AALBORG UNIVERSITY
DENMARK

ArtAbilitation 2006

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Publication date:
2006

Document Version
Publisher's PDF, also known as Version of record

Link to publication from Aalborg University

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ArtAbilitation 2006

Conference proceedings

Edited by A.L. Brooks

Contents

Citation of published papers: Author surname, firstname initial (2006). Paper title. In Brooks, A.L. (ed.) Proceedings ArtAbilitation2006, Esbjerg, Denmark, 19-20 September, 2006, pp. XX-XX.

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- "A human being would lack nothing, if one were to admit that there are a thousand ways to live" – Canguilhem
- "Man, as yet, has no means of imagining the nature of his own experience in space. Until artists have provided him with adequate forms to express what he feels in space he will not know the meaning of experience" - Herbert Marshal McLuhan
- "You expect me to tell you what art is? If I knew, I would keep my knowledge to myself" - Pablo Picasso

ArtAbilitation was conceptualized in October 2004 following an invitation to bring the ICDVRAT event to Esbjerg, Denmark for 2006. The idea behind the initiative was manifold as was also the intention with the unique title... Art in (reh)abilitation…. Art in (h)abilitation…

Firstly, the idea for 2006 was to offer a supplemental contribution to ICDVRAT in the form of reported activities that were art related, worthy to be termed as research, and written under a scientific methodology.

Secondly, to present work in the field that had given a direct benefit for individuals and/or communities where children or adults had different abilities. - these presentations were recognized as having a non-scientific form but yet there was an important story to tell. Once told it was felt that the story would inspire potential future research projects.

Thirdly to introduce international, national and regional industries whose product are associated to the field: this with an eye toward future collaborations in both research and education.

Fourthly, to create a "happening" so as to give opportunities for the synergizing of energy between students at an international, national and regional level. As we are sponsoring gratis PhD student places we also wished to give a great experience of Esbjerg to those who are not involved in the delegate events but who are future researchers.

Fifthly, to offer a forum where representatives from the targeted communities, i.e. persons with different abilities; could attend and feedback to their networks of our targeted goals in Esbjerg.

To support the initiatives set out above it was important to first realise a research laboratory and team that could be a first class collaborative partner in national and international projects. The Sensorama lab was achieved in Spring 2006 to an initial first stage level through funding by the city of Esbjerg, Aalborg University and assistance from SoundScapes (a small Danish research and development SME). The research team now consists of four post-doc researchers - interdisciplinary and multinational (three assistant professors from Sweden, France, Slovakia and an associate professor from UK). For the ICDVRAT/ArtAbilitation event a visit to experience the lab was offered to delegates.

To close, I reflect on the points above: The first point has been successfully realised by 13 papers which underwent blind-peer-review by an international programme committee of high standing. Total number of abstracts were 28, which for our first conference, was very satisfactory. Selected papers from ArtAbilitation will be featured in a special edition of the international journal "Digital Creativity" in May 2007.

The second point is realised by guest presenters who exemplify their story through practical demonstrations in the foyer area (including live music). Alongside these presentations are exhibitors who are either students who show their projects, representatives from the disabled community or companies who show products. In this way we are satisfying points three, four and five simultaneously. Additionally, student events that are hosted by our local students take place in the evenings so as to reinforce opportunities for student networking and optimal experience.

Amongst the targeted goals of ArtAbilitation are to establish a conference that will be the foundation for contributing to a new regional profile for health and wellness in the Southern Denmark region - especially in accord with new potentials in technological research, community practice and 'edutainment' issues. To this end we are anticipating collaborations with our neighbouring University who have a health science/promotion curriculum, and a number of the other institutes in the region as well as nationwide. Industrial collaborations are also anticipated.

On behalf of the organising committee and volunteers, we would like to thank you for attending and sharing your research, work and indeed life through ArtAbilitation…

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Interactive flashlights in special needs education

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Abstract

Flashlight torches are cheap, robust, familiar and fun and so make interesting devices upon which to base interaction technologies. Computer vision software has been developed that can recognise and distinguish between different flashlight beams and these can be used to activate digital media including audio, video or special effects. The technology appears to 'magically bring to life' objects and areas of the environment merely by shining a torch on them and has been used successfully to enhance visitor attractions such as museum exhibits and displays. This paper considers the potential for using this technology in special needs education, providing a means for children to explore their immediate environment and discover something new. Potential applications for supporting learning are proposed and a feasibility study is presented. Three case examples were conducted to assess the practicalities of configuring interactive learning experiences within the school environment and pupil's responses to the technology.

Keywords: flashlights, multimedia interaction device, learning disabilities, interactive learning space

1. The *Enlighten* interactive flashlights system

Flashlights are excellent tools for exploration and discovery, particularly in darkened environments, and the pools of light they cast focus attention and provide immediate topics for discussion. They are readily available in a variety of physical forms (sizes, shapes weights, powers and designs) and mountings (including handheld, head-mounted, stand mounted and vehicle mounted). They are also relatively safe, in terms of being shone into eyes and onto delicate surfaces.

Enlighten is a novel interaction system that uses ordinary flashlight torches to explore and interact with displays and objects in the environment. The user simply shines an ordinary torch over the surface of interest. When the torch beam is positioned over one of a set of pre-defined targets, the system recognises the flashlight and triggers the appropriate system response (Benford et al. 2004). Responses can include any computer-driven effect such as playing an audio recording or video sequence, switching on a machine or triggering a special effect.

Figure 1 Equipment required

Figure 2 Main control panel
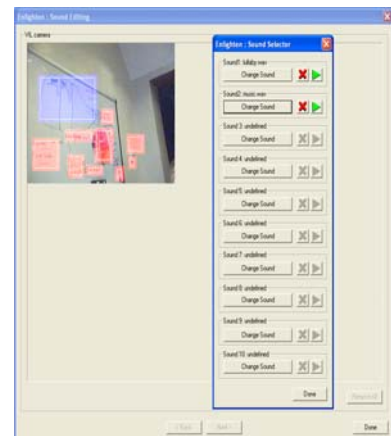
Figure 3 Assigning audio files to target zones

A key advantage of the system is that there is nothing special about the flashlights or the interaction surface used and there is no need to attach any sensors, transmitters or other devices to the surface. Enlighten uses computer vision techniques to identify and respond to different flashlight beams. This means that the system is portable and can be positioned in almost any environment. All that is needed is a standard desktop PC or laptop, Enlighten software, a standard web-cam and suitable flashlight torches (Figure 1). Use of standard equipment ensures that the system is affordable and readily available. The main constraint that affects

Enlighten is lighting. The computer vision techniques underpinning Enlighten require the local illumination to be fixed, or vary only slowly. The technology may not be suitable for some environments, which have very bright or highly variable lighting. Enlighten also requires space to mount video cameras so that they can get a sufficiently wide and interrupted view of the surface of interest.

To date, the most common use of Enlighten has been to trigger audio responses, and the current version of the software reflects this. Enlighten consists of two key components: a configuration system for interactively defining targets and flashlight torches and associating them with sound files, and a run-time system that detects and tracks flashlight beams and triggers the appropriate sound file whenever one hits a target. Configuration begins once the camera is in position. A familiar and simple graphical user interface is used to set up configuration of an interactive experience. The main control panel allows access to different modes of configuration including camera selection, target creation, sound selection and torch training (Figure 2).

A user can create target zones in the visual scene by simply 'drawing' boxes over image that the camera sees. These target zones can be repositioned, resized or removed using standard cursor click and drag techniques. In sound selection mode, the user clicks on a target zone to open the 'sound selector' window specific to that target zone (Figure 3). Sound files can then be attached to the target zone using standard drop-down menus. Once the targets are defined, the system is trained to recognise the torches to be used. The user simply plays each torch in turn over the surface while Enlighten extracts and stores a description of up to 10 different torch beams. Torch 1 is used to activate sound 1 assigned to each target, with subsequent torches activating subsequent sounds/audio files accordingly.

Figure 4 shows a pair of torches being used to interact with a poster showing the planets of our solar system (Green et al. 2004).

Figure 5 shows the two flashlight beams extracted from the image sequence. Enlighten detects, describes and recognises the individual torch beams (labelled as Class 0 and Class 2). In this demonstration system torch 0 triggers children's spoken descriptions of the planets, while torch 1 triggers samples from Holzt's Planets Suite.

Figure 4 Two-torch interaction

Figure 5 Torch recognition

Key features of Enlighten are that it:

- Is easy to use: Enlighten is very easy to learn and simple to use
- Is child friendly: Flashlights are especially appealing to children
- Is entertaining: Enlighten creates magical experiences in which everyday flashlights bring ordinary surfaces to life
- Is personalised: Different flashlights can trigger different responses, providing personalised experiences for different users
- Supports exploration and discovery: Flashlights offer the ideal means to explore dark areas. Shine a flashlight over a surface to reveal specific features and activate multi-media explanations and information about these features
- Supports shared interaction: Several flashlights can be used together providing an interaction experience, which can be shared by groups. Different responses may be triggered by each flashlight, providing a montage of effects to be explored collaboratively

Enlighten has been installed in a variety of situations. An early version was used to allow children to interact with projected graphics within a StoryTent (Green et al. 2001, see Figure 6). In the first large-scale public trial visitors to the caves beneath Nottingham Castle used Enlighten to access audio clips describing the history behind key features of King David's Dungeon (Ghali et al. 2003, see Figure 7). Approximately 150 visitors used the system over a two-day period. Lessons learned from these installations led to technical improvements to the system, which was then used in interactive storytelling sessions with groups of 4 - 7 year old children and a professional storyteller at the 2004 Nottinghamshire Show (Reeves et al. 2006). Enlighten has recently been commercialised, and a number of installations are currently underway in the museums and heritage sector (www.visibleinteractions.com).

| Figure 6 Enlighten in the StoryTent | Figure 7 Enlighten in Nottingham caves |

2. Potential for application of the Enlighten interactive flashlights system in special needs education

The majority of our work on Enlighten has focussed on the value and properties of the flashlight as an interactive device, with particular emphasis being placed on its application in the museums and heritage sector. As a direct pointing device, it is easy to see how use of a flashlight to trigger targets located in the physical environment, could provide a stimulating activity for improvement of gross motor and hand-eye coordination skills. There is, however, an alternative view of Enlighten, which gives additional reason to believe that it may have a role to play in special needs education.

Leaving aside the use of the flashlight to indicate the physical surface(s) and object(s) involved, the core operation of Enlighten is to create associations between sections of the physical world (elements of a poster, areas of a cave wall) and pieces of digital media (audio, video, computer programs, etc). Enlightens' ability to recognise individual flashlights means that there are potentially N layers of media, where N is the number of flashlights, overlaid on the physical targets (Figure 8). The mapping between these two sets of entities may therefore be:

- One-to-one: A given target might be associated with a distinct media object, which is triggered by all the flashlights
- Many-to-one: Multiple targets might trigger the same media object
- One-to-many: Different flashlights might trigger different media from a given target

Null mapping is also possible; there may be no response associated with a particular torch/target pairing.

When exploring an interactive surface via Enlighten, users can be thought of as either exploring the physical surface, revealing digital media, or searching the space of digital media by moving their torch over a physical environment. The distinction between the two is the perspective taken by the user: are they focused on the physical or the media space? This distinction leads to two complementary ways in which Enlighten might be used to help students learn from and form links between physical objects and more abstract pieces of information:

- Interesting and motivating objects can be used to encourage students to explore the physical surface and so become exposed to digital information
- Interesting and motivating media might be used to encourage students to pay closer attention to the physical environment
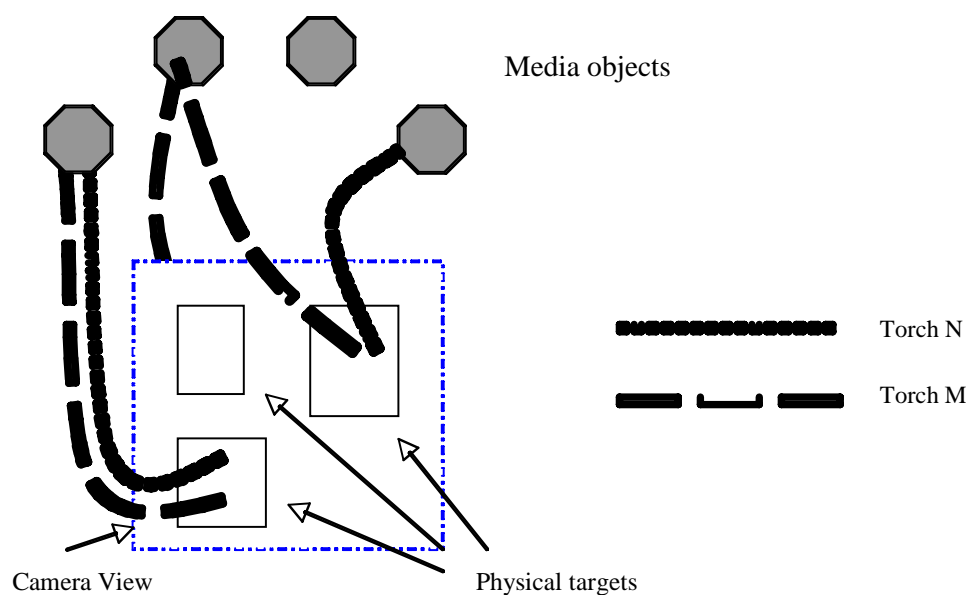
Figure 8 Mapping physical targets to media objects

The model in Figure 8 is a comparatively simple illustration of the most common use of Enlighten to date: using flashlights as a direct control interface to activate pre-recorded audio files. However, the system is more flexible than this and is also capable of varying responses over time. For example, Enlighten can be configured such that target N only responds to torch 1 after torch 2 has accessed target M. Alternatively, target K may play audio clip X the first time it is accessed by torch 3, but video clip Y thereafter.

This ability to vary response over time could be used to allow teachers to design activities in both the physical and media spaces. Physical clues could be used to encourage students to seek out rewarding media, or hints given in the media objects might lead students to seek out rewarding objects in the physical world. However, at this early stage, our research focus is at a more basic level. We are exploring potential use and utility of the Enlighten interactive flashlight system as a tool to support teachers providing special needs education. In the following sections we present teacher opinions regarding suitable ways in which the technology may be used to facilitate learning for their students, and consider practical issues surrounding set up and use of the system in a school environment.

3. Practical evaluation of using the Enlighten system in special needs education

The Enlighten system was demonstrated to teachers at the Shepherd School in Nottingham. Shepherd School is one of the largest special schools in the UK for pupils with severe and profound learning disabilities, and it has always endeavoured to use the latest innovative IT teaching strategies for its pupils. After an initial review of the system, a list of potential application uses was generated. These applications varied in terms of learning support offered to students.

Table 1 shows a list of learning skills supported by the system that may be suitable for students with different degrees of learning disability; profound and multiple learning difficulty (PMLD), severe learning difficulty (SLD) and moderate learning difficulty (MLD). It can be seen that many of the skills listed are applicable to more than one group of students. This is because of the flexibility and ease of 'experience configuration' offered by the Enlighten system, providing a teaching resource that can be presented in different ways. Control over what is placed in the visual scene and what digital response is to be activated is given to the 'experience designer', in this context, teachers. Portability of the Enlighten system also means that it can be set up in different environments, and easily moved from one location to another. Thus, teachers can construct a learning experience to suit an individual pupil's needs or preferences. This can then be easily reconfigured to enhance learning progression or to suit the needs of a different pupil.

Whilst there is overlap of uses for students with different degrees of learning disability, it was considered that interactive flashlights would be used in different ways for pupils in each group, utilising different aspects of the Enlighten system to facilitate different types of learning.

Potential learning skills supported	PMLD	SLD	MLD
Motor control	●	●	
Visual tracking	●	●	
Hand-eye co-ordination	●	●	●
Learning cause and effect	●	●	
Control over the environment	●	●	
Memory jogger		●	●
Listening skills		●	●
Making choices		●	
Communication		●	●
Independent learning			●
Lateral thinking skills			●

Table 1 Potential learning skills supported by the interactive flashlight system for children with different degrees of learning disability

Profound and Multiple Learning Difficulties (PMLD)

Pupils with PMLD tend to have profound learning disabilities and two or more other disabilities. These can be hearing, visual, physical and autistic spectrum disorders in many combinations. Due to their profound learning difficulties, communication is usually pre-verbal and learning skills are the very earliest level of development. The main use of interactive flashlights for these students would be to extend learning experiences offered by sensory rooms. These are currently used to enhance areas such as motivation, concentration, relaxation and visual training, although they have been used for supported learning (see Hogg et al. 2001 for a review).

Specific features of the Enlighten system for use in this context were that:

- Torch operated images within the sensory room could be easily changed (reconfigured), offering variety in terms of control over the sensory environment and responses produced. This could provide additional motivation for students to explore the environment and, potentially lead to improved interactive learning
- Torch activated sounds could provide excellent stimuli for visual tracking/scanning etc.
- Torch beams and computer activated sounds could provide extra clues in the development of understanding of cause and effect
- The torch could be used to control aspects of the environment, for example when torch is shone on a CD, the music plays

Severe Learning Difficulties (SLD)

Pupils with SLD tend to find literacy and numeric skills quite difficult. Some of them will understand basic everyday language, but may be unable to express themselves effectively.

The Enlighten system was viewed as providing an additional means for these students to communicate their choices or needs and to use this as an early stage training method for using more complex communication aids such as liberator™.

- Pupils could communicate their choices or needs by shining the torch onto photographs, objects, symbols, etc. This could be used to teach them to associate selection of an object, or symbolic representation of it, to express their desires. This activity could be enhanced by activating audio of item label (name) and sound effects representing some feature of the item (e.g. 'car' and 'sound of engine running'; 'dog' and 'barking')
- The previous configuration could also be applied to fit in with the 'Objects of Reference' scheme used throughout the school. Objects of reference are physical objects associated with an activity, such as a wooden spoon representing cookery, fixed onto cards with a text label and pictorial representation of the activity. These are used to provide a combined tangible and visual reference of planned activities for a pupil (Pease et al. 1988). Interactive flashlights could further enhance this scheme by adding audio text, triggered at different locations around the school, providing students with another cue with which to match activity with location and thus find their way to their next classroom or activity
- When the torch is shone on a book, the book could tell its story – to encourage listening skills in children who are unable to read

Moderate Learning Difficulties (MLD)

Pupils with MLD may have some basic writing skills, but they may have difficulties using these to any degree. They may find learning difficult and it may be difficult for them to access information using reading skills. It was considered that Enlighten could be used to provide these students with an additional learning method through which they can access information.

Suggested applications of Enlighten were:

- Pupils who are unable to read could shine a torch on a talking object to gain information independently
- Pupils could develop lateral thinking skills (e.g. four different torches could be shone onto one object to gain information from four different curriculum areas such as health, social, maths, science)
- Non-readers could learn to use the library by shining a torch on "speaking reference points"

4. Feasibility case studies: pupil responses to the interactive flashlight system

Potential uses of this technology for special needs education appear to be many and varied and, as with most educational tools, are limited only by the creative imagination and resources available to teachers. Successful implementation of the technology as a flexible teaching resource will be affected by the ease with which experience reconfiguration can be set up, and acceptance of the technology by students. In order to try and assess this, we conducted a feasibility study at the Shepherd School. Three learning experiences were selected from the list of ideas generated. In one day, all three learning experiences were designed, created, configured and tested. Objectives of the study were to assess:

- How easily the room could be configured to support a specific learning experience
- How easy it was to reconfigure the experience for a different purpose
- Reliability of the Enlighten system to cope with reconfiguration
- Children's responses to the interactive flashlight system

Case study 1: Learning cause and effect

Kathleen is an 11 year-old girl with PMLD. Although she is unable to walk she can shuffle around on her bottom. She has very weak hands but can hold a spoon to feed herself with some supervision. Kathleen communicates by use of body language; she laughs when she is happy and whines when she is unhappy. Through this means she is able to show others when she wants something and when she does not want what is offered to her. It is difficult to focus Kathleen's attention on anything. When she is in a dark room with lights on she is obsessed by an infinity box.

Objective of study:

- To introduce Kathleen to torches, to assess her ability to grasp the torch and shine it on a wall
- To observe Kathleen's responses when a torch light is shone on objects attached to a wall

Kathleen was introduced to a lightweight torch. She grasped the torch well using a palmer grasp and she obsessively held the torch light up to her eyes whilst she looked at the full beam. With physical prompts, Kathleen could not be encouraged to shine the torch on objects on the wall. However, when an adult directed the torch beam, although not always consistent, she did make some good visual responses and she "smiled" when the torch shone on objects on the wall (Figure 9). Kathleen did not make any movement towards objects on the wall, but when the torch dropped to the floor and rolled away she moved towards it and retrieved it immediately.

Case study 2: Making choices and communicating these

Polly is a 9 year-old girl with SLD. She can walk and can hold objects. Polly has difficulties with communication and her main means of communication are by changing her facial expressions and by looking at things that she wants.

Objectives of study:

- To introduce Polly to torches, to assess her ability to hold it, track the beam and shine it on a specified place
- For Polly to shine the torch on photographs to communicate her needs

Polly held, looked at and studied the torch. Initially with help she shone the torch on the floor and visually tracked the beam. Polly needed physical prompts to help her accurately shine the torch on the photographs, and it was easier for her to control the torch if an adult first helped her to position it in the centre of the target area (Figure 10). However, on two occasions she did manage to do this herself. Polly showed understanding of the relationship between shining the torch on talking photographs of objects and being given the real object. Through this means she was able to communicate a request to be given the object she wanted (Figure 11). She smiled and showed enjoyment throughout.

Case study 3: Independent Learning
A user group consisting of four young people aged 12 - 19 years with MLD were asked to assess using the Enlighten system to obtain information about an artefact representing a subject of interest. The students could all communicate well and are able to give their opinion regarding their likes and dislikes.

Objectives of study:

- To seek students' opinions on using torches to find out information

The four young people were all able to use the torch to trigger audio information about Sumo Wrestling. A visual reference object (a Sumo body suit) was hung on the wall and when torches were shone on different areas of the body suit this would trigger audio recordings describing different aspects of the subject (Figure 12).

The students were asked in what ways they could find information. They listed; television, video, Internet, books and someone telling you. They also said that it could be difficult to find information, particularly when they had to search for it, for example, when using the internet or looking at reference books. All said that they liked using the torch but one boy said he would rather use the Internet. Two out of the four students said that they would like to do more work with the torches.
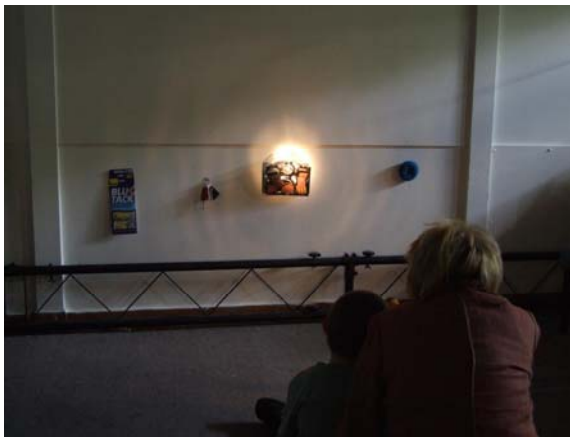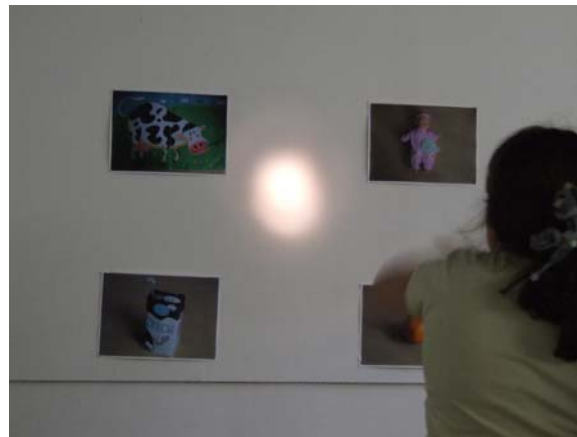

Figure 9 Cause and effect

Figure 10 Controlling the torch

Figure 11 Communication

Figure 12 Finding information

5. Conclusions

Our objective was to assess potential use of the Enlighten interactive flashlight system for supporting learning in special needs education. Teacher opinion was that flashlight torches could provide a motivational tool for learning and have the potential to be used to improve visual attention in children with profound learning difficulties. For more able children, torches could be used to assist communication and provide a means for pupils who do not read to easily access learning independently. However, as a platform technology, providing a flexible resource that can be re-configured for different applications, successful implementation depends not just upon demonstrated learning outcomes, but also upon the ease with which an interactive learning experience can be set up within the school environment.

This early stage feasibility study set out to assess some of the practicalities of using Enlighten within a special needs school and also to gauge children's responses to the technology. The proposed applications required set-up of visual content, recording of audio responses, creation of target areas, assigning audio files to each target area, and training torches under different levels of ambient room illumination.

The technical trials were very successful. It was possible to create and reconfigure Enlighten for different experiences quickly (under 30 minutes including recording audio content) and the system worked reliably in both darkened room (Figure 9) and light room (Figure 11) conditions. The feasibility case studies were positive and this encouraged us. The children appeared to respond to the flashlights in different ways according to their learning needs. The pupil with PMLD was more interested in the torch itself than its effect on the environment. The pupil with SLD did recognise the relationship between the torch and the 'objects of reference' positioned on the wall and she did manage to use the torch to communicate her preferences. The students with MLD immediately recognised the relationship between the torch and triggering of targets on the object of interest. Not all of the students liked it; this may reflect their lack of interest in the subject chosen, but some students want to do more work with this technology. These students will be invited to assist with further design and development of interactive learning experiences.

The interactive flashlights system is suitable for pupils with different learning needs and/or physical capabilities. However, successful use to facilitate learning requires careful design of each interactive learning experience to suit the learning needs and interests of children. The next phase of our research is to set up trial studies to examine specific learning objectives and to see how easily teachers can create and re-configure interactive learning experiences suitable for their pupils.

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Tink Tank –An interactive space to make exercise fun for children with various abilities

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Abstract

The children in SETU (A Developmental Intervention Centre) have been enjoying Tink Tank for the last eight months. Every Monday in SETU is celebrated as "Tink Tank" day. Tink Tank is a universal concept aimed to make certain exercises fun for children with various abilities. As a result of being inspired by the children's present toys I developed a new space to make their exercises more interactive and fun. The tank has four different environments (water, jungle, galaxy and springtime). Each environment is associated with an exercise. The exercises include (blowing, gripping, hand eye coordination, fine and gross motor coordination and hand exercises). The exercises provide auditory, tactile and visual stimulation. The more they exercise the brighter the light becomes, the movement becomes faster and the music becomes louder. The table of the tank teaches colour, shape, numbers, alphabet and expressions.

Keywords: interactive play therapy, exercise stimulation, multi-sensory play, developmental toys, edutainment, disability.

1. Introduction to Tink Tank

Play is how kids grow; it is what they do. All children need opportunities to discover and actively explore the world around them. The importance of play in a young child's life cannot be over-stated; it affects all areas of development. However, for many young children with disabilities, play is often limited.

The term 'developmental toys and games' may give an impression that the fun element has been relegated to a back seat, however this is not the case as Tink Tank is not only a developmental space but also a fun space. It is a space with universal appeal. Tink Tank has been designed with a holistic concept in mind for children with various abilities that not only addresses single barriers but also offers a combination features to provide the greatest access for all children. Tink Tank is a universal concept aimed to make certain exercises fun for children with special needs. It is an open-ended space that promotes discovery and offers a variety of learning opportunities for all children. Certain elements allow more children to successfully interact and play. It is a flexible, customisable, user-friendly platform with inherent multiple activities.

