that the vibrotactile feedback leads to too low bow velocities, as the student is focused on finding the right trajectory. A possible solution to this problem is to use an additional single vibration motor that signals that the student should increase their bowing speed.

3) Placement of Motors

We will explore how to position the vibration motors most effectively. The right upper arm, close to the elbow, seems a natural location for guiding the bowing trajectory, as the movement of the upper arm plays an important role in the control of this movement. The single motor for stimulating bow velocity will be initially placed on the right wrist or hand. Vibration motors to correct the violin position will be placed on the left hand or arm.

10. CONCLUSION

We have described the current stage of development of a system to support the teaching of good posture and bowing technique to novice violin players. These motor skills are challenging both to teach and to learn. We have demonstrated that using an inertial motion capture system we can track in real-time: i) a player's bowing action (and measure how it deviates from a target trajectory); ii) whether the player is holding their violin correctly. We have described some initial experiments that show that vibrotactile feedback can guide arm movements in one and two dimensions. It seems more effective to use opposing pairs of motors that provide 'pushing' feedback, than to signal separate components of a movement on both motors. We will continue to investigate how best to provide vibrotactile feedback to violin students as it has potential to provide intuitive feedback that does not lead to cognitive overload.

11. ACKNOWLEDGMENTS

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An Advanced Framework for Whole Body Interaction

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ABSTRACT
Whole Body Interaction has emerged in recent years as a discipline that integrates the physical, physiological, cognitive and emotional aspects of a person's complete interaction with a digital environment. In this paper we present a preliminary framework to handle the integration of the complex input signals and the feedback required to support such interaction. The framework is based on the principles of Autonomic Computing and aims to provide adaption and robustness in the management of whole body interaction. Finally we present some example case studies of how such a framework could be used.

Keywords
Whole Body Interaction, Motion Capture, Autonomic Computing

ACM Classification Keywords

Human Factors; Artificial, augmented, and virtual realities; Interaction Styles

1. Introduction

Bill Buxton [1] mused on what future archaeologist would make of today's humans extrapolating from our current computer technology and came up with a being with one eye, a dominant hand and two ears but lacking legs, and a sense of smell or touch. He argued for greater involvement in the whole person and their senses in human-computer interaction. Researchers and artists have responded to this challenge by exploiting the various technologies that fall under the general banner of virtual reality, and support whole body interaction. In our own work with artists [2] we have seen how they use camera vision and motion capture in novel interactions.

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However, despite the technological and methodological advances we are still some way off from a completely integrated approach to Whole Body Interaction. Let us give a definition of Whole Body Interaction:

The integrated capture and processing of human signals from physical, physiological, cognitive and emotional sources to generate feedback to those sources for interaction in a digital environment.

From this definition we can see that some approaches to HCI do not give us an integrated view of interaction. For example, Ubiquitous Computing [3] is more concerned with the notion of 'Place' rather than capturing the full range of actions. Physical Computing [4] is more concerned with artifacts than the physical nature of humans. Of course it is the nature of research to focus on certain, measurable aspects of interaction within the scope of a research project. However, in doing so we can loose sight of the larger, richer picture and the possibilities of Whole Body Interaction. Whole Body Interaction requires an interdisciplinary approach and interactions between the following disciplines

- Physical – we need interaction with Sports, Movement Science and Artists on the physical capabilities and limitations human being
- Physiological – sharing with clinicians and psychologists on the reading and interpretation of physiological signals
- Cognitive – the long history interaction between cognitive psychologists and computer science has been the bedrock of HCI
- Emotional – Psychologists, Artists and Game Designers have sought to understand and introduce knowledge of human emotions into interaction design

From this collection of disciplines we can see there is quite a rich interplay of knowledge required before we can begin to support a truly integrated Whole Body Interaction system. It would also be the case that as further research is carried out in the contributing disciplines; our understanding of how we can support Whole Body Interaction would evolve. Furthermore, there are a vast range of possible applications areas for Whole Body Interaction including, Games and Entertainment, Medical, Military, Education, Sports, Household, the Arts and so forth and each application area would have its own requirements as to accuracy of movement, the nature of any feedback and robustness of the system. And within each area individuals will learn and evolve their physical skills as they interact.

From this opening set of requirements we can see that we may need a complex system to manage Whole Body Interaction. However, if we are to allow domain experts to exploit Whole Body Interaction then we need an approach which allows them to express their domain knowledge; for example of movement, cognition and physiology, in their own terms.

The rest of the paper is structured as followed. In section 2 we explain Autonomic Computing as a basis for managing complex Interaction. In section 3 we present our framework based on Autonomic Computing. In section 4 we present some illustrative case studies, and finally in section 5 we discuss our conclusions and the future implications of our work.

2 Autonomic Computing and Interaction

Autonomic Computing systems [5] were proposed by IBM as a way of managing the configuration and management of complex systems without continuing user human involvement. Such systems could include farms of servers, monitoring equipment in the field, Cloud-like distributed systems of services, wireless sensor networks and autonomous robots. Autonomic Computing systems borrow and adapt ideas from biological systems in order to support their on-going self-management. Thus such systems try to take care of

- Reconfiguration in the event that one or more components fail or go off line
- Real-time service selection: as circumstances change new services may be selected to cope with them
- Self-Monitoring of the status of the whole system supporting self-repair

Though originally envisaged as supporting embedded or autonomous systems without much human involvement, the principals of Autonomic Computing have been used in complex interactive systems. Here the requirement is to support characteristics such as adaptability, robustness, self-repair and monitoring of the interaction. We require the system to be able to cope with emerging complex issues after it has been released to the end users without further monitoring or maintenance by the original development team. Ideally we would like the end users to provide their own on-going systems configuration based on their expert domain knowledge.

In our own work on post-operative Breast Cancer decision support [6] we used the mechanisms of Autonomic Computing to support the integration of components in a complex decision making process. The key challenges to such a system were

- The modeling of clinical decision-making processes – these processes could evolve over time and vary from hospital to hospital
- The governance of adherence to guidelines and patient safety
- Integration of rule-based guidelines modeling with the data mining of historical treatments data to provide a cross-cutting approach to decision support
- Providing multiple views of decision data
- Generating user interface(s) to the above

Thus we can learn general lessons about supporting the requirements for rich and complex interaction scenarios where we need to support evolving processes, quality criteria, the integration and cross-working of components and the engineering of the final user interface.

2.1 Autonomic Computing and Whole Body Interaction

From the opportunities and challenges posed by both Whole Body Interaction and Autonomic Computing we can see how the latter can support the former. For example, in using multiple sensors for motion capture (accelerometers, 3/5 axis gyroscopes, ultrasonic transducers etc) we face potential problems of the sensors malfunctioning, temporarily dropping signals or giving error-prone signals. So we need a sensor management layer to ensure the robustness of the input data. We can triangulate this data with data from, say, markerless camera-based motion capture [X] or stored kinematics models to smooth and correct the data.

Our stored kinematics model may give us a generic model of possible and allowed motions that can be used to ensure the safety of the human operator. However, we may also wish to model an individual's patterns of motion to either compare them with some norm or adapt the responses of the system to the individual. So there would be a machine-learning layer to capture and analyse the individual's performance.

Equally, if we are considering the emotional state of the person, we may wish to collect patterns of psycho-physiological data in an attempt to infer emotional states. Again we would need the appropriate machine-learning component in our framework and a means to integrate the data from that component with the other components. So we could combine signals from the physical and physiological states to adjust the responses of the system to the user, e.g. to recognize they are under stress and change the nature of the feedback given.

3 An Advanced Framework for Whole Body Interaction

The full details of the implementation are outside the scope of this paper, and further details are available in the given references[6,7]. To summarize, the implementation is executed through the Cloud architecture; the federation of services (component agents) and resources, with appropriately derived user interface descriptions. It is defined to enable the autonomic framework to function as a User Interface production module using the specially developed language, Neptune that allows management objects to be compiled and inspected at runtime. A system space provides persistent data storage for service registration and state information giving the means to coordinate the application service activities into an object model and associated User Interfaces based on the recorded interaction model and functional requirements. Reasoning can then proceed based on the Situation Calculus model, whereby the user interface descriptions are derived, inferred or adapted. Neptune exposes policies and decision models for system governance, derived from the Situation Calculus/Extensible Decision model, as compiled objects that can be inspected, modified and executed at runtime. Thus the system can evolve as modelled by the logical specification in a safe and predictable manner giving the adjustable self-management required. Neptune objects are executed on demand through an event model exposed by the Cloud architecture.

The system controller with an associated Observation System controls access to and from the individual services and resources within the Cloud. It brokers requests to the system, through the contrived User Interface, based on system status and governance rules, in Neptune objects, derived from the deliberative process as stated above. An overview of the Observation system is shown in Figure 1.

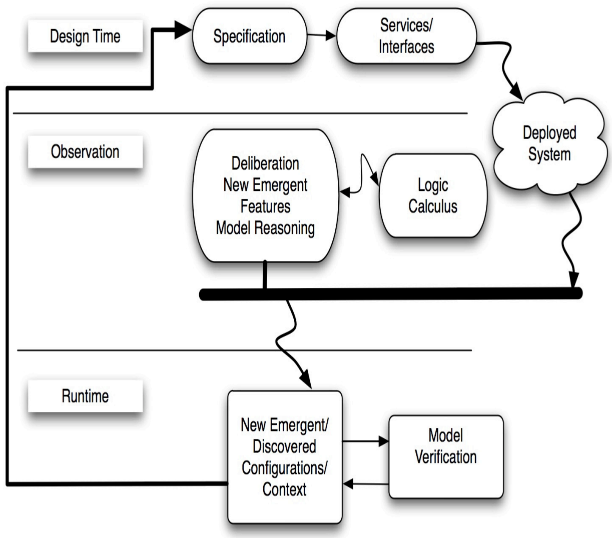

Figure 1. The Observation system

Each service and resource when it first registers itself to the Cloud sends a meta-object serialized from an XML definition file. This meta-object contains the properties and state data of the service it is describing and is stored within the System Space at registration. Each service maintains its own meta-object and updates the System Space when changes in state occur. The XML definition file contains all information required for the Cloud to discover the service through registration contained in the service element and prepare the appropriate User Interface. In addition to the meta-objects exposing properties of a service within the Cloud, they also describe the interface events that can be fired, caught and handled, allowing multi-modal interfaces to be composed. The event model begins by the service informing the System Controller when an event is fired, which itself marshals this event to the System Space to provide the appropriate scope. It should be noted however, that the event model is abstracted from the components within the system, and is controlled by the Neptune scripting language that sends and receives the appropriate event calls to the controller. The Neptune scripting language is structured in terms of rules, conditional statements and variable assignments that are translated from the Situation Calculus specification to software system objects, encapsulating all the logical inference processes and variable instantiations for the production of the most relevant interaction model and associated interface. An overview of this process is shown in Figure 2.

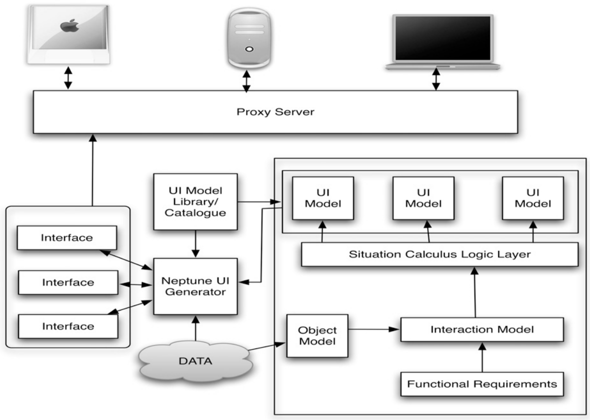

Figure 2. User Interface Production at Runtime

In this way the base rules for deliberation to control the Cloud architecture, through enhanced user interaction, have been transcribed, from the Situation Calculus reasoned representation, into Neptune objects that can be modified as a result of Observation System deliberation on system events.

4 Case Studies

To demonstrate the validity of the framework we present 3 case studies from current research work at Liverpool John Moores University.

4.1 Assessment of Risk of Falling in Older People

As the population in the more advanced countries ages there is an increasing burden on health services and budgets, not to mention personal risks and frustrations for older people. One of the major risks for older people is falling. As a result of a fall, elderly people are more likely to break a major bone such as a hip or femur. They will then become bed-bound and loose their mobility and independence. The risk of premature death after a fall increases. These risks may be exacerbated by other factors such as diabetes, balance problems, Parkinson's disease and so on. At Liverpool John Moores the Caren platform [8] has been used to help measure issues or gait and balance. However, such platforms are large and expensive and thus not available to most clinicians who are diagnosing and caring for elderly people. It is also difficult to bring elderly people to such as facility. Ideally we would like a mobile system that would support

- Research and Investigation of the general factors promoting the risks of falls
- A clinical diagnostic system that would help clinicians to identify at-risk individuals

- A personal mobile device that would warn elderly people that they were developing a fall risk

In the research system we are required to capture as much data as possible and compare it with existing models of potential fall situations and look for correlations with our clinical data, such as evidence of other diseases. We would need tools to visualize the data and help us refine our understanding of fall risks. For the diagnostic and alert models we would require a simplified physical model but a more robust management of the sensors to both ensure that risks were captured and that false positives were avoided.

4.2 Sports Excellence

In sporting academies it has long been a goal to discover next generation sporting champions. With the rising costs associated with their training and the potential loss of such talent due to poor management, attention has been drawn to scientific methods for talent prediction, training and programme development. Current methods are ad hoc in nature and rely heavily on human expert judgment including metrics and benchmarks. Whilst, research into scientific methods and test beds for sport science is not new and has already produced and/or enriched the talent of many world class names such as Lance Armstrong (cycling) and Amir Khan (boxing) to name but a few. Due to cost and time constraints often such laboratory based facilities are only available to the very few, and the techniques used are either intrusive or laboratory based, hence limiting their applicability to those sports that require mobile performance measurement (telemetry).

Using our framework we adopt a multidisciplinary approach where results from world-class research expertise in gait analysis for sportsmen, and advanced wireless body-area sensor networks and high-stream data analysis and visualisation are combined [9]. The framework aims to develop a fundamental understanding into full-motion modelling and analysis methods including associated test beds to support the prediction and follow up of potential sporting champions. Rather than utilising both marker and markerless motion capturing techniques we utilise advances in Micro-electromechanical systems that when connected to the body and switched on form an ad hoc peer-to-peer body area network. Ultrasonic transducer pairs, 3/5-axis gyroscopes, and accelerometers allow fully body motion to be captured. The challenge is to collect information from these data sources in real-time and perform predictive analysis of movements for the intended purpose of detecting movements, reactions and techniques typically associated with current and past world champions.