Tink Tank is a platform that assists children to learn about cause and effect, fine motor skills, eye-hand coordination, spatial concepts, auditory, tactile, visual stimulation, fine and gross motor skills and more. One can easily customise Tink Tank to the needs and abilities of each of the children. This complete cause and effect motivational centre is being used in a therapeutic and educational environment in India. Tink Tank is designed in such a way that many senses can be simultaneously stimulated, which can help in the training of deficient physical functions. This encourages the child to become active and develop creative talents while playing. It is a specifically designed environment, which enables children with special needs to create a range of sensory experiences for therapy, learning, relaxation, play, stimulation, control, physiotherapy, communication and fun. The concept is to create events and focus on particular senses such as tactile, vision, sound, all of which can be manifested in many ways, through special sound, visual effects, tactile experiences, vibrations, and the use of music in various combinations.

Tink Tank is a play space in which the children can completely relax without being conscious of the exercise involved. It gives biofeedback proportional to the amount of exercise a child does and enables children with different degrees of disabilities to change and influence their environment in a positive way. The child's curiosity is stimulated by Tink Tank's colours, shapes and sounds. These factors inspire the children to play and feel joyful; experience surprises, gain knowledge and simulate success. Tink Tank does not have a standard model; rather it can be modified according to requirements and conditions. It can be used as a teaching tool for children with specific learning disabilities. This is a way to improve the quality of learning by interactive play for children with various abilities.

2. Design Process

The design process began with brainstorming. The user study was done in an early developmental intervention centre (SETU in Ahmedabad). Interacting with children, parents, therapists, teachers, specialists as well as other designers was a part of the research. Following observations of the children exercising and playing with the toys supplied by the institute it became obvious that they did not enjoy their existing daily routine. A number of concepts were generated to tackle this problem area. The prototype evolved after a number of iterations. Tink Tank was designed keeping in mind sanitation, safety, hygiene, and child psychology, as well as social, ethical and aesthetic aspects. A working prototype was made keeping in mind the cost and space constraints.

3. Tink Tank Final Prototype

Figure 1 Tink Tank

The Tink Tank consists of two boxes. The upper box is made from clear acrylic with four compartments that are each colour coded to match different environments. Each of these environments is designed for a child with disability to exercise playfully and is described in section 4. The lower box is described in section 5.

4. The Upper Box Environments

Figure 2 'Spring/Summer' environment

Figure 3 'Enchanting Galaxy' environment

Figure 2 shows the Tink Tank's 'Spring/Summer' environment of flowers and fruits inside the tank. When a child exercises with the hand gripper the wind chimes inside rotates with a soothing sound and the yellow light intensity in the box increases.

Figure 3 shows the 'Enchanting Galaxy' environment which has colourful glowing stars and planets. When a child blows into a disposable plastic tube the planets starts revolving. The red light intensity increases according to the amount the child blows and the music "Twinkle twinkle" plays along.

Figure 4 The Tink Tank Green environment

Figure 5 Child and the blue waters environment

Figure 4 illustrates inside the Tink Tank's 'Junglee Jungle' Green environment. When a child uses the hand exerciser (Figure 2 foreground), the light intensity increases according to the pressure and the music is activated. The jungle environment is filled with plastic plants and wild animals. When a child uses the hand exerciser, the light intensity increases according to the pressure and the music is activated. Figure 5 shows a child using Tink Tank's 'Blue Waters' environment where plastic fishes with metal mouth can be moved by a magnet that is held and manipulated by the child on the acrylic wall of the tank. The magnetic fish love to be fed by the magnetic food by the children. This helps the child in fine motor coordination. As the fish feed an interior light turns on and the air pump is activated.

5. The Lower Box Games

The acrylic 'environment' tank sits upon on a square wooden box that has a different activity game on each of its sides (Figure 1).
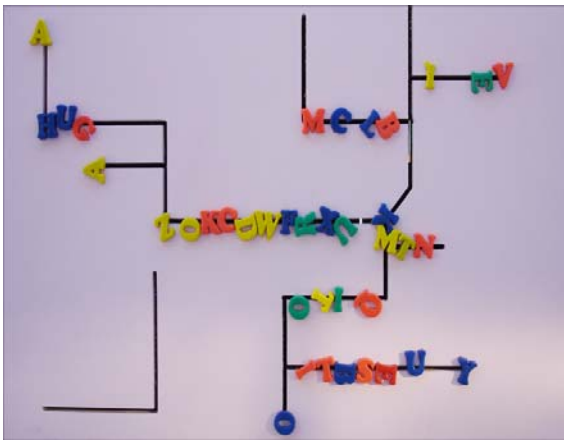
Figure 6 Alphabet Grids (side 1)

Figure 7 Magnetic Turn Taking (side 2)

The 'Alphabet Grids' game is on one side of the lower box. This game consists of colourful plastic alphabet with a protrusion that can slide through a slot in the box (Figure 6). These can be arranged in any manner and be used as a learning aid for different age groups. For younger children it can be used to teach alphabets and for elder ones it can teach formation of words.

The Magnetic Turn Taking Game is on a second side of the lower box (Figure 7). In this game there are four magnetic Disney characters and three shining stars. There is a path made with magnets on which the characters can be fixed. Each child takes a turn and rolls a die .According to the number on the die the child moves forward on the path to reach a destination. Whenever the child lands on a glowing star, he gets an extra turn. The child who reaches the end of the path first is the winner. Targeted is learning concepts involved in turn taking in which the Disney characters are individuals and the stars represent an extra chance.

Figure 8 Numbers Grid (side 3)

Figure 9 Shapes, Expression and Colours (side 4)

The 'Number Grid' activity is on the third side of the lower box (Figure 8). Here there are plastic numbers and functions (addition, subtraction, division multiplication and equal symbols) with a small protrusion made of aluminium rod which can slide through a slot in the box. These numbers and symbols can be arranged in any manner. This activity can be used as a learning aid for different age groups. It can assist in arithmetic with basic numbers to simple equations. On the forth side of the lower box are twelve wooden pieces of different shapes painted with various facial expressions (Figure 9). Each piece can be put into any of twelve different holes that are on the side. Children can play with each of the pieces and then locate them back into the hole that corresponds to the shape. Targeted is the child's learning to recognise and differentiate shapes, colours and painted face expressions.

6. Tink Tank helps through the emerging play stages

Sensory Exploration Play
The young child uses his/her senses to "explore" objects in the same undifferentiated way with repetitive movements. Tink Tank is multi-sensory, e.g. the harder, you blow into the tube, the faster the planets which are plastic balls rotates along with the light intensity increasing, thus motivating the child to exercise more.

Functional Play
The child manipulates objects in a functional manner, and then combines objects. He further sees how his action triggers reactions inside Tink Tank.

Constructive Play
The child begins to sort and build with various objects. Materials are used in simple and then more complex ways. Creative expression begins to emerge, e.g. two sides of the lower box are made of grids on which there are numbers and alphabets in the form of a puzzle. Children can create there own words by bringing words from different parts of the grid together. The complexity of the game is determined by age and ability.

7. Tink Tank and Universal Design Concepts

Multiple Ways of Presentation: The design appeals to children's sensory (sound, vision, touch) abilities. It has multiple colours, textures, dimensions, movement and sounds. It is designed in such a way that play is intuitive. Tink Tank's feedback encourages a child to continue exercising.

Multiple Ways of Use: All children can use equivalent ways for playing with Tink Tank. A variety of actions can stimulate with toys. It can be dismantled completely and be used in different positions and places. It can be adjusted to the child's preferences and requirements. It is easy to use and accepts a variety of movements. Tink Tank is adjustable and stable

Multiple Ways to Play: Tink Tank appeals to children at varying developmental levels and abilities. It encourages use for more than one purpose. It holds a child's interest and encourages exploration and discovery. It can be played in different ways and adjusts for age/levels. It promotes use in more than one way. Your child can choose to play in this space alone or with other children. It encourages the child to be active (physically and mentally). There is no right or wrong way to play. Its use promotes discovery and encourages imagination.

8. Tink Tank caters to:

Attention Grasping: Tink Tank is attractive and colourful with lights and music to make it the focus of attention.

Turn Taking: In this kind of structured group activity, children with autism learn to take turns with others, wait until their turn comes and respond to the speech and actions of others. They learn social skills and behaviours, which increasingly enable them to join in activities with other children.

Social Interactions: The four sides of Tink Tanks lower box each has a different game or puzzle. The one with letters on a grid helps the child to practice learning in series of alphabets; first making small words and later bigger and more complicated words. In this kind of structured group activity, children with autism learn to take turns with others, wait until their turn comes and respond to the speech and actions of others. They learn social skills and behaviours, which increasingly enable them to join in activities with other children.

Physical Activity: In Tink Tank, one can remove the shapes and put it back. Pass the shape from one hand to another. It even has hand and blowing exercises.

Fine motor coordination: The alphabet and number grid puzzle as well as the magnetic fishes in the Tink Tank help in exercise of finger coordination.

Social Relationships: It is important to build a warm relationship with a socially and emotionally withdrawn child. These children may feel threatened when other people attempt to occupy their 'space', especially if they are relative strangers. Through gradually introducing them to Tink Tank they gain growing familiarity and are likely to accept the presence of others and the pleasurable experiences from playing together.

Children need to be motivated if they are going to make the effort to interact with others, they need to have a reason to communicate. It can be rewarding for the child to learn different ways of controlling his or her world. Thus in Tink Tank the child can control his or her own environment, and can move the galaxy, control the sound, intensify the light etc.

Biofeedback: As all the compartments in the tank are activated by an exercise and the amount of that exercise generates a corresponding amount of movement, light or sound, Tink Tank can be considered a mechanism to achieve biofeedback.

9. Tink Tank in the future

Around twenty-five children have been playing with Tink Tank for the last eight months - every Monday at SETU is called "Tink Tank Day". Tink Tank can be used in a wide variety of establishments such as schools, hospitals, nurseries, resource centres, leisure centres, and residential houses for elderly people, community resource centres, psychiatric hospitals and centres, private houses and many other places. On a larger scale it can be used in exhibitions and Amusement Parks.

10. Conclusion

Tink Tank is a student project and despite time, money and technological constraints it has been realised as a prototype. At present, it is electronic, but in the future when manufacturing with the latest technologies of wireless computing it can be sturdier and safer for children to use. After user testing, it has been seen that the children enjoy doing these exercises and thus such environments are useful for children with special needs.

The therapeutic efficacy of play therapy has not yet been proven scientifically. Some contend, however, that it is virtually impossible to scientifically prove the efficacy of any psychotherapeutic model, new or old. They argue that the variables are simply too vast, infinite in fact, making a controlled experiment impossible.

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Explorascope: an interactive, adaptive educational toy to stimulate the language and communicative skills of multiple-handicapped children

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Abstract

Very young non- or hardly speaking children with severe disabilities need active guidance to stimulate interaction with their environment in order to develop their communicative and linguistic skills. Augmentative and Alternative Communication (AAC) systems can help this process, provided that they are tuned to this specific user group. *LinguaBytes* is a research programme, which aims at developing an interactive and adaptive educational toy that stimulates the language and communicative skills of multiple-handicapped children with a developmental age between 1 – 4 years. In this article we show which guidelines we consider essential for developing this tool. We have developed several concepts based on these guidelines, of which we elucidate one called *Explorascope (E-scope)*. E-scope consists of a tangible toy-like interface that is adaptable to an individual child with respect to his or her cognitive, linguistic, emotional and perceptual-motor skills. A user test with the first version of E-scope shows that adaptive, toy-like educational tools are promising and useful for this user group.

Keywords: tangible interaction, computer assisted learning, toy design, adaptability, multi-handicapped children

1. Introduction

Problems in the development of language and communicative skills can have grave repercussions to the psychological development of young children, especially with respect to social and emotional maturation and the ability to be self-supporting. According to Heim (2001), the early parent-child interaction and the communicative development during the first years of a child's life lay the foundations of language acquisition. In the event of severe disabilities, the interaction is not starting or progressing normally, which causes extra stagnation of the communicative and linguistic development. This stagnation can be reduced by scaffolding, i.e. a significant adult guides a child through the Zone of Proximal Development (ZPD) which refers to the gap between a child's existing abilities and what she/he can learn with the guidance of an adult or a more capable peer (Vygotski 1978). Therefore, it is of great importance to enhance and optimise the interaction between parents and non-speaking children and stimulate communication and linguistic usage.

Several tools make use of multi media techniques to support multi-handicapped children and train their cognitive, perceptual-motor, language and/or communicative skills, such as *BioBytes* (Voort et al. 1995), *IntelliKeys* (IntelliTools), *Leaps and Bounds* (Semerc). Despite their success, these and other augmentative and alternative communication (AAC) systems are not tailored to very young non- or hardly speaking children with severely impaired motor and cognitive skills. The cognitive load of these systems is high, i.e. most AAC devices are not organised in ways that reflects how young children think (Shook & Coker 2006). Moreover, the current generation of AAC systems are not particularly appealing to young children in comparison with toys (Light & Drager 2004). They resemble PCs as for structure (menus and decision trees) and/or input (mostly button-like) and output (often screen-based display) (Hummels et al. 2006, in press). Despite the useful endeavour to develop a variety of special input devices, one could wonder why young children are placed behind a desktop computer, which was originally designed for office work. Moreover, PCs are typically designed for exclusive use, i.e. one person sitting behind the screen with input devices, which is far from ideal to enhance interaction between parent and child. In addition, these systems do not capitalise on current technology and multi-media possibilities (Shook & Coker 2006; van Balkom et al. 2002; Hummels et al. 2006, in press), which are aspects that can enhance adaptation to an individual child and offer the possibility to use a variety of strategies to improve language and communicative skills.

A study by van Balkom, de Moor and Voort (2002) shows the necessity of having an interactive training system for this specific user group. The study resulted in a three-year research programme called LinguaBytes[1], which aims at developing an interactive and adaptive educational toy that stimulates the language and communicative skills of multiple-handicapped children between 1 – 4 years old.

This paper describes one of the educational toys that are under development, called ExploraScope (E-scope). We start by explaining the guidelines we use for the development of these educational toys. Subsequently we show what kind of educational toys we are aiming for. Next, we clarify what E-scope is and does, how it is used and how therapists and children perceived it during a user study.

2. Guidelines

After an extensive literature research, we have formulated eight main guidelines for the development for our new educational toy:

- Learn: Our goal is to enable children to improve their language and communication skills by providing them with opportunities to experience and learn about the meaning of new lexical concepts and providing them with possibilities to practice in various ways and at different linguistic levels, coupled to their personal level. The concepts are offered in various ways, e.g. speech, symbols, drawings, photos, movies, objects and text
- Adaptability & personalization: Due to the diversity of children with respect to their cognitive, linguistic and perceptual motor skills and limitations, and their needs and interests, it is beneficial to create adaptive and personalised products. This optimizes the learning settings and avoids frustration
- Technology: Nowadays technological developments like miniaturization, embedded intelligence, sensor technology, wireless networking and rich media, offer a whole new scope of possibilities for innovative adaptive designs, which is not profoundly capitalised on by current AAC systems
- Challenge: Challenge, which is a key element of motivation, engages children by stimulating them to reach for the boundaries of their skills and to take initiative for interaction (Csikszentmihalyi 1990). We aim at challenging multi-handicapped children to capitalise not only on their cognitive and linguistic skills, but also on their perceptual-motor skills
- Playful, tangible interaction: Since we are physical beings we learn to interact with the world through our physical skills, how limited they may be. Therefore, especially with young children that explore the world through play, we focus on playful, tangible interaction in accordance to current trends in toys
- Independence: Feeling independent is an essential part in the motivation of children while learning. Independence gives the feeling of being in control, which enhances the satisfaction of reaching goals. This demands much of the intuitive quality of the product
- Teach & monitor: Next to children, the system will be used in cooperation with therapists and parents. We aim at an educational toy that evokes communicative and social interaction. Moreover, recording and displaying performance data of a child in a user model enables therapists and parents to gain a clear understanding of the progress of that child and adjust their strategy accordingly, if not done already automatically by the adaptive system
- Frame of reference: Finally, we like to base our design on the children's mode of living and the way they perceive their environment in order to inspire them, and stimulate their imagination and curiosity

With these guidelines we aim at a system that enhances the self-confidence of non- or hardly speaking multiple-handicapped children between 1 – 4 years old and that stimulates them to learn.

3. Our approach

Based on the guidelines, we are designing several concepts through a research-through-design approach, i.e. through the act of designing resulting in experiential prototypes, and subsequently testing these prototypes in real life settings, we generate scientific knowledge (Pasman et al. 2005). In this case we generate knowledge about novel, adaptive & tangible AAC systems for improving language and communication skills, which has to result in a theoretically and experientially sound product.

When we design interactive products, the process typically moves through several cycles of designing-building- testing, in which each iteration refines the product. The iterative design process of LinguaBytes consists mainly of two phases: conceptualisation and specification. During the conceptualisation phase, we explore the scope of the new tangible tool, by building and testing a comprehensive set of concepts / prototypes. The most appropriate concept will be further developed, completed, built and extensively tested during the specification phase.

The first conceptualisation round of LinguaBytes started in 2004 with E-scope, which will be further explained in this paper. We have just finished the second round of the conceptualisation phase, which consisted of building and testing four simple concepts based on interactive books, prints, and tangible objects.

We are currently in the third round of this phase in which we are building and testing two interactive tangible sketches of educational toys (see Figure 1). The conceptualisation phase will end with an extensive long-term user test of a full working prototype of the final concept, which is based on the findings of the first three rounds. It goes beyond the scope of this paper to elaborate on all rounds; we will only focus on the first round: designing, building and testing E-scope.

Figure 1 Ring-based design (upper left), InteractBook (upper right), PictoCatcher (lower left) and ObjectSlider (lower right).

E-scope is a ring-based design that can trigger an auditory play by rolling it across a drawing or activate a movie by turning the upper ring and pushing buttons (Figure 1, upper left). InteractBook plays a sound file after turning the page (short story/sentence) and when touching the depicted PCS symbols (related word) (Figure 1, upper right). PictoCatcher is an interactive marble course where each marble with an enclosed PCS symbol is related to a story and triggers a movie when entering the wooden box (Figure 1, lower left) and ObjectSlider starts or alters an animation by placing the related tangible objects next to the screen (Figure 1, lower right).

4. E-scope: an adaptive tangible controller

In the remaining part of this paper, we explain E-scope, a tangible controller that enables young children to learn simple concepts (e.g. sleep, clock, bear) through tangible interaction and play.

The prototype of E-scope consists of a wooden ring-shaped toy with sensors and actuators, a computer with a wireless station and a screen (see Figure 2).

Figure 2 E-scope consists of a wooden toy, a computer with a wireless station and an optional separate monitor (left). The upper and lower ring of E-scope communicates with the computer through radio transceivers (right). All sensors, actuators and batteries are built into the layers of E-scope.

Figure 3 E-scope configurations: Using pictures (upper left); integrated LCD screen (lower left); with separate screen (centre), or with a variety of input devices making it possible for a severely motor handicapped person to operate it (right).

E-scope is adaptable to a child and can be used in different configurations (see Figure 3). A child can listen to stories or play educational games by rolling E-scope over pictures that are lying on the floor. Every picture triggers a matching story. The buttons can be used for further deepening of the concept. E-scope can also be used on a table. By turning the upper ring and pushing the buttons on the wooden ring a child can interact with stories shown on an integrated or a separate screen, depending on the ergonomic and social requirements. If necessary, E-scope can also be attached to alternative input devices, for e.g. one button or eye-movement interaction. In this last case, the upper ring is rotated by use of a motor. The different configurations all require a different level of motor skills and have different social impact. Moving the E-scope over the floor is suitable for children with gross motor difficulties, but with the ability to move their entire body by crawling and gliding. It is a very playful and informal way of interacting, especially when the therapist is also sitting on the floor. Children with gross motor difficulties and who have less control over their entire body can push an additional big button. Turning the upper ring requires more control and coordination between both hands and pushing buttons requires fairly fine motor skills of at least one hand. The position of the screen has next to ergonomic aspects also clear social implications, because it determines

how the therapist and child are positioned in relation to each other. Not just the way of interaction is adaptive, but also the complexity of stories, which means that children of different cognitive levels can use E-scope. In the early developmental stages, the stories use simple concepts and are self-running. After that, the child could learn to push buttons and attach meaning to the colour of that button, which is linked to specific actions in the stories. Finally, the child could learn symbol systems such as Picture Communication Symbols (PCS) that are printed on a ring that can be placed on E-scope. This ring is recognised by the computer using photo-interrupters and linked to the related stories, see Figure 4.

Figure 4 E-scope can be used with or without symbols

5. Multi-media content

The stories that are offered by E-scope aim at being rich and engaging. Therefore, they use a variety of visual and auditory output such as photos, drawings, movies, symbols, spoken stories, sounds, songs and written text. The graphical style aims at being realistic for an optimal recognition of the concepts to be learned, but which enough freedom to stimulate the imagination of the children (Figure 5). A small user study with two children indicated a preference for photos compared to drawings.

Figure 5 Different graphical styles: photos (left –to-right, 1 and 3) and drawings (2 and 4).

For children who have problems with attachment and recognition, such as autistic children, child-related photos can be imported and voice and sound recordings can be made with E-scope. Therapists and parents can also use this option to focus on a specific or actual topic, such as telling the story of a day with pictures of that child's environment or the birthday of a family member. Using a built-in menu, which is operated through the upper wooden ring, one can customize the E-scope. By turning this ring, one moves through the different screens, as if they were placed behind each other. If the desired screen is shown, it can be selected by pushing one of the buttons. This brings the user to the next menu levels, which can be browsed through in the same way. By turning the ring to the right, one goes deeper into the menu, and by turning to the left one goes back up again (see Figure 6). Extra feedback is given through LEDs and sound.
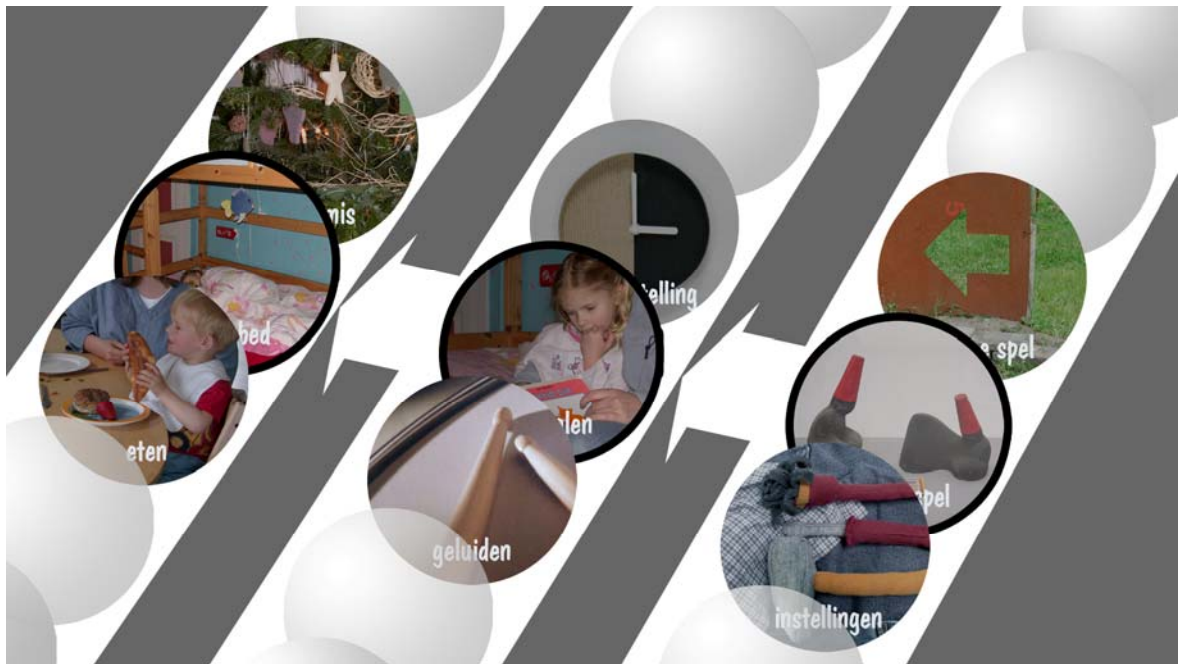
Figure 6 E-scope upper ring turns through the menu screens

By turning the upper ring the user goes through the screens of the menu, as if they were placed behind each other (Figure 6). On the first level one can select the overall functions like preferences, choice game and previous game (Figure 6, right). If one selects 'choice game' by pushing an arbitrary button when this picture is displayed in E-scope, one gets the different options for the second level (Figure 6, middle), for example sounds, stories and contrast. When selecting e.g. 'stories', one can choose different stories like eating, going to bed and Christmas (Figure 6, left images).

6. E-scope prototype

To develop a working prototype of E-scope we designed software architecture with three subsystems, briefly discussed in the next sections and illustrated in Figure 7.

Figure 7 System diagram
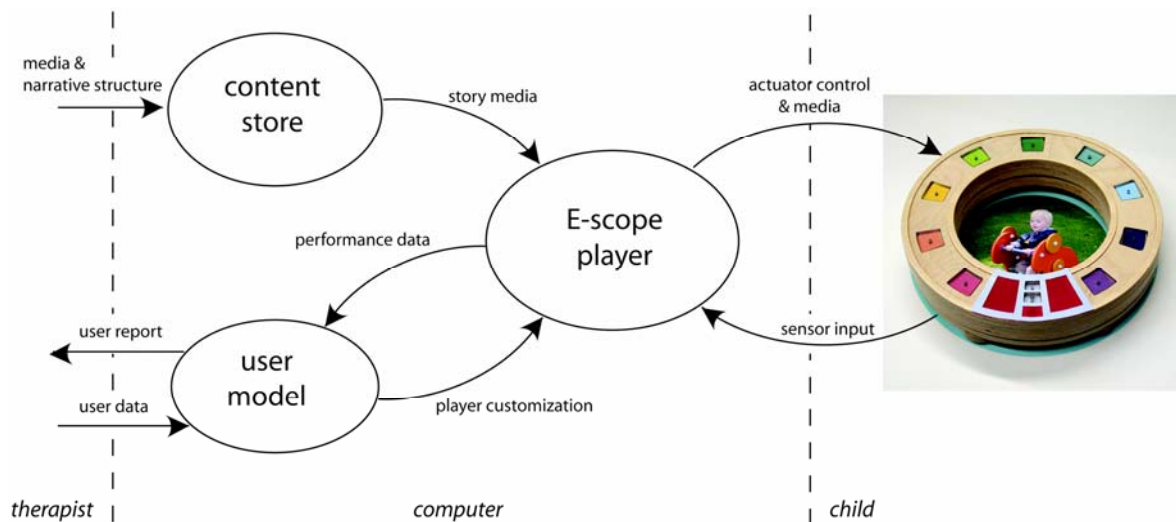
6.1 The content store
The content store is a collection of stories and games. The scripts for the narratives are developed based on literature on the linguistic development in the first years of a child's life (van Balkom et. al. 2002). From these scripts, all elementary content material like photos, movies, drawings, spoken text, etc. are created and imported into the content store.

The next step involves linking these elements into narrative structures like arranging the pages of a story. Then the conditions for page transitions are defined; these are coupled to specific actions on the tangible controller, e.g. a button press. The conditions can also be seen as educational targets, the reward for pressing the right button is getting to the next page.

For example, within the story *"Jitte goes to bed"*, the first page consists of:

- A picture of Jitte who is tired (see Figure 5)
- A sound file with a voice saying: "Jitte is tired, she wants to go to sleep"
- And the condition: move to the next page once page is presented

The second page consists of:

- A PCS icon of the word 'sleep'
- A sound file with a voice saying "sleep"
- A picture of the words 'sleep' in text
- And the condition: wait for button press of button showing the PCS icon 'sleep'

By placing these files in the content store and after assigning links and conditions, the final story that will run on E-scope can have the following outcome:

> E-scope starts by saying, "Jitte is tired, she wants to go to sleep" and meanwhile showing the photo of Jitte lying on the couch.

> Subsequently, the system automatically starts page 2 and the voice is saying, "sleep" while showing the PCS icon of 'sleep' and with the text 'sleep'.

> Now the child has to push the 'sleep' icon on the ring, or any button when no PCS icons are used, or even no action at all when the E-scope is running in automatic mode.

> The word 'sleep' is repeated again and subsequently the following scenes appear until the entire story with nine scenes is played.

Therapists and parents can add to the content store with stories tailored to the needs of an individual child, although the majority of stories will be imported beforehand. The current version has two stories 'Jitte goes to bed' and 'the children's farm'. Only after having tested the different concepts (e.g. E-scope, PictoCatcher and ObjectSlider) and having decided upon the chosen concept, the stories and games will be further developed.

6.2 The user model
E-scope can adapt content browsing to the physical capabilities, knowledge level or concerns of the child through the user model subsystem.

The system can also record performance data in the user model to enable the therapist to gain insight into the progress of a child. For example, the first time when the child uses E-scope, a profile has to be made, stating the level of motor skills (ability to push buttons, use of specialised input devices, preference to use at a certain place etc.), the cognitive and linguistic level (vocabulary, pronunciation, mental development, mastering of certain games etc.), attitude (level of independence, social interaction, level of communication etc) and personal concerns (preferred graphical style, hobbies, preferred subjects etc.).

6.3 The E-scope player
E-scope can adapt content browsing to the physical capabilities, knowledge level or concerns of the child. The E-scope player subsystem is tightly coupled to the content store and the user model. The E-scope player interfaces the tangible controller and detects the configured page transition conditions, upon which it schedules the playback of content on the next page and updates the user model to reflect the progress made. For example, if the child has a fairly low linguistic developmental level and rather fine motor skills, the E-scope player subsystem can decide to use the coloured buttons and show the next page when an arbitrary button is pushed. When the child is not responding and no button is pushed within 5 - 10 seconds, the E-scope can give a hint on the screen or through its LEDs or speech.

7. First user test and conclusions

The current version of E-scope a not a fully implemented product, but a prototype to enable us to evaluate the interaction with it, the playfulness, the general impression, and get feedback for further development. This

first version of E-scope was tested with three children and three therapists in the Rehabilitation Centre St. Maartenskliniek in Nijmegen, The Netherlands. E-scope was explained to the therapist before the actual therapy began. Two children used the '*Jitte goes to bed*' story, one on the table and one with help from the therapist on her wheelchair, and one child used the '*the children's farm*' story on the floor (see Figure 8). Each session took half an hour and was conducted during a 'regular' speech therapy session. The sessions were annotated by an observer on the spot and also videotaped for further analysis afterwards. The therapists were interviewed after their session with respect to their general impression, feasibility of the concept, challenge, playfulness, the support for learning, tangibility, the suitability for teaching, connection frame of reference of the children and graphical style.

Figure 8 Therapists test three children with E-scope

Figure 8 shows E-scope being tested by three children with their therapists. Child 1 (left) preferred using an E-scope with an integrated LCD display. Child 2 (middle) was persuaded to listen to short stories by rolling the E-scope over large drawings that were lying on the floor. Child 3 (right) preferred moving the E-scope across the table, turning the upper ring and pushing the Picture Communication Symbols (PCS) on the wooden ring to hear and see stories on a separate screen. The test indicated that the overall concept is promising and useful. The therapists were very positive about the toy-like appearance and its playful, engaging and sensorial character. They were enthusiastic about the diversity of interaction style and multi-media output, thus supporting different strategies and skills, which is hard to do with the currently used methods and tools. Moreover, the therapists preferred further adjustments to improve the personal fit. For example, the therapist from child 1 would like to use E-scope with an integrated motor that can be operated through eye-movements.

Working with a novel toy and two observers was a bit too much for the autistic child 2. His therapist advised us to enable his family creating their own, familiar content (images from home and speech from his parents). Moreover, if child 2 could get familiar with E-scope by using it frequently as a regular toy, e.g. a musical instrument; it could help the speech therapy with E-scope. The therapist from child 3 wanted an integrated screen to enhance social interaction by sitting opposite each other with E-scope in the middle. The children gave a similar impression when looking at their behaviour. The two girls were very enthusiastic. Child 1 was clearly excited by the stories and graphics, and seemed to feel enjoyment during interaction (laughing frequently) and she had a proud look on her face after having selected the correct PCS symbol several times. The toy amazed and captivated child 3 who had her eyes wide open and who was showing a beautiful concentration. The tangibility of the toy challenged her to push the buttons frequently and she was delighted to receive the movies as a kind of reward. Child 2 was very restless and was overwhelmed by this deviation from his regular routines. However, despite this behaviour, he immediately understood the working of E-scope and interacted with it frequently. E-scope will be further developed in the near future and tested again with children. The findings of the studies are used to enhance the development of other concepts. The results of the overall conceptualisation phase will be an extensive user study with a full-working prototype.

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Notes[1] LinguaBytes is a cooperation between Viataal-Research, Development & Support (RDS), Radboud University Nijmegen and Delft University of Technology. The Phelps Foundation and seven other Dutch funds sponsor the project.

Interactivity in work with disabled

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Abstract

This paper reflects upon a case study where exploration, play and empowerment in interactive therapy sessions with audio and visual stimuli resulted in achievement, self-esteem and a shared pride between a young adult with profound and multiple learning disabilities (PMLD), his mother and the special teacher that conducted the sessions. Following the gift to the mother of a video recording that depicted the young adult's progress as a result of the sessions it was found that upon viewing he was able to recognize himself and associate to his activities. Further, when watching alongside his mother, the recorded material became as a mediating reference for his communication. Conclusions consider contextual parallel activities from earlier research where digital paintings that were printed from screen shots of interactive sessions and recorded auditory achievements were presented to helpers and family of similarly severe disabled users.

Keywords: Curiosity, novelty, concentration self-expression, cause and effect, therapy.

1. Introduction

The study included in this paper is based at a special school in Landskrona, Sweden, where eighteen students between the ages of 8 - 55 years attend a single session of interactive audiovisual stimulus therapy every week. The duration of a session is mostly between 15 - 45 minutes in length depending of the individual. The students have a variety of diagnoses and all are severely disabled with mental retardation. All sessions are filmed on video and edited for the purpose of monitoring progress. All students are given a copy of edited sessions from the year to reinforce the experience and to show to their families and other people figuring in their life. The work has evolved from that reported earlier as a result of three European research projects. In the first, titled 'CARESS'[1] (Ellis 2004) solely sonic elements (music scale tones) were used as the feedback stimulus in response to (1) sensors that were attached to the body and/or (2) movement within a linear ultrasound sensor that is commonly used in the field of disability called Soundbeam[2]. The second research project was a feasibility study funded as a future probe by the European Network for Intelligent Information Interfaces[3] titled Twi-aysi[4] (Brooks et al. 2002), acronym for 'The World Is As You See It'. This feasibility study was an extrapolation from the ongoing evolving body of research titled SoundScapes (Brooks 1999, 2002, 2004, 2006) where 3D non-invasive sensor technologies were developed to empowered adults and children with severe disabilities to control audiovisual feedback from intuitive and natural gesture as a means for treatment and analysis. The third research project segued directly to the feasibility study and was called 'CAREHERE'[5] (Creating Aesthetically Resonant Environments for the Handicapped, Elderly and REhabilitation) and reported in Brooks & Hasselblad (2004). CAREHERE was funded as a European Project under Framework V IST (Information Society Technologies) Key Action 1 supporting the programme for Applications Relating to Persons with Special Needs Including the Disabled and Elderly. Multimodal stimuli feedback including the forms reported in this paper were used in CAREHERE.

Multimodal stimuli interaction involves a (student input) *feed-forward action to system multimedia feedback response* (student stimulus), which evolves as an iterative loop that empowers an intuitive engagement with the interactive environment that is confronted by the student. The selected feedback is idiosyncratic and reflects knowledge gained from participatory input from those closest to the students, e.g. family, helpers or therapists. Mostly the tailored content is targeted as giving fun, playful and/or creative experiences to the student. This can be in the form of concrete feedback such as specific interactive digital games that address the competence level of the student and where the student views his or her input results on a large screen that is positioned directly in front for targeting immediate associations, - or it can also be abstract composing with sounds or visual feedback such as painting, colouring or a combination of the choices available. The main

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[1] http://www.bris.ac.uk/caress/
[2] http://www.soundbeam.co.uk/
[3] http://www.i3net.org/
[4] http://www.bris.ac.uk/Twi-aysi/
[5] http://www.bris.ac.uk/carehere/

thing being that the personal profile initially created is continuously evolving according to input device and output content feedback selection so as to optimise the student engagement in a fun and joyful manner.

This is referred to as "ludic engagement" (Petersson 2006, Brooks 2006) and is optimally created through non-invasive interface technology i.e. non-worn sensors that are capable of sourcing bio-signals; which in this particular case study focuses upon movements and utterances. Such a loop enables the student opportunities in which he can play and express himself through a safe and challenging environment. In the environment there are no inherent expectations of the student and no rules to obey in how to act - besides the damaging of microphones through overly zealous engagement as in the case study herein reported!

The created interactive environments and the experiences generated for the student offers an ideal situation from where to collect data of the effect on the user (input/output) with minimal corruption through his or her research bias. Video recordings enable post-session analysis and inter-coder annotations to be made so as to further refine the system and inherent selections in an iterative manner. The resulting activities of the student when confronted by the interactive environment have led to the hypotheses that are the foundation of the SoundScapes body of work. In this article specific game content is not involved.

Since most of the students do not have the physiological means to express their wishes, preferences and desires, the interactive environment becomes a tool for communication, wherefrom the therapist or facilitator is engaged to interpret what he or she understands as potentially being the student's current thoughts, concerns and desires. This defining of the meaningful communication is sourced from the student's non-verbal body language, nuances of gesture and the ability of the therapist or facilitator to 'feel' through the tacit knowledge that is gained from experiencing and sharing the interactions with the student. As the system is affective to the student's expressions, the designation of the specific "moments of communication" by the therapist or facilitator is imperative to the student gaining optimal experience, and hence training potential benefit from the concept. This optimal scenario is encountered when the challenges that are embodied in the interaction with the environment confronted by the student matches a competence that is garnered from the created and evolving personal profile. In other words, the play aspect within the interactive environment offers opportunities for the student to communicate through self-expression and to approach a state of *flow* (Csikszentmihalyi 1991, 1996). Additionally, the adaptive features of the environment provide appropriate opportunities for the student to achieve mastery and enhance communication.

In this paper, the play is considered as social, where the adult (therapist/facilitator) is of decisive importance for the development of the play (Bateson 1976, Vygotsky 1978, Olofsson 1987). In line with the activity theory (e.g. Vygotsky 1978, Leontjev 1982) we consider communication as a part of the play. This is in contrast with the communication theorists (e.g. Bateson 1976, Olofsson 1987), who primarily look at the play as communication. In line with Lisina (1989) we consider this view as limited as the play also, beside the communication, contains a content, human and social functions, which are communicated through the play and, accordingly, have to be considered. Thus the overall aim of this paper is to illustrate how adaptive interactive environments, which can be tailored to match a user, can stimulate and empower play and communication through self-expression. More precisely, the aim is to take the student's experiences within the interactive environment and the parent's descriptions of the student's progress as starting points to interpret how the student understood the content of the play and the communication and the interaction embodied within the play.

In line with Petersson and Bengtsson (2004) we regard empowerment as a dynamic concept that concerns individuals' possibilities and resources associated with growth and development in everyday interactions. By this, we take on a holistic and process directed view on empowerment (in contrast to considering empowerment as a mental state), where the play in the interactive environment serves as mean to enhance the individual's communication through the feed-forward, feedback loop (self-expression). At a philosophical level, this view enable experiences with an outcome of a more positive self-perception and belief in the own ability and capacity (Petersson and Bengtsson 2004).

2. Method

The aim of this research was descriptive and centered on achieving an understanding of how interactive environments can stimulate and empower play and communication through self-expression. The decision was that this aim was best achieved by qualitative research methods. A case study using observation was conducted with one child with multiple disabilities who was interacting with digital technology as an assistive means to empower his interaction in a responsive environment. Additionally, documentation in the

form of an unsolicited letter from the mother of the student and open-structured interviews are referenced in the case study. In this way it was hypothesized to be able to define characteristics of play and communication in interactive environment for use in therapy.

2.1 Description of Rasmus

Rasmus is 16 years-of-age and has an estimated intellectual age of 2½ years. According to the neuropsychiatric judgement Rasmus has an extreme motorical impulse driven over activity, profound mental retardation, Angelman´s and Pader Willy´s syndrome and epilepsy. He needs constant supervision both in the outside and inside environment. He has severe concentration problems and is very difficult to handle in conflict situations because of his strength and size. He pinches, spits, kicks and bites both himself and others and is very demanding to work with. Waiting, social interaction, obstinacy and sticking to rules are other areas where Rasmus could have problems. Most of the time he is in good spirits but he is very difficult to motivate and engage in any activities.

2.2 Material

Digital technological assistive means, as described above, are used to empower Rasmus to extend his own limits through interacting with multimedia. The multimedia is real-time corresponding auditory, visual and vibratory feedback that is manipulated as a direct result of feed-forward movement. To achieve the auditory feedback a number of devices were used. The main device used was the Soundbeam. This consists of a sensor head (Figure 1 shows two) and a control unit (Figure 2) that together empower the playing of music without any need for dexterity or strength. The sensor head emits an invisible linear ultrasonic signal to detect movement within a defined range. Detected movement results in a corresponding signal generation from the sensor's controller unit as MIDI (Musical Instrument Digital Interface) information, which in turn is routed to a sound module. The sound module contains synthesised digital algorithms that closely replicate known musical instruments. The sounds can be determined by a user profile that saves favourite selections and combinations. Presets in the Soundbeam controller enable blues or other scalar improvisations. Thus the ultrasonic beam acts as a non-intrusive interface within which interference and subsequent movement change activates a signal transform that subsequently results in an auditory representation of the movement that is direct and immediately available for associated correspondence by the student initiating the action. In the sessions with Rasmus a number of touch-sensitive switch controllers were also used as tactile stimuli and these were also routed to the Soundbeam controller to empower him to create further favourite sounds.
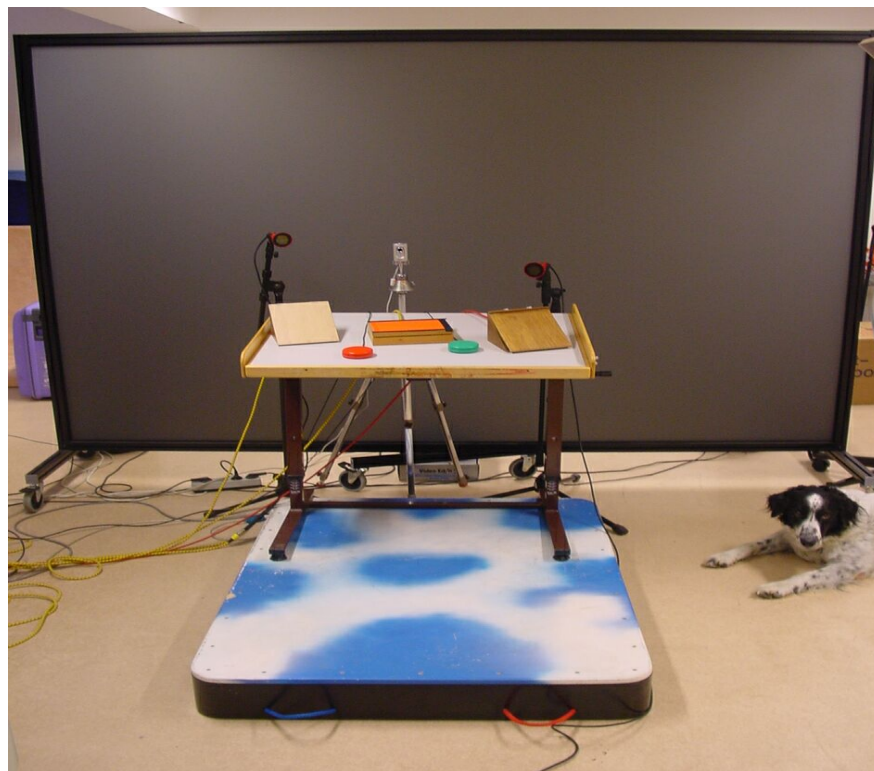

Figure 1 Two Soundbeam sensors on stands plus camera on tripod in front of the back projected Perspex screen. The table with tactile switches rests upon the vibroacoustic soundbox platform

Figure 2 (left) Soundbeam control unit (upper left), stereo sound module and stereo effect processing unit (left middle), speaker protection unit for vibroacoustic soundbox[6] (white) with wireless microphone upon it. All rest upon the main system stereo amplifier

A microphone and a sound processor (Figure 2) were additionally used for collecting Rasmus' utterances so as that he could make strange noise effects from generating his own personal sounds.

The sounds that result from Rasmus' movement were routed to a vibration soundbox box that contains an amplifier feeding a low frequency speaker array. The wooden box resonates to the sound and enabled Rasmus to 'feel' variations in pitch frequency that changed as a direct result to his movements.

The visual feedback attributes of the system was through a video camera sourcing movement data which was routed to a computer running programming software called Eyesweb[7]. Specific algorithm patches that were developed as a result of a parallel research study were used (Brooks et al. 2002, Brooks & Hasselblad 2004, Camurri et al. 2003). The patches were called "body paint" as they enable the user to be able to digitally paint from body and limb gesticulations where dynamic and range of movement directly correspond to colour change and saturation.

The body paint visual signal is generated from the computer and routed to a LCD projector that back-projects the image onto the rear of a large screen. This screen is constructed of the material Altuglas Black 'n' White (a form of Perspex) within a box frame profile made from aluminium. The frame is mounted onto supporting wheels for ease of mobility. The screen is positioned directly in front of the user so that the (approximate) one-to-one representation of the user can be directly associated (Figure 3-5). This concept relates to the use in institutes for people with physical disabilities of a traditional silver mirror in body proprioception (awareness) associative training by physiotherapists (Brooks 1999, 2002, 2006).

2.3 Session Procedure
Rasmus' first session was in September 2005 and lasted about 7 minutes. At first it was thought that Rasmus was a little afraid of the massive sounds and the vibrations. He also seemed afraid of seeing himself and the visual projections. It was considered that possibly he was not interested and could not concentrate on the activity. So for the next session the vibration box was taken away. However, Rasmus made it very clear that he wanted it back. He then exhibited much more interest and the session lasted for 15 minutes.

In three weeks the sessions progressed so that due to his elongated engagement a time limitation had to be set at 35 minutes as other students needed to have their session.

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[6] http://www.soundbeam.co.uk/vibroacoustic/index.html
[7] www.infomus.dist.unige.it/EywMain.html

Figure 3 Rasmus sitting upon a chair on the vibroacoustic soundbox which enables him to feel the sounds he generates from his movement in the Soundbeam sensor whilst creating video and sound effects with head, hands and utterances

Figure 4 Rasmus plays with video special effects which distort his face – his response is immediate joy

Figure 5 Rasmus in serious concentration as he multi-tasks in playing upon the tactile trigger switches which creates sounds he can feel from the soundbox whilst painting through gesture dynamics

2.4 Data collection and Analysis

Total observation timeline for the case study ranged circa 28 sessions over a period of one (1) year, with a mean duration of 30 minutes per session.

In this study, a qualitative observation guide based on the exploratory aim of the study and a review of literature was used. Three topics guided the observation process: (1) the child's perception of the interactive environment, (2) specific interests and (3) achievements. All sessions were video taped. On a regularly basis the parent of the student was involved in the reviewing of the collected and edited video tape data. This approach is in line with related research where we have developed a methodology named *participative involvement through recursive reflections* (Brooks and Petersson 2005a).

Video and observation annotation were central to the analysis. The transcribed observations were coded separately by one of the three authors and then checked for validity by the parent and the helper. The data were analyzed using an explorative, inductive method (Atkinson and Delamont 2005).

Ethical considerations were made and the parent was approached about the study, informed of the goals, and were asked to give permission on behalf of the student beforehand.

3. Results

The results are based on the analysis of a case study including weekly therapy sessions using digital technology and the analysis of open-structured interviews with the parent to the student involved in the case study. The student's actions within the interactive environment were the basic unit of analysis. Our findings presented the facts that it was useful to apply an *inclusive participative analysis* (Brooks and Petersson 2005) of the video material to understand critical emerging elements in the progress of the student's communication.

Two main themes emerged from the data that were related to the child's interaction with the digital technology. These themes were: (1) "My expressions causes funny effects" [section 3.1], and (2) "I need guidance – at least for a short while" [section 3.2].

The results pointed to motivational potentials in the form of novelty and curiosity from self-expression within an interactive environment. The choice of the digital devices was astute through their ability to generate variance of multimedia feedback and to project the stimuli across a required range of physical wall space.

The 'physical-ness' of the units, i.e. being robustly real and touchable with inherent audio and visuals, also seemed to offer a conduit that the student liked and which facilitated progress in his play and communication according to the therapist and to the parent.

3.1 My expressions causes funny effects
Through exploration Rasmus quickly exhibited a clear understanding of how all devices were to be operated. Often he discovered a special effect, e.g. a sound, and remained with that for a session. These discoveries resulting in an understanding of the device contained an exploratory driving force, which, in turn, led to that Rasmus started to experiment with the multimedia feedback.

When experimenting he showed a high degree of concentration he exhibited happiness and surprise, often laughing out aloud as he experimented with his movements, facial expressions, voice, rhythms and sign communication. On occasions he got up from his chair and started dancing. In other words, this exploration and experimentation took the form of a variation of responses from Rasmus. The feedback stimulated his curiosity, which reinforced his own input (feed-forward) and his curiosity.

Rasmus enjoyed to experiment with his voice in the microphone. As stated previously, over zealously he destroyed two microphones by putting them in his mouth so this activity was curtailed. Initially he showed surprise when experimenting with his expressions, but after a while he developed self-awareness and speech ability skills based on the understanding of the cause and effect attributes of the interaction.

3.2 I need guidance – at least for a short while
During the year that Rasmus was attending the sessions there were only two occasions where he refused to participate. On these occasions he showed quite clearly that he was going to sit on the chair at the back of the session room where his helper would normally sit and that he would observe the teacher and the helper performing the interactivity with the system.

When he himself was engaged in the interaction with the system it was observed that regularly he would turn away from the screen in front of him so as to look back to his helper or the teacher[8] for confirmation.

It was important for Rasmus to experience not only surprise, but also familiarity in the features of the environment. Here, the adult (teacher or helper) was bridging Rasmus' "old" knowledge to the "new", by confirming and challenging him – the means of bridging being dependent on each particular situation and often improvised through experience. Both the surprise and the familiarity awakened the curiosity to explore and to experiment. However, the surprise, more than the familiarity, had the power to attract Rasmus' attention. This showed that his exploration of the interactive environment was activated by the surprise, and initially dependent on the familiar aspects of the situation. Shortly after the surprise Rasmus was absorbed by the exploration and play, and the teacher could take a step back in the guidance of Rasmus.

4. Discussion

Key components that are required for play and communication will be discussed relating to individuals engaging with digital devices and multimedia feedback. Through cause and effect and the surprise feature of the interaction (based on Rasmus' input or feed-forward action) he could acquire new abilities, interactions, expressions, and emotions, enabling a mastering of the exploration and practicing of skills. An observation of progression from unintentional to intentional was evident through the sessions especially where surprise from explorative actions resulted in playful intentional activity that resulted in achievement from doing.

4.1 Exploration – a form of motivation
The interactive therapy sessions indicated an enhancement of the quality of play and communication, which, in turn, facilitated explorations and experimentations that were utilized in the therapy. Berlyne (1950) refers to interactions such as reported in this case study as *instrumental exploration*, motivated and learned by the cause and effect and *surprise exploration* awaked by pure and simple novelty. This is to say that the

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[8] teacher is used interchangeable with therapist or facilitator

instrumental and the surprise exploration achieved from the interactive environment have relations as forms of motivation due to the novelty (see also Berlyne 1950). However, these statements relate to problems that demand further investigated. What was shown though, was that the interactive environment had the potential to evoke the student's interest in expressing and practicing otherwise limited skills. This interest was not just *in* the session but also *on* the session as reported by the mother's letter to the teacher. This *in* action and *on* action reflection relates to the design and educational theories of Donald Schön (e.g. 1983, 1991) and relates to the SoundScapes concept as reported in Brooks (2006) and in Petersson (2006) relative to her theories on non-formal learning in interactive environments.

Vygotsky (1981) states that play is the source to a child's development. When the child is playing a potential development zone is created – the Zone of Proximal Development (ZPD). The ZPD is defined as the distance between the actual level of development, - which is determined through the child's own way of solving problems - and the potential level of development, - which is defined through guidance of the adult (Vygotsky 1978). By facilitating Rasmus' optimal experience of the interactive play through the bridging of his old knowledge to the new, the teacher created a fit between the skill level of Rasmus and the challenge offered by the digital device/system. However, and as stated above, the guidance from the teacher was crucial in relation to the awakening of Rasmus' curiosity, which in turn was initially important in order to create familiarity. When the initial familiarity was established the surprise by novelty was the driving force for the exploration. In that way, the interactive play offered an experience where Rasmus was able to experience surprise, awareness, and growth.

5. Conclusions

In this case study the goal was to illustrate how interactive environments stimulate and empower play and communication through self-expression. According to Rasmus' teacher, helper and mother he has gained better concentration and is more harmonious and exhibits an increased sense of happiness with an improvement in his well-being apparent. Also his understanding of cause and effect has improved so that he better understands the consequences of his actions. Rasmus is aware and happy when it is time for the session and is always eager to go to them. He also more readily accepts when his time is up for the session.

Through working with such case studies as Rasmus therapists and teachers have stated realisation at the power of creativity. Through giving a success to children and adults with functional impairment an important self-worth is evident as they get an opportunity to show the achievements from their activities to those around them in their daily lives away from sessions. As a life quality this is important. The research is subjective and based upon teacher and parent reports correlated to video annotation. The triangulated research material is cross-informing of the progress for the students. The approach of bringing in parents to view sessions and to give interviews is important for the continued development of the research. Only those closest to the student can judge from the tacit knowledge inherent of living each and every day with the student.

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e-Skin: Research into wearable interfaces, cross-modal perception and communication for the visually impaired on the mediated stage

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Abstract

Today our cultural events are dominated by visual information based on sight and sound, but hardly at all on the combined senses of touch and sound. Visually impaired users, lacking sight are not often able to engage in cultural events. Compensated audio-description or talking books are standard products that visually impaired people can buy to imagine feature film stories or decide what is happening on the stage. Very little theatre, dance or art events exist in which these people can actually participate. Interfaces are not often designed which promote communication between impaired actors, nor allow them to navigate and control audio-visual information on the mediated or digital stage. As neuroscientists suggest, the unique cross-modal potentials of human sensory perception could be augmented by electronic devices, which in turn might communicate with sighted audiences. Our research group is interested to address these problems by constructing ergonomic HCI (Human Computer Interfaces) that can explore the above problems including research into orientation, cognition mapping and external audio-visual device control. Consequently, we are implementing our discoveries in artificial systems, which can interact intelligently with people on the digitally simulated stage.

Keywords: HCI, cross-modal interaction, visually impaired users, mediated stages, ergonomic design.

1. The e-skin approach

"E-skin" is a set of interfaces, which constitute our past and present attempts to electronically simulate the perceptive modalities of the human skin: pressure, temperature, vibration and proprioception. These four modalities constitute our biggest human organ, constantly detecting and reacting to environmental realities. Our research team is engaged with the mimicry of skin, alongside extensive user testing to assure we make relevant developments for cross-modal potentials, including tactile and acoustic feedback, cognitive mapping and embodied interaction. Cross-modal interaction is the label used in neuroscience to describe how certain features of objects perceived in ones sensory modes go-together with features in another sensory mode.

We are particularly interested in the relationship between tactility and acoustic feedback as well as the mediated stage as a feedback loop or "visual substitute". What is the actual relationship between pressure and sound, temperature and volume and proprioception and vibration? Our group explores cognitive mapping, touch, movement, electro-stimulation on the skin itself, gesture and relief differentiation, in order to uncover some answers to this large question. Cognitive mapping exercises or tests about the composition of acquired codes, stores, recalls and decodes, determine relative locations and attributes in the spatial environment of the stage itself.