Using our novice and world champion martial arts collaborators we aim to evaluate the framework. Martial artists are equipped with body area sensor networks that dynamically connect to sub-networks in the gymnasium, such as gloves, footwear and the floor, including the sensors attached to the opponent. The sensors in one body area network form a coupling with another indicating that they are in combat mode. This allows attacks given by one subject to be compared against the defence techniques of the other. Building on techniques from artificial intelligence (neural networks) and autonomic computing a predictive module will collect information in real-time and rank the potential of new students using data from existing world champions.

4.3 Operator Performance in Simulators

Operators of complex systems, from automobiles, to aircraft to nuclear plants face they possibility of errors and mistakes when they become over-loaded or stressed. We can put operators in stressful but risk-free situations in simulators to assess people's reactions to stress and propose avoiding or alerting actions. Work on Biocybernetic Control [10] has looked at the collection of physiological data such as heart rate, breathing rate and galvanic skin response to look for patterns in the data in moments of stress. However, such data does not always correlate with actual stress and potentially dangerous changes in operator behaviour in stressful scenarios. We would need to look for other factors such as body posture, head tilt and eye gazed to assess the alertness of the operator; have their physical responses to the controls changed, has their head titled forward due to fatigue or have their patterns of eye gazed changed from normal?

5 Conclusions and future work

We have presented the beginnings of an advanced framework for whole body interaction. Having learned lessons from other domains we have applied the principles of Autonomic Computing to provide a framework that supports the requirements for system evolution, robustness and self-monitoring which are necessary in the complex field of Whole Body Interaction. Our illustrative case studies show such a framework could be used in a number of areas. These demonstrate the requirements for robustness in the use of sensor, pattern discovery and adaptability.

There are of course many challenges to the wider development and use of Whole Body Interaction systems. We need further investigation of the physical capabilities and limitations of humans in full body interaction. As Buxton [11] more recently observed we still only have a good knowledge of interaction involving the hands and arms but little beyond that. We are still at the early stages of understanding emotion in interaction let alone whole body interaction [12]. However, without a rich and evolvable framework, developments in these supporting areas will fail to provide the expected potential benefits.

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http://lister.cms.livjm.ac.uk/homepage/staff/cmsdengl/WBI2009/.

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Vocate: Auditory Interfaces for Location-based Services

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ABSTRACT
This paper discusses work being carried out by the *Vocate* module of the *LOK8* project. The *LOK8* project seeks to develop location-based services within intelligent social environments, such as museums, art galleries, office buildings, and so on. It seeks to do this using a wide range of media and devices employing multiple modalities. The *Vocate* module is responsible for the auditory aspect of the *LOK8* environment and will seek to exploit the natural strengths afforded by the auditory modality to make the *LOK8* system user-friendly in multiple scenarios, including instances where the user needs to be hands-free or eyes-free, or when screen size on a mobile device might be an issue. We look at what kinds of services the *Vocate* module will be seeking to implement within the *LOK8* environment and discuss the strengths and weaknesses of three possible approaches - sonification, auditory user interfaces, and speech interfaces.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – Auditory (non-speech) feedback, Evaluation/methodology, Interaction styles (e.g., commands, menus, forms, direct manipulation), User-centered design; H.5.2 [**User Interfaces (D.2.2, H.1.2, I.3.6)**]: Natural language, voice I/O; I.2.7 [**Natural Language Processing**].

General Terms
Design, Human Factors.

Keywords
Auditory user interfaces, sonification, speech interfaces, location-based services, contextual awareness, audio navigation.

1. INTRODUCTION
The *LOK8* project's objective is to deliver context-specific, location-based services within an intelligent environment. It seeks to do this using a wide range of media in multiple modalities via screens, projectors, head-mounted displays (HMDs), mobile devices, speakers, and so on. The *LOK8* system will make use of media within the environment to provide scaleable content depending on the context, location and personal preferences of the user. In its most immersive form the *LOK8* environment will present users with personalised, interactive avatars that will guide them via speech and gestural interaction but beyond this it will seek to exploit the advantages afforded by multiple modalities to make content delivery scaleable and to make the *LOK8* environment user-friendly in situations where it might not be practical or desirable to attend to a visual display or manual interface. The project is divided into four distinct modules: the *Vocate* module, which handles the auditory aspect of the environment; the *Avatar* module, which handles the visual aspect of the environment; the *Tracker* module, which handles positioning and locationing within the environment; and the *Contact* module, which provides the dialog system for the environment. This paper details work within the *Vocate* module of the project relating to auditory interfaces. It discusses the advantages that audition has over other modalities and outlines what types of services *Vocate* will be trying to implement using audio. It will also consider how *Vocate* might realise these implementations using three possible approaches: sonification, auditory user interfaces and speech interfaces.

2. VOCATE
The *Vocate* module will seek to implement a number of features within the *LOK8* environment. Firstly, it will seek to provide a hands-free navigation system that can both guide users to target destinations within the environment as and when they are requested, and also point out salient information relating to the environment itself (or objects within the environment) as and when it becomes relevant to the user's spatial context. This type of navigation system reduces the necessity for visual aids such as maps, which can be cognitively demanding in situations where you are in transit and may need to focus on your immediate surroundings; they can also be impractical on mobile devices where screen real estate might be at a premium – a key issue given the trend towards smaller and smaller handsets in many modern mobile devices. Secondly, *Vocate* will seek to provide an auditory version of the *LOK8* environment's menu interface that can be interacted with remotely, either via the user's mobile device or possibly via intercoms located throughout the environment. Such a menu system would allow users to continue to interact with the *LOK8* environment even in situations where their focus and attention cannot be devoted to the manual operation of their mobile device; it would also remove the burden on the visual modality when screen space on a mobile device is limited. Finally, *Vocate* will seek to provide realistic speech interaction with the *LOK8* avatar when it is in operation within the environment. This multimodal approach

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in particular will seek to provide the most immersive and natural interactive experience within the *LOK8* environment and will likely be collaborative across all four project modules. It is the aim of the *LOK8* project that this multimodal, avatar-based approach will lead to more intuitive, naturalistic human-computer interaction, and away from the physically constrained, traditional methods of computer interaction such as the mouse, keyboard, and even the touchscreen. Each of these design tasks has its own unique challenges, *Vocate* will be considering these in relation to three possible approaches: sonification, auditory user interfaces, and speech interfaces.

3. AUDITORY INTERFACES

Audio information is processed faster neurally than both haptic and visual information (2ms for audio, compared with 10ms for haptic and 100ms for visual information [13]), this lends the auditory modality well to the delivery of certain types of information, such as alerts and alarms, particularly when one considers that audio notifications are generally harder to ignore than visual notifications. Audio is also hands-free and largely focus-independent, which makes it a suitable modality for the delivery of information in scenarios where the user may be in transit or have their eyes and/or hands occupied with a cognitively demanding task [11]. Factors such as these, combined with the fact that ever-improving technology is allowing for acceptable quality audio to be increasingly possible on smaller and cheaper devices, place audio in a unique position when considering multimodal solutions to user interface design problems and physicality issues.

3.1 Sonification

Sonification is defined as the use of non-speech audio to convey information [14]. The underlying concept of sonification has been around for many years, early examples would include the hourly chimes of a clock tower to convey the time of day, the foghorn, and Morse code. Today modern technology allows designers to incorporate sonification systems into a wide range of devices. There are, however, a number of inherent obstacles when it comes to sonification that the sound designer must consider. Firstly, not all types of information are suitable for sonification. For example it may be quite straightforward to get a listener's attention by using a high-frequency alert but what if the designer then wants to use sonification to communicate something quite complex to the listener, such as the identity of people who work in the building they are currently in? This brings us to our second obstacle - lack of established design conventions. While there are numerous examples of systems that have sonified quite complex information and data sets, such as pie charts [9], daily weather records [8], market information [12], and patterns in DNA and RNA sequences [6], many would argue that the field of sonification still lacks established design conventions. Sound design does not have the same wealth of recognised guidelines and design principles that the visual arts have, perhaps because audio is less tangible in nature, but organisations such as ICAD (International Community for Auditory Display) and ISCRAM (Information Systems for Crisis Response and Management) are working to change this. A third factor the designer must consider is the environment in which the sonification system is to be used. We make use of a considerable amount of auditory information in our surrounding environment on a daily basis, this would include naturally occurring sounds as well as existing auditory displays, such as doorbells and telephone ringtones. One must take care to design a sonification system that can work in tandem with this ambient information and not against it, this can be done effectively by studying the target environment and testing any proposed systems in comparable conditions [1][17].

3.1.1 Relevance of Sonification to Vocate

In terms of the *Vocate* project sonification could be of particular use when it comes to the implementation of the audio navigation system. Sonification lends itself well to the communication of spatial information within an environment because the information being conveyed is generally physical in nature rather than abstract and therefore simpler to convey. The use of stereo spatialisation and volume modulation can allow the sound designer to 'place' auditory information within the soundscape as if it were coming from an actual physical location relative to the user. This approach has been used in several systems to communicate the location of both target destinations and objects of interest within an environment [18][20][24]. While some systems, such as the *Ontrack* system [24], use the listener's music of choice as the source signal for spatialisation and modulation, there is also existing empirical research into the efficacy of using beacons that could be leveraged for the *Vocate* project [20][23]. The beacon approach generally uses spatialised sonar style pulses of sound to indicate a destination or path through an environment, the tempo or volume of the beacon signal usually increases as the user approaches the target destination. Over longer distances several beacons may be placed between the user and the target destination, as each beacon is reached the next one in the series becomes active. Studies have found that broad spectrum sounds, such as pink noise bursts, are more easily localised and have been found to encourage greater performance. It has also been found that a moderate capture radius (i.e the area within which the system deems the user to have reached the beacon, thus triggering the next beacon to become audible) is preferable to a very large or very small capture area e.g. greater than 9ft or only a few inches.

On a slightly more abstract level sonification has also been used to communicate when a user has moved from one surface or area to another [23], for example moving from the pavement onto the road, or from the Italian Renaissance section of an art gallery to the Romanesque section. What makes this more abstract is that with this approach these different surfaces and areas have to be allocated their own unique acoustic characteristics in some way so as to differentiate them from each other and there aren't always natural acoustic mappings available to the designer, the level of difficulty in this regard depends on the context and in some cases it may be more expedient to use speech notifications.

The *LOK8* project aims to be used in social settings such as museums, art galleries and shopping centres, with this in mind it must be considered that using headphones or earphones could discourage social interaction between users within the environment because each user would be operating within their own private audio space. Previous sonification systems have attempted to address this issue, for example Stahl's *Roaring Navigator* [18] developed an 'eavesdropping' system whereby if multiple users were in close physical proximity, those who were not currently listening to anything in their headsets could pick up a certain amount of the audio that other users were listening to. Another possible solution to this issue would be the use of bonephones. Bonephones are open-ear headphones that use vibrations to transmit sound directly to the cochlea via the bones of the skull thus allowing external ambient audio to remain audible via the ear canals. Tests have shown that although bonephones do not perform as well as headphones when it comes to stereo spatialisation they are still sufficiently effective when used in audio navigation scenarios [23]. The unique physical advantage of being able to bypass the outer ear completely also allows bonephones to be used by anyone suffering from conductive hearing loss.

3.2 Auditory User Interfaces

An auditory display is defined as the use of sound to communicate information about the state of an application or computing device to a user; this definition suggests the unidirectional flow of information from the device to the user. An auditory user interface on the other hand is defined as a superclass of auditory displays that allows for auditory input to also flow from the user back to the device, usually in the form of speech [15]. By this nature auditory user interfaces are less constricted than sonification or speech interfaces alone and as such are the easiest to integrate into a multimodal environment. In the past a lot of research in the field of auditory user interfaces has been driven by the need to develop alternative user interfaces for the visually impaired but it has since come to be seen as an area of considerable potential in its own right, both in terms of exclusively auditory user interfaces and augmented audio-visual user interfaces, such as the *JMusic* system [4], which allows users to map the run-time behaviours of Java programs onto musical parameters and hence monitor these behaviours continually. The ability of audio to operate on the periphery of a user's awareness is particularly useful in this regard as it can allow a system or device to give continual feedback without necessarily leading to cognitive overload. Many mechanical devices physically generate sounds during operation that over time users learn to interpret as indicative of the operational status of the device as a whole e.g. the way in which a mechanic might listen to an engine to hear what's wrong [11]. The digital nature of many modern devices has, in many cases, done away with this physical form of feedback but a carefully considered auditory ecology within any system can reintroduce some of this functionality.

3.2.1 Relevance of Auditory User Interfaces to Vocate

In terms of the *Vocate* project auditory user interfaces arguably offer the best option for the implementation of the auditory version of the *LOK8* menu interface. The *LOK8* menu interface will be the most basic mode of interaction with the *LOK8* system, offering access to all of the functionality that the *LOK8* environment has to offer; this might include the ability to query objects of interest within the environment, the ability to query one's location within the environment, guided tours within the environment, information relating to available services and amenities, and so on. While the *LOK8* menu will also likely feature a traditional graphical user interface, a stand-alone auditory version of the menu will offer equivalent functionality in situations where the user requires to be hands-free and/or eyes-free, or when screen space on a mobile device is limited - the main advantage of non visual user interfaces in terms of physicality is that they effectively render the physical issue of screen size redundant.

Audio is serial in nature and while this offers some advantage over the visual modality when it comes to complex data comparisons [5] [16], it is something of a weakness when it comes to menu design as the visual modality, unlike its auditory counterpart, can quite easily continually present multiple objects of interest, such as menu options, to the user. Despite this physical limitation there are still inherent qualities in audio that lend themselves to menu design. The human auditory system is particularly adept at filtering audio information into perceptually meaningful elements by a process that Bregman describes as 'auditory scene analysis' [3]. The three main aspects of auditory scene analysis are segregation, segmentation and integration. The human auditory system applies these filtering techniques to divide audio information into 'streams'; a stream might be made up of one quick audio event such as a loud bang (an example of segregation), or it might be made up of a collection of associated sounds such as a choir singing (an example of integration). Whether sounds are segregated, segmented or integrated with other sounds depends on several parameters including pitch, frequency, timbre, volume, tempo, spatial location, and so on. An example where the human auditory system uses these phenomena to great advantage is 'the cocktail party effect' [2], whereby a listener can zone in on one speaker in a room full of conversations and extraneous noise. Empirical studies regarding the parameters and thresholds that effect auditory stream perception have enabled sound designers to design auditory systems that can present users with multiple streams of audio information in such a way that the streams can be kept perceptually separate from each other and brought in and out of focus when necessary [7][10]. This, combined with techniques such as 'skimming' (the ability to skim segments of an audio stream to give an indication of the whole stream), help counteract some of the negative aspects of audio seriality. *Vocate's* auditory user interface could adopt a combination of this speech-based approach along with other techniques and principles leveraged from sonification to give the user additional feedback regarding the operation of the menu system.

3.3 Speech Interfaces

Speech interfaces are interfaces that utilise speech recognition and/or speech synthesis to communicate with a user. The obvious advantage that speech interfaces have over other auditory interfaces, such as sonification systems, is that they can communicate with the user using natural language. Having said that, speech interfaces are arguably the most difficult and time-consuming of all auditory interfaces to implement and speech itself brings with it it's own problems. An obvious problem with adopting a speech interface is that language becomes a factor. While sonification can often transcend linguistic and cultural boundaries speech interfaces are limited to the languages that the system and its users share common knowledge of. While speech is often the best option for communicating highly complex or specific information it is not necessarily a suitable option when communicating ambient information; it is often common in ambient displays to abstract the data being communicated in some way in order to render the display easier to interpret and experience on a peripheral level [19]. Speech interfaces also require a lot of back-end work. The corpora with which the system is trained have to be rigorously compiled and the most effective speech interface systems use multiple forms of data input, such as lip-tracking, gaze-tracking, and gestural input, in order to model the system's responses and output. This is because speech communication is generally quite physical in nature, with much information and meaning conveyed via body language and backchannel communication; failure to address this physical aspect of speech communication can lead to less efficient speech interface systems.

3.3.1 Relevance of Speech Interfaces to Vocate

We have already discussed how speech interaction might be highly suitable for aspects of the *LOK8* auditory menu interface but it will also have application when users are interacting with the *LOK8* avatar. The goal with the avatar is to have a character that the user can interact with as if it were a real personal assistant or tour guide. The fact that all four modules of the *LOK8* project will be collaborating on this aspect of the environment in particular means that the multimodal approach necessary to achieve effective human-computer speech interaction should be possible. For example the *Vocate* module will look at speech signal processing along with the *Contact* module, which will also be working on the dialog manager and modeling how the avatar will behave and react in relation to the input the *LOK8* system receives. The *Avatar* module will not only be working on the visual design and aesthetic of the avatar, but will also be looking at optical recognition for the purposes of obtaining gestural input. Finally, the *Tracker* module will allow the *LOK8* system to display the audio and visual output in the correct context for the user based on their location and position. It is the goal of the *LOK8* team that a well-rendered avatar-based interface with audio-visual input and output will encourage more natural and intuitive interaction between the user and the environment and transcend some of the physical constraints of more traditional human-computer interaction methods.

A further option in relation to speech interfaces is that there are now several off-the-shelf products available on multiple platforms and mobile devices, such as *Vlingo* (available on Blackberry, iPhone, Nokia and Windows Mobile), *Voice Control* (Apple's new speech interface system for the iPhone 3GS), and *Google Mobile App* (available on iPhone), that promise a lot of the functionality that *LOK8* is seeking to implement. Although testing would be required on such products to ensure that they both possess the requisite functionality, and adequately plug in to the rest of the *LOK8* system, they would certainly be an option worth considering.

4. CONCLUSIONS

In this paper we outlined the work of the *LOK8* Project and specifically the role the *Vocate* module plays within that project in developing auditory interfaces. We discussed some of the unique qualities that audition has to offer as a modality for communication and interaction, such as its hands-and-eyes-free nature and fast neural processing rate. We discussed the pros and cons that different auditory interfaces might offer in terms of the specific services *Vocate* seeks to implement within the *LOK8* environment i.e. a hands-and-eyes-free navigation system, an auditory menu interface, and natural speech interaction with an avatar. Sonification lends itself well to the communication of physical information and any form of information that has natural acoustic mappings but it is not always suitable for complex, detailed interactions. Speech interfaces can be highly effective when it comes to communicating directly with a user in more complex interactions but they require a lot of back-end work as well as multiple forms of data input for more naturalistic systems. One must also consider that language may become an obstacle when using speech interfaces as a certain level of fluency with the language(s) used by the system may be required of the user, unlike with sonification which can often transcend such linguistic boundaries. Auditory user interfaces offer umbrella solutions that can leverage strengths from both sonification and speech interfaces but one must take care to consider the environment the auditory system is to be deployed in and make use of existing empirical data wherever possible. Finally we discussed the fact that recent off-the-shelf products offer much of the functionality that the *LOK8* system seeks to offer and that such devices might be worth considering should they stand up to testing within the overall *LOK8* environment.

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Bodily interaction and communication in an Art Exhibition hall

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ABSTRACT
We present an analysis of the ethnographic material we have collected at the Vårsalongen art exhibition at Liljevalchs Konsthall in Stockholm. In our future design, we are particularly addressing 1) how to involve bodily aspects of experience, and 2) how to design for collective experiences within groups of friends. This entails practical design work of integrating hardware and software as well as empirical investigations of peoples' conduct and experiences at an art exhibition hall with a particular focus on bodily ways of expression and interaction. We also outline our current concerns in mapping out some theoretical issues that we are inspired by in order to make sense of our empirical investigations and in our design attempts.

Categories and Subject Descriptors
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms
Design

Keywords
Shared experience, bodily experience, embodied experiences, ethnography,

1. INTRODUCTION
Our work involves exploration of a number of aspects that have been found to be of critical concern for the design of social and leisure oriented mobile technologies such as sharing, individual action, and how to integrate these with bodily forms of interaction. This works investigates interaction and shared experiences among group of friends and we are have used the Vårsalongen at Liljevalchs art Exhibition hall in Stockholm as a case to explore this design space. We are particularly addressing 1) how to involve bodily aspects of experience and interaction, and 2) how to design for collective experiences within groups of friends.

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The aim of this paper is to map out a set of conceptual dimensions for the understanding of central qualities of interaction in co-experiences among groups of friends. Thereby, we attempt to contribute to HCI in way that more systematically incorporates sensitivities to the role of the body, bodily interaction, and bodily experiences in HCI theory and interaction design. We are particularly inspired by three lines of research that deal with aspects of the body in understanding human experience and interaction. To achieve this we have firstly, looked at three theoretical strands that address the role of the human body in perception and experience. This has included a) phenomenologically oriented theories of thinking and action, and particularly the work by Maxime Sheets-Johnstone and her notion of thinking in movement as a basis for human perception [6], b) Shusterman's philosophy of somaestethics that argues for how increased bodily awareness contribute to the inclusion of pragmatist philosophy for improving human life conditions (not included here) c) ethnomethodological studies of social conduct and communicative action that pay sensitivity towards the role of bodily action in meaning making (not included here). Secondly, we are conducting design oriented studies in collaboration with an art Exhibition hall in Stockholm to explore how to design artifacts that allow groups of users to engage in bodily and emotionally augmented communication with one another. This involves the design of physical artifacts and interaction spaces for bodily and emotional engagement for shared experiences among groups of friends having at the art exhibition hall. This has both involved ethnographic investigations of visitors with a focus on bodily forms of conduct and engagement, as well as design workshops. We combine practical design work of integrating hardware and software with findings from empirical investigations of peoples' conduct and experiences. In particular, we emphasize how findings where bodily ways of expression and interaction are prominent can be brought in to our design explorations. To start with, this paper outlines our current concerns in mapping out some of the theoretical issues that we are inspired by in order to make sense of our empirical investigations and guide our design attempts.

2. THE MOVING BODY AS CENTRE OF PERCEPTION AND EXPERIENCE
Physical dimensions of human-technology relationships are increasingly making room in interaction design research. This development is two-folded. One side regards the character and qualities of the physical artifacts and the material circumstances

that we interact with and around. The other side puts the physicality of our bodies and its consequences for human action and perception at centre stage of interaction design research. These two aspects of physicality are closely intertwined since physical shape, form, texture, size, etc., of interactive artifacts and settings have immediate consequences for the interaction we engage in with these objects. In recent studies, bodily aspects of experience, such as touch and movement and how to design for such qualities of interaction have been addressed [3][5]. A common theoretical starting point for much of such work is phenomenological perspectives on action and perception. Phenomenology has played a central role in the renewal of the conceptual starting points of human-computer interaction starting with Winograd's & Flores' introduction of Heidegger's concept of tool use for the understanding of cognition in relation to computational artifacts [8]. This was a first move away from conceptualizing the cognitive and action oriented aspects of HCI in represenationalist terms. This shift was continued in a more empirical fashion by Lucy Suchman [7] and other ethnomethodologists, leading up to Dourish's notion of embodied interaction[1]. Dourish's notion of embodied interaction has contributed to putting social action and its embodied character on the HCI agenda. The idea of embodied interaction largely comes from ethnomethodology and phenomenology with an emphasis on how social performances in relation to contextual and material circumstances contribute to the shaping of the entire interactive settings. However, scarcer within HCI are philosophers such as Merleau-Ponty[4], who attempted to overcome dualist conceptions of mind and language, and instead explain human perception in a non-representationalist fashion with a focus on our corporeal existence and how the specific characteristics of our bodies shape our perception and sense-making.

In Maxime Sheets-Johnstone's recent book "The corporeal turn"[6] she aims at putting the body at centre stage of human cognition, while not reducing the mental to something purely material or physical. She extends the ideas of Merleau-Ponty by arguing for how bodily movement should be understood as the essential characteristic from which to understand thinking and perception. Rather than viewing body movement as a consequence of mental processes, she proposes movement as the basis for cognitive processes, through the notion of thinking in movement. Through this notion she captures some key elements necessary for arriving at a conception of human thinking that does not get stuck in dualist notions of mind and body and questions such as how the mind controls the body, how mind can arise in physical matter, or how mind represents and stores memories. Central elements in this conception includes 1) the dynamic evolving non-discrete character thinking, 2) the non-separability of thinking from doing, 3) the non-separability of thinking from expression, 4) that meaning is not to refer, or to have a label, 5) that humans are not symbol-making bodies but existentially resonant bodies, 6) and that movements constitutes the thoughts themselves.

Hence, sensing the world and acting in it, do not belong to two separate domains, but are part of the same experiential world. Thereby, showing how the idea of separating thinking from its expression, how a thought in the head exists prior to its expression, denies the idea of thinking and acting as a dynamic process created by a mindful body.

The reason why we are engaged in the perspective on the body proposed by Sheets-Johnstone is because we believe that it poses a set of specific challenges and opportunities for designers of computational technologies that seriously attempts to integrate bodily interaction and experiences with a mindful perspective of human perception that takes our whole bodies into account. The notion of thinking in movement embraces an inevitable dynamic characteristic, which cannot be understood as an assemblage of discrete events, such as gestures, postures, and steps in dance for instance, occurring one after the other. Rather, there is a constant unfolding of the activity (e.g. the dance), which if broken into discrete parts always loses some of its meaning. What we find challenging with this idea of putting dynamics at the core, is that a designer that attempts to build technologies for bodily engagements such as movement or touch, in the end, only have the sensing capabilities of the computational material to work with, and these are always limited by its discrete and representational structures. From a design point of view, an essential consequence of taking such a viewpoint on human perception, is that how much or what we can actually sense through sensor technologies is then not the concern, rather what becomes the primary concern is the practices of interaction of the human body that we should pay sensitivity to. Coming back to dance as an example, to meaningfully design technology that is incorporated with the practices of improvisational dance, does not necessarily have to mean finding more sophisticated ways of sensing how a particular movement is carried out such as rhythm, timing, synchronization, effort, feeling, or snappiness, but to see the movement of the arms as a potentially central aspect of the meaning making practice of the dance.

In HCI, these issues have recently started to be addressed through notions such as full-body and whole-body interaction. A technological interpretation of these notions suggests design technologies with greater and greater sensor capabilities aimed towards including a larger range of human actions and senses in interaction. We argue that we need to make room for incorporating bodily interaction in a broader sense than simply measuring the movement of body parts, by actually attempting to understand the role of our bodies in our everyday interactions with technology and its consequences for design. Hence, we favor a human-centered interpretation of such notions which can provide a lens from which to view the human body in interaction with technology.

Our approach for studying this theme was to start by conducting ethnographic observations of groups of friends at the Liljevalchs Art Exhibition Hall.

3. LILJEVALCHS OBSERVATIONS

The Vårsalongen exhibition at Liljevalchs art exhibition hall is a yearly event that has been going on since 1921 in Stockholm. The exhibition invites professional as well as amateur artists to anonymously send in art pieces. Usually, about 3-4000 pieces are submitted. Among the submitted works, a jury selects about 250 pieces that is presented at one of the Stockholm's most prestigious and well-known art exhibition halls. The Vårsalongen attracts a wide array of visitors ranging from people with a strong interest in art to people that have who have a yearly tradition to visit the exhibition (and rarely visit any other art exhibitions).

Our initial study of groups of visitors at the Vårsalongen investigated communication and interaction among them. The setting was chosen for two reasons. First, because visits to art exhibitions are a common way for groups of friends to spend time together, and second, because the Vårsalongen have a tradition of stirring up emotion and engagement both among visitors and in the press.

Note that the particular purpose of this work is to understand bodily aspects of shared experience of groups of friends engaged in social activities, rather than understanding the aesthetic dimensions of collaborative meaning making and interpretation of art works. Visitors experience of art works and the aesthetic dimension involved in that is of course a key aspect of the visitors' experience. But, contrary to much other HCI related work conducted in similar settings [Heath et al; McCarthy & Wright; etc] such as art galleries and museums our aim is not to contribute to the design of novel technologies in support for particular art experiences (e.g. [2]). Instead, our work aim at designing technologies for groups of friends to use in expressing themselves to one another, and thereby providing new dimensions aspects to their experience before, during and after the visit.

In our studies we started by conducting observations of visitors in the art exhibition hall in a paper and pen fashion. Based on the initial observations we decided to focus more closely on how visitor groups interacted as they moved around in the exhibition hall, making video recordings of their visits. In total 5 groups were videotaped and about 5 hours of video was collected. The material was analyzed using interaction analysis with a particular attention paid to how the participants use their bodies as communicative resources throughout their visits, and on bodily ways of interacting and expressing themselves. We explored the material from a number of different perspectives ranging from the specific details of creating a shared experience around an art piece to how they organized their visits. Here we present two excerpts to illustrate 1) how they uphold a number of conversational projects throughout their visits, 2) how they make an effort to creating shared visual experiences around an art piece.

3.1 Maintaining parallel conversational projects through bodily expressions

One finding that we would like to advance here regards the multitude of communicative projects that participants establish and maintain throughout their visits, and the interactional resources they use in such communicative processes.

Below we exemplify this with an excerpt from a pair of women, Vera (V) and Maria (M). As we enter their conversation they are verbally discussing an exhibition by the photographer Gursky at the Museum of Modern Art in Stockholm. Maria has seen the exhibition and is very excited about it. Vera who has not seen it associates to another photo exhibition (at gallery Kontrast) that she would like to go to. Up to turn 18 all their verbal interaction is concerned with the other photo exhibitions and if they could possibly go there. However, in the middle of turn 18, Maria shifts topic by saying "green green house aa:h", which works as description of the art works they are standing in front of (which are named Regional vision I & II), something that had not been verbally talked about previously.