Our mediated stage is a hybrid platform using surround sound and three screens with related potentials of communication and movement and gesture as well as audio-visual response or what theorists call "embodied interaction". As Paul Dourish (2001) suggests, "Embodied interaction" is not so easy to achieve without taking into account physical and social sensorial phenomena, which unfold in "real time" and "real space" as part of the particular environment in which the visually impaired are situated". Therefore our impaired user's relationship to the stage and their consequent levels of skin perception are very important to the development of e-skin. Although Dourish posits that "embodied interaction" can replace the screen, we are interested in the mediated stage as an incorporated platform because digital screens and sounds are an integral part of our society and our cities: a combination of both real and simulated realities. However, HCI interfaces which fall into the category of impaired applications on mediated platforms are often hindered by other complications. First, most commercial enterprises consider interfaces for the visually impaired in cultural environments to be uninteresting investments, due to small market value, and second, communications difficulties often occur when research initiatives cross-disciplines between the arts and the sciences. Our team and our impaired participants, struggle on because we find the subject and the embodied potential use of e-skin challenging and empowering.
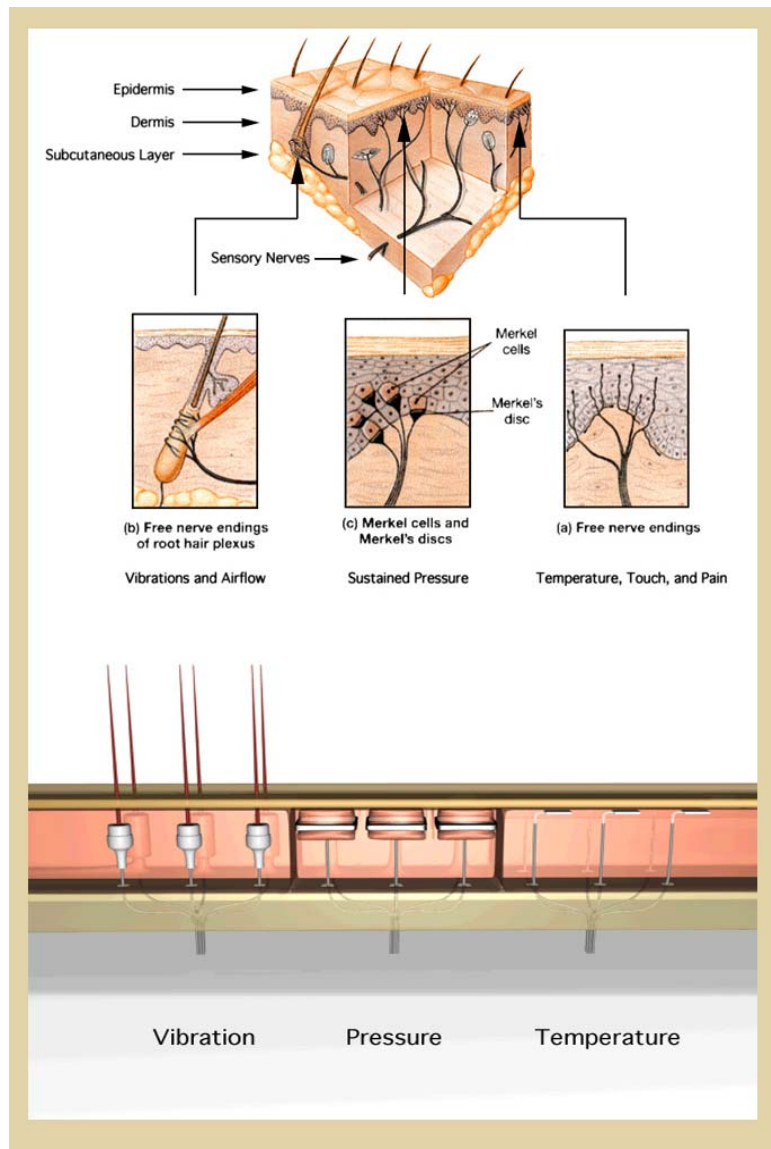
Figure 1 Skin modalities © Bisig & Scott

So far our methodology has been to simulate the skins modalities with off-the shelf electronics tied to a mediated audio-visual environment or stage and then invite our impaired users to test them. Not only can wireless technologies be used to transport electronic tactile and sound cues, virtual communication between visually impaired participants be increased but could also serve as a communication protocol for non-impaired audiences. We believe that tactile stimulation and acoustic feedback by an impaired actor could be transferred into visual stimuli for a sighted audience.

After developing and testing two prototypes, our group still continues to explore the theoretical and practical potentials of cross-modal tactile and sound interaction alongside digital visual output. On the one hand we are developing tactile feedback and electro-stimulation onto the human skin itself, by constructing wearable circuits embedded with micro sensors, actuators, wireless technologies and pocket size computers. For example acoustic and tactile feedback can easily be utilized for navigation and orientation. On the other hand, we are conducting workshops in simulated and mediated stage scenarios, where we can explore more universal levels of metaphors, cross-modal interaction, communication and comprehension in relation to the combinations of tactility and sound. Through our workshops we have found that electro-tactile simulation can definitely improve the cognitive mapping of mediated spaces, particularly if complimented by metaphorical associations, which are linked to cultural preferences like music or nostalgic abstract sounds from childhood. This paper will trace our previous research, user-oriented workshops and our basic, applied and theoretical goals.

2. Previous research

Our previous research was conducted in two prototype stages and then in a set of specialized workshops. The first set of e-skin interface prototypes was called "Smart Sculptures". These shell-like shapes were built by Jill Scott (HGKZ), Daniel Bisig (AI LAB), Rolf Basler (ZMB Aarau) and Andreas Schiffler (HGKZ) using basic wireless portable PICs or programmable micro-controller based technology, body temperature sensors, piazzo vibration sensors and pressure pad sensors. The modality of proprioception was mimicked by infrared technology and tilt sensors imbedded in three interfaces. All interfaces were linked to a central Linux server and three client Mac computers running Java Scripts. Through these interfaces and clients, the users communicated to three screens and a four-channel surround sound system. The content on the screens depicted the molecular and neural layers of real human skin and the participant was able to navigate though the layers in real-time. The pressure sensors triggered sounds, the temperature sensors variegated their volume and the tilting of the interface shifted the image. The vibration sensors controlled the speed and response of animated figures on the screen. Two visually handicapped people, one with 10 percent vision and another with 2 percent vision were invited to test the interfaces on this mediated platform.

We not only concluded that skin-based modalities could create unique forms of cross- modal interaction within media environments, but we found that the visually impaired actually prefer portable combinations of tactile and acoustic feedback. The results showed that sound feedback can only be a valuable navigation device, when it is received alongside other embodied sounds in the environment, as visually impaired people often create a type of tongue-clicking sound, which bounces of solid objects and helps them navigate. Blocking the ears severely hampers navigation.
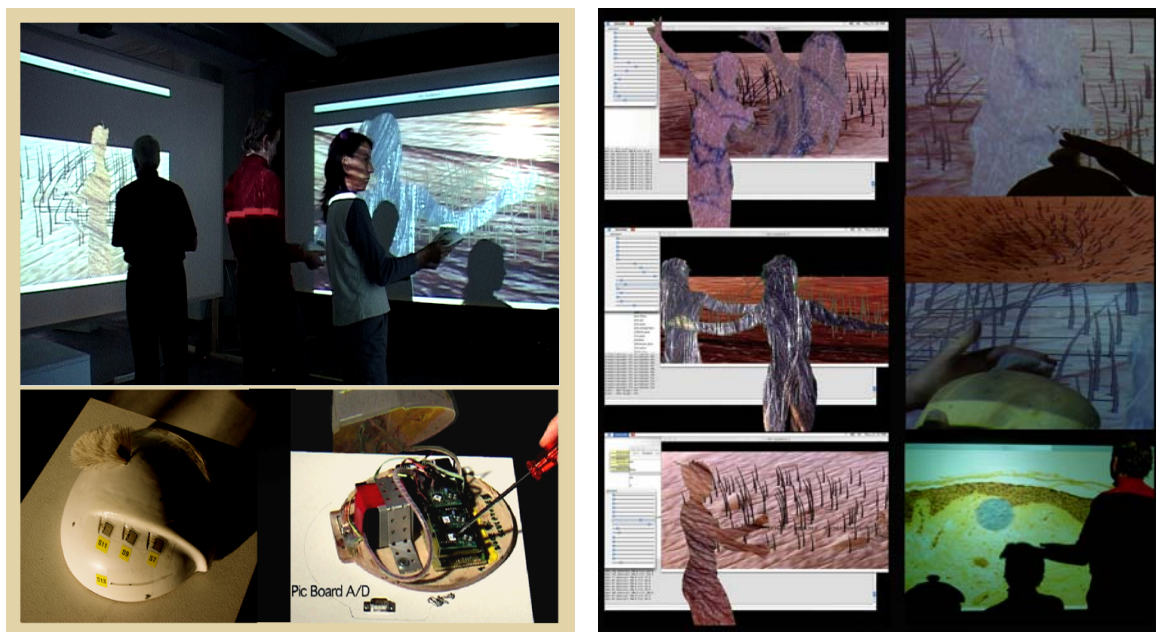

Figure 2 (left) Prototype 1: controlling the mediated stage with 3 interfaces based on 3 skin modalities (right) details of the screen display © Bisig & Scott

They also preferred to customize their own sound samples and once they learnt the associative relationship of the visual database, they enjoyed manipulating visual information on the screens. We continued to design two new mediated stages, which might be more customizable and incorporate more wearable tactile and sound feedback. Our focus turned to the potential of tagging objects so that they could be identified through sound feedback by speakers placed directly on the shoulder and RFID (Radio Frequency Identification) tagging was brought for tests on movable stage-screens and on the bodies of the users. This led us to the second stage, which was also funded by the KTI (The Swiss Bundesamt for Innovation and Technology).

Alongside the difficult endeavour of finding industry support, we developed another e-skin prototype test with RFID- tracking using a PDA (Personal Digital Assistant) with sound files and batteries located on a belt. We conducted tests in both shopping environments (related to our industry potentials) and also with non-impaired dancers for the mediated stage. In dance and theatre, one has more control over the design of objects on the stage; by comparison, in a supermarket there are two many similar looking objects, confusing light, and often too many obstacles in the way.
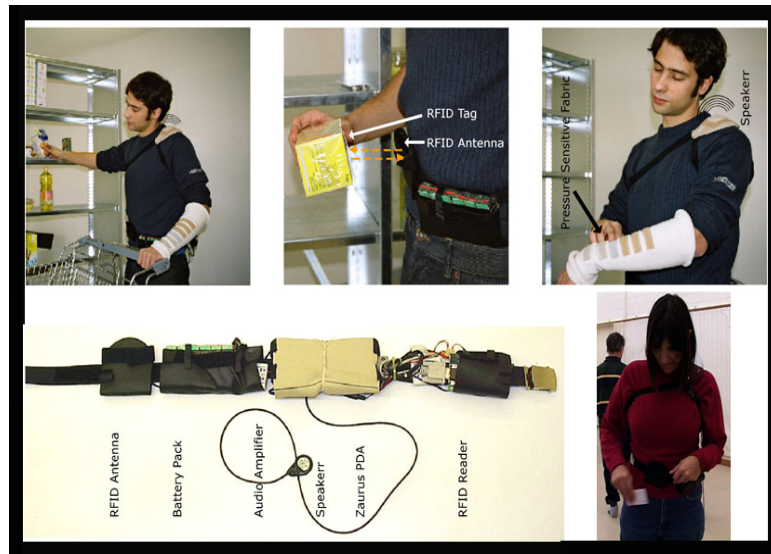
Figure 3 Prototype 2: RFID belt and wearable interface tests © Bisig, Schiffler & Scott

Certainly the RFID prototypes, and their associated sound files were successful aids for recognition of objects, which contained different substances but shared similar shapes. However tracking the location of the objects in a complicated environment would have required a much more extensive-raged RFID system. Our collaborators, GlobIS Systems ETHZ, conducted a feasibility study in the form of questionnaires to see if visitors could use this RFID based e-skin as a cognitive map when they attended cultural events. The events were the Edinburgh Theatre Festival and the Zurich Museum Night and the results suggested that such an interface could be worn to improve navigation and access to information.

When the RFID prototypes were tested with our eight visually impaired people in workshops, the aim was to see how our visually impaired participants could associate more abstract sounds with the contents of objects (like the sound of knife cutting, with the actual object: bread). Not only were the identification of aspects in highly dynamic and complex environment considerably improved but also our visually impaired participants said they felt a new sense of empowerment.

As we were interested to discover more about cross- modal interaction from users, this stage led to new workshops based on pattern recognition though the skin-perception in relation to cognitive mapping. How might be these modalities be electronically simulated or aided by simulation and incorporated to act intelligently with the real world?
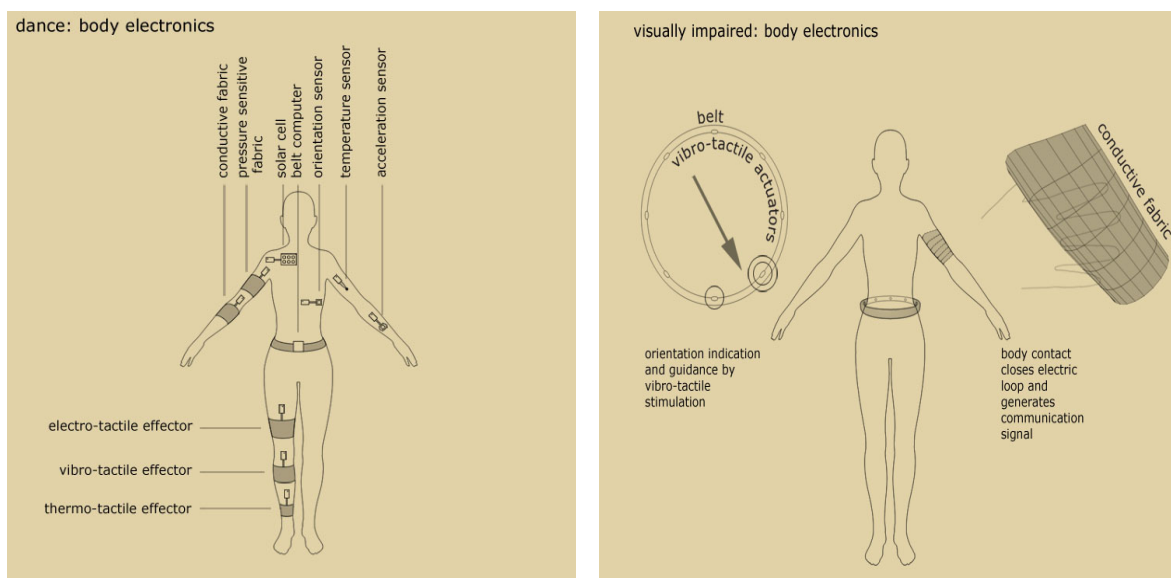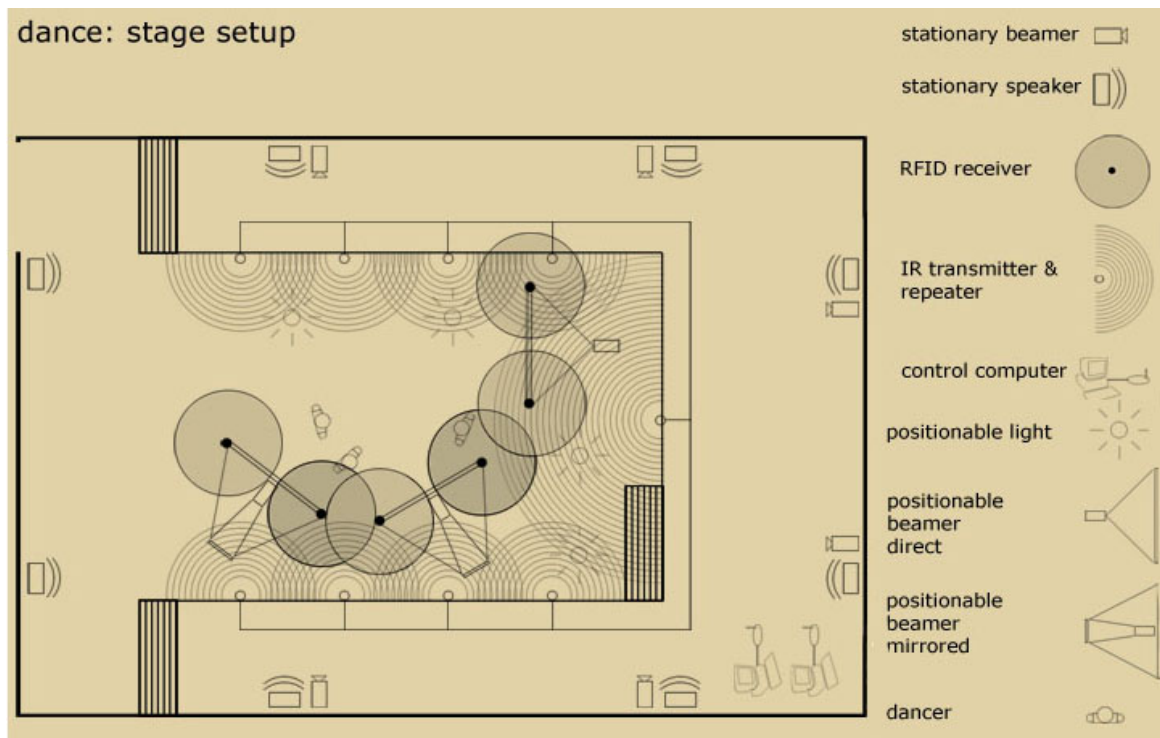

Figure 4 Body electronics © Bisig and Scott

Figure 5 Designs of movable screens and mediated stage © Bisig and Scott

User-oriented workshops:
Our research methodology combines basic and applied research, with constant user testing as inspiration for further development. The workshops were conducted with new partners at Tanzhaus Wasserwerk where we had large amounts of space. Extra participants were organized by the Wohnheim für Blinde und Sehbehinderte, Zürich and movement improvisation specialists were employed. (The Carambole Dance Company, Zürich).

Our testing was observed by "ergonomie & technologie" GmbH and two new PhD students joined the tests: Peter Schmutz from the University of Basel, Department of Psychology and Valerie Bugmann, media artist HGKZ). The four weekend workshops were divided into tasks based on touch, tactile substitution as well as sound and movement/navigation. Some participants were congenitally blind and others impaired by early accidents. The age range was from 20 – 60 years old. A basic list of tasks and results were as follows:

Figure 6 Task 1-4 workshops results with impaired participants: Andrea Kuehm, Freddy Gromme, Diego Metzger, Pascal Leinenbach, Helen Larcher, Claudia Gatti, Martin Meier, Peter Fisler © Scott

Task One: Electro-Touch Sensitivity and Pattern Recognition

We measured the visually impaired participants' touch sensitivity levels using electronic skin stimulation as a cue to orientation. Although each participant had a different idea about importance of touch culturally and functionally, there was a general agreement about the recognition of patterns though skin stimulation. Results: They all agreed that a type of Braille electro pattern-stimulation on the torso could be easily learnt. The majority of the participants proved to have superior tactile perception and could learn to recognize patterns on the arm of the skin, but had they did have some difficulty recognizing patters with dots more less than 2 cm apart, an aspect which could be problematic for miniaturization of the e-skin interface.

Task Two: Tactile Substitution

We set up scenarios in which the visually impaired could participate in cognitive mapping exercises. Could electro patterns stimulate map recognition in the spatial realm? By applying pressure on the arm, we explored the relation between the arm stimulation and relief differentiation mapped on the floor of the workspace. Two relief maps were tested, a grid and a rope road. These were inspired by the success of raised guidelines in the road, which are already used in Zurich for navigation with a cane. Results: These tests had very positive results, they proved that tactile stimulation from the interface itself on the arm, could increase navigational and orientation abilities. However, the wrist and its stimulation patterns had to be oriented towards the direction the participants were already travelling, in order to not be confusing.

Task Three: Improvisation and gesture-based communication

Along with the guidance of professional improvisation experts, we tested the perceptive levels that the visually impaired participants. What relationship do they have to their own body, to other bodies through touch and how aware are they about the meanings of gesture? Would it make sense to include gesture-recognition actuators in the e-skin interface in order to increase their confidence and interaction with others? Results: All participants agreed that movement workshops would help their communication potentials. They felt that trained movement people and stage directors would really help them to increase their perception, attention and motor abilities. Furthermore they thought that it would be excellent if they could "feel" gestures from another impaired actor.

Task Four: Sound and Navigation

We conducted a questionnaire about sound cue preferences, including the tested of other products available on the market, which use sound as a directional navigation aid. We also and tested the potentials of bone-phone sound substitution and conducted a questionnaire about sound customization. Could the creation of customized sound cues in relation to individual metaphors, not only help mobility and deter obstacle collision, but be transferred as a communication code to the server, which could re-transfer it and allow it to be "felt" on someone else wearing the e-skin interface. Results: All the visually impaired participants wanted to create their own personal sound cues for navigation. While speech plays an important role in directional guidance, abstract and discrete sounds are more preferable. Furthermore, the bone phones transducers, which are able to discretely transmit these sounds through the skull bone, which leave the ears free were a most valuable addition. The participants thought that these personalized cues could enhance their hearing and smell, but they could also imagine that a gesture could be "felt" by another human's tactile perception. Customized sound cues were very preferable to Ultra-sonic frequency modulation or alarms.

These workshops enabled us to study the different approaches by the participants to body awareness, touch sensitivity and cognitive map navigation, giving us a clearer idea of how the next stage of the e-skin interface should be designed. Our third stage of e-skin is related to the results from these workshops. We not only learnt that the tactile feedback can compliment sound as a navigation device, but that tactile pattern stimulation can be easily learnt and that accompanying sound cues can be very easily memorized. Bone phone transducers are an excellent way to transfer acoustic feedback. Although RFID tagging can help in the finer selection of smaller obstacles and the reorganization of them on the stage, combinations of different sensors in tandem, might be more valuable for larger mediated stages. As current research into cognitive mapping suggests (Ungar et al. 1996) the ways in which visually impaired deal with increasing levels of modern devices like mobile phones and GPS, needs more exploration. We are suggesting that visually impaired participants might be able to experience the control of audio-visual devices using more intuitive electro-tactile response and customized sound cues. Consequently, the current e-skin research goals-are to create more flexible skins for cross-modal activity, increase the potentials of communication for the mediated stage, further assess navigation and orientation aids currently on the market and create acoustic feedback which can augment cross-modal activity.

3. State of the art comparisons

These new goals combined with the actual building of a mediated stage at the beginning of our research, have intensified our investigation into four research agendas; the potentials of embroidered circuits for flexibility and available, HCI (Human Computer Interfaces) in which sound and/or touch are already utilized, and other interfaces and workshops for the visually impaired. While large amount research has been taking place in robotic and flexible skins, we found that the10-year-old research into embroidered circuits was in need of new directions.

In HCI, we have found hardly any interest in the design of tactile and sound cross-modal interfaces, which can control and communicate with others on the mediated stage, a great deal of current research is worth mentioning. Of great importance to our research is the excellent work of the well-known neuroscientist Paul Bach -y- Rita (Kaczmarek & Bach-y-Rita 1995). After many years of research and clinical work, he has recently developed an application for the visually impaired called "Brainport". This device, which promises to hold the ultimate answer to augmented vision, allows for camera-captured luminosity levels to be transferred to a micro-array pattern generator. This pattern generator can be worn directly on the tongue and help guide the visually impaired to navigate. There are also a few commercial successes in relation to sound and navigation for the visually impaired; these directions also include evaluation and optimization by users right from the start of the interface-developmental process. We have conducted a fair amount of research into these devices; however, we do not have the space in this paper to elaborate on a full comparison. One of our main interests is to find currently available products like the "Bonephone" by Sonortronics[1], which can be modified and integrated into the e-skin interface. The Bonephone accessory serves as underwater acoustic device, which alerts the diver of the presence of metallic objects. If e-skin must be unobtrusive, usable and ergonomic then acoustic feedback must not block or interfere with the visually impaired navigational hearing requirements. So our workshops act as usability tests to scientifically test existing devices as well as the prototype devices we have constructed ourselves. At present HCI interface design for the congenital impairment is based on outdoor navigation problems, rather than interaction problems, which occur indoors, where our home environments are becoming more mediated and open to digital information flow. For the mediated stage more sophisticated and wearable devices are needed. While most acoustic interfaces block the ears, blocking off surrounding sounds (essential cues for navigation) further research in needed in cognitive science in order to understand how cross-model reception works. It is our team's conviction that a combination of studies in sensory perceptions from a psychological perspective with studies about the perception of content in a cultural environment would inform the design of interfaces.

4. Current developments of e-skin.

According to the neuroscientist Baddeley (1992) visually presented material is stored and processed in the visual working memory and auditory information is processed in the auditory working memory. Both systems have limited capacity. Thus, presenting information through alternative modalities, which include touch, makes use of the cognitive architecture and may help keep the cognitive load at a lower level. Part of our user tests have involved research into the accuracy of "feeling with the minds eye" (Sathian et al. 1997) and exploring the potentials of touch, which have already been conducted in clinical psychology (Verry 1998).

There have also been some very interesting studies on the involvement of visual cortex in tactile discrimination of orientation (Zangaladze et al. 1999) which proves that the eye muscles are still engaged in active orientation even though the patter arrays are not received by the visual cortex. As Merleau-Ponti (1962) suggests the phenomena of cross-modal perception in relation to cognitive mapping of an audio-visual environment still needs exploring because the feedback loop of perception itself, is already mimicked in these technologies. Currently we are combining basic and applied investigations with user tests in cross-modal interaction.

4.1 Basic: wearable embroidered circuits, sensors and computers.
In our previous work mentioned earlier in this paper, we have already experimented with hand-held electronic interfaces to control and trigger associations in a 3D mediated stage because we were interested to construct a device which might improve the level of audience immersion and we achieved a high level of automatic real-time control of the audio-visual information with these devices.

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[1] http://www.sonotronics.com/udr.html: Accessed May, 2005

As Dourish (2001) further suggests, the cognitive patterns derived from the sense of touch are an essential component of embodiment and need to be explored at a much deeper level. Many of the physical interfaces that designers have invented tend to concentrate on a level of perceived realism by the grasping of objects and providing force feedback (Stone 2000). Rather our team is interested in interface research, which is capable of providing texture sensation through electro-tactile (Kajimoto et al. 2003), temperature or air pressure stimulation (Asamura et al. 1999). In terms of communication, gesture recognition from actuators placed on the electronic circuit might also loop though the digital feedback on the stage. As Mais suggests (2006) gesture recognition should be based on symbolic gestures, which are gestures within each culture that have come to a single meaning such as "OK". Directive Gestures like "put that there" compared to iconic gestures, or ones that are more about size, shape or orientation should also be considered. We suggest that gestures of unimpaired people can be actually felt by visually impaired people through actuation of points on the embroidered circuit of the smart fabric directly placed on the visually impaired users' skin. After exploring polymers and flexible devices for our first stage of e-skin[2], we decided that flexible fabrics were more suitable for the base of our e-skin interface.