9. V: is it still there

10. M: yea:h it is still there I think it goes on for quite long(.) really so so so cool (.) you got to see it

11. V: (inaud)

12. M: aah (reads label, see picture)

13. V: eh:h however I believe that the picture of the year is still at gallery Kontrast (.) or there was an opening last thursday I think

14. M: mm:huh

15. V: I'd like to see that

16. M: yeah(.) we could go there (Vera gestures towards right photograph, see picture)

17. V: yea:h(.) I think so

18. M: but the picture of the year eh: (.) is'nt that it it is is press press photography that is (.) green green house aa:h

19. V: at least something open(.) a lot

20. M: no print (.) regional vision (.) regional vision could it be like this that here (.) where are you (.) that here is the forest inside and here is the forest outside

21. V: mmm (.) wow

What is interesting about the shift of topic in line 18 is that nothing in their verbal conversation has up till this point explicitly referred to the art work and the shift of topic comes rather abruptly without any previous verbal conversational markers as would be expected. Instead, the communicative project of collaboratively viewing the artwork is maintained through subtle bodily actions that allow them to coordinate their joint efforts of exploring the art work and creating a shared visual experience. Two of the key physical actions in that process that we identified regards firstly, Maria's reading of the label beside the art works at turns 11 and 12, and secondly, Vera's gesture at turn 16 and 17 with her left hand from the left piece towards the second which ends with an opened palm. These actions together with subtle confirmations during turns 9-18 serve as means for maintaining the communicative project of viewing and experiencing the artworks, which at turn 18 is then shifted to be a topic also at the verbal level.

A key issue that stands out from this excerpt regards what can be expressed through verbal language and what people utilizes other interactional resources for expressing. Here, bodily actions such as gaze, posture and gesture provide resources for the participants to orient themselves together with their interlocutor and establish co-vision and co-experience of the art exhibition, while verbal language is used for conversations that can drift beyond the particular setting and context. Bodily practices is used for looking and experiencing particular art works as well as for orienting and structuring how pairs and groups move around in the exhibition hall.

3.2 Creating a shared experience with art pieces, designed for individual viewing

In the following excerpt, Johan, Arvid and Amanda, three work colleagues, are exploring an art piece, named "Reveal 8-bit", a "peep hole" in a plastic box that shows small figures inside that are playing a video game. What we would like to emphasize in this excerpt is how the three friends do detailed work of body posture, gaze, and pointing together with language to construct a shared experience out of looking at an art piece that through its very small viewing hole is specifically designed for individual viewing.

1. Arvid: Somewhere there is a Nintendo

2. Johan: oh

3. Arvid: hehehe (.) peep hole (leans forwards and looks, see picture below)

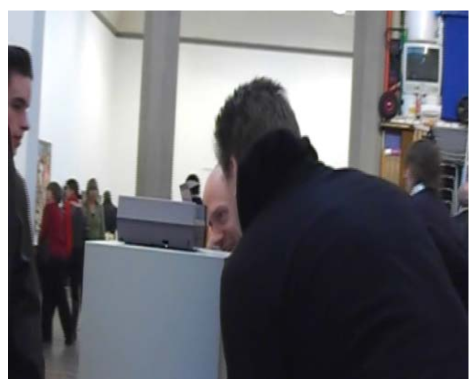
4. Johan: (leans forwards and looks, see picture below) (2 s) ah shit there are small figures in there

5. Arvid: Yeah ahaha (2 s)

6. Johan: (moving closer, see picture below)

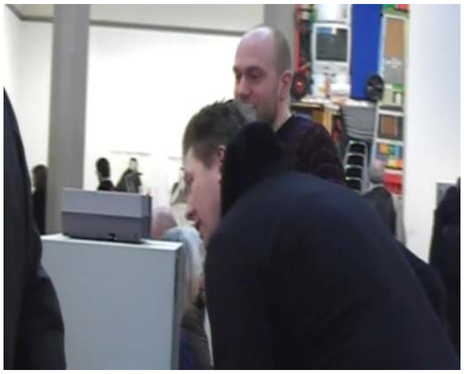
7. Arvid: (rises) hehe

8. Johan: eh but is it a game in there too [some rally game



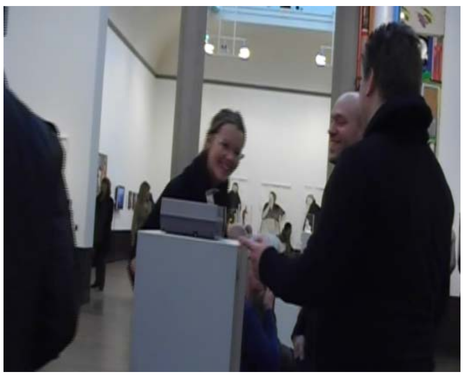
9. Arvid: (bends forward, see picture above)[something (rises)

10. Johan: can you see it from there too (leans to view from Arvids´angle, see picture below)



11. Arvid: no (.) only (down there)

12. Amanda: (..)



13. Johan: hey check this out (points the peep hole on the ”whole” box, see picture above)[this we should have in our WII room, huh

14. Arvid: [ahhaha lets buy it

15. Amanda: (..)

16. Johan: there is small figures in (points straight in through the little peep hole, see picture above) this one and they have one (points to the left inside the box, see picture below) screen there where you they sit and play (.) some rally game

17. Anna: ahhaha

18. Janne: isnt that cool (4s) show it to Fred and he´ll buy it on the spot huh

The physical actions of collaborative eye work (pictures at lines 3, 4, 7, 8, 10), detailed pointing actions, and changes in posture (pictures at lines 13, 16 and 17) are prominent in this sequence. These quite elaborate actions are used to establish a shared focus for what they are looking at, in order to be able to talk about the art work with a shared set of references. This allows them to take their collaborative experience further so that they can associate to shared experiences and activities. Such a shared exploration of an art work provides opportunity for the production of deeper and joyful experience that can spawn conversations and associations that contribute to maintaining and furthering their relationship.

4. FINAL REMARKS

This paper outlines our theoretical framework and a few excerpts of our empirical data. In the Supple project (http://designingsupplesystems.blogspot.com), at Mobile Life centre at Stockholm University, Sweden we are aiming at designing a supple system, to deploy at the next Vårsalongen exhibition, 2010. A supple system is a device that combines custom-built hardware, sensor technology, and wireless communication, to interact with end-users and create a physical, emotional, and highly involving interaction.

We are in the middle of a process of finding the design concepts that we will use in our future design, where we will use results from our ethnographic studies in our hardware and software, and design and deploy our prototypes in lived experience iterations.

5. ACKNOWLEDGMENTS

We thank all the visitors at Vårsalongen, in particular the participants in the video observations; Liljevalchs Konsthall; the Supple project at Mobile Life Centre / Stockholm University; Södertörn University College.

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Physical contraptions as social interaction catalysts

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ABSTRACT
Can the likelihood of social interactions between strangers be increased by the spatial intervention of interactive physical structures? This paper describes three room-sized mechanical contraptions which were designed to neccesitate the increased physical awareness of, and induce cooperation between, all people present within a single space. Reactions observed upon the installation of these intended social catalysts at art gallery events are described. A discussion exploring the possible factors contributing to the apparent successes of these contraptions concludes the paper.

Categories and Subject Descriptors
H.5.2 User Interfaces; H.5.3 Group and Organization Interfaces D.2.2 Design Tools and Techniques, J.5 Fine Arts

General Terms
Design, Experimentation, Human Factors

Keywords
social catalyst, installation, intervention, ergomomics, proexemics, design provocations, kinesthetic empathy

1. INTRODUCTION
Two artists, one male, one female stand nude in the narrow doorway of a museum forcing anyone who wished to enter the museum to squeeze in sideways. Visitors could choose for themselves whether they preferred to face the naked female or the naked male. This 1977 performance by Abramowic and Ulay [3] created for each visitor, a brief, but intense moment in which it was impossible to ignore the presence of the artists.

This example of engineered proximity contributed inspiration for the attempts described below to give all visitors to various art gallery spaces an increased physical awareness of other such visitors over more sustained periods whilst allowing everyone to remain fully clothed.

1.1 Three Social Catalyst Contraptions
Blender, Heads Up of The Table and *Social Whirls* are part of series of art installations by the author designed to foster positive face-to-face interactions between strangers who may not otherwise interact. Each contraption, or to borrow a concept from CSCW research: *social catalyst* [6] presented participants with a shared physical obstacle which was intended to create a situation in which there were no predetermined rules as to how to behave. Providing a novel constraint on “normal” behaviour was intended as a route to dissolve the everyday norms (both internal/individual and social/collective) which may inhibit social interactions. This in turn, could provoke and encourage a fluidity of interaction between strangers.

All the contraptions described were installed for social occasions in art exhibitions in the United Kingdom. The projects are similar in that they all concern face-to-face situations and aimed to provide a mutual experience, context, and a social catalyst for participants, irrespective of and independent of common verbal or written language. All three contraptions also have a wooden finish and their room filling scale creates an obstruction. They all provide the opportunity to dramatically increase the mobility of a normally rigid spatial element of a social environment. Their differences lie principally in which aspect of the environment they each make flexible. *Blender* consists of a move-able walls, *Heads Up of The Table* a moving table top and *Social Whirls* a floor that moves when stepped upon.

1.2 Applications
Although originally developed within a fine art context, this work is also hoped to offer a contribution to a variety of discussions including those around kinesthetic empathy [1] and provide material for reflective design [5] practices concerned with interaction.

2. BLENDER
Is it possible to mix together the dynamism and mobility of an open standing reception with the comfort and focus of a cosy seated gathering?

2.1 Turn dynamics of spatial activity inside-out through constant circulation
Blender (Figure 1) was intended to create a dynamic continuously circulating social situation which might spark interactions between seated and standing guests by providing an intimate but reassuringly temporary space for them to come into mutual contact.

Furthermore, it was hoped to invert the normal spatial dynamics of a social reception where people on the edge may lean on walls whilst those “working the room” shift around in the centre. An aim of this contraption was thus to create a social situation in which being a stationary “wall flower” was impossible since the edge of the circular space contained the fastest moving part of the contraption.

Proceedings of the Third Workshop on Physicality
Physicality 2009*,* 1 September 2009, Cambridge, UK
Devina Ramduny-Ellis, Alan Dix, Joanna Hare & Steve Gill (Editors)

Figure 1. plywood, metal and rubber wheeled construction with thirty chairs, 7m x 7m x 2.2m

2.2 A propeller in a seated circle

The contraption developed could equally be likened to a large revolving door or as a giant four bladed non-motorised propeller. This "Blender " was positioned at the centre of a fixed circle of chairs. The four revolving door wooden panels or "blades" were shaped and sized so that they would pass closely over the knees of guests seated on the chairs (Figure 1).

Figure 2. The blades passed close over the knees of seated guests

This revolving door was engineered around a sure axle - the structural column of this ground floor gallery. Thus, despite its considerable weight, it was easy to push the panels from any point except very close to the column (video available). The circle of chairs filled the width of the room and so in order to progress to the rest of the exhibition, refreshments and toilets, guests needed to revolve the barrier by pushing and/or moving in the same rotational direction as and when another guest pushed the doors (Figure 2). The blades were constructed of flexible, rounded plywood in order to safely "bounce" off any visitors that were taken unawares by sudden movements.

2.3 Observations

As the *Blender* was rotated the seated and standing guests seemed to find themselves unable not to smile at each other. Seated visitors were frequently observed offering and giving courteous assistance to those standing by trying to push the blades in the direction that those standing were attempting to walk.

Figure 3. Seated viewers could temporarily "see" and "be" in two "rooms" at once

Seated participants commented on appreciating being able to "see round the corner" of the blades or "be in two rooms" at once (Figure 3). When the blade was directly in front of them, they were able to see and so in a sense "be" in two segments at once. This gave them the ability to partially choose their fellow occupants of a segment (both seated and standing) and thus affect who could interact with who. This ability was appeared to be used both very lighthearted (e.g. jokingly "winding people up" by interfering with standing persons interactions with other seated people) and in order to continue interactions once they began. It seemed to be used for choosing to be with fellow segment occupiers of both prior and new acquaintance.

The quantity of interaction between seated participants was unexpected. There were many instances of a full circle of seated participants cooperating in spinning the structure even though they couldn't all see each other. This occurred in two ways: Either some seated participants would join to accelerate the speed of a direction chosen by others. And/or the signal of which way to push was transmitted (by both verbal and nonverbal signals) like along a "chain" by those seated guests who could see each other.
On several occasions there were instances of participants developing what could be said to be games with these barriers including trying to spin the blades as fast as possible and when the structure was moving fast, trying to leave it until the last fraction

of a second before jumping out of its way. These games occurred as both cooperative play and solo (socially obstructive) exertions. This energetic play had the effect of encouraging people to sit down.

Walking on seats appeared to be a social taboo that no one was willing to break. However some seated guests shuffled along the seats slowly but even if determined to navigate the obstruction in this way, they eventually found their way blocked by other more steadfastly stationary seated guests.

Several guests that had not visited this particular gallery before were hesitant to approach and touch the contraption irrespective of whether or not it was moving as they did not realise that there was another room and services on the far side of the *Blender*. Many of those whose initial apprehension of the *Blender* was of it steadily rotating in a certain direction, were startled by changes in speed and/or direction of movement. Several made queries and speculations regarding what kind of motor was inside it.

The scale of *Blender* meant that it was possible for the blade to come to a halt out of reach of a seated guests who wished to push it. In such instances it was typical that other seated participants that could reach the blades would then "pass" blades to other seated participants in what seemed to be an effort share control, exertion and reward of keeping the contraption moving.

Standing guests improvised a variety of means to negotiate the direction of the room, including calling out through the walls, asking seated guests to pass messages round and looking around the edge of the panels (Figure 4). When people that had simultaneously been standing in different segments met up, they seemed to be connected by their shared experience of the obstruction. Emotions then expressed included apologetic ("sorry that was me pushing that way") and relief "I am glad you weren't in a hurry").

Figure 4. Effecting direction of revolution required negotiation

3. HEADS UP OF THE TABLE

How to reduce guests' tendency to stick close to whoever they arrive with &/or are already familiar with? How to counteract the effect of how as a space becomes smaller, strangers are more likely to appear to actively ignore each other?

3.1 Rotate spatialy prominent roles around a common barrier and hazard

Heads Up Of The Table was developed for a much smaller scale space than *Blender* (Figure) and so the approach was concerned more with aiming to provide a single unifying talking point and a talking "facility" rather than a division into separate cosy areas.

Figure 5. In situ view: the scale of the revolving table was designed to fill a room

The intention was to invert the typical art gallery spatial configuration where the work displayed often surrounds the viewers and thus visitors are all looking in different directions, and thus not normally looking at each other.