On the basic side our focus is wearable embodied circuits embedded with micro controllers, sensors and computers. This focus includes the re-design of the interfaces to aid easier movement in the space, the construction of tests with embroidered circuits and perceptual analysis and the incorporation of wireless control potentials in relation to touch and sound. Our actual goal is to convey spatial information through pattern stimulation onto the human skin and vibration motors, while outputs from pressure sensors, actuators and temperature sensors provide audio-visual control and communication to other users.
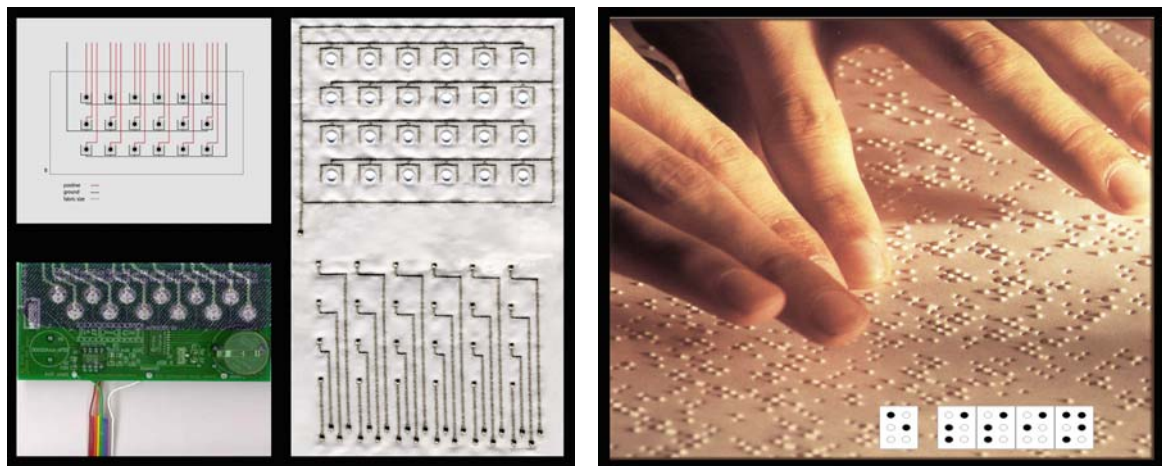

Figure 7 Base of e-skin: an embroidered circuit[3]_ Brail dot matrix patterns have electro stimulation potential[4]

Our current circuit has been designed with two layers so as to maximise the levels of resistance between them. The ergonomic challenge is that e-skin should feel like an interactive second skin rather that an extra costume component. While Human Computer Interaction is of major interest to interface designers and media artists, skin-based modalities have not yet been researched as potential designs for embroidered circuits. Embroidered electronic circuits have valuable tactile potentials (Kirstein et al. 2003), and these potentials can receive in coming communicating gestures from other visually impaired actors. Temperature feedback will also be used as a proximity detector onto the skin, a metaphor, which connects to childhood games of nearer and warmer objects. Braille letters, which consist of a dot matrix, could be mimicked by electro-tactile stimulations to produce coded messages on the skin. According to our workshops with sensitivity tests, the above feedback sensations can be made on the back of the hand, arm or on the torso.

4.2 Applied: systems integration, workshops, mediated stage
The applied aim is to create eight devices, which can control a mediated stage. The final cultural event will demonstrate the interface and the results of the workshops to other cultural planners and directors, who might be encouraged to also use e-skin for their projects. While navigation and communication on the street requires selection, analysis and decision, attending and participating in a cultural event like dance theatre requires different levels of interaction like gesture and reaction, communication and proximity awareness and

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[2] http://www.mal.uic.edu/CAMNA/ MEMS_Announcements/announcements_7_27_01.html, Accessed February 7, 2006
[3] © Bischof Textiles St. Gallen; Bugmann and Scott [3] © Wohnheim für Blinde und Sehbehinderte, Zürich

controlling or using the digital real time potentials of the environment itself as a communication device. With our prior history of designing immersive mediated environments (Hahne 2003), we are confident that augmented realities can help to explore more ergonomic wearable interfaces on the mediated stage. HCI Interfaces, which can cross borders between real environments (e.g. the streets) and indoor virtual environments (e.g. or audio visual environments), are also rare. Even though, the congenitally impaired person may use his or her well-trained sensitive tactile and acoustic skills to easily differentiate between indoor and outdoor environments, access to devices, which can develop more creative potentials indoors in mediated environments are sadly lacking. The mediated stage is an important test ground. One in which, impaired participants can actively participate in acting, communication and movement.
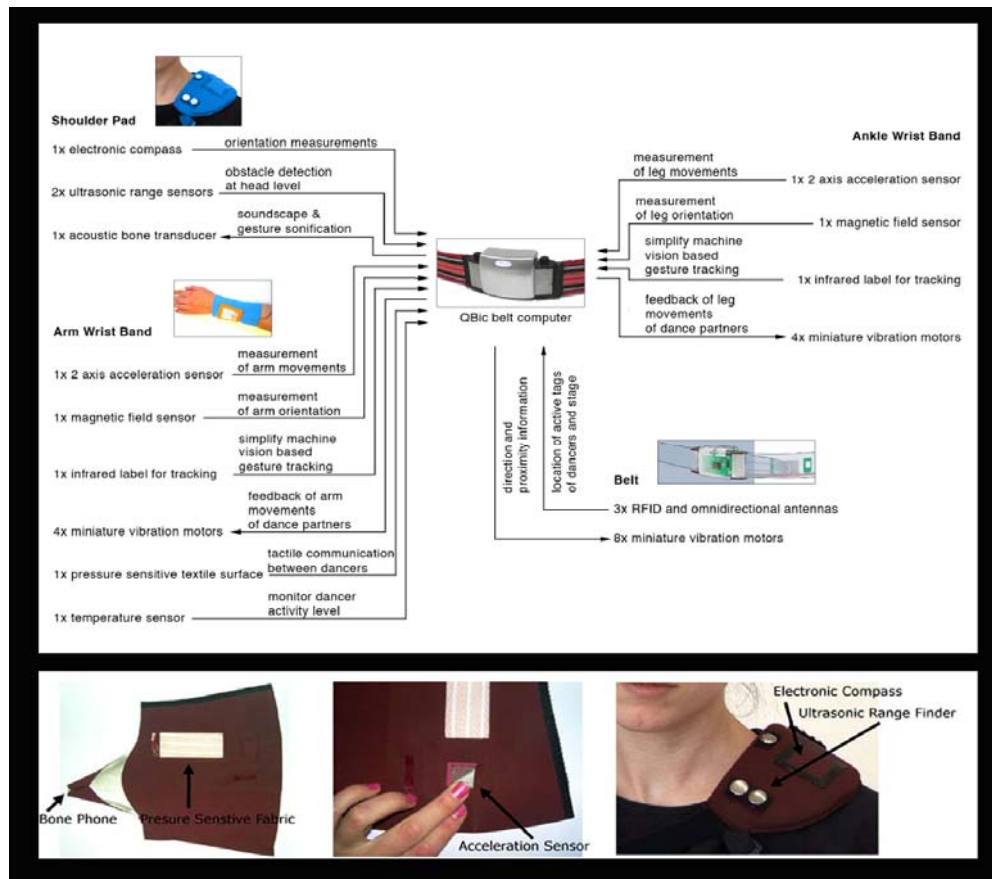

Figure 8 Technical diagrams with QBIC computer, © Schiffler & Scott

On the applied side we are concentrating on two stages of Systems integration with the mediated stage including user workshops. Here e-skin the e-skin circuit and its sensors would be integrated into a client computer system and two navigation sensors (Compass and ultrasound) as well as linked to sound feedback (bone-phones). This integration will increase their awareness of space, of each other and of their proximity to obstacles on the stage. By further studying study the user's movement, communication and customization potentials and strategies, the workshops participants will become consultants. Finally they will help to develop their own content in relation to the subject of skin, and demonstrate the results of the project to the public at Tanzhaus Wasserwerk. The first stage is to integrate the costume components of the basic research with "off the shelf" bone phones for sound, compasses for vibration direction and accelerometers for gesture recognition and ultrasound for obstacle collision. These components will be linked with the embroidered circuit to a small wearable computer called the QBIQ, which is in turn linked to a central server controlling the stage. This computer will store various languages, sounds and memory routes within a belt integrated computer called the QBIC[5]. The current model is batch produced at the Wearable Computing Laboratory of the Swiss Federal Institute of Technology in Zurich as a research platform to collect and compute sensory data for medical monitoring and context recognition projects. The second stage is to workshop this integrated system and use RFID and WIFI technologies to link it to an audiovisual stage or platform.
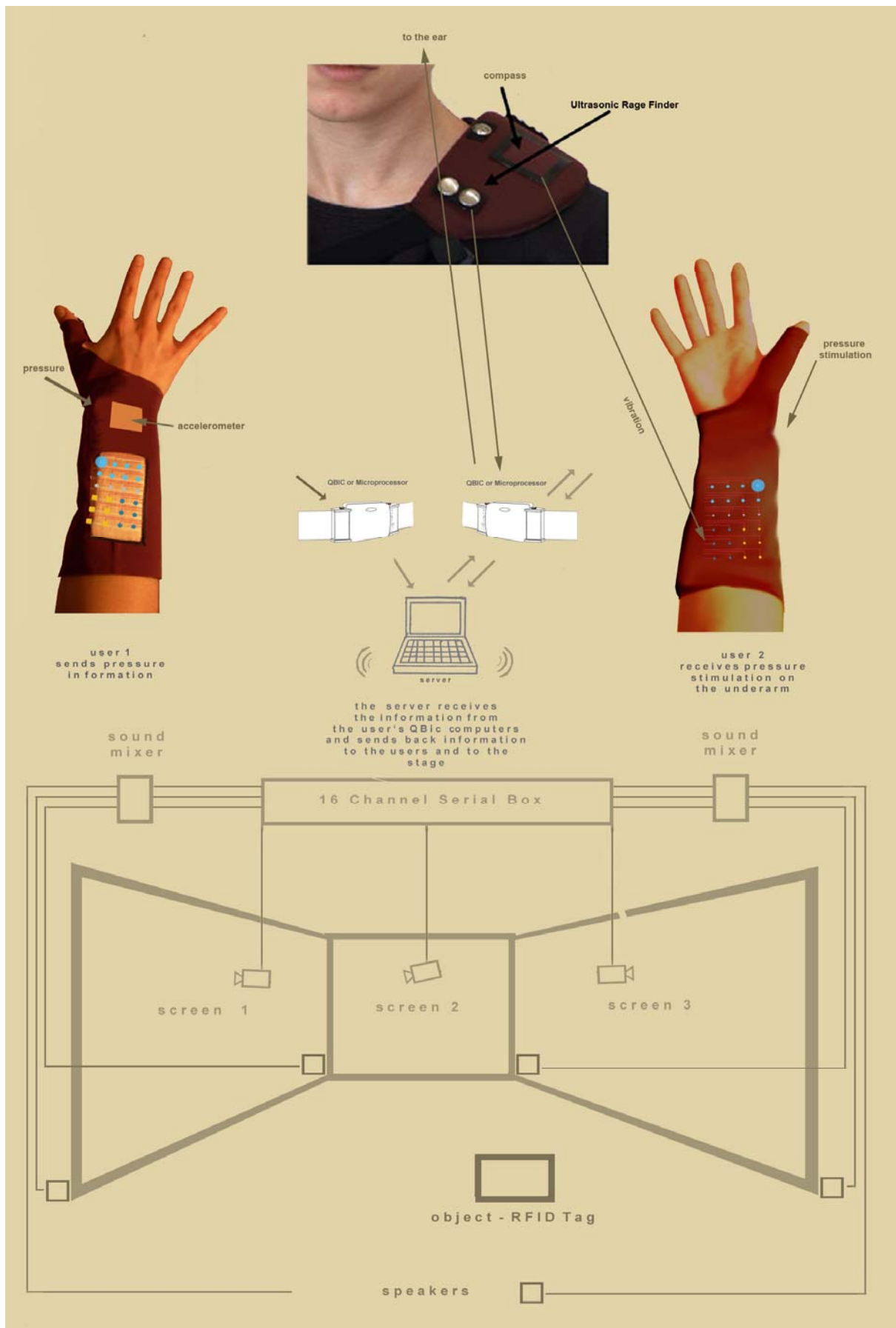
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[5] http://www.ife.ee.ethz.ch/qbic/index.html Accessed February 7, 2006

to the ear

compass

Ultrasonic Rage Finder

pressure

accelerometer

QBIC or Microprocessor

QBIC or Microprocessor

vibration

pressure
stimulation

user 1
sends pressure
information

server

user 2
receives pressure
stimulation on
the underarm

the server receives
the information from
the user's QBic computers
and sends back information
to the users and to the
stage

sound
mixer

sound
mixer

16 Channel Serial Box

screen 1

screen 2

screen 3

object - RFID Tag

speakers

Figure 9 Current design diagrams: e-skin for the mediated stage © Scott
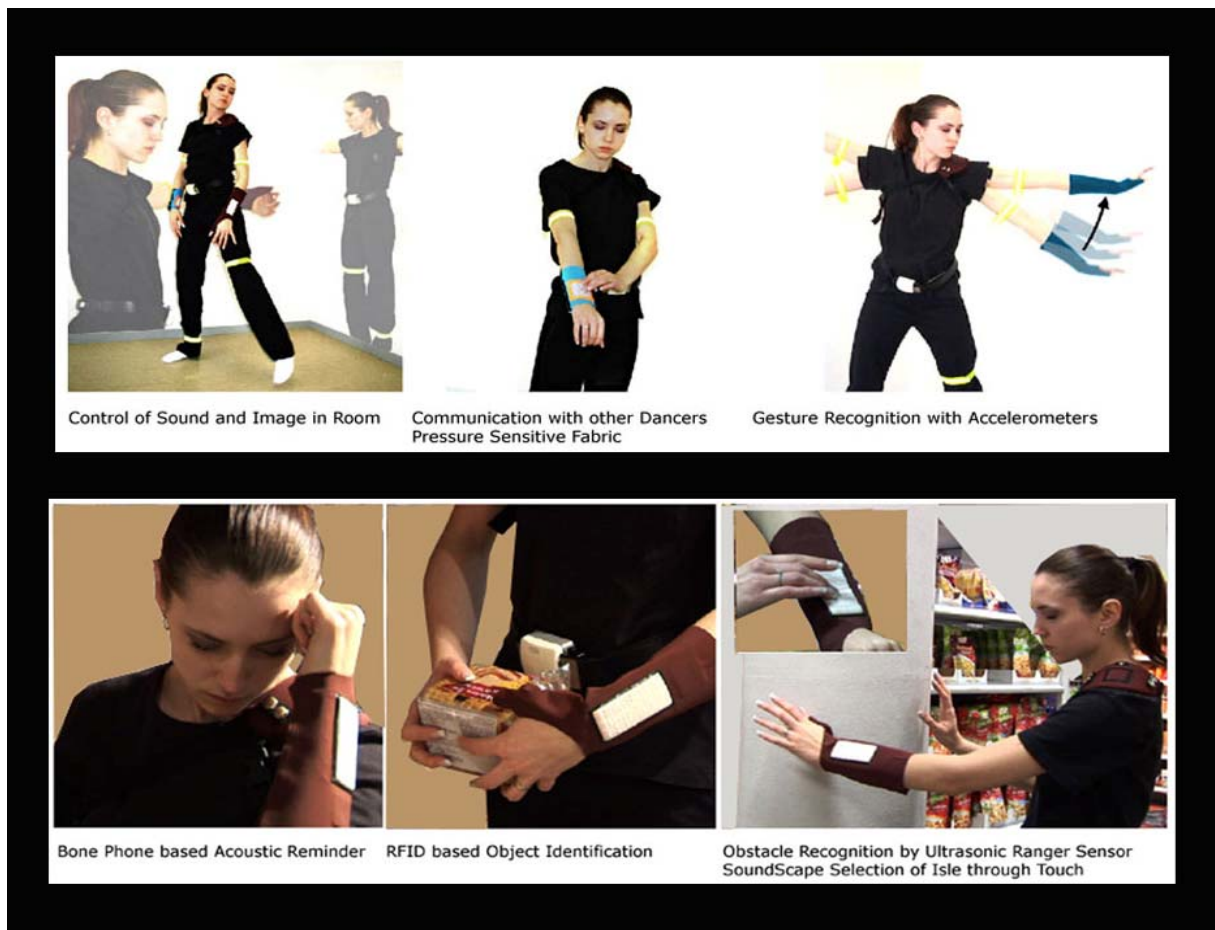
Figure 10 Dancer wearing e-skin for the mediated stage © Scott

5. Conclusion

Our users hope that there is a real possibility of a third stage of e-skin to become closer to the concept of embodied interaction. This can be achieved by augmenting the participant's movement, communication, navigation and control skills and also by working with the potentials of cross-modal education. As movement specialists at The Institute of Special Needs Education at the University of Oslo, Norway[6] have experienced, new movement education for the visually impaired causes a large increase in individual expression and builds up confidence, aspects which most HCI developers are not exploring along side their own engineering and computer science methodologies. By encouraging a combination of interface development and movement alongside the measuring of responses using social science methodologies, the Department of Psychology in Basel and the company Ergonomie and Technologie can helps us to assess the navigation, information and communication of our users. We need to not only identify inherent problems and inconsistencies in e-skin, we are working toward the development of a device that "talks their language" and prove that the human body, is also "embodied" in relation to the senses of tactility, proprioception, hearing and cognitive mapping. Therefore, the third stage of e-skin is based on "human and universal" aspects using acoustic and tactile feedback combinations to access more metaphorical associations. Our aim is to "humanize technology" for the visually impaired. In addition, through the output potentials of the audio and visual information, non-visually impaired persons in the audience could gain more insight into "the world of the visually impaired". Currently, our mediated cities are causing more social separation between impaired and non-impaired people.

We are also beginning to explore the educational potentials of neuromorphology, where tests for inherited eye diseases are conducted. Perhaps sound and tactile metaphors about this research, can inform the development of scripts for the e-skin mediated stage and metaphors can be found to augment essential "visual information" from impaired persons to a sighted audience. With our first two prototypes we have already discovered that electronically enhanced perception can complement visual forms of interaction on the stage

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[6] http://www.isp.uio.no/AboutISP.html: Accessed May 2, 2006.

and communicate with the audience in a new way. The next step is to train visually impaired actors to create their own theatre, using e-skin to activate, communicate with others and control the mediated stage. Thus this third stage of e-skin with its enhanced wearability and its continued reliance on the four main skin-based sensory modalities of perception, might not only complement "visual forms" of interaction and empower deeper perception on the stage, but communicate with the audience and with other impaired participants in an embodied way: focussing on ubiquity, tangibility and most of all, shared awareness, intimacy and emotion.

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Use of "Phantom" as a basis for a new form of art therapy in schizophrenia

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Abstract

Art therapy implicates the subject in a first person perspective, and thus arouses the perception of himself as an agent: his agency. Precisely, this sense of agency is altered in schizophrenia, and this impairment is proposed to be the essential etiopathogenic mechanism of schizophrenia. Action-monitoring is knowned as a basis of the sense of agency, through the comparison between the intention and the result of the action (the sensory feedback). In this perspective, we conceived a cognitive paradigm evaluating action-monitoring. We used a virtual reality tool allowing a manipulation of sensory feedbacks. Finally, we put foward the training to those sensory-motor tasks associated to the manipulation of the feedbacks, as a treatment for agency's impairment. As this tool can be customized for art therapy applications, we propose here a new form of art therapy, based on sensory integration and action monitoring.

Keywords: schizophrenia, agency, self-monitoring, haptic, art therapy.

1. Introduction: the sense of agency

1.1 Alien control and agency
One of the main pillars of mental health consists in continuously maintaining the Self's integrity. Psychiatric disorders such as schizophrenia are characterized by difficulties in determining the boundaries between the external world and the subject. The schizophrenic dissociation comprises many symptoms which all have in common an articulation with the subject's disintegration, psychic disorganization and depersonalization. Certain patients may not feel in control of their movements (as well as emotions, thoughts…) and think that they are a passive instrument in the hands of an external will. They may also believe that they are controlling others' movements. This is what Janet (1937) respectively called the attribution's trouble by default or by excess. Schneider (1955) characterised those symptoms as first rank symptoms. This ability to attribute the intention of an action to its agent is commonly called sense of agency. Several authors, as Jeannerod (1997) and Frith (1992), consider the disruptive mechanism of agency as one of the essential etiopathogenic mechanisms of schizophrenia.

1.2 "Shared representations" and the "Who system"
Neuroscience provides theoretical explanations, indorsed by empirical results, for those aberrant symptoms. Since the discovery of the mirror neurones by Rizzolatti et al. (1996), and many others which followed, it has been understood that the approximately the same cortical areas – called shared motor representations by Jeannerod (1997) – were activated when the subject is performing, preparing, imaging an action and also when he is observing someone else performing the same action. Therefore, it is a genuine challenge for the individuals to attribute the action to its author. Jeannerod (1997) hypothesized a "Who system" allows the appropriation of the action to its agent.

1.3 Specific treatment of self-produced sensations
The processing of the sensory feedbacks of self-production actions is different from sensory information produced by the external world, as Helmholtz (1967) showed for the vision and Angel (1982) for the touch. Indeed, when the gaze changes its direction, the image of the world moves on the retina but remains still for us. This is not the case when the eyes are moved passively. Moreover, a self-produced tactile stimulus is perceived as less ticklish than the same stimulus generated externally. Thus, in the case of self-produced actions, the sensory feedbacks can be attenuated or even annulated.

Those affirmations are corroborated by neuroimaging. Right inferior parietal, among several areas – which is known to be an indicator of others' movements (Ruby 2001) – is less activated with a self-produced tactile stimulus compared to the same stimulus generated externally (Blakemore 1998). This area is also hyper-activated in case of a distortion applied to the sensory feedbacks of a self-generated action (Farrer 2003). Likewise, in the apes, Hietanen and Perrett (1996) showed the superior temporal sulcus – STS – is activated in case of passive movements, when seeing other's movements, but not in case of self-generated movements. Thus, there would be an annulation of the sensory consequences of self-produced stimuli.

1.4 "Internal efferent model"

All these experimental results point the particular treatment set aside for self-generated actions. Ito (1970) and Wolpert (1995) elaborated a theoretical explanation for this specificity: the "internal efferent model". This theory relies on a neurophysiological basis: the existence of a copy of the motor command named the efference copy (Von Holst 1954) and (Sperry 1950). The individual monitor the action by the use the efference copy without waiting for the sensory feedbacks. It enables an anticipation of the consequences of actions, a comparison to the actual sensory feedback, an immediate and effective adjustment of the motor command, and at last, the distinction between the sensory consequences of willed actions and the sensory information provided by the external world. A deficit in this mechanism prevents the identification of the sensory information as a consequence of a willed action, and may have a major effect on the attribution of the action and thus damage the sense of agency.

1.5 Schizophrenia, Agency and "Self-monitoring"

The sub-vocalisations of schizophrenic patients with auditory hallucinations are correlated to the hallucinations (Gould 1949). Thus, the hallucinatory phenomenon is the consequence of an external attribution of the inner speech. Frith (1989) showed the difficulty for schizophrenic patients with alien control to monitor an action without an actual sensory feedback. He came to the conclusion of a deficit of the efficiency of this mechanism which is named "self-monitoring" resulting from a deficit in the use of the "internal efferent model". Schizophrenic compared to normal subjects, need bigger distortions of sensory feedbacks of self-generated actions, to notice the distortion, and thus keep on attributing the action to themselves for a bigger distortions (Daprati 1997) and (Franck 2001).

Moreover, self-produced tactile sensations are not attenuated in schizophrenic patients as in normal subjects, as shows Blakemore (1998). And the right inferior parietal cortex is already hyper activated is case of self-generated actions in schizophrenic patients, as well as when a distortion is applied to the sensory feedback in normal subjects (Spence 1997).

Thus, in schizophrenic patients, some intended acts are treated as the consequence of an external will. According to Chris Frith, the experience of alien control reflects a disorder in the "self-monitoring". Thus Frith (1992), Jeannerod (1997) and many other authors suggest that schizophrenia is pathology of the sense of agency, (including the negative symptomatology). As Proust (1995) suggests, what is defective in schizophrenic subjects is probably not rational thinking, but the self-attribution of intentions. The perception-action loop – the mechanism of self-monitoring are the basis of the sense of agency.

2. Basic methodology: conception of a cognitive paradigm

Monitoring a continuous action, whereas the sensory feedback is alternatively available or absent, involves switching from sensory feedback to efference copy. This should be a paradigmatic illustration of the efficacy of the "self-monitoring". An experimental study of this type should be able to quantify this "self-monitoring" ability. Thus the results of such a study should be an indicator for the subject's sense of agency.

Training patients in switching from efference copy to actual sensory feedback with this disposal should also be proposed to recalibrate the altered sense of agency of schizophrenic patients.

In this paper, we will present a pilot study investigating the potential of "Phantom" material measuring the central monitoring abilities. We measure the performances of twenty control healthy subjects in order to valid this test.

2.1 Subjects

Twenty normal subjects volunteered for this study. None of them reported evidence of neurological or psychiatric problems as assessed by the Mini International Neuropsychiatric Interview (Lecrubier 1997). Other exclusion criteria are an age under 18 and over 35, and familial antecedent of schizophrenia and bipolar disorder.

2.2 Material

"Phantom" is an arm with tactile feedback simulating the palpation of a 3-Dimensional object visually represented on a monitor screen. "Phantom" incorporates the sense of touch into computer applications through force (kinaesthetic) or tactile feedback with a haptically enabled application. With "Phantom" one has an immediate, constant, on line feedback of his movement.

In our experiment, the 3-Dimensional object is a cylinder. The articulated arm enables the user to manipulate a ball. In all sessions, we measure the ability for the subject to make a ball turn around of a 3-Dimensional cylinder without losing contact, as fast as he can.

In a first session, the articulated arm moves at a certain height only. Therefore, the task is made in a bi-dimensional horizontal plane. In a second session, the arm moves in the three dimensions, and a 20mm high ring surrounds the cylinder. The subject is asked not to move the ball outside the ring.

The dependant variables are the number of turns realised in the allowed time and the percentage of time spent in error which are - in both conditions (2D & 3D) - the percentage of time spent without contact between the ball and the cylinder, and - only in the 3D condition - the percentage of time spent outside the allowed ring.

Subjects pass two conditions in the 2D as in the 3D tests. In the first condition, the ball is continuously visible except in the rear-side of the cylinder. When the ball goes from the front-side to the rear-side, visual information is lost, and a few schizophrenic patients have developed experimental delusion of control. In the second condition, we introduced a discontinuity in the visual feedback. The ball is alternatively visible or invisible.
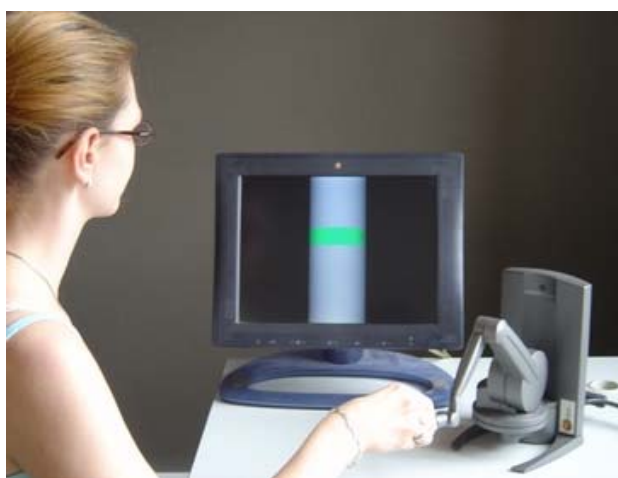

Figure 1 Subject performing "Phantom"

2.3 Design
The experience is about 20 minutes long. It is composed of 22 tests (each one lasts 45 seconds), split up into two sessions. In the first session, subjects pass the 2D condition. They first discover the device in an acquisition phase composed of three 2D tests with a continuous visual feedback. Then, subjects take eight tests: one half has a continuous feedback and the other half has a discontinuous feedback, according to the following design:

For one half of the subjects:

Discontinuous	Discontinuous	Continuous	Continuous	Discontinuous	Discontinuous	Continuous	Continuous

And for the other half:

Continuous	Continuous	Discontinuous	Discontinuous	Continuous	Continuous	Discontinuous	Discontinuous

In the second session, subjects pass the 3D condition. They first discover the 3D application in an acquisition phase composed of three 3D tests with a continuous visual feedback. Then, subjects pass eight tests: four tests have a continuous feedback and the four others have a discontinuous feedback. The subjects pass those 8 tests according to the same design described in the 3D session. The subjects beginning with the continuous condition in the 2D session are also beginning with the continuous condition in the 3D session, and similarly for the ones beginning with the discontinuous condition.

We compare the performances (number of turns realised and percentage of time spent in error) of the continuous and the discontinuous conditions, within the 2D and the 3D sessions. According to our hypothesis, those differences indicate the disability of monitoring an action due to a discontinuous visual feedback, and thus indicate the capacity of central monitoring.

2.4 Perspectives

This test is now validated in healthy subjects. We are able to test the performances of schizophrenic patients and to compare them with the ones of the control subjects.

To a larger extent, we expect to continue those experiments in order to prove that training schizophrenia patients at "Phantom" tasks with a discontinuity in the sensory feedbacks participates in recalibrating their altered sense of agency. This hypothesis will be further investigated in a longitudinal study.

This application can be improved in a task asking multimodal sensory integration abilities to the subjects who perform it. The delimitation of the ring can be at the same time haptic (the texture along the ring is smooth whereas it is rough outside), visual (the ball is visible, the ring is colored) and auditory (meeting the ball with the cylinder inside the ring, gives a continuous tone whereas passing over the band or losing contact with the cylinder doesn't provoke any sound). Initially, all sensory feedbacks are provided. Then, while performing the task, roughness, tone, ring's coloration or ball's visibility can be suppressed and reintroduced and those modifications are unpredictably iterated, while the subject is performing the task, so that he doesn't expect it. This kind of task asks the subject to switch, not only from a sensory feedback to an efference copy but also from a sensory channel to another one. This could be another track to treat the altered sense of agency of schizophrenic patients.

Thanks to its easiness of creation of applications, "Phantom" can also be used as a tool for art therapy.

3. Art, agency and perception-action loop

What is therapeutic in art therapy programs? It is a common assumption that Arts involves high cognitive abilities, including high levels of outside world and self-representations. Thus, the efficacy of art therapy merely lies in a catharsis through a free expression of the Self. Art therapy allows an exploration of the patient's inner world in a non-threatening way through a therapeutic relationship for people for whom verbal psychotherapy would be impossible.

But isn't there a place for more basic mechanisms? Isn't artistic creation also an experience deeply rooted in the perception-action loop? For example, feeling the paintbrush touching the canvas, feeling the bow brushing a violin string… Performing art (as any sensory-motor tasks), constantly implies the perception-action loop.

Of course, those two levels of processes are implied while performing art, and both concern the first person in action. Making a piece of art requires initiatives, and enables comparison of the final result with the initial goal which allows a subject to attribute his creation to himself. Art performances specially illustrate those two levels of the sense of agency.

As shows the latest review of literature about art therapy for schizophrenia patients (Cochrane Collaboration 2006), there are very few evidences for an efficacy of art therapy. The authors emphasize on the lack of randomised studies. Maybe should we also try new strategies based on new theoretical approaches?

4. Proposal of "Phantom" as a basis for art therapy

We focus on the fact that the therapeutic mechanism of art therapy could also get trough a rehabilitation of the perception-action loop using sensory-motor tasks. Using "Phantom" implies more strongly the self-monitoring of the action, especially when it comes multimodal and sensory feedbacks are modulated. We suggest that the multiple applications which can be associated to "Phantom" illustrate this reduction of art to one of its component: the perception-action loop and should be used in art therapy program. In this reductive conception of art therapy, creativity wouldn't anymore be the aim, but would become the means. Creativity would be a means to make "Phantom" training ludic, playful, in order to interest the subject, to excite his curiosity.

One of the original applications of "Phantom", as it is commercialised, is in the artistic sector, such as painting, sculpting, CAD...

It is easy to create multiple applications with "Phantom". Such applications as reproduction of drawings, with a tone indicating the subject is going out of the line can be created.

Moreover multimodal sensory integration can be easily proposed. In a painting application, colours can be chosen and applied on a virtual canvas. They can be associated to tones. As well, "Phantom" can be used as a tool to sculpt a virtual piece of wood, and tones can be associated to deepness of the erosion. Though, subjects get more than only one sensory feedback to monitor their action. Those feedbacks can be alternatively and suppressed then reintroduced and this can be constantly iterated during the art performance. Thus, subjects will be trained to switch from a sensory channel to another, a feedback to an efference copy, and, according to our hypothesis, would train their agency's skills.

Figures 2, 3 and 4 Examples of virtual pieces of art

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Innovative Implementation in Socket Design: Digital Models to Customize the Product

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Abstract

The paper presents an innovative approach based on digital data and computer tools to optimize lower limb socket prosthesis design. The kernel of the approach is a stump's detailed geometric model, with external surface and inner bones. To obtain this model, we integrated RE laser scanning and two medical imaging technologies, Computer Tomography (CT) and Magnetic Resonance Imaging (MRI). The model obtained can not be directly used to build the socket by using Rapid Manufacturing technologies. We demonstrate this assertion by comparing digital model of the limb with the positive plaster cast acquired by an orthopaedic technician during the traditional manual manufacturing process. The comparison evidences some differences concentrated on critical zones, whose deformations strictly depend on technician's manipulation. The analyses of the causes of the mentioned differences can furnish guidelines for physics-based simulations able to reproduce effects obtained by the technician.

Keywords: lower limb prosthesis design, custom socket, 3D digital modelling, reverse engineering.

1. Introduction

The paper presents an innovative approach based on digital data and computer tools to optimize lower limb socket prosthesis design; as described in the next section, design and manufacturing of a socket are processes where computer aided methodologies and tools are not intensively used. The main aspects of the methodology we propose are summarised in Figure 1. We consider, as the first time, the problem of the reconstruction of a digital model of the stump; it requires a measurement phase and a following CAD modelling task. Then, physics-based simulations on digital model are necessary to obtain deformed shape of the stump similar as much as possible to that one that stump assume during motion of the patient or during manipulations of orthopaedic technician. Finally, the last two steps concern the design of the socket over the deformed shape of the stump and the manufacturing of the socket using Rapid Prototyping (RP) techniques.

In previous years, some researchers have investigated aspects concerning the proposed methodology. To reconstruct the digital model, solutions described in literature have been taken into account and compared, beginning from stump's measurement procedures. Actually, the stump is measured manually, so several measurement protocols have been developed to control and reduce problems of accuracy depending on the instruments used (Geil 2005), on the operators' skills (Vannier 1997), on the measurement conditions and on the status of the patient's stump. Markers on the limb identify anthropometric standard dimensions, usually in correspondence with the articulations (Andriacchi 2000). In the case of trans-tibial amputee, important parameters are stump length (from the under patella support to tibia apex) and femoral-condyle position, these points identify zones with less variations of shape and volume of the skin than the other parts of the stump. Markers are also used as reference for the reconstruction of biomedical images and for human gait analysis (Cappozzo 1996).

In the last years, there have been residual limb analyses concerning stump's measurement and interactions with socket (Commean 1998), and its variations during patient's life (Zheng 2001, 2005); these studies evidence how to control modifications of lower limb's morphology, especially for the global limb conformation and skin condition, to guarantee a permanent prosthesis comfort and realize, when necessary, the necessary functional socket adjustments. All these researches highlight how digital-based technologies can help socket process design. Some studies analyze the interface pressure between the residual limb and the prosthetic socket, applying Finite Element Analysis tools to simulate pressure distribution and to define material properties assumptions (Ming 2000, Lee 2004).

Recently researches have investigated RP technologies applications both to the production of the positive plaster cast of the stump and to the manufacture the socket (Cheng 1998). Efficiency and velocity of RP technology are a valid support for "custom fit" products, and produces cost reduction even during test evaluation. Technologies such as Stereo Lithography Apparatus (SLA), Selective Laser Sintering (SLS) or

Fused Depositing Modelling (FDM) produce prototypes with strong mechanical properties compared with 3D Printing, but are much expensive, for what concern hardware, consumer materials and productive process (Freeman 1998, Herbert 2005).

The geometric model of the residual limb of the lower leg plays the main role on the approach we are proposing. This model is essential to permit physics-based simulations, detailed design with CAD tools and RP. In this paper we discuss methods and tools to reconstruct a geometric model of the stump and we demonstrate that this geometry is not directly usable to produce the socket, presenting a comparison between a geometric model obtained integrating RE and medical imaging technologies, with the plaster cast produced by means of the traditional manual process by orthopaedic technician.
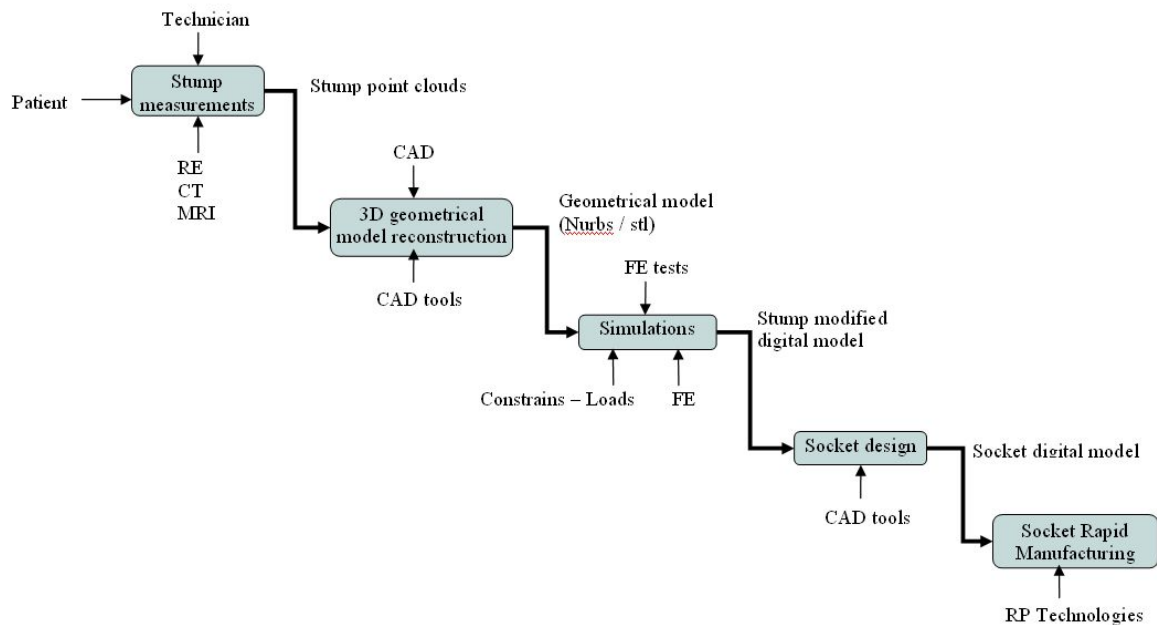
Figure 1 Proposed approach

2. Traditional manufacturing of a socket

Socket is the interface between the amputated lower limb and the kinematic chain of the prosthesis: unlike other components, such as links and foot are modular, socket is custom made on the stump, because it is responsible of prosthesis comfort and must guarantee amputee's suitable movements.

Until now, sockets have been designed and manufactured with handicraft methods by an orthopaedic technician (Figure 2): he has to mould manually some chalk bandages on the stump, pressing on the landmarks which correspond to loaded zones of the stump into the socket (Figure 3), like the under patella zone and popliteal fossa.

Figure 2 Measurement of stump with liner

Figure 3 Chalk negative cast with critical zones

In this manner the technician acquires the shape of the stump; this is a manipulated model, subjected to deformations especially on fleshy parts, and such a configuration could be different from one technician by another, depending on his/her skill. Through chalk casting on the negative plaster cast, it is possible to obtain the stump model, comparing measures with the ones taken directly on the stump. If the measures are different, the orthopaedic technician files the model till the measures coincide: this last model is used to make socket by lamination. A specific attention, as shown in Figure 4 and 5, is due to the definition of the most critic zones of the stump, like the tibia apex and other bone protrusions (cyan zones into the positive cast), which are maintained without compression to avoid residual limb charge against socket.

Figure 4 Negative cast with opening into critical zones

Figure 5 Positive cast

The choice of the socket material is a very important aspect in the design and manufacturing processes of limb prosthesis; materials will influence the comfort of the prosthesis for amputee. Often, socket is thermoformed over a plaster cast of the residual limb after being heated at high temperature, usually around 300-400 °C. The hot plastic is moulded to the plaster model using vacuum pressure to ensure an exact fit over the cast.

3. Reconstruction of the digital model of the stump

The first step of the proposed innovative process considers the reconstruction of the digital model of the residual lower limb; to obtain this model we integrated different technologies such as medical imaging (Computer Tomography CT and Magnetic Resonance Imaging MRI) and a non contact laser scanning. The external geometry is modelled by data coming from the laser scanning; bones can be reconstructed from both CT and MRI (Colombo 2006). For patient's posture during the acquisition phase, we defined a configuration which reproduces lower residual limb's position during manual measurements for chalk manufacturing, realizing a supporting device which maintains the residual leg with an angle of nearly 30° between femoral bone and tibiae, while the patient is lying on a bed and the stump is totally relaxed and without stresses or compressions on the muscular masses. In order to guarantee repeatability of acquisition set-up, and to have some more fixed parameters for limb configuration, we used markers to identify anthropometric standard points. They identify zones with fewer variations of shape and volume than the other stump parts. We used lead shot markers both for laser scanning and CT, tablets of vitamin E in the MRI, as shown in Figures 6 -7.
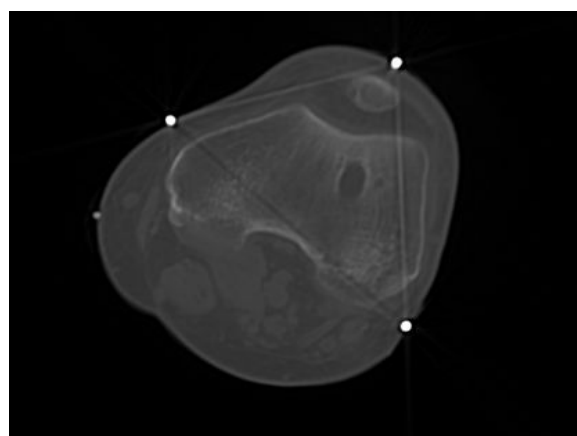

Figure 6 Stump with markers

Figure 7 CT image with markers

To acquire the geometry of the limb external surface, we used a typical Reverse Engineering tool, the laser scanner Minolta Vivid VI-9i™, which permits to obtain a model with a high quality in morphological details, necessary for the following studies of limb/socket interactions (Figure 8).

The 3D digital models made of tasselled surfaces have been reconstructed with a good precision, the standard deviation of the models' alignments was about 0,3 mm (±0,1mm) for all the 4 test-cases we considered the difficulties of the 3D digital reconstruction are related to stump deformability due to muscular contractions occurring during acquisition.

We accept this tolerance according to socket's operability: amputees always wear some liner on the residual limb to avoid damages to the skin, and its thickness compensates little shape variations.

This methodology, which assures both 3D digital data and RGB textures, allows:

- To acquire, in the less invasive way for the patient, the morphology of the stump

- To have textured digital models which permit an easy evaluation of the assessments and/or alteration suffered by limb, for the normal post-surgical course and for skin's abrasions and blisters

- To detect the variations of shape and volume due to incorrect pressures at the limb-socket interface, evidencing also the possible changes depending on the posture

In CT analyses we adopted a slice thickness of 5mm, to assure the minimum X-ray exposure according to an accurate bone reconstruction. MRI slices have dimension 20x20 cm, 256x256 pixel, pixel size = 0.78/0.82 mm, to reduce the acquisition time and avoid muscular movements (Figure 9).
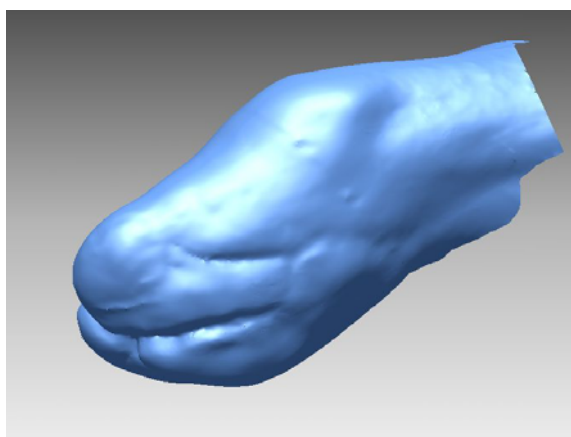

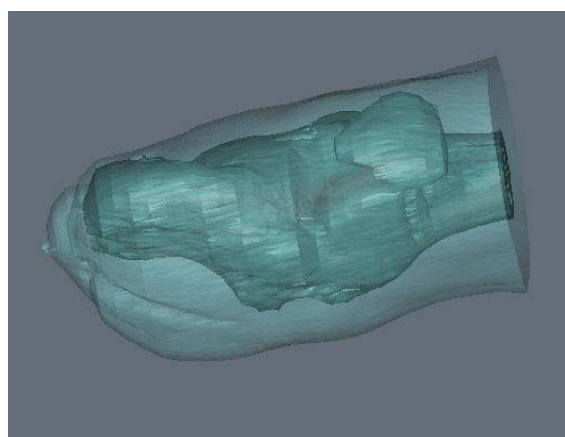Figure 8 Laser digital model   Figure 9 Complete digital model

This methodology was tested experimentally on four patients with amputated limb below the knee; the patients were three men and a woman, from 25 to 40 years old, with a stump length of approximately 10 cm below the tibiae plate (trans-tibial amputation).

4. Comparison of stump's digital models

To evaluate the possibility to use previously described model as a virtual cast to design and manufacture socket, we compare this model with the digital one obtained through RE of positive plaster cast made by an orthopaedic technician. In this manner, we want to highlight possible differences and critical zones, whose deformations strictly depend on technician's manipulation.

We considered a positive plaster cast, obtained from the limb wearing a Thermoliner™ Cushion TFFR, 6 mm thickness, by Alps™, and 3D digital model, whose volume was increased of a surface offset of the same thickness. The comparison shows that volume variations concern mainly the posterior muscular masses, which are more manipulated from technician, while the anterior part has the same global shape, due to the presence of the tibia (Figure 10).

In detail we notice that:

- The digital models correspond into bones critical zones, such as tibia protuberances, at both corner to the crest (Figures 11 and 12) and at the inferior extremity (Figures 13 and 14): these are the zones where orthopaedic technician assure no loads on stump, to avoid problems on bones/socket interface; the plaster cast profile (red line) is outside the stump.
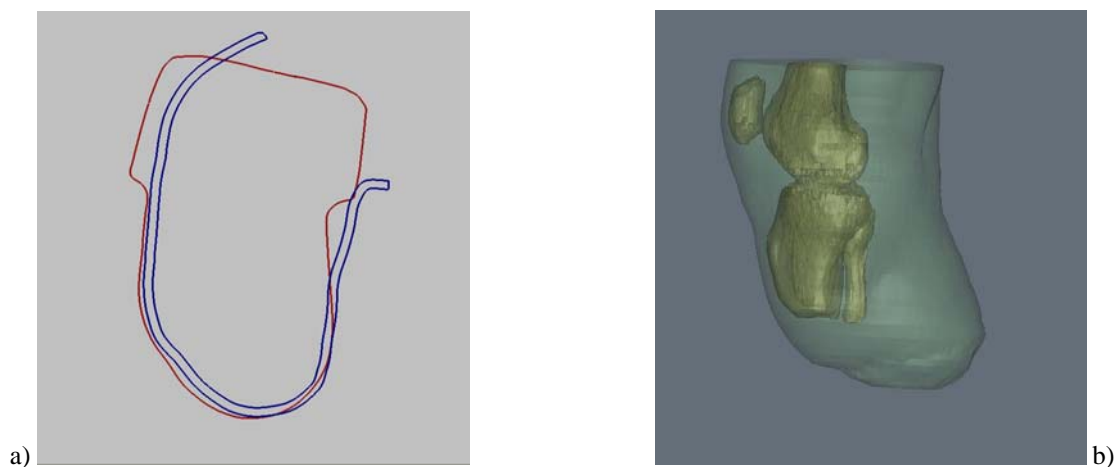
a)

b)

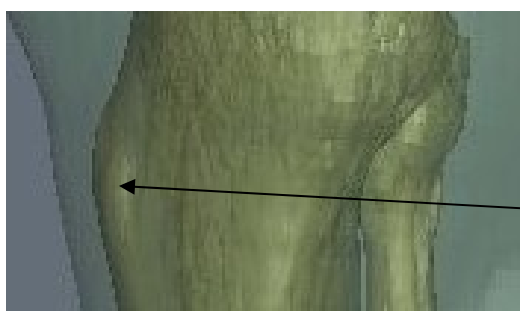Figure 10 Sagittal section on limb and plaster cast: a.) sectioned, b.) 3D limb with bones.

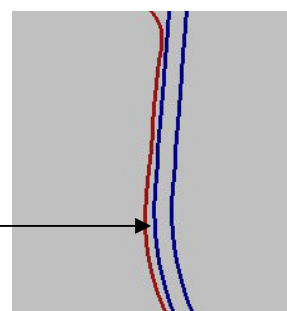Tibial crest

Figure 11 Tibial crest.

Figure 12 Detail on tibial crest.

Tibial apex

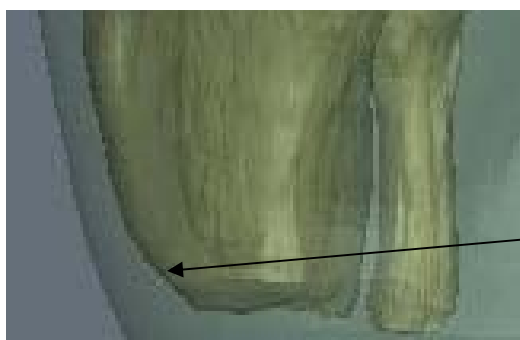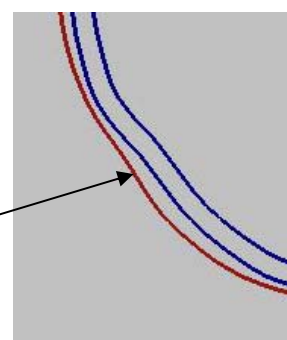Figure 13 Tibial apex.

Figure 14 Detail on tibial apex.

Significant differences between plaster cast and the stump are localised in two zones, where stump digital profile (double blue line) exceeds the plaster cast one. These situations occur:

- At the popliteal zone (Figures 15 and 16), where orthopaedic technician exerts pressure on stump, to guarantee the maximum socket adherence and create a closing zone to enable socket movement and to avoid stump contact with the bottom of the socket

- At the fleshy parts that remain on the bottom of the stump (Figures 17 and 18), which orthopaedic technician manipulates to reduce and compact volume, which is useless to socket functionality

These observations highlight the zones whose modifications are directly connected to technician's manipulations during plaster cast acquisition; further simulations to define interactions that generate this modification will be done on this digital model, adapted to be used with FE tools.
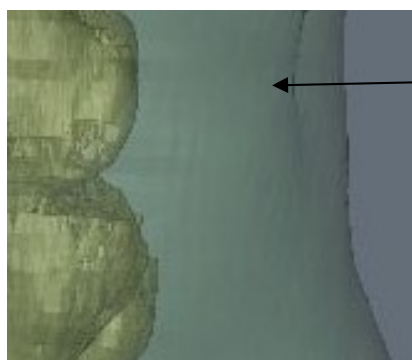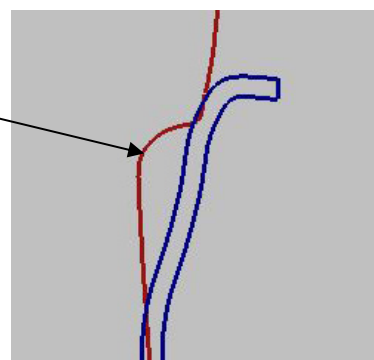

Figure 15 Popliteal zone

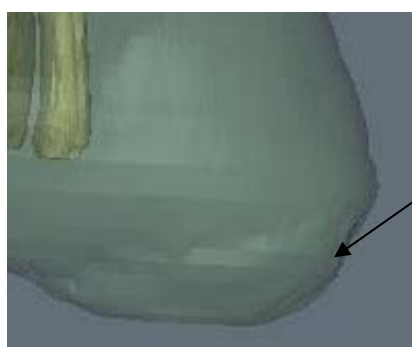Figure 16 Detail on popliteal zone.
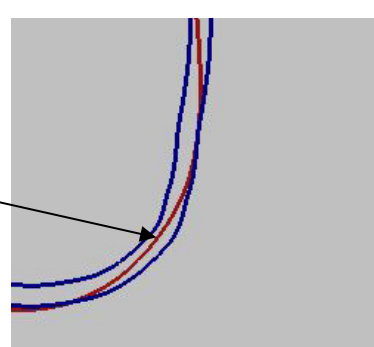

Figure 17 Posterior fleshy parts.

Figure 18 Detail on posterior fleshy parts.

5. Future works

As previously stated, further activities will concern physics-based simulations to evaluate interactions between limb and socket in order to improve design procedure. To this purpose, we must be able to determine pressure distribution at the interface between limb and socket depending on forces acting on the prosthesis during the movement of the patient. Experimental setup to measure this map is very important to obtain data necessary to refine simulation procedure and results.

The last topic of the proposed approach concerns the use of Rapid Manufacturing (RM) technologies to produce a socket of high quality and completely adequate to realize its function. In our approach we intend to use RM to produce a cast equivalent to that one produced in traditional way by orthopaedic technician; then it is possible to form physical socket customised for the specific patient. Experimental tests and setups must be defined to verify behaviour of the socket and evaluate the validity of the proposed approach.

6. Conclusions

In this paper we present a methodology to customise prosthesis socket. All the phases are "computer aided" and all the data involved in the process are digital. The paper, in particular, discusses problems related to geometric model of the stump. First, we analyse three different technologies to reconstruct geometric model, in particular RE based on laser scanning to acquire external geometry of the stump and CT and MRI for the inner parts. The acquired model can not be used to produce directly the cast and then the socket; we demonstrate this assertion by comparing geometric model acquired and the cast obtained in a traditional way. Some differences in the geometries have been highlighted; they are due to a direct manipulation of the orthopaedic technician; the discussion of the results permit to identify guidelines for further physics-based simulations finalised to reproduce in virtual model effects obtained in physical cast by the technician.

Papa and Ing. Stefano Rampoldi; for the equipments used on the tests, Intermedica s.r.l for Orfit equipments and Mrs. Antonia Rocchi, Ortopedia Panini snc of Milan and Mr Marco Buzzi, Alps and Mr. Fabio Vendraminetto for Alps liners.

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Facilitating the experience of agency through an intersensory interactive environment

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Abstract

The project presented provided a group of elderly participants in sheltered living conditions with an intersensory environment in which participants create expressively, by the use of their voice or movements, events which are specified auditory, visual and/or tactile. Being part of long-term research the *i*Muse project explores the effect of additional visual feedback for this specific client group. Through interviews and video-based behavioural observation an account is given of the change in experienced control during *i*Muse sessions with and without visual feedback. The effects in terms of experience and observed behaviour are evaluated in relation to specific impairments as well as individual aesthetic preferences.

Keywords: wellbeing in elderly, person-centred intervention, inter-sensory therapy, vibroacoustic sound therapy

1.   Introduction

The power and effectiveness of sound and music in enabling people to come to terms with, sometimes even overcome, disabilities has been noted by many authors (Boyce-Tillman 2000, Storr 1992, Wigram, Saperston and West 1995). Aspects from all these areas provide the grounding for this intervention, which is essentially non-invasive. Emphasis is placed on providing an interactive environment in which a high level of experienced control of action can be achieved through *aesthetic* interaction with sound.

The increasing loss of autonomous agency is a deeply felt problem for elderly people. Agency is understood in the sense of Fischer (1980) as intentional action including the skill to organize and control behaviour in order to reach a certain goal in a specific domain of action (Fischer, Bullock, Rotenberg, and Raja 1993). According to this approach agency is the result of a dynamic interplay between affect, cognition and motivation (Mascolo, Fischer and Neimeyer 1999). The age-related decline of physical, cognitive or emotional functioning can have a profound effect on the experience of agency (Fung, Abeles and Carstensen 2003). The presented project provided an environment which aimed to meet all three components of agency: at cognitive and physical level a maximum of continuous and fine-tuned control of multi-sensory events was given in the hands of the participants in order to support the experience of control. In order to create an emotional/affective positive experience, aesthetic preferences were taken into account in choices of timbre of sounds, type of visual patterns of change as well as colour schemes. The feedback in all sensory domains aimed to create a relaxing and individually effective experience. Motivation was assumed to result from interactions meeting diverse individual needs such as relief of pain, anxiety or a lack of stimulation, and from the active involvement of participants in shaping the content of the sessions.