Approaching any social "circle" by oneself may be intimidating and thus is often done discretely, or through the support of a firendly accomplice. This contraption sought to invert such subtle attempts to join a group interacting in space by amplifying the saliency of any entrance into, or exit from the room in which this contraption was installed. A mechanism for isolating and emphasising each entrant to the room was hoped to increase the potential awkwardness of approaching a group to the point of ridiculousness and thus provide a humourous common experience to all gathered around the table.

As the legend of King Arthur makes clear, it is not possible to spatially discren an order of precedence amongst those seated around a round table. Even though the conceived circular table was not perfectly symetrical it was hoped to maintain such equality by rotating the focus of social attention over time.

Figure 6. Showroom demonstration view of *Heads Up of The Table* to illustrate the whole contraption in action

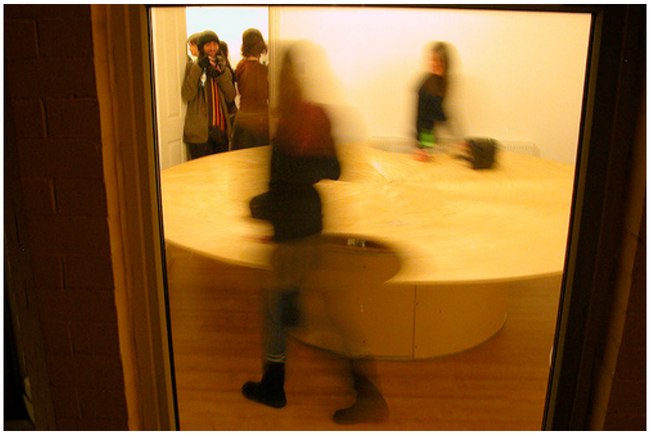

Figure 7. In situ view as seen through external window of room

3.2 "Heads Up" a table to be in and at

A large circular revolve-able table was installed in the centre of an otherwise empty bay-windowed dining room. The diameter of the table surface was only 5cm less than the narrowest point of the (nearly square) room.

Cut away from two opposite ends on the face of the table surface were two circular gaps sized as to allow a person to stand in them. Upon a light push, the table surface rotated (either clockwise or anti-clockwise) so that in order to navigate the room, a participant had to walk into one of the subtracted circular gaps at either opposite "head" of the table and then push the table in the direction of "orbit" that they wished they wished to walk.

Figure 8. Several guests squeezed into the the space designed for a single person

3.3 Observations

Most guests appeared to give the other occupants of the room a larger than normal quantity of attention and the table was responded to with good humour by all who entered it.

Several groups of friends succeeded in squashing two people at a time in the gap designed for one (Figure 8), most of these doubles proceeded to do multiple rotations

The weight of the table top and difficulty of gripping and pushing a thin rounded surface meant that little spinning of table was done by those not positioned within the circular gaps. Thus, contrary to intentions, those at the "heads of the table" experienced the bulk of social attention and physical control of the dominant object within the room. This appeared perhaps to be a heady cocktail for several guests.

Many appeared so transfixed by spinning the table that they directly interacted very little with either friends or strangers in the room. Many guests made prolonged and repeated multiple rotations of the room. This meant that others wishing to enter or leave the room during their circuits had to ask for the assistance of those continually pushing. It appeared that whilst in the room, guests did not discuss much other than the table.

4. SOCIAL WHIRLS

How to turn the socially unproductive nervous energy of standing receptions into something less rigid and more touchy feely?

Figure 9. Social Whirls comprised 28 independently revolve-able circular floor panels

4.1 Loosen inhibitions through movement and fear

It was hoped that Social Whirls (Figure 9) would provide a catalyst for spontaneous for physical contact between people for reasons of safety and/or reassurance for example hand-holding and shoulder steadying is both more likely and socially acceptable in situations where the floor is unstable.

It has been said of standing social receptions that people rotate in a slow, but awkward dance. The provision of a dynamic floor was hoped to question and accelerate such movements to the point where awkwardness was dissovled.

Figure 10. Visitors were perhaps more attentive to the floor than each other.

4.2 Floor panels that spun with body weight

Revolve-able circular floor panels were installed to fill a balcony that connected the two halves of large museum space. This parquet style floor was designed to match the appearance of the floorboards of the existing museum. Inset into this floor were 28 circular discs. Each of these discs were mounted on unseen ball-bearings which meant that a disc would rotate when stepped upon.

Figure 11. Many visitors danced despite the absence of music

4.3 Observations

Social Whirls appeared well received with much smiling and laughter from most guests probably due to a variety of causes such as embarrassment at being unsteady on their feet or a light hearted giddiness. Although there was much hand holding observed this was appeared to only between people with existing bonds. Few instances of physical contact between strangers was observed.

Guests differed very widely in terms of their frequency, duration and intensity of interaction with this contraption. Most brief visitors were understandably nervous and in concentrating their gaze downwards to the floor (Figure 10) were giving the strangers around them no more attention than usual. Many prolonged/repeated visitors invented various games to play on the contraption. For instance, despite the absence of music the contraption inspired much enthusiastic dancing, particularly in a "twist" style (Figure 11). Many strangers dancing at the same time were observed exclaiming to each other both verbally and through physical gestures. Children viewed the floor as a play surface suitable for sitting on and manipulating with their hands (Figure 12).

Figure 12. Children also interacted with the floor whilst seated

5. DISCUSSION

5.1 Limitations of these trials

Many of the concepts of the contraptions appeared successful and that, furthermore additional means of fulfilling their broad aims were discovered during testing. However these apparent successes should be qualified by acknowledging the limited context in which they were installed and a consideration of other factors which may have contributed to their acting as social catalysts.

A principal limitation, is that the audiences at an art gallery event are likely to be more accepting and welcoming of novel experiences than people in most other social situations. Ascertaining if such contraptions have potential for improving social interactions in other contexts requires further investigation. Also it maybe instructive to conduct similar trials in different countries where the norms of social interaction and spaces within which it occurs may be very different. For instance, in contrast to the western concept of space as empty areas or room, Random [5] describes how to the Japansese, space is a living uninterrupted flow always rich in complex interactions between people and objects.

Additionally in these art venue trials only very initial short term responses were recorded. Social relationships commonly develop over much longer periods of time. It is not known if people that first met through or within one of these contraptions went on to have further encounters.

A longer period of participants' exposure to the contraptions would also have proved instructive. It is possible that the sheer novelty of the objects was a major factor in enhancing the social atmosphere around the contraptions. For instance one could speculate that when elevators were a novelty, travel between floors was more of a social occasion than now when they are commonplace.

5.2 A playful puzzle

Although the *Blender* seemed to spark the most interaction between strangers, the responses described suggest that all of these projects succeeded to varying degrees as social catalysts within these particular contexts in both expected and unexpected ways. What is not clear is what were the most important factors in this success. Did these projects appear to produce interactions through successfully innovating concepts in spatial intervention or was the successes due more to other formal or contextual factors?

Given that many participants found pleasurable ways to interact with the objects either when they were solo participants and/or ways to manipulate the objects without being particularly interactful with other participants it seems apt to consider whether the most important factor in participant reaction was seeing the objects as some kind of toy and/or the situation as a game. It seems reasonable to speculate that when adults willingly engage in almost any group play (particularly non competitive games) that a lighthearted atmosphere which promotes the likelihood of social interactions will result.

None of these projects were labeled as toys. It was through a process of discovery and exploration that participants discovered, shared, discussed and tested such playful properties. As a result of discovering for themselves such potential, players perhaps felt a sense of ownership of their "games" and hence were keen to play on for such long periods.

Although the moving parts of these contraptions were relatively simple, the fact that the ball bearings and castors were hidden from view (Figure 13) created for some viewers an initial sense of confusion and apprehension. The use of transparent materials to produce contraptions in which all working parts were clearly visible could result in less "trial-and-error activity" [6] by participants in their initial exploration of the contraptions and a clearer representation of the "task state" at all times.

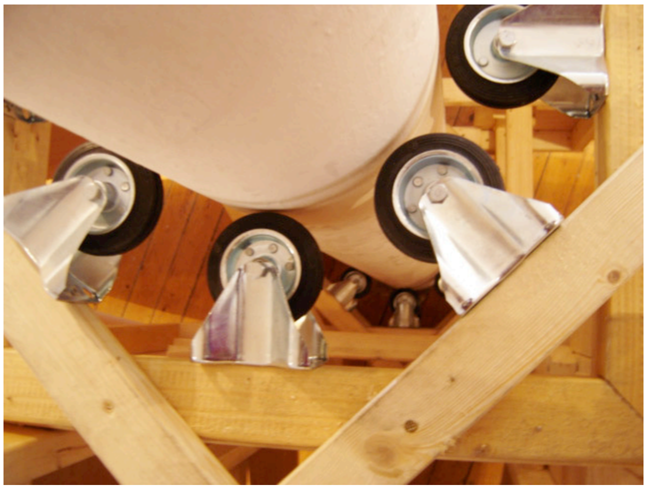

Figure 13. The non visible internal workings of *Blender* as seen from above

5.3 Other contributory factors

All of the contraptions were of a wooden either a large number and/or large scale of curves. It is likely that positive reactions to the properties of wood could have contributed to overall success of the projects. For example, many commented on the nice smell of sawdust and/or would stroke the curves of the wood. Such signaling of a simple easily non controversial pleasure may have contributed to a sense of solidarity amongst participants.

At each location where these contraptions were installed, there were more conventional art gallery spaces in adjacent rooms within which visitors could socialise and view non-interactive artworks. It is possible that the contraptions appeared successful as they acted like a kind of filter or magnet attracting venue visitors most interested in physical activity and spontaneous interactions to focus their gallery visit around playing in and around the contraptions. If so, then it seems reasonable to assume that visitors more inclined to gentler and/or more sedentary viewing experiences would gather elsewhere in the venues - away from the contraption.

5.4 Small group space as small group catalyst

Although mindful of the limitations and other potential contributory factors outliined above, the following tentative comparision is proposed: Appropriately scaled semi-enclosed space seems the most important attribute that a contraption may provide.

Social Whirls and the table contraption both provided a visually open space whereas the *Blender* was much more enclosing. The floor based work could perhaps be more accurately described as a series of individual contraptions closely spaced together. Thus in contrast to the other two pieces, *Social Whirls* allowed for more independent exploration by separate individuals, although given the simplicity of the contraption, the individual responses by *Social Whirls* visitors varied less. The openness of *Heads Up of The Table* and the greater ease with which it might be monopolised by one or two users seem to reduce its effectiveness as a social catalyst. The cosy spaces temporarily provided by the panels of the *Blender* appeared more conducive to social interaction than the more unified and all encompassing experience environment engendered by the table and the common activities facilitated by *Social Whirls*.

However, the range of unpredicted responses to the these relatively simple mechanicsms, and other accidental discoveries outlines the value of further questioning of assumptions concerning the relationship between space and interaction.

6. ACKNOWLEDGMENTS

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Making a Case for Biological and Tangible Interfaces

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ABSTRACT

We are at a crossroads in understanding fundamentally how to approach interactive systems and Human-Computer Interaction (HCI). Human-Centred Design (HCD) and Activity-Centred Design (ACD) models are the base to which interactive system approaches should be readily defined. By compartmentalizing User Interfaces (UIs) in terms of ACD or HCD, a clearer understanding arises on how Graphic User Interfaces (GUIs), Tangible User Interfaces (TUIs), and Organic User Interfaces (OUIs) operate. It is the belief that using an ACD model in HCI allows for embodied approaches, which are easily manipulated in the physical environment. In GUI modeling, cognition is the precedent; in TUI, physical models are conduits to digital information; in OUI, GUI, and TUI both are relevant – the design necessitates cognitive and physical elements.

Categories and Subject Descriptors

C.3.3 **[SPECIAL-PURPOSE AND APPLICATION-BASED SYSTEMS]**: Real-time and embedded systems, D.2.2 [**Design Tools and Techniques**]: User Interface, D.2.6 **[PROGRAMMING ENVIRONMENTS]**: Interactive Environments, F.1.1**[MODELS OF COMPUTATION]** Self Modifying Machines, H.1.2 **[USER/MACHINE SYSTEMS]**

Keywords

Ubiquitous Computing, Tangible User Interface, Organic User Interface, Human-Centred Design, Activity-Centred Design, Graphic User Interface, Biological Systems, Embedded Systems

1. INTRODUCTION

There are two schools empirically that exist within the theories of interaction: Human-Centred Design (HCD) and Activity-Centred Design (ACD), as Don Norman [1] coins it. Fundamentally, any dialogue on interactive design is irrevocably shunted into talks of future design capabilities and what is on the horizon. However, as a community of designers the dilemma of interface design seems to boil down to these two schools of thought: Human-Centred and Activity-Centred models. We are in an age dominated by HCD. Computational dexterity is only as expansive as whether its ubiquity calls away from ease of use, or whether cognitive factors, both on the parts of computational models and human ones, are at odds, harmonious, or in the face of Artificial Intelligence (AI), an eventual possibility. "To the Human-Centered Design community, the tool should be invisible, it should not get in the way. With Activity-Centered Design, the tool is the way."[1] The two major questions here: does the tool need to be invisible at all? Why must the tool be dominated entirely by the user? Dourish [2] and DiSessa [3] arrive at similar conclusions: to be actively engaged invisibility should not be warranted as an empirical guideline. For DiSessa providing a meaningful, personal, and flexible interaction is incompatible with invisibility which proffers a model "inaccessible" [3]. What is proposed here is an alternative view on Human Computer Interaction, using "organic" user interfaces combining Tangible User Interfaces (TUIs) and biology as a tool to expand HCD to Environment-Active Centred control. Organic User Interfaces are defined as biologically determined interface design, which proposes alternative frameworks of construction, detracting from current digital mediums such as the Graphical User Interface (GUI). The outcome to these designs: the human is the tool. Within this proposed outcome, ubiquity in design is nested outside the screen and into the actuated physical environment.

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2. HUMAN-CENTRED DESIGN IN GUI

In HCD, the construct of the doctrine is that the tool dictates the activities which can be achieved. For example, personal computing has a broad array of activities that can be performed using the device. There is no specific activity that defines its purpose. It is therefore a Human-Centred computational model. It carries out a broad array of inputs and outputs, and the outcomes are variable. Mainly, GUI has been the dominant example of Human-Centred design, which started from the success of the first GUIs Apple Macintosh and Microsoft's Windows operating systems. GUIs have become the standard in most branches and foundations of the interactive arts. GUI has been in existence since the 1970s and it first appeared commercially in the Xerox 8010 Star System in 1981. [4] Since the 1970s advent of the first GUI, there has been little movement past GUI as a standard. Rather, efforts are made on creating products with high usability, or "user-friendly" strategies to enhance the GUI rather than replace it, which greatly circumvent the fundamental underlying problems with GUIs.

Multi-touch and haptic technologies, such as Apple's iPhone[i], the Optimus Tactus Keyboard[ii] from Art.Lebedev Studio, and most recently Microsoft's Surface Computer, a multi-touch computer interface, are contemporary improvements on standard GUIs. Though multi-touch and other haptic-based technologies are breakthroughs in Human-Computer Interaction (HCI), these technologies are adapted to 'accessorize' an already faulty GUI. Microsoft's Surface Computer, which will be commercially available within five years time, is a flat-bedded computer screen in which users can touch a graphical interface to perform a variety of tasks. It is the personal computer's answer to the Apple's I-phone. Bill Gate's coined this new multi-touch personal computing as a "Natural User Interface". [5] The idea represented is to disengage from the old PC GUI terminology and in favor of a holistic approach, using hands directly on the screen. However, upon closer inspection, there are minimal differences between these new "natural user interfaces" and the old graphical interfaces. The difference in the interface design is where the user is able to touch and the way in which hands are used for tactile commands to perform a task. The output generally remains the same; the activity to achieve the outcome is different. Perhaps, pinching, spinning, and wiping as gestural commands are more intuitive than clicks of a mouse, allowing for feedback in a more real-time rapid response, however, the same principle applies: a series of learned actions are required to perform a task for a variable output. "We're adding the ability to touch and directly manipulate, we're adding vision so the computer can see what you're doing, we're adding the pen, we're adding speech," Bill Gates told BBC News. [6] As Gates succinctly comments, multi-touch and haptic technologies serve as an additive rather than transformative quality to the GUI. In addition, with multi-touch and gestural interfaces, cultural relevance to sign specific gesture commands is problematic.

> "In a gesture interface, this can be translated to selectable gesture vocabularies if it should become a problem that an emblem is illogical to another culture. Furthermore, if a culturally dependent gesture is used, this does not necessarily mean that it is utterly illogical for people of other cultures to learn it." [7]

GUIs are, at heart, a purely cognitive process divorced from any physical application in the world. Although advances have been made to create a gesticulative GUI to bring into a physical domain, this model still acts under a cognitive constraint. GUI necessitates a certain skill set, steeped in memory and recall on the part of the user. Normally digital models, in theory, are constructed for humans to offload burdensome cognitive processes. However, this is generally accepted *quid pro quo*: the user benefits only from engaging in a learnable behavioral process, to make offloading easily and readily possible. This is defined as a skill set, and, depending on software, will have multiple learnable processes rather than a universal constant. Therefore, 'skill' in these computational modes is like remembering a recipe in order to use an application for a desired outcome. [8] The newer generations, haptic interfaces, allow cognitive processes to be carried out on a basic physical level, but the level of the physicality is still inherently learned and not wholly intuitive. The model still lies on a think-first-and-then-do-later approach, rather than the ability to just act.

Multi-touch is just one facet of haptic technology that is being applied to the GUI. Eye-tracking is another extension of the human facility that designers are investigating to extend the capabilities of the conventional user interface for the sake of usability in a HCD model. Development has come mainly out of the need in the health sector to design interfaces suited for the disabled, but does not fall short of the full spectrum of human users. For example, Eun-Gyeong Gwon & Eun-Jae have developed eye-tracking software called 'I Contact', in which a user's gaze can control cursor movements or scrolling mechanisms in personal computing. From a psychological standpoint…

> "eye-movement analysis could be used to develop new metrics to evaluate the effectiveness of what we produce. A second possibility, which is probably more compelling from a computer graphics perspective, is the use of eye-tracking for gaze-contingent applications." [9]

Though eye-tracking may benefit the disabled in computing and task performance, for Norman, this haptic interface is a step backward for the evolutionary relationships of user and computer in HCI.

> "All too often what we do is try to figure out what the existing work practices are and try to automate the ones we know how to automate and leave people with the rest, which is usually the absolute wrong mix of activities for a person." [10]

The inherent problem that exists within these additive haptic qualities is that it simply shifts the fundamental usability issues that are present in the GUI onto the new additive interface. One of the fundamental problems with all types of GUIs, Ishii contends, is that

> "the GUI, tied down as it is to the screen, windows, mouse, and keyboard, is utterly divorced from the way interaction takes place in the physical world. When we interact with the GUI world, we cannot take advantage of our dexterity or utilize our skills for manipulating various physical objects, such as building blocks, or our ability to shape models out of clay." [11]

There is a necessity in physicality. The feedback response is instantaneous. Just as a clock is giving time in a real-time response, as should any model. When models are divorced from the physical, the feedback is not instantaneously felt, or even seen. Decoupling of sense and time restricts any form of embodiment. When a tool is physically acted upon, the result is twofold: causality is instantly observed and time is inherently felt. The interaction between tool and user is substantiated by the result felt in the present. This coupling between user and tool allows for embodiment. [12]

In addition to GUI's inability to reinforce the physical world, Clancey argues that inherently computer processes are not designed for each individual user's perception and representation base.

> "At heart, we've misunderstood the nature of representations. They are inherently perceptual-constructed by a perceptual process and given meaning by subsequent perception of them." [13]

3. ACTIVITY-CENTRED DESIGN IN TUI & ORGANIC UI

It is possible to argue that designing HCI as an ACD model could further revolutionize the way in which interfaces are created. ACD is created for a very specific task. In Norman's standpoint, in ACD the tool "is the way." [14] For example, within the design of a hammer as a tool, it is explicitly clear the activity defines the tool for which it is drafted. The hammer is constructed for a specific task, divorced from any human usability or decoupling issues. The learning curve for the hammer is reasonably low comparatively to any computational model. What is meant by the former statement, simply, is that there is a fundamental difference in a tangible reality between gaining knowledge for use versus learning skills with the tool. In a tangible world, using a tool, such as a hammer, is dictated by what Gibson calls "visual cues" and by touch. "Visual Cues" define texture, depth, and proportion, which help the user understand properties of use. Whereas, touch dictates weight, dimensionality, and ease of movement, which also gives clues to how the object is to be used. Skill is only determinate with exploratory learning while using these senses. It is argued that triggering a sensorial experience with all senses helps create defined perceptions of how to use a tool. [15] For example, if one looks at a bicycle, one could construe how the bicycle is of use through ocular and tactile processes. However, this does not make him a skilled rider. On the opposite hand, GUI tends to blur the lines between use and skill because it is only triggering a select number of senses, without any exploratory learning before incurring a cognitive process. Simply put, GUI models are performatory by nature, rather than exploratory based upon the senses they use. In addition, GUI has no intended specialization, therefore usability is hampered even more. Further, "We interact with clocks, refrigerators, and cars. Each has a motor, but there is no human-motor interaction specialization." [16] There are few processes involved in ACD, whereas in GUIs there are many. For example, personal computing has 3-5 small tasks in order to access a larger application to perform a major task such as word processing, whereas cars, clocks, and refrigerators do not rely on smaller tasks in order to fulfill a large task; its transparency and usability are functionally apparent.

> “There are more objects of interest than meet the eye: in many applications users must manipulate secondary objects to achieve their tasks, such as style sheets in Microsoft Word, graphical layers in Adobe Photoshop or Deneba Canvas, or paint brushes in MetaCreations Painter.” [17]

Because of the transparency, physicality, and specification of each model's use, these tools are ‘harmonious’ extensions to the human capability. They are designed for what they do, and they do what they are intended, therefore there is no need for a human to extract himself from his physical environment to adapt to the features of the interface. In HCD, specifically GUIs, humans must adapt to the working environment of the tool in order for it to function. Its rules are separate from the physical world. Though perhaps it is intuitively designed in a virtual computational realm, in corporeality these rules are aberrant. In simple terms, we click a couple of buttons; wait a while and then we are finally introduced to an application to fulfill a larger task. Whereas with a car we push the gas pedal and we know by an exploratory process the car will move forward; apply the breaks and the car will stop. There is no more than one task in order to make the car stop. One pedal motion stops the car, one pedal motion makes the car move. It is the transparency and simplicity of the interface, coupled with the use of a variety of senses that allows for it to feel as an extension to human agency.

Tangible User Interfaces offer interesting solutions between digital and physical interfaces, by attending to an Activity-Centred Model.

> "Tangible User Interface (TUI) aims at a different direction from GUI by using tangible representations of information that also serve as the direct control mechanism of the digital information. By representing information in both tangible and intangible forms, users can more directly control the underlying digital representation using their hands.” [18]

TUI allows the user to manipulate the digital representation, rather than be defined by it. TUIs also seamlessly integrate physical manipulation with digital design, where the outcome is specifically designed for a performed task. Therefore, the need to learn any command processes is either negligible or fairly low. The most important achievement in TUI is bridging the gap between input and output by displaying outputs and inputs on the same surface, helping to integrate perception and action seamlessly into one environment.[19]

3.1 Curlybot

For instance, the Curlybot (*Figure 1*) is a toy designed for children to learn intuitively about complex maths and computational concepts. The toy "remembers" each child's movements, pauses, including minute gestural qualities the child might emit over a period of time. It is able to repeat the child's gestures full stop. [20] Clancey would agree.

> "Programs are only manipulating structures syntactically; they are not interpreting them, but only indexing their properties as in a database. The main error of AI and Cognitive Science has been to suppose that the interpretation of a representation is known prior to its production. But the meaning of a representation is neither pre-definable nor static; it depends on the observer." [21]

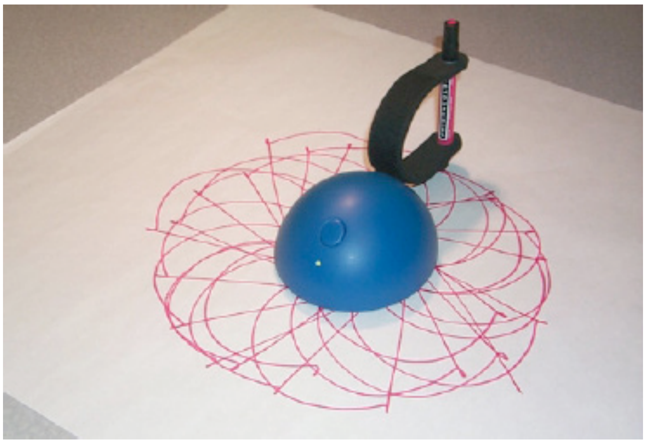

Figure 1. Curlybot

Symbols and representations in TUI are open-ended in application, meaning they require only the user to establish and determine specific depictions of the digital information. The Curlybot's function is to repeat gestural commands performed by the user. These commands are specific entirely to what the user wants to generate, therefore the learning curve is negligible. There is no need to understand the underlying automation processes in order for the digital information to be displayed. “A child can map ideas from his or her mind directly into a clear physical instantiation of the ideas”. [22] The process of mapping of ideas from a cognitive sense to a physical sense is well defined, without abstracting the construction to a series of multiple learned processes to incur feedback. As Ishii (2008) explains, TUIs serve as a liaison between the digital and physical domains, allowing ease of use for both the human user and the computational processes happening "under the hood."

> “A Tangible User Interface (TUI) is built upon those skills and situates the physically embodied digital information in a physical space. Its design challenge is a seamless extension of the physical affordance of the objects into digital domain.” [23]

From Ishii's standpoint, ubiquity is a misnomer in interface design. Invisibility comes with physicality and ease of use, rather than embedded computational systems present in all facets and functions of daily life. Therefore, in the case of the Curlybot, its design is Activity-Centred because it is a tool for gestural representation, whereas in a Human-Centred Model it would use gesticulation as a tool for the bot to move or perform another pre-produced task.

3.2 DARPA Thought Helmet

Another progressive step away from GUIs is the advent of the use of brain activity. The U.S. Army awarded a $4 million contract to execute a "thought helmet" that would use brain waves as a way to provide communication amongst all troops. The outcome: "direct mental control of military systems by thought alone." [24] Another United States government group, Defense Advanced Research Projects Agency (DARPA), is working on the "Brain Machine Interface" ("neuromics"), which devices are controlled by thought-power.

> "Thus far, researchers have taught a monkey to move a computer mouse and a telerobotic arm simply by thinking about it. With arrays of up to 96 electrodes implanted in their brains, the animals are able to reach for food with a robotic arm. Researchers even transmitted the signals over the Internet, allowing remote control of a robotic arm 600 miles away. In the future they hope to develop a "non-invasive interface" for human use. Says DARPA, in integrating physical and digital domains that it is on its way to "turn thoughts into acts." [25]

The implication of this process is re-imagining the relationship between cognitive processes and the physical environment. This computational model shows that it is merely a conduit for cognition to commit a physical action. In GUI modeling, cognition is the precedent; in TUI physical models are conduits to digital information. Therefore, if successful, these models would serve as a direct link to the physical and actuate real-time and instantaneous feedbacks with no instruction or learned behaviour. In these models the natural universe dictates the functions of the computer model, where "the distinction between 'interface' and 'action' is reduced". [26]

3.3 Animats

Similarly, researchers at the University of Reading are at work on an interface using brain activity. "Animats" (*Figure 2*), as they are called, are run on the electrical patterns of brain matter.

> "If they can do so reliably, by stimulating the neurons with signals from sensors on the robot and using the neurons' response to get the robots to respond, they hope to gain insights into how brains function. Such insights might help in the treatment of conditions like Alzheimer's, Parkinson's disease and epilepsy." [27]

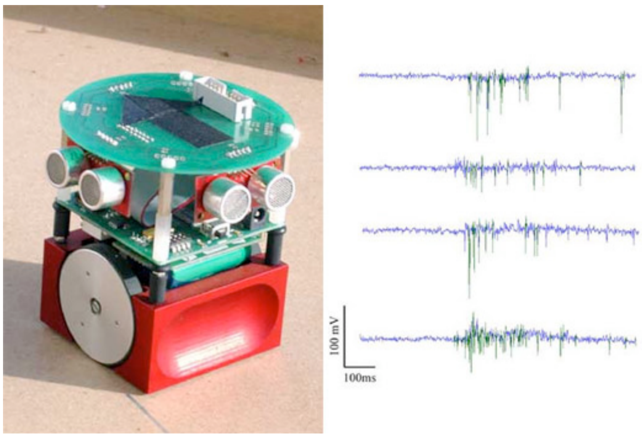

Figure 2. Animats

Using Brain activity and thought processes as functions of interface design offers a new duality in computational models. They serve as both intangible systems of interface design as well as an infusion of biology into these models. These intangible systems are similar to TUIs in that they rely heavily on specific user interpretations and perceptions to perform tasks. The human mind is the tool in which these commands are performed. Interestingly enough, this model would act similarly to that of a GUI type of interaction as well – depending on cognitive conditions to create commands, rather than physical ones. These systems rely heavily on the user without physical or automated restraint. Therefore, there is direct result from brain functions (input) to actions performed (output). "The future of computers is not artificial intelligence, says Peter Bentley, but true intelligence, in the form of software based on human biology." [28]

Intangible Interfaces or Reality-Based Interactions (RBI), in larger contexts, create a new environment entirely. Neither computational models nor humans are constrained by the environments which they habitat; having to adapt to the constraints of either. Although these systems would be of high value in terms of flexibility and ease of use, as the Boston Globe conjectures that "if this type of research continues to advance, it will obviously pose ethical challenges. Any new technology brings with it a large number of subtle trade-offs." [29] For example, the U.S. Army is currently investigating these ideas in their "Bio-Revolution" programs in order to "harness the insights and power of biology to make U.S. warfighters and their equipment […] more effective." [30] Effectively, high usability factors in the Intangible Systems, interestingly, are some of the main problematic features of its implementation.