2. The *i*-Muse project

2.1. Context of development

Many approaches or therapies work from the outside – in, with a stimulus being provided by an external agency. In traditional music therapy this is provided by the therapist often playing the piano or other instrument 'at' or 'to' the client, or in time with the client's movements. Person-centred music therapy (Hatfield and McClune 2002) gives more importance to the individual, often within a group situation. In contrast, Sound Therapy, VAST and *i*MUSE are one-to-one events, underpinned by aesthetic appeal and individual control, an experience from the inside – out. In the three approaches listed above, which can hitherto be concatenated as *i*MUSE, the emphasis is on the therapist providing a live acoustic environment, which is optimised, to the individual.

Physical movements from the client can result in sounds that are both pleasing and potentially expressive, and in time the environment and the sounds can be individualised to enable maximum expression and response from the client. The approach presented here also differs from multi-sensory approaches known as Snoezelen or 'sensory' rooms where many stimuli are given in order to compensate for a lack of stimulation (for detailed information see e.g. Baillon, Diepen, and Prettyman 2002). Control of these environments by users is restricted to the use of

on/off switch triggering e.g. sounds. The different visual, auditory and tactile stimuli are not related to each other and are designed to invite mainly passive attention and relaxation through ongoing stimulation.

In contrast, in the intersensory environments presented here the participants created, by the use of their voice or movements, events which were specified auditory, visually and/or tactile. Changes of feedback were closely related to changes in several parameters of action. The approach invites active engagement and interaction through action-specific feedback as well as passive relaxation. Effects were expected to vary according to individual needs and to become apparent over middle-and long-term with weekly sessions.

In research contexts the potential of multi-media feedback in virtual environments is explored for meeting the needs of users with disabilities for active engagement and interaction. Examples are projects in special needs and rehabilitation contexts (Brooks et al. 2002) or the 'Mediate' project for children with autism spectrum disorders (http://www.port.ac.uk/research/mediate/). While the effectiveness of multimedia environments has been demonstrated, little is known about the reasons for this effectiveness.

The study presented was a first step to systematically vary the type of multimedia feedback in order to explore the effect that, in this case, visual feedback has when added to sound and tactile feedback for actions. Increasing understanding of the perceptual, cognitive and emotional processes involved in this type of interaction will allow better specifying user needs and adapting the design of multimedia environments accordingly. The present pilot study also aimed to explore several research methods in order to better describe and evaluate the effectiveness of these types of interventions.

2.2. Method

Subjects: 13 participants (3 male, 10 female; average age was 78 ranging from 67 to 92) who were from sheltered living accommodation in the Northeast of England. All were living independently but had 24 hours access to support by the agency running the communal centre. Participants were free to join sessions after a demonstration and could stop at any time.

Material and apparatus: An Alesis microverb was used for sound processing vocal activity, with reverb and delay programmes selected. Physical gesture was captured via Soundbeam. The resulting MIDI data were used to control an FM7 softsynth. The vibroacoustic facility was provided by a Soundchair which converts audio into vibration over three areas of the body – the back, the seat and legs. Output from the Microverb and the FM7 was sent to a Tascam Portastudio 4-2-4. This was used as a mixer and also to replay the vibroacoustic tape. G-Force visualisation software converted the MIDI signal into changing graphical patterns.

Sessions were video-recorded with one digital camera.

Procedure: The study was designed so that half of participants started without and half with added visual feedback. After five sessions the visual feedback was added for the first and removed for the second group for two sessions. In the remaining three sessions participants were free to choose which types of activities and feedback they wished. All sessions were video recorded. Three semi-structured interviews were held in order to monitor experienced physical and mental health problems (Health questionnaire); the effectiveness of sessions related to the experienced health problems after five sessions (interim effectiveness questionnaire), and a more detailed questionnaire (final questionnaire) after the tenth session concerning effectiveness, motivation and wishes for future developments.

A typical one-to-one *i*Muse session took about 30 minutes. Participants were seated in a vibroacoustic chair which transformed sound into vibration. In a number of sessions additionally sound was transferred into complex changing visual patterns through visualisation software (G-Force).
The session usually consisted of three parts:

- Social or solitary interaction with the microphone – the voice feedback is processed e.g. as reverb, delay or pitch transposition.

- Solitary or social interaction using Soundbeam – lateral hand- and arm movements in the beam caused sound feedback depending on the distance from the ultrasonic sensor. Synthesized sounds used varied from bells to orchestral and hybrid or 'fantasy', all containing low frequencies which can be felt most effectively through the Soundchair.

- Relaxation – calming music with added low-frequency sine tones between c. 40 -120Hz was played.

2.3. Data analysis
The project aims to combine qualitative description of case studies with quantitative modes of data analysis.

2.3.1. Interviews
<u>Health questionnaire</u>: Before the start of sessions semi-structured interviews using questionnaires were held with participants in order to identify experienced problems and needs at sensory, cognitive, physical and emotional levels of behaviour. Note that only areas that were related to the iMuse interactions were included.

<u>Interim effectiveness questionnaire</u>: Effectiveness of and preferences for the three parts of the intervention and types of feedback were monitored after the first five sessions.

<u>Final effectiveness questionnaire</u>: Additional to the question from the former questionnaire motivation and required changes in sessions were discussed by an independent interviewer.

2.3.2. Systematic behavioural observation
A micro-analysis of behavioural change (Lee & Karmiloff-Smith 2002) was carried out by analysing series of individual sessions with respect to physical movement and facial expression. The goal of this analysis was to move from demonstration of changes in behaviour to a structural description of individual change. In this context one example will be given for this type of analysis. An observation scheme was developed for interaction with the Soundbeam in which the size (small, medium, large, irregular), and type and duration of facial expression (neutral, positive, negative) were coded. 'Observer' software was used for coding the video sequences and descriptive analysis of the data.

2.4. Results

2.4.1. Interview results
<u>Health questionnaire</u>

As Figure 1 demonstrates sensory and physical impairments were diverse with a high frequency of experience of pain.
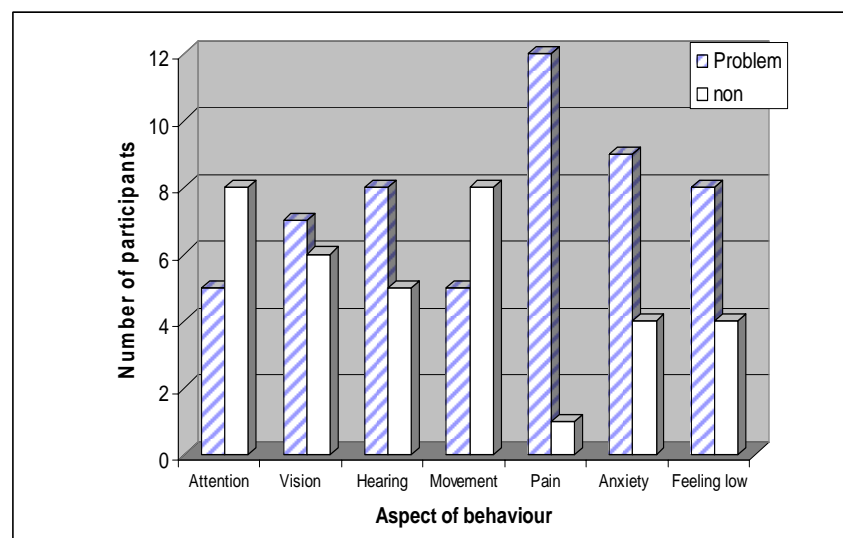

Figure 1 Experienced areas of impairment for n=13 participants of the *i*Muse study

Six original participants from one of the two sites we worked with were leaving the study due to organisational problems. Therefore the remaining data are from a reduced sample of 7 participants (1 male, 6 female).

<u>Interim effectiveness questionnaire</u>
After five sessions semi-structured interviews were held in order to review the sessions and assess experience of change. Figures 2 and 3 give an overview of experienced improvements in the areas of pain and stress relief (anxiety) for the group without visual feedback (Figure 2) and the group with visual feedback (Figure 3).

Experienced effects seem higher for sessions with visuals compared to sessions without. The low number of participants makes it impossible to statistically test the significance of differences in experienced effects.
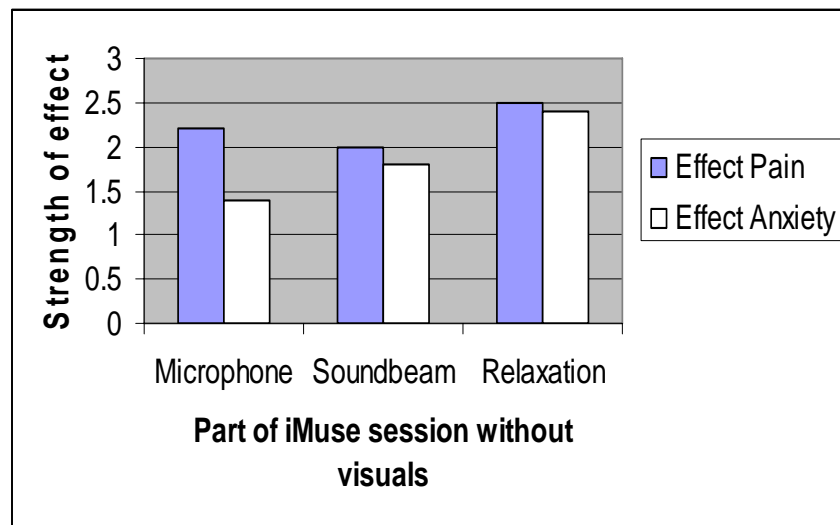

Figure 2 Experienced strength of effect of the parts of the iMuse sessions on pain and anxiety problems after five sessions **without** visuals. Experienced strength was measured on a rating scale 1= little or non effect; 2 = some effect; 3 = strong effect; N=4.
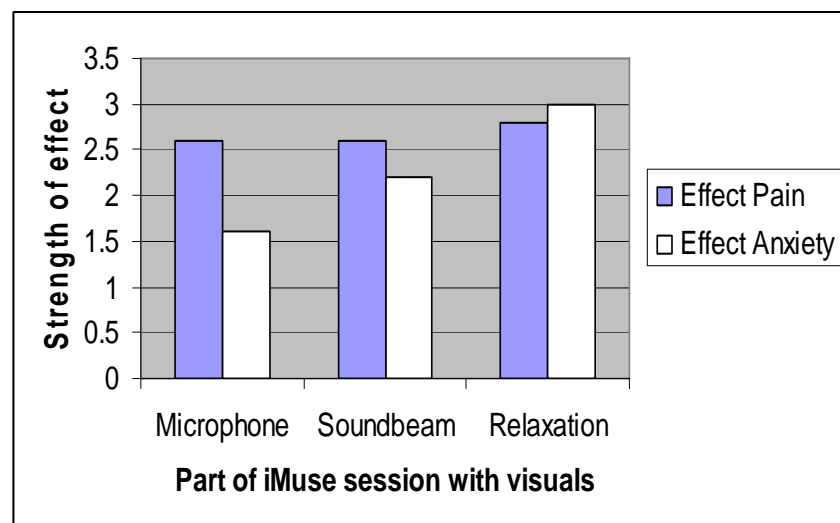

Figure 3 Experienced strength of effect of the parts of the *i*Muse sessions on pain and anxiety problems after five sessions **with** visuals. Experienced strength was measured on a rating scale 1= little or non effect; 2 = some effect; 3 = strong effect; N=3.

Final effectiveness questionnaire:
For sessions 6 and 7 the availability of visuals was reversed for the two groups. For the last three sessions participants were free to decide if they wanted visual feedback or not. Sixth of the seven opted for visuals in all parts of the session. One male participant was opting against visuals for the first two parts of a session but wanted them for the relaxation part. The experienced effectiveness after 10 sessions mirrors the results of the group with visuals after five sessions. Two participants with hearing problems reported that the presence of visuals would give them a clearer idea of the events ("It is as if I can hear better when I watch the patterns", citation Participant 4).

Figure 4 shows the effectiveness for all assessed areas of problems with the addition of 'Beauty', an assessment of the role that aesthetic appeal played for participants' experience. Of particular interest is that the role that the aesthetic appeal or experienced 'beauty' of both the visuals and the sounds play for the experienced effectiveness was rated as important or very important by all participants. Figure 4 gives an account of the role which the three different feedback modes (sound, vibration and visuals) play for the experienced effectiveness of the three parts of an *i*Muse session. Vibration was rated highest by all over all parts of the session while sound is seen

differently depending on the source of sound. Visuals are experienced as medium important for all parts of the sessions.
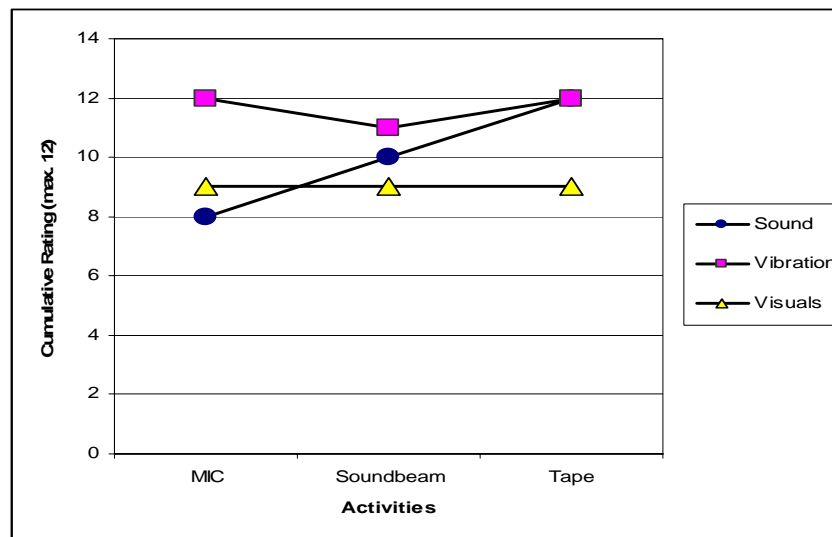

Figure 4 Cumulative rating of the role of the three feedback modes for three parts of the iMuse sessions after 10 sessions. 0 = no or negative effect; 1= little effect; 2 = medium effect; 3 = strong effect (N=4)

2.4.2. Systematic behavioural observation

Observational data give an idea of patterns of observable action during sessions. Figure 5 gives an example of changing arm/hand movements during the use of the Soundbeam depending on the presence of visual feedback for one participant. The overall time analysed is 25 minutes over five sessions without and 25 minutes for sessions with visual feedback. Small, medium and large movements describe rhythmical patterns of movements lasting minimal 5 seconds while irregular movements describe fast changes in size and timing of the movement. The frequency of movements increased overall for episodes with visual feedback. The large differences in irregular movements indicate a higher level of exploration in the presence of visual feedback. Measurements of positive facial expressions showed that the duration of positive facial expression increases with the presence of visual feedback.
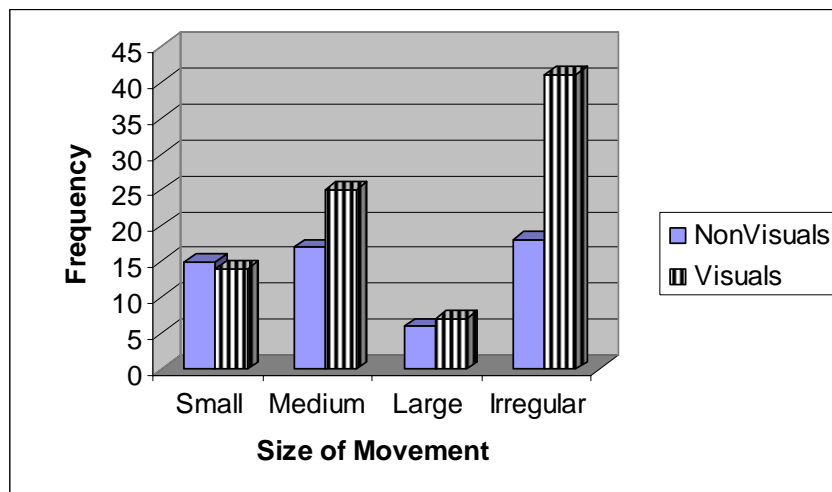
Figure 5 Comparison of the frequency of four types of arm movements during Soundbeam use with and without visuals over 10 sessions by one participant.

3. Discussion and conclusion

The pilot study intended to compare experienced effectiveness of iMuse sessions with and without visual feedback in order to learn about the additional role the visual domain could play in the sound and vibration based intervention method. The data from structured interviews show experienced effectiveness in all parts of the intervention and an overall preference for the presence of visual feedback. When comparing auditory, visual and

tactile feedback, the role of visualisation seems equal for the different activities of *i*Muse sessions with minimal fluctuations in opinion between participants. The role of visuals was seen by all participants in the aesthetic-affective domain while vibrations were seen as the main component for change in physical state. Sound was experienced in its aesthetic and relaxing meaning during the relaxation tapes and more functional for producing specific patterns of vibration in the other parts of a session. It is important to realise that the roles of different feedback domains could change with changing needs for control and with differing motivations.

Observational data suggest that the level of exploratory actions trying to manipulate the feedback increases sharply with the presence of visual feedback. When relating this to the interview data, the meaning of this increase in activity seems to be related to the motivation to produce beauty. Further data analysis will reveal if this is an effect which can be found in the majority of participants or is individual specific. The active exploration of feedback control reflects increasing levels of active cognitive engagement. The analysis of facial expression gave a description of a changing emotional dynamic due to the presence of visual feedback. At cognitive /physical level the awareness and realisation of control is sufficiently high when based on auditory and tactile feedback only. Therefore the added value of visuals here seems to lie in motivational and affective factors which in turn spark cognitive curiosity. This role could change depending on perceptual and motor skills of participants. However, the role of experienced beauty through visual feedback has been surprisingly stable over participants with different needs.

The small sample used can only give very preliminary insights for other multimedia environments. The concept of agency seems very fruitful in trying to capture the complexity of the interplay between cognitive/physical, affective and motivational factors in relation to different feedback modes. Further research needs to concentrate on the diverse roles feedback modalities can play in order to formulate design criteria for interactive multi-media environments. The combination of interviews and observational analysis has proven to be fruitful for the improvement of our understanding of interactivity.

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Picturing Sound – An overview of its efficacy

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Abtract

This paper presents three case studies selected from a sample of teenage children (n = 11) having severe disabilities. Personalised audiovisual environments are created with a targeted goal to encourage interaction, creativity and artistic expression from the teenagers. The feedback stimulus is directly linked to the child's gesticulations for a sense of associated control to be available for recognition. Non-intrusive sourcing of gesture is through camera data mapped to computer vision algorithms. Intervention strategies from staff and helpers within such user-centred environments are questioned. Results point to the positive benefits for these children such as increased eye-to-hand coordination, concentration duration, and improved communication. These findings corroborate with other research in being indicative of the potentials in utilising such interactive multi-sensory environments in special schools and institutes as a supplemental tool for traditional methods.

Keywords: Interaction, Communication, Empowerment, Therapy, Contingency Awareness

1. Introduction

The use of interactive causal multisensory environments is a promising supplement to promote augmented physical awareness and recovery in (re)habilitation of people with sensory and physical impairments. The term (re)habilitation is used to define those people who are in rehabilitation as well as those who are impaired in a way that has limited their developmental experiences. This study looks at the development and implementation of a Multimedia Multisensory Environment (MME), which is an interactive environment that stimulates multiple senses, principally sight, hearing and touch. The particular MME in the study responds to the movements of a person in the 'activated air' space (Brooks 2004) that the system creates, allowing them to become expressive and artistic communicators through sounds and images and thus able to directly affect their immediate environment. The term Assistive Technology (AT) is used to describe such enabling technology. With this enabling and empowering facility in mind, the school curriculum for many pupils with Severe Learning Difficulties (SLD) and Profound and Multiple Learning Difficulties (PMLD) often focuses on increasing communication skills (including self-expression) and experiential learning due to the complexity of the individuals handicap (e.g. The P-Scales 2005).

2. Background and purpose

It has been stated that Information and Communications Technology (ICT) has the capacity to revolutionise the design, delivery and implementation of user-defined interactive learning experiences to pupils with learning difficulties and especially those with SLD and PMLD (e.g. Lancioni et al. 2001, Standen, Brown and Crombey 2001). Basil (1982), reports that people with SLD and PMLD may have limited opportunities for social communications and therefore can live essentially passive lives. One possible reason is a belief that these people are non-communicators (Ware and Evans 1986). Brinker & Lewis (1982) and Schweigert (1989) indicate that these people are more likely to develop using object interactions. Piaget (1952), states that the general sequence of development in children with and without handicaps is both universal and invariant. With this in mind, the notion must be added that 'contingency awareness' or the acknowledgement of cause and effect is critical in a child's development (e.g. Watson 1966). Whilst Barber (1994) states 'failure on one item does not automatically indicate failure on the next, more complex, stage of development' (1994, p.50) it is not unreasonable to suggest that as well as infants and school-age children, many older people with physical and intellectual difficulties may not have passed through this crucial developmental phase due to this limitation of learning experiences. This minimised social contact due to carer's perceptions that the individual is a non-communicator can be related to the field of developmental cognitive psychology, particularly in educational terms to Vygotsky's 'Zone of Proximal Development (ZPD) (1978). This is defined as 'the distance between the actual developmental level as determined through independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers' (Vygotsky 1978, p.86). If a carer or more capable peer believes the person to be a non-communicator then this opportunity to create a ZPD or to allow a person to enter a

ZPD is missing and therefore crucial learning opportunities can also be missed. The guide, peer, - or as referred to by Wood, Bruner and Ross (1976), the 'scaffolder' - in this particular study is the reactive immersive multisensory environment titled *Picturing Sound*.

There is also significant incidence of depression in people with physical and intellectual difficulties. Esbensen et al (2003) validate an assessment tool (ADAMS) to determine anxiety and depression in people with mental retardation. However, scrutiny of the participant samples revealed 40% had severe or profound mental retardation as well as around 68% had physical and/or sensory impairment. It would appear that the importance of maximising the engagement of these people in personal, meaningful, relevant and pleasurable activities cannot be underestimated if they are to enjoy an equal quality of life in a truly just world (Rawls 1999). Research in the field of viable alternative physio-therapeutic possibilities, for example, Brooks et al. (2002), Reid (2002), Kizony, Katz and Weiss (2004), indicates there may be a subliminal cerebral level available when an experience becomes so enjoyable, that atypical activity occurs, i.e. an activity that the user does not normally engage in. This paper posits that case study 1, described later in section 3, adds some weight to Brooks' (1999) theory of *Aesthetic Resonance* as outlined below.

Prior to Brooks' explorations (1999), Ellis's work with the Soundbeam device (1995, 1997) generated the term 'Aesthetic Resonation' from his work based on his concept of Sound Therapy. Aesthetic Resonation is described by Ellis (1995) as those moments where a child can be seen to be totally engaged by, and enraptured in her or his sound experiences, this through the internal motivation generated by the audio feedback the device produces from the movement and gestures the child makes. Brooks' (2002) definition is different in the respect that Aesthetic Resonance can occur when 'the response to an intent is so immediate and aesthetically pleasing as to make one forget the physical movement (and often effort) involved in the conveying of the intention' (Brooks et al. 2002, p. 205).

The body of research concerning the motivational aspects of the uses of technology with people with physical and intellectual difficulties in education is relatively sparse. However, Bozic and Murdoch's (1997) and Blamires (1999) are two fairly recent volumes that explore the directions and potentials of these new technologies in education. The British government has placed great emphasis on the use of ICT in schools e.g. *Shaping the Future for Special Education* which was published by the Welsh Office (1999), which stated there would 'be more effective and widespread use of Information and Communications Technology to support the education of children with Special Educational Needs (SEN) in both mainstream and special schools' (p.32).

Recent reports by the British Educational Communications & Technology Agency (Becta 2005, 2006a) carry a wealth of statistical data on the current use of ICT in schools. The reports contain a range of information from teacher competence in ICT, quality of use of ICT, pupil access to ICT, teacher use of ICT in planning. It does not however address in great detail the use and deployment of advanced technologies and there is no mention of the term 'assistive technology' (AT) in either report. The 2005 report states that the document by the Office for Standards in Education (Ofsted 2004) argues that in special schools '…*the full potential of ICT to raise pupils' achievements across the curriculum has not been fully realised*' (Ofsted 2004, p.36). It indicates the governments New Opportunities Fund (NOF) initiative provided a sharp rise in teacher competencies in ICT however the 2005 report concluded there are still serious issues in ubiquitous access, reliability of networks, a lack of collaboration in the deployment of ICT, lack of workforce expertise and the need for an overall effective management system. The 2006 document reports acceleration in the development of practice but there remains '*a high variation in the adoption, deployment and use of technology*' (Becta 2006a, p.60). A more recent report from Becta on AT (2006b) highlights the lack of training opportunities in AT for both teacher and learner, and when it is available it is at a basic level. Training therefore remains a key issue- These advanced technologies are in many cases relatively inexpensive to set up and even simple programs used simply have generated phenomenal data as the results section indicates. Training must, it would appear from the literature (Becta 2005, 2006a, 2006b), continue to focus on high levels of teacher attainment in the uses of these technological developments and be shared as widely as possible.

The aim and purpose of this study therefore was to create an interactive MME and evaluate the efficacy of the system from analysis of data gathered from individual users in tandem with interviews with staff. This would propel the development of the system based on observations and interactions of the users and to compare these with the observations and comments of support staff. One particular aim was to see if, in the case of the more severely disabled users, an action could be seen to be intentional rather than random and to see if the 'afferent-efferent' loop closure took place (Brooks et al 2002). Additionally, an aim was to test the

hypothesis of aesthetic resonance proffered by Brooks (2004). As this was a probe study, i.e. the system had not been used before; the outcomes could not be pre-prescribed.

3. Methods

A sample (n=11) of pupils between 11-17 years-of-age that attended a special school for disability were selected by their teacher to take part in the study. Selection was based upon the students potentially gaining a positive experience from the interaction with the MME.

A qualitative method of enquiry was undertaken under a four step strategy of (a) design the case study, (b) conduct the case study (c) analyze the case study evidence, and (d) develop the conclusions, recommendations and implications (Yin 1994, Tellis 1997).

Following an initial meeting with the contact teacher outlining the design and potentials of the system consent letters were sent to parents informing them of the study and offering their child being included. Permit to record videos and to present as research artefacts was also agreed upon by the parents. An outline of the aims of the study was made available for all support teachers and an explanation of the system was given to each pupil. Once all ethical consideration were addressed the sessions were initiated with a teaching assistant in attendance at all sessions to ensure the child's comfort.

Before sessions began one day of videoed observation was undertaken to determine baseline of behaviour. Four sessions took place with each child in the exploratory study. Each session involved a non-intrusive means to empower the child to be in control of manipulating digital audiovisual feedback. A tactile vibrating cushion that responds to sonic input was placed under the child so as to enhance the experience (e.g. Skille 1991). Follow-up post session visits were also included to assess beyond the immediate and short-term effects.