4. INTANGIBLES & TANGIBLES: FUTURES IN BIOLOGY

On the opposite side of the coin, research into the infusion of biology into digital systems is being investigated. Empirically,

> "all the fundamental principles of biological evolution have proved troublesome when applied to technology. It is not at all clear what evolves […]. It is not clear whether, or on what grounds, 'selection' might be said to occur, or at what level." [31]

4.1 Transistor evolution

Adrian Thompson, a British engineer, has done experimentations on evolutionary prospects in transistor performance coupled with a programmed computer to discover how well the transistors performed various tasks. The transistors were distinguished between high and low pitch tones. The first generation performed poorly, with exception of a very few. The computer was programmed to save the better performing chips and combined them into hybrid models, adding a few modifications into the design. These modified 'off-spring' were able to distinguish tones better than the "parent" models, which produced a third generation. They continued to mimic evolution for a few thousand different rounds, and the end result was the computer producing chips with high performance, although Thompson is unclear as to how exactly it works. [32] Experiments such as Thompson's transistor performance, although it is unclear as how it is able to function, creates a glimpse at a bigger picture. The bigger picture resonates a scenario in which creating automated systems that take on biologically adaptive traits, autonomous to human intervention, could eventually aid in the development of non-specific generation of automated task performance. The self-automated models could potentially carry out "aware" commands automatically without the need for manual system maintenance by its human counterparts. Organic Digital Interfaces (ODIs) run autonomously, without any laborious effort from its human counterparts. If we turn back to the car metaphor, ODIs operationally are concurrent to a self-driving and modifying car.

4.2 Solar Ivy

A less sophisticated but equally viable ODI is SMIT's solar ivy project called GROW (*Figure 3*).

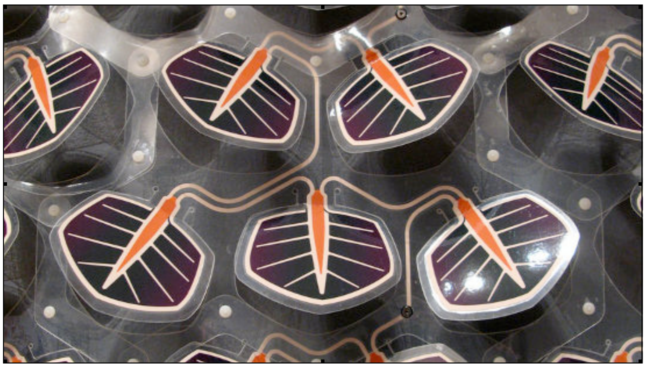

Figure 3. Solar Ivy

> "The panels, which can be fitted for new and existing construction, can give off as much as 30 watts per square meter of energy with minimal intrusion to the building. A later version of the solar panels will incorporate wind technology, enabling the Leaves to generate an additional charge when they flutter." [33]

A more sophisticated GROW iteration, which incorporated piezoelectric technology, was displayed in 2008 in New York at MOMA (Museum of Modern Art) (figure 3). The solar panels are shaped in an ivy-like structure and are attached to the exteriors of buildings conjoining both an aesthetic and self-engaging system. Piezoelectric generators on the "stems" of the solar ivy panels are used to pick up movement of the wind and generate electricity from it. [34] GROW's Tangible Interface is autonomous to human intervention. It uses other organic processes, such as UV light from the sun to perform the task of generating electrical outputs. Self-generating processes such as GROW are pioneering the way for self-sustainable technologies, melding Tangible Interfaces, Biology, and Design.

5. DISCUSSION

It has been established that HCD models are models in which humans must adapt to the tool in which they use. GUIs are HCD models in which a broad array of activities can be performed, with no specific activity that defines its purpose. Because it does not warrant a full extent of a sensorial experience, it is likened to a performative process rather than an exploratory one. GUI does not have distinct visual or tactile "cue" or "clues" that allow for an exploratory process to discover the way in which it is to be used. It requires specific inputs for specific feedbacks, and specific application. ACD models and TUI's alternatively are more open-ended in application, requiring the user to explore rather than conform or adapt to the tool. TUI uses a dictum of using touch without relying on learning behaviours to incur a response. The process of mapping of ideas from a cognitive sense to a physical sense is well defined, without abstracting the construction to a series of multiple learned processes to incur feedback. It uses an exploratory tactile method to aid with a faster feedback response, which solidifies how actions affect digital information. TUIs use physical space to manipulate digital information for an open feedback loop. Inversely, DARPA's Thought Helmet technology allows for cognition to become physical action, allowing the interface to be merely an intermediary between thought and action. It allows cognitive forces to manipulate the physical space. Therefore, unlike TUIs there is no need to affectively interface with digital information to return a response. Finally, purely organic models prevail, with self-generating and regulating processes that don't require human intervention or manipulation. The tool becomes a tool. ACD and TUI models progressively step further to a sense of embodiment and agency that are applicable in native tool use in real environments using sensorial experience to qualitatively define use and skill. Biological models inherently are native, meaning they are environmental. Though the interface maybe subtle, its natural system is effective at fitting to a larger biological system structure, embedded 'naturally' into the human environment. It is now the technology adapting to the corporeal world, rather than the user and environment adapting to the technology.

6. CONCLUSION

The modern day marvels over GUI additions such as Natural User Interfaces, Microsoft's Surface Computer, eye-tracking, and other Haptic Design interfaces are not transforming the underlying problems created with the GUI. The underlying problem exists with creating a design to overcome inherent representational/ perceptional processes in the command functions of the GUI. Mainly, GUI is focused in HCD which compromises humans physical environment, processes, cultural, and command languages and subjects users to adapt to the technology rather than the technology being adaptive to the activity. TUI and biologically stemmed research into creating ODIs will revolutionize HCI by conforming the digital tools to the physical environment, or subtracting numerous and non-intuitive tasks that rely on the human user by making the processes automated on the side of the computational model. The outcome of an Activity inspired design will ease the burden off the user and create a space of intuitive and equal exchange.

7. ACKNOWLEDGMENTS

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Enacted Experience and Interaction Design: New Perspectives

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ABSTRACT

Interaction design is now of sufficient maturity to warrant a critical discourse of its own. To date much of the published material which refers to interaction design has tended to reflect upon examples of its practice or to draw upon research done elsewhere (computer science or cognitive psychology for example) in order to give validity to its own accounts. Interaction design's is a synergistic consequence of other fields which it uses in order to create its own creative and strategic practice; this is both its strength and weakness. Interaction design can become shaped by the fields it draws upon. The authors of this paper take a cautious view of the cognitive and user models that are typically applied in the development of interaction prototypes. Our ideas, presented here in the spirit of a critical conversation, are founded in an intellectual insistence that interaction design presents a strategic extension of an embodied model of the human as an enacted being. In this paper we outline a way by which interaction designers can understand their role to be an orchestration of that enaction, not merely a mechanistic organiser of 'perceptions' of, 'behaviours' of and the 'understandings' of, systems.

Keywords

Interaction design, design theory, enaction, holsomatic.

1. INTRODUCTION

In order to facilitate a supposedly more seamless interaction between people and the technologies they use, interaction designers often employ metaphorical allusion and ideas of tacit social affordance. While these approaches have had an undoubted positive effect upon the design of effective interactions they have tended to prevail in academic discourse at the expense of the development of a more subtle understanding of ways in which humans are enacted beings. Enaction does not necessarily imply cognitive understanding, but rather a more embodied and intuitive, perhaps pre-perceptual way of being. In this paper the authors propose that, through a new critical discourse, interaction design is best placed to engage in a theoretical anticipation of the means for people to seamlessly participate in the benefits of technology. Interaction design's strategic position as a creative arbiter of science and art means that it should seek the design and implementation of new human experiences which are as real, and as integrative, as those which we take to be a natural evolutionary inheritance.

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Any ambition of interaction designers in creating seamless and fluid flowing interactions should not necessarily imply a blind acceptance of established interaction methodologies. This foundational paper must be read as a speculative intervention, rather than an instructive reflection of research data; it is intended to be read in a similar manner as one might regard a designer's sketch. The paper introduces our research project and suggests avenues of speculative enquiry, outlining the beginnings of a new 'holsomatic' approach to interaction design. Such a holsomatic approach argues that humans can be understood to be enacted by means of a 'soma', in which the organic human and the inorganic technological are considered to be coextensive.

2. RATIONALISING EXPERIENCE

2.1 Science and the Irrational

Being no better than our ancestors we still have a tendency to consign things for which we can find no rational explanation for to the realm of the spiritual. For some people this alignment of the Fortean with the spiritual is in itself a reasonable enough explanation. Spirits are often a comforting way of describing something beyond the rational. Science on the other hand cannot reasonably accept the spiritual explanation. If something tends to go against the rationality of science and appears beyond intellectual foundation, then science has a habit of consigning it to the occult and beyond reasonable discourse or, worst of all, beyond rational investigation. One consequence of this history is that phenomenological evidence of enaction is largely consigned to the anecdotal. Murphy's 'In the Zone' [19] is a wide-ranging collection of carefully transcribed anecdotes of so-called 'Transcendent Experiences in Sports'. This text, published by Arkana, (a somewhat alternative new-age publisher) is consigned among other fringe titles. Murphy is the co-founder of the Esalen Institute, his book is couched in somewhat obscure terms, and although its contents are presented in a largely rigorous fashion, it tends to find mysticism and avoid scientific explanation. These experiences, it seems, are not understood to fit with orthodox science and are often described as being mystical – a notion reinforced on the cover description of the text: 'remarkable and mystical things happen to people during sports …' [19]. In a chapter called 'Mystical Sensations' a motorcycle rider describes the experience of riding at considerable speed: 'you feel a calmness throughout your body, even though you know intellectually that you're right on the brink of disaster' [19, p.11]. Murphy and White describe these experiences and point to how people describe this in a rather taciturn manner. Do we sense a growing unease in the reader here; a sense that this paper is verging into rather embarrassing territory? Embarrassment is reflected in many of Murphy's interviewees, apparently reluctant to admit a sensuality that appears to diminish their sense of themselves as understanding 'users' of their perception describe their experience as if it had not really happened without them being conscious of being 'in control', but had simply felt as if it had been automatic.

The phenomenology of enaction is only just beginning to emerge from the realm of the occult, for example in the inclusion of some extraordinary esoteric phenomena by Burger, [3] into academic scrutiny. 'Ouija boards' and phenomena such as 'phantom limb' and 'out of body experiences' were once condemned to languish in the realm of the occult, the concern of the ignorant or the insane who often claimed a connection to some supposed externalised spirit or energetic force. The use of the Ouija is explicitly paranormal; its discussion in rational conversation runs the risk of consigning the speaker to the fringe. However, in 'The Illusion of Conscious Will', the neuroscientist D M Wegner [27] describes a number of scientific 'explanations' of the Ouija and other supposedly occult phenomena. These explanations focus upon the nonconscious function of the soma. The nonconscious should not be confused with the unconscious, as Freudian psychiatry might understand it, but a reference to the functions of the soma that operate beyond human sensuality. Wegner suggests that the function of the soma cannot be entirely understood to be accountable in consciousness. Wegner [27] cites the experiments of the neurophysicist Benjamin Libet [15] and colleagues whom tested the timing between the commencement of somatic activity and the subsequent conscious willing of the movement. Wegner suggests that Libet's research presents a challenge to ideas we might have of somehow being in charge of our bodies and by extension of our free will. This idea is outlined extensively in 'The User Illusion: cutting consciousness down to size' by Tor Norretranders [20]. Wegner suggests that this nonconscious functioning of the body may go some considerable way to explain these aspects of the occult as being moments when the nonconscious reveals itself in ways we are forced to account for in our social lives.

2.2 Rejecting the Reduction of Experience

Julien Offray De la Mettrie's 'Man a Machine' [7] is sometimes cited as an example of how science reduces the essence of humanity to that of a mere machine (such as [5]). While it may appear superficially to make that claim, in Man a Machine De la Mettrie actually made a far more subtle proposition for the condition and experience of being alive to emerge from the enacted condition of being in the world. Far from suggesting that mankind was a zombified product of the mechanism of the body, De la Mettrie argued that the world is a product of human interpretation, which is itself conditioned by the world. In his own terms De la Mettrie was clear that humans had evolved to be in the world, and proposed, rather unpopularly in his time, that humanity was naturally inseparable from the world as a being of nature.

'Man's pre-eminent advantage is his organism. In vain all writers of books on morals fail to regard as praiseworthy those qualities that come by nature, esteeming only the talents gained by dint of reflection and industry. For whence come, I ask, skill, learning, and virtue, if not from a disposition that makes us fit to become skill-full, wise, and virtuous? And whence again, comes this disposition, if not from nature? Only through nature, do we have any good qualities; to her we owe all that we are.' [7]

De la Mettrie argues that while the corpus is a form of machine, the human is more than the sum of its mechanistic parts. De la Mettrie argued that while the body and the soul can be understood in isolation, no true picture of the human could be built unless they are considered as one whole. De la Mettrie returns our attention to energy; he suggested that it is the food necessary for the machine that can influence the soul, and courage or stupidity though considered to be essentially a matter of the soul and the domain of the philosopher, it could not be separated from the somatic influence:

'Nourishment keeps up the movement which fever excites. Without food, the soul pines away, goes mad, and dies exhausted. The soul is a taper whose light flares up the moment before it goes out. But nourish the body, pour into its veins life-giving juices and strong liquors, and then the soul grows strong like them, as if arming itself with a proud courage, and the soldier whom water would have made to flee, grows bold and runs joyously to death to the sound of drums. Thus a hot drink sets into stormy movement the blood which a cold drink would have calmed.' [7]

For De la Mettrie it was impossible to reduce mankind to understand him. One can understand something of his nature and behaviour and something of his functioning but can never reduce him as one might a machine of his making.

'Man is so complicated a machine that it is impossible to get a clear idea of the machine beforehand, and hence impossible to define it. For this reason, all the investigations have been vain, which the greatest philosophers have made à priori, that is to say, in so far as they use, as it were, the wings of the spirit. Thus it is only à posteriori or by trying to disentangle the soul from the organs of the body, so to speak, that one can reach the highest probability concerning man's own nature, even though one can not discover with certainty what his nature is.' [7]

Almost a century ago Wyndham Lewis and the Vorticists, foresaw a new humanity unbound from the constraints of culture. They foresaw a being centred in an ego set in the midst of a swirling and energetic extended condition. This new being would be capable of extending the human further and further into the universe, but would always remain centred on an essentially consolidated ego, bound in some fluid manner to the material body. Set in the midst of an emerging technological culture, the Vorticists proclaimed resistance to technology as, 'a vampire sucking the town's heart and as a gloomy circus. It stirs sentimental, nostalgic feelings which stifle the new generation' [2]. The new ego would be a new sense of being that can be understood now, perhaps as a nascent attempt to understand life as something that was embodied and enacted outwards, rather than resolved outside the body and transmitted to it via the senses. Marinetti [16], like Wyndham Lewis, sought to extend the somatic potential of the body beyond its physical border. Marinetti, however, sought to unbind the ego from physicality and saw in this a glorious destruction: 'Art is the need to destroy and scatter oneself.' The 'body' as a contained entity, had no objective meaning for either Marinetti or Wyndham Lewis. For Marinetti this was an optimistic sign of emerging transcendence from the vileness of the biological organism, though Wyndham Lewis took issue with this claim [18].

2.3 Behaviorism and Cognitivism

The Vorticists can be understood now as a largely unsuccessful attempt to resist mechanistic models of the human mind and to put in place a more enacted and dynamic model of being. Contemporary cognitive models of the human as a psychology owe much to the emergence of the study of the human mind during the late nineteenth century, particularly to the laboratory work of Wilhelm Wundt at Leipzig University in 1879 and William James' research in the USA. James is widely credited with establishing the form and scope of psychology and to a considerable extent his model shapes psychology today (see [12]). Early psychologists were emerging in a climate where mind and being had become modelled on somewhat mechanistic models of the human. The Vorticist objection was to the emerging project of reduction of the mind to a largely mechanistic model. The implication being that such a mechanistic reduction might set in train the logic that it would be possible to regulate, or condition, human behaviour. Ivan Pavlov is perhaps the best known today among the researchers who established the field of 'classical conditioning'. Pavlov proposed that an entirely predictable and instrumental model of human behaviour and action might be eventually discovered and conditioned. One way to observe the history of design is as a strategy that has tracked the model of the human as a thinking machine. Design has certainly become consolidated in recent times by the collusion of the instrumental and reductivist methods with the introspective studies of Freudian psychoanalysis. Cross [6], for example, has argued that design, as we understand it today, is rooted in the scientific understanding of human behaviour and recalls Van Doesburg's call for a new spirit in art and design:

'Our epoch is hostile to every subjective speculation in art, science, technology, etc. The new spirit, which already governs almost all modern life, is opposed to animal spontaneity, to nature's domination, to artistic flummery. In order to construct a new object we need a method, that is to say an objective system' [6, p.49].

'Behaviorism' became established as a strategy primarily through its application in various forms as models of behaviour and expectation in factories [11] and offices through Gilbreth's ideas of work efficiency and time and motion studies [21] and other Taylorist modes of scientific management in advertising, marketing and market lead ideals of design aesthetics [13]. Pure behaviorism, however, is no longer understood to be a viable model of the human. During the 1960s models of the human as social construction emerged via theorists such as the American psychologist Burrhus Skinner (who had developed the 'Operate Conditioning Chamber' in which animals win rewards by responding to learned stimuli), attempting to establish a verbal model of behaviorist construction [22]. Rather famously Noam Chomsky was moved to public disagreement over the political and libertarian implications of Skinner's model [4]. Skinner proposed that behaviour was determined by the linguistic understanding of the world; such a model remains surprisingly pertinent in semiotic models of design, and arguably in tangible models of interaction also.

It has been suggested that Chomsky misunderstood the subtlety of Skinner's thesis; nevertheless it is now widely held that Chomsky's criticisms of Skinner can at the very least be seen to encapsulate a new intellectual move during the second half of the twentieth century. Like the Vorticists some half a century before this new move would be against reductivist and behaviorist models of being and towards a reinvigorated model of the human as a significantly more complex construction. If Skinner can stand, for the sake of argument, for a mechanistic model of human understanding that suggested knowledge was externally acquired, then Chomsky argues for a much more subtle coding of human behaviour that results from deep structures of innate behaviour of the species [4]. If this shift tells us anything, it illustrates a dramatic move towards understanding the human as an internally reducible mechanical object - as opposed to external behavioural states - fundamentally separating the cognitive attributes of the human species from the body and world. The intellectual transition provided by Chomsky, among others, in the mid-twentieth century had much bearing on the so-called 'cognitive revolution' within psychological disciplines, notably through the loose federation of sciences dealing with knowledge and cognition – the cognitive sciences. For interaction design this can be seen as an historically significant move, especially within the precise context of Human-Computer Interaction (HCI) where the development of technology and the interaction modes provided was both influenced and provided impetus to the understanding of the human as cognitive, information-processing, and disembodied beings. The interaction designer here becomes a manager of the symbolic communication between two systems of rational logic - the computer and the cognitive apparatus of the perceiver - in order, theoretically, to attune interactions to be as seamless as possible ([26] provides a more detailed explanation of the limitations of this method).

2.4 Phenomenology and Embodied Interaction

In recent times there have been attempts to bring the intellectual impetus of cognitive science together with phenomenological philosophy, particularly the work of Maurice Merleau-Ponty [17] and to some extent in the earlier post-Hegelian ideas of Heidegger and Husserl. These philosophies deal with the 'embodied' experience of being in the world, rather than the constructed cultural conceptions humans build about themselves. The relationship between embodiment and cognitive science will be discussed further below. Before this discussion though, it may be that the term embodiment is already familiar to the interaction design community as a result of Paul Dourish's [9] introduction of the concept to the context of human interactions with digital computer systems and artefacts. Dourish presents a model of 'embodied interaction' through drawing heavily upon a number of the key figures in phenomenology that he identifies as important to the development of embodied interaction; Husserl's phenomenology; Heidegger's hermeneutic phenomenology; Shultz's phenomenology of the social world and Merleau-Ponty's phenomenology of perception. It appears that, in his choice of phenomenologist, Dourish is intent on positing embodied interaction as a methodology that resists genealogy in structuralist or cultural–theoretical method and thereby eschews the orthodox history of interaction design. He starts from his summation of embodied phenomena as 'those, which by their very nature occur in real time and real space'. Dourish proposes that 'embodiment is the property of our engagement with the world that allows us to make it meaningful' [9, p.126]. He locates interaction design in phenomenology by arguing that the physical experience of being-in-the-world cannot be separated from the 'reality of our bodies presence in the world', hence 'Embodied Interaction is the creation, manipulation, and sharing of meaning through engaged interaction with artefacts.' [9, p.126]

Reflecting on interaction design history as it is written, Dourish suggests that the design of human technological interaction has shifted from a focus entirely in the machine foundation in protocols (switches, dials, etc.) towards tangible models of interaction that are distributed and intuitive. Examples are posited of digital systems that 'lend themselves naturally' [9, p.42]; these are interactions where people appear not to have to think to act. Dourish is rather uncritical in his understanding of an action; he does not explore what difference there may be between natural or tacit actions, for instance.

Dourish outlines the framework of social computing and, reflecting the thinking that prevails in contemporary design communities, argues that sociological approaches should underpin interaction methodologies. Dourish describes how, after Suchman [23], interaction can be understood as an activity system; we have certain behaviours when we are engaged in activities that interaction designers would be wise to build upon. In this context, tangible interaction and social interaction appear to have a lot to offer one another, Dourish arguing that both aim to 'smooth interaction by exploiting a sense of familiarity with the everyday world' [9, p.99]. He calls upon the concept of metaphorical interaction, but goes on to propose that a collision of ideas of situatedness with ethnomethodological approaches will bring individual experience into the social frame.

3. ENACTED EXPERIENCE

3.1 Enactive Cognitive Science

It is possible to contrast Dourish's interpretation of embodiment as a socially conditioned situation to a slowly unveiling paradigmatic shift within the aforementioned cognitive sciences, where there appears to be a slowly growing conviction that the Cartesian picture of formal, logical, well-defined units of knowledge is upside down; that a radical paradigmatic or epistemological shift is rapidly developing. At the very centre of this emerging view is the belief that the proper units of knowledge are primarily concrete, embodied, incorporated, and lived [24]. Neuro-psychologists, such as Bermūdez and colleagues [1] have argued for some time that the body is the foundation of the sense of the self. In recent years, works such as Lakoff and Johnson [14] and Varela, Thompson, and Rosch [25] have laid out embodied approaches to cognitive studies that attempt to understand what it means to be human in everyday, lived experience. 'If we examine the current situation today, with the exception of a few largely academic discussions cognitive science has virtually nothing to say about what it means to be human in everyday, lived situations' [25, p.xv].

Embodied approaches to understanding human cognition mark in some respects the intellectual drift toward connective, rather than reductive, thought. Emerging from what might be termed an orthodox scientific methodology, embodied understandings of cognition attempt to bring rigour to the subjectivity of lived experiences. 'On the other hand, those human traditions that have focused on the analysis, understanding, and possibilities for transformation of ordinary life need to be presented in a context that makes them available to science' [25, p.xv].

Varela, Thompson and Rosch's The Embodied Mind can be understood as an attempt to reconnect separations of mind, body and world and to bring these hitherto separate epistemes into one conversation. By understanding that the human experience of being is inseparable from the physicality of the reality in which it is situated, an alternative is posited to representational models of cognition in which the world is understood as filtered through senses, rather as one might experience a gigantic and immersive picture show. Varela and his co-authors offer 'embodied' models where the world is 'enacted' through series of complex 'structural couplings' – that is, many tiny connections of sense, experience, imagination, memory, knowledge and other somatic systems, interacting to form a meshwork of impressions of being in the world. If representational models suppose a fixed world that is experienced, then the world in embodied thinking is entirely constructed. Varela's concept of 'structural coupling' reflects, although differs from, James J. Gibson's earlier model [10], which while rejecting representation relied upon a largely visual model of the world, albeit one determined by species and habitat. Where Gibson recognises that the experience of the world is determined by the way in which a species is independently evolved in it, Varela and colleagues describe an 'enacted' concept that distributes the world into the species, and the species into the world. Taking this position, the world is understood to be a lived experience enacted in somatic functions, and so humans must learn to be in the world. While some aspects of that world are constructed for some humans by others, this does not mean that these aspects necessarily contain any truth about the world. Dennett [8] sets out a neat and concise review of Varela's 'enactivist' approach in opposition to the dominant 'cognitivist' approaches to cognition:

'*Question 1:* What is cognition?

Cognitivist Answer: Information processing as symbolic computation-rule-based manipulation of symbols.

Enactivist Answer: Enaction. A history of structural coupling that brings forth a world.

Question 2: How does it work?

Cognitivist Answer: Through any device that can support and manipulate discrete functional elements; the symbols. The system interacts only with the form of the symbols (their physical attributes), not their meaning.

Enactivist Answer: Through a network consisting of multiple levels of interconnected, sensorimotor subnetworks.

Question 3: How do I know when a cognitive system is functioning adequately?

Cognitivist Answer: When the symbols appropriately represent some aspect of the real world, and the information processing leads to a successful solution to the problem given to the system.

Enactivist Answer: When it becomes part of an ongoing existing world (as the young of every species do) or shapes a new one (as happens in evolutionary history)' [8, pp.206-207].

3.2 Implications of Enacted Experience

Perhaps the easiest way to emphasise the difference in these approaches might be to consider the act of speaking. A cognitivist approach might focus upon the meaning and construction of the words. How has a vocabulary been learned; what is the value of the words used; how are the words used differently in cultures and in changing contexts, for example. An enactivist approach might study the processes whereby the words are formed nonconsciously by the tongue in the palette; how this process is learned as a child; how words are assembled in the mind prior to their vocalisation and how in conversation their delivery is nuanced, seemingly without any thought being given to the process on the part of the speaker. The enactivist approach places the somatic system at the centre of the process. Assuming the speaker does not speak from a predetermined script, many systems are at play in the formation of the conversation in design terms. Re-contextualising Dennet's review into the realm of designing technological interactions has profound consequences for the way in which we might understand the processes designers implement when relating human beings to technology.

Question 1: What does design do when it humanises technology?

Cognitivist Implication: Design manipulates symbolic images by which people read the world so that they can make sense of and give value to technologies (semiotics).

Enactivist Implication: Design enables people to enact in the world by enabling potentiality of the whole human as a distributed soma (Holsomatic).

Question 2: How does design work?

Cognitivist Implication: Designers create the means to project simple or multiple and complex symbolic meanings. These symbols are primarily experienced by people in reference to a codified cultural understanding of referents.

Enactivist Implication: Designers intervene in the complex processes by which people form an experience of their world. Their task is to enable people to experience the world 'naturally' without necessarily needing to attach meaning to individualised interactions.

Question 3: How do I know when design is functioning adequately?

Cognitivist Implication: When people understand the symbols they encounter and react appropriately.

Enactivist Implication: When people incorporate the designed world seamlessly as part of their experience of being.

In taking each question in turn and looking at the implications for design in the 'cognitivist' and 'enactivist' answers to each question it becomes possible to see how enacted or embodied approaches to cognition place a rather different emphasis upon the realisation of the self as a constructed (cognitivist) entity in separation to technology or a self-enacted construct formed through complex coupling in which technology is understood to be coextensive with the soma (holsomatic). Looking back at Dourish's understanding of embodiment as a socially conditioned situation, and its subsequent adoption within the interaction design community, is somewhat far removed from Varela's understanding of embodied and enacted cognition through 'structural coupling'. Dourish appeared to be on the brink of a profound move, towards a distributed view of cognition and the soma, but returns the interaction design discourse to the safety of materiality and behaviorism. Arguably, then, rather than transforming the discourse, Dourish entrenches it in its methodology of analysis. A design methodology that calls for familiarity as its guiding principle is likely to find it difficult to progress, especially when the interaction with a potential new technology may be considered ineffable.

4. CONCLUSION

This paper has discussed how the diverse disciplines drawn upon and applied by interaction designers have a history of mechanising human experience into reducible and scientifically observable behaviours or measurable cognitive phenomena. In this paper we have attempted to fathom how interaction design might be able to integrate itself as a strategic practice in light of an alternative argument of holsomatic experience, or more broadly that of being enacted, embodied and extended. The paper has discussed how Dourish's 'embodied interaction' has provided usefulness for understanding the lived experience of human interactions with technology but is restricted by grounding itself in the contemporary trajectory of interaction design. In highlighting the implications of enaction to designers, the paper attempted to provide speculative foundation to a potentially profound shift in the contemporary discourse of interaction design from models of humanity that are dominated by the social reduction to behaviours or a cognitive reduction to particular mental processes.

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