Semi-structured interviews and discussions with teaching staff regarding typical behaviour of each student showed positive response in each case. Typically the staff members were asked to note behaviours by the pupils and contrast them with their behaviours in other class contexts or situations. Staff also offered observations during the sessions and this is discussed in the conclusions section of this article. Three case studies have been chosen as representational of the sample and their diversity of engagement within the MME.
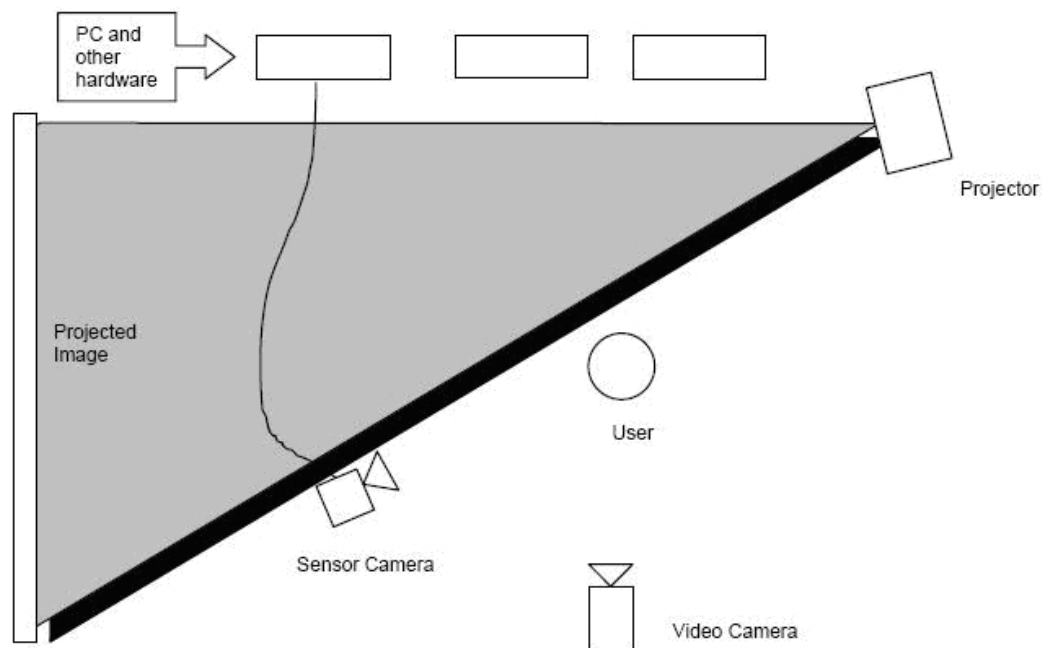
4. System Design

Figure 1 system arrangement

Eyesweb© is the name given to a graphical programming software environment developed at the University of Genoa[1]. The software was used in the European IST 5th framework project CAREHERE - with people with Parkinson's disease in Italy (Camurri et al. 2003) and with learning disabled and severe disabled youngsters in Sweden (Brooks and Hasselblad 2004). In both instances the Eyesweb 'bodypaint' algorithms that were developed under CAREHERE in Sweden were used.

The software uses 'blocks' that represent C++ algorithms that can be connected to make a 'patch'. The patch enables a camera to be used as a movement sensor where any movement in the camera's field of view is captured and processed via a computer. The processing is selectable as manipulated visual output relative to user dynamic input, and/or as MIDI (Musical Instrument Digital Interface) signals for manipulating or triggering of sonic feedback via a sound module/synthesizer. The resulting processed feedback is viewed on a large screen or heard via a sound system.

5. Method of analysis

The method of video analysis was qualitative, based in part on *Layered Video Analysis* (Ellis 1996) and the body of work that has evolved into what has been termed *Recursive Reflection* (Brooks and Petersson 2005). Layered Video Analysis (Ellis 1995) involves dissecting the video recording from the sessions into various activity components e.g. physical movement, aural or facial responses, responses to timbral qualities; and layering these into sequential accounts of particular activities thus building a record of progression in identified modes. Recursive Reflection (Brooks and Petersson 2005) involves analysis of the video but in a broader, collaborative holistic way as sessions are first viewed by the researchers and subsequently where appropriate by parents, carers, support staff, i.e. the views of those closest to the participant are thus included in the post-session video analysis/interpretations. In a similar manner to layered analysis a focused progression is addressed however Recursive Reflection differs mostly due to the maintaining of the original video recordings so that the original session data can be returned to for later reflection following advances in learning. This approach centres upon a participatory action research paradigm that is synthesized by a hermeneutic interpretation (Brooks 2006).

Collected field data included: video footage of pupils (in the Picturing Sound environment and in the normal classroom environment); the interviews and discussions with staff (immediately following the sessions and upon subsequent visits); staff notes and author's field notes from the sessions.

Case study 1
Case study one was a female 13 years-of-age with verbal competence. She had general learning difficulties and her right arm had become lame and unused ever since an operation to remedy incidences of epilepsy had gone wrong. The arm now hung by her side unused. The first session lasted around 15 minutes in which a swirling metallic synthesizer sound was selected along with a preset drum beat as the audio feedback. In her 1st session, she began 'painting' using her 'unused' right arm almost immediately the Eyesweb© processed image was switched on for a period of 5 minutes; calling to her friend to look at the images she created. A senior member of staff commented about her surprising use of her dysfunctional arm with the system. Van Raalte (1998) reports similar findings in his work with a person who uses their partially paralysed arm within his Bodysynth© system. In the brief interview following the session the pupil expressed enjoyment of the activity i.e. by talking with her friend animatedly.
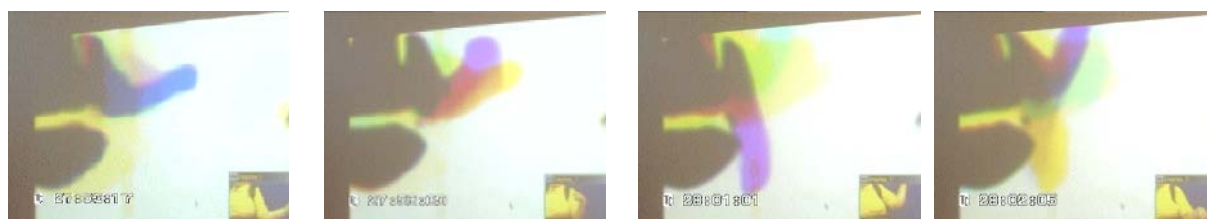

Figure 2 Case study 1 images 1-4 viewing left to right

In Figure 1 the inset image (lower right corner) shows the source image whilst the large image shows the processed Eyesweb algorithm of the source; the image sequence is numbered left to right (1-4). The blue area in image 1 indicates the initial area occupied by the child's arm; image 2 shows that her arm has moved up into the purple area whilst the yellow area indicates the previously occupied space. Image 3 shows her arm

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[1] http://www.infomus.dist.unige.it

pointing down (purple area) and image 4 her arm pointing up (purple area) whilst the 'ghosted' yellow area shows the previously occupied space. Note her arm position in the inset window in image 3 corresponds to the processed image in image 4. This inherent latency is typical in such image processing.

In the pupil's subsequent session of around 20 minutes, the camera was positioned to optimize the capturing of data from the 'x' axis, i.e. the left/right movement of her arm to maximise the audio and image feedback.

This time the sound was a swooping clear synthesizer timbre. When asked to try to move her disabled arm, she replied 'that's my bad arm', but within a minute she was using it to paint again for several minutes, seeming to forget it was her bad arm. She also made tiny movements with the fingers of her good arm, and from the video data, she appears to be visually immersed in the environment as her eye gaze was firmly directed at the screen. Again in the interview following the session the user enthused about her experience stating that 'it was good that was!'

Case Study 2

Figure 3 Case study 2 on floor mat with inverted image on screen – helper (left) author (right)

Case study two was a 15 years-of-age male without verbal competence. He had acquired severe physical and intellectual difficulties as a result of an automobile accident when he was 8 years-of-age. His first session indicated that camera positioning was critical in capturing the maximum expressive gesture possible. The system set-up was as above but his physical disabilities meant he could only see his image with great effort due to his head position when in his wheelchair as the projected image was too low. In spite of these hindrances the video analysis revealed the user made significant efforts to see his unprocessed image and vocalised his utterances frequently. The teaching assistant (TA) also noted he had smiled on seeing his initial image, as the video revealed on reflection. This vocalising increased when the Eyesweb© processed image was switched on a few minutes later and his attempts to view himself increased from around 1 second when his unprocessed image could be seen to 3 or 4 seconds with the processed image. The teaching assistant advised that the user vocalised when he was happy which is corroborated in Brooks' case study of Martin (2002) where a severely handicapped boy vocalized freely when controlling a 3D virtual spaceship by moving his head. In session 2 the teenager was placed on the floor with the screen image inverted so he could see himself as if he were upright. Again the camera was positioned to capture the maximum amount of movement of his limbs. A calm soothing sound was chosen and again he made repeated vocal responses, uttering an 'aaaaaah' sound. He initially focussed his gaze on the camera recording the scene but video analysis indicated a shift toward the screen image over the course of the session. In his 3rd session and based on his vocal responses in his first session, the addition of a lapel microphone processed through an effect unit[2] to produce a pronounced echo provided him with an additional expressive channel. His vocalisations being echoed back to him, on recognising this, his sound-making appeared to increase.

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[2] Korg Kaoss pad: www.korg.com/gear/info.asp?A_PROD_NO=KP2

Figure 3 shows case Study 2 in his final session. The scene shows his image inverted so he can see his image the right way up. This was the session where the TA said she had never heard him be so vocal and the picture captures him 'shouting'. This final session began with him smiling when placed in the space and blinking his eyes to communicate an affirmative response when author 1 questioned him if it was nice? Again the microphone was used repeatedly as he vocalized his 'aaaaah' sound, in varying volumes and pitch. When asked whether he wanted his image on the screen as previously he again communicated affirmatively through his eyes blinking. Toward the end of the session an unfortunate but significant incident occurred, and was reported by the TA in attendance as a seizure that occurred as a result of his enjoyment and over-excitement of what was experienced. Following the post-session interview the staff member remarked that the boy had seen author 1 early in the day and as a result, with memories of his previous three sessions, had been in a state of excited anticipation all day up to the session start. Following the seizure (which lasted less than a minute), the sound source was changed to a very relaxing, calm timbre and the TA reattached the microphone. After a few minutes, he began again responding vocally. It must be noted that the TA clarified the situation for those present and the incident did not seem to affect the outcome of the session in a negative way. In the follow up interview the TA stated she had never heard him be so vocal as in this final session.

It must be noted that observations from the early sessions indicated a traditional microphone on a stand was considered far too intrusive and cumbersome, the feet and arms of the stand cluttering the area and also showing up on the processed Eyesweb© image generated by the user.

Case Study 3.
Case study 3 was a 15 years-of-age, non-verbal, non-ambulant female with cerebral palsy. In her 1st session of 15 minutes, there was far too much interference from staff members for a true analysis of her responses to the environment – for example continuously they kept calling out for her to initiate vocalising and movement. In the second session however, the environment was far quieter. The user was highly stimulated by the sounds her movements made when she was activating the sensor sound module[3]. The sensor area was placed within reach of her right arm (Figure 5, image 1). The tone produced a swooping harsh sound she clearly found amusing as she laughed and smiled. Observations indicated that she had a clear understanding that her movements were generating or affecting the sounds she heard.

Figure 4 Case study 3 images 1-4 viewing left to right

The first image in figure 5 shows the location of the sensor sound module with the girl looking down at it after a short period of exploration in which the sounds respond to her movement. The second image shows her reaction beginning when she causes the device to make a radical change in sound. Image 3 shows her laughing even more in response to the sonic feedback and image 4 shows her looking back down at the device after a lull in the sonic feedback.

The girl's eye movements indicated an apparent lack of interest in the visual feedback of the space but the video of her interaction with the sensor indicate profound levels of aesthetic resonance with the audio sounds her movements generated. This state can be likened to (a) the psychological state of *flow* (Czikszentmihalyi, 1990) that is achieved when there is a perfect match between the demands of an activity and the ability of the participant where total immersion occurs, and/or (b) as an Autotelic i.e. intrinsically rewarding – experience (e.g. Steels 2004).

The 3rd session had both MIDI sounds generated from the Eyesweb patch and the sensing device (see footnote); again there was very little interest in the visual aspect however the first author posits that a much larger screen may have yielded different results. The 4th session generated similar positive interactions, however technical and logistical problems interrupted this session, and the instances of engagement in the space were somewhat brief. At the end of each session the user signed 'yes' when asked if she had enjoyed the experience whilst smiling and motioning her body to suggest a positive communication.

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[3] Alesis Airsynth™ - http://www.alesis.com/news/press/airsynth.html

6. Results summary

The results indicated significant differences in attention span or engagement in the environment with each child compared with attention in other activities or typical classroom situations as the case studies and results illustrate. This manifested itself according to the different sensory or physical impairments of each child. The exploratory study yielded indications at the potential of MME in special schools education curriculum. Despite the limited number of sessions and related interviews findings indicates at the potentials of bringing such systems into the mainstream curriculum for special schools.

7. Conclusions

The aims of this study were to evaluate the effect of a MME on different pupils with learning difficulties. Also to observe any phenomena that could constitute aesthetic resonance and to explore whether instances of the closure of the 'afferent-efferent' loop took place.

As with any prototype system there were teething problems, wires trailing, difficulties with projection, external noises and interventions and technical failures. All of these however contribute to the development and refinement of the system specifications and analysis methodologies, and therefore expanding and refining the research procedure.

The findings corroborate with those reported in Ellis (1995), where he reports pupils make clear gestures and indicate through smiles and laughs they are aware it is them who are creating and affecting the sounds they hear. Also Brooks (2004) indicates the potential for possible self-training programmes in physical rehabilitation. Case study 1 adds some strength to this theory. The work this paper outlines and references points to the need for continued research into how this technology can be further adapted and personalized to enable and empower those with disabilities to increasingly access the world around them in ways never before achievable. The potential for these new subliminal therapies (Brooks, 2003), both in the physical sense, as in case study 1, and the intellectual developmental sense, as in case studies 2 and 4, is a vein of research rich in possibilities.

The question that remains is can these user-definable systems enable and empower the most severely disabled pupils to eventually become better communicators and less dependent on others, or rather, independent? The authors suggest that in view of the results gathered here, further research and development of these types of system can help to make this a reality. Unlimited access to these technologies for as many people as possible must remain a priority. As indicated, the importance of high levels of teacher competence to utilize these advances is critical if the empowerment and enablement they bring is to enter the mainstream curriculum. Continuing Professional Development (CPD) in deploying these technologies must remain at the heart of the governments training strategies for greater accessibility to the curriculum for those with least access to it.

Implications in education of such non-formal learning potentials (e.g. Petersson 2006) for such people with different abilities must be accounted for over the current traditional methods. On reflection available tools could in future be adapted to supplement the method used of the reported study so as to satisfy the 'hard science' sector e.g. The Geneva Appraisal Questionnaire (GAQ[4]) and Geneva Emotion Analyst tool[5], both which are based on Scherer's Component Process Model of Emotion (Scherer 1993); also the Code for the Classification of Emotion Antecedent Situations and Responses tool[6] may be adapted. Inter-coder annotation is planned for the future work utilising the Anvil software tool[7] so that a clear indication of progression between and over a series of sessions is monitored. The use of such tools is speculated to enable us to approach the determining of patterns in human responses to the multimedia stimuli from a physical and psychological perspective.

The explorative study suggests that the design of this kind of system, to supplement in special education, must be able to adapt to each individual user in addressing their abilities and preferences. A selection of devices was used in the study so as to optimise the experience for the user and to maximise the potential input data relative to the abilities of the individual. A variety of multimedia content was used and findings

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[4] GAQ English version: http://www.unige.ch/fapse/emotion/resmaterial/GAQ_English.pdf
[5] http://www.unige.ch/fapse/emotion/demo/TestAnalyst/GERG/apache/htdocs/index.php
[6] http://www.unige.ch/fapse/emotion/resmaterial/CodeAppB.pdf
[7] http://www.dfki.de/~kipp/anvil/

indicated that self-modulating sounds and images can confuse as a direct association is needed to motivate proprioceptive training and to support closure of the afferent-efferent neural loop (i.e. cause & effect via the Stimulus – Response chain – see Scherer). The emotion and communication theories of the Geneva Emotion research Group[8] are inspiring for the future development of the system in respect of the human response to the feedback content.

The next step is to achieve funding to undertake a longer-term investigation as a secondary exploratory study in designated surrounds that optimise the potentials for the children so as to achieve data that is not corrupted by the interference of well-meaning staff members who are unfamiliar with research methodologies. The paradigm of the research is further being developed with the goal of more clearly defining the methodological and theoretical framework for the future iterations of the work.

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[8] http://www.unige.ch/fapse/emotion/publications/geneva_studies.html

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Real-time composition of image and sound in the (re)habilitation of children with special needs: a case study of a child with cerebral palsy

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Abstract

This paper presents a single case-study of a child with cerebral palsy conducted within the framework of a research project examining the potential benefits of real time interactive image and music composition on the (re)habilitation of children with special needs. An interface was designed to simultaneously present audio and visual feedback stimuli. The child had low mobility of upper limbs, was in a wheelchair and had a short attention span. Sessions took place over a six month period. The first thirteen sessions were analysed. Quality of movement control improved across sessions as well as the quality of the sound produced, revealing growing intentionality on music production. Independent assessments made by the multidisciplinary team of therapists who were delivering rehabilitation services to the child revealed gains in most behavioural skills.

Keywords: aesthetic resonance, cerebral palsy, music therapy, multi-sensory environments, movement rehabilitation
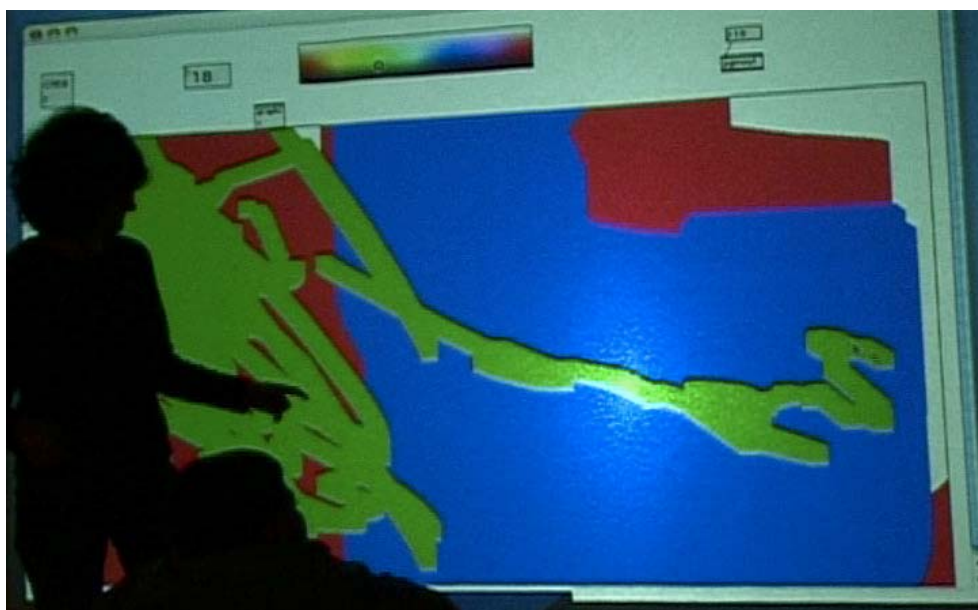
1. Introduction

Figure 1 Illustration of a frame of a session

Interfaces that offer multi-sensory feedback in the field of rehabilitation and special needs can provide a means to promote artistic activity in which the feedback is so attractive that the child is motivated to reach new dimensions of expression. This principle draws from the Aesthetic Resonance theory that refers "(...) to a situation where the response to an intent is so immediate and aesthetically pleasing as to make one forget the physical movement (and often effort) involved in the conveying of the intention" (Brooks, Camurri, Canagarajah & Hasselblad 2002, p. 205). The interface used in this study functions as a hyperinstrument where the visual feedback provides a kind of musical score as a visualization of the music produced. Hyperinstruments were primarily invented for people who are not musically educated but who nevertheless wish to express themselves through music (Machover 1992). The image can help to develop a better musical skill and vice-versa. The drawing feedback patterns can give clues for building musical patterns. Also the music heard can inspire the paintings and graphical patterns.

The aim of this study is to determine whether an interactive multi-sensory interface promotes intentional music and graphics making, increase of movement control and enhancement of the quality of life of a child with motor-cognitive disabilities. The products of intentionality are the structured musical or visual units obtained. When control is observed, intentionality is also present even if the product is not an organised musical/graphical pattern. Additionally, the investigation sought to explore whether enjoyment and motivation were promoted mainly through intentional activity and to what extent musical production depended on simultaneous graphical feedback.

Artistic expression involves intentionality. The products are the structured materials observed. As Herbert Reads (1949) writes "Art, we must admit, is not the expression in plastic form of any one particular ideal. It is the expression of any ideal that the artist can realize in plastic form". (p. 19)

This interface provides a free improvisational environment where this process could be observed.

Developmental studies on musical improvisation show that there are different stages within learning processes along time. Kratus (1996) establishes several levels: (1) *exploration* (random sounds), (2) *process-oriented* improvisation with presence of "some micro-structures but no macro-structure" (p.32), (3) *product-orientated* with four more levels of relationship between micro and macro-structures. Other authors like Prével (1979) state "children's very first improvisations reflect their motor energy" (p.14). According to Prével when children start to control their movements "they begin to alternate different colours of sound, vary the intensity of volume, and make accents, conclusions, and even introductions" (p.15).

At the musical (melodic) level, the concept of structure is based upon the motif that can be defined as an organised sequence that is repeated or varied in a musical context (Cambouroupoulos 2001). The visual units can be also classified as organized or random. In this study the child had low vision and, although he could focus on the visual feedback, revealed a predominant focus of attention on the sound and music production.

2. Method

2.1. Participant

The child (J.) is a 13 years old boy that has low mobility of upper limbs, doesn't speak and moves with the aid of a wheelchair, has a short span of attention, low vision and cognitive difficulties. A grid based on the ICF (International Classification of Functioning, Disability and Health) was created at the centre of rehabilitation to represent the functionality of this participant through use of a detailed questionnaire.

2.2. Set up and procedures

The equipment used to implement the sessions consisted of a video projector directed to a white wall or onto a screen, two pre-amplified monitors, two video cameras, tripods and a laptop. The computer was connected to the video projector and to the sound amplifiers in order to produce auditory and visual feedback. The cameras were used to collect data from the sessions in two different ways; recording both the facial expressions and the projection on the screen. In some sessions a mirror was positioned behind the child and with only one video camera it was possible to capture both simultaneously.

This interface was designed by a computer programmer in Max/MSP – a graphical programming environment - according to the goals of this study. It produces sound and graphics that should remain registered on the screen. The programmer explained how the patch works and can be edited. The pitch range was a chromatic scale that can be modified in range and direction. It was used mainly in the left to right direction (lower to higher pitch) because this is a gesture that is easier for this participant to achieve.

Several kinds of feedback (graphics with sound, just graphics or just sound) were manipulated to assess how the child was interacting with the system. This was first done by editing the visual area for giving sound feedback on just one side of the screen. This didn't produce the expected response, because the child would 'wonder why it isn't working' and would stop interacting. It was decided to keep both feedbacks active when screen was being projected. The 'just sound', or 'just graphics', feedback was achieved by simply turning off either the screen or the sound.

The instrument (timbre) could be changed, as well as the thickness of trace and the colour. Interaction was achieved through a one button wireless mouse. A two-button computer mouse was used initially, but this did not work because the level of dexterity of the participant did not allow him to be able to manage the two buttons.

Other parameters like e.g. duration of notes could also be changed, significantly altering the sound effect of each timbre. The timbres used were selected among the ones that have a short reverberation period, so that the participant has a learning environment where he is able to compose motifs with materials he has become acquainted with.

Some parallel activities took place during the sessions to motivate the user and to assess how musicality might improve if the adult for example, dances to the music created by the child.

3. Results

Data was obtained from analysis of the first thirteen sessions. This analysis was done using detailed observations of behaviour for each ten seconds of interaction.

The level of activity was compared within and across sessions (Figure 2), the number of musical motifs and time spent on intentional production (Figure 3), the effect of "on-line" graphic feedback in musical intentionality, and enjoyment and motivation in the act of creation assessed by facial and vocal expressions.

The parameters observed were:

- Presence and quality of control: weak, moderate or high
- Presence of motifs, their duration and type
- Emotional reactions: laughter, vocal utterances and facial expressions
- Time spent in parallel activities: which activities and what reactions happen during those extra-session time

The difference between intentional and non-intentional can be obtained through the assessment of various parameters, particularly direction of gaze and control of velocity. It can also be evaluated through repeated sound patterns where the graphical feedback is not what is actively followed.

The percussive motifs are the ones that stand as products unequivocally due to intentional activity. The creation of e.g. parallel graphic traces that are translated into parallel chromatic scales can make us question whether the intentionality was directed towards the graphic or music composition.

Although it is clear that there is an organized sound pattern, it is not absolutely evident if it was made in order to create a particular graphic effect or a particular sound effect. Nevertheless at this moment a pattern defined as a musical motif is created.

With this interface it is possible to evaluate the preference of the participants toward graphical or musical composition.

We can conclude that the participant of this study reveals a higher aptitude to the sound composing. This could be because of his low vision, low dexterity and/or due to his natural aptitude.

The quality of the musical expressions is assessed by its degree of complexity and sophistication.

Alternating between two motifs consecutively would already be considered a sophisticated musical pattern.

In drawing the quality can be assessed by the use of a greater amount of resources for its achievement, namely different sizes of trace or patterns of colours and more accurate representative drawings.

Results showed that the child increased the frequency of his interactions (Figure 2). Intentionality was preserved even when visual feedback was removed. Indicators of enjoyment and motivation increase across sessions and were mainly associated with intentional activity.
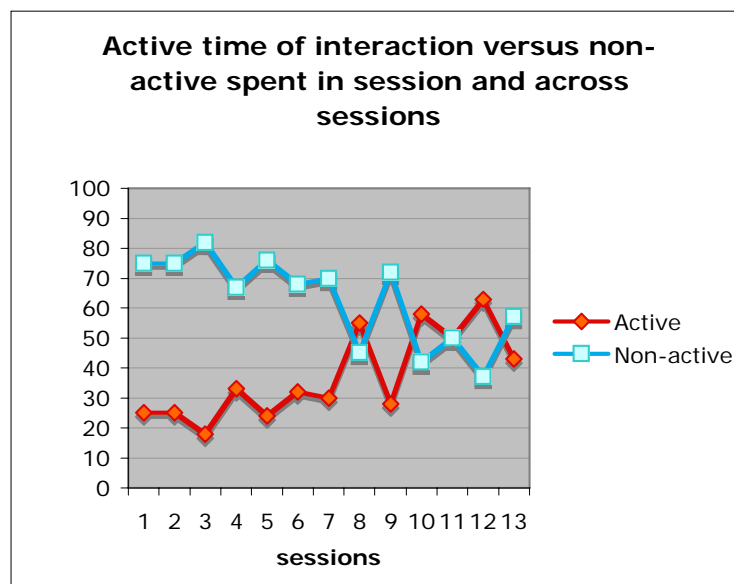
Figure 2 Active time spent on sessions versus non-active

The percentage of motifs increased across sessions (Figure 3). Regarding the quality of motifs, the data indicates that the child was producing more accurate and sophisticated patterns in later sessions.
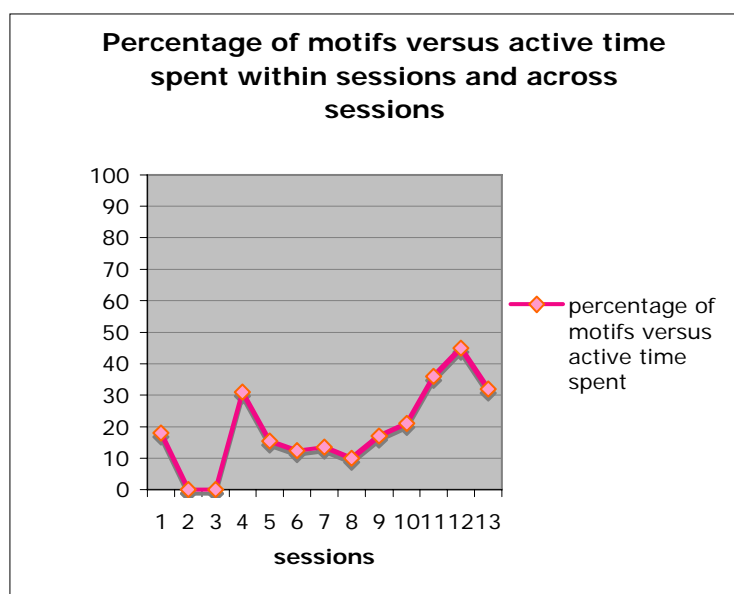

Figure 3 Percentage of musical motifs: across session analysis comparing the total time of being active with the time of musical motifs produced.

The analysis of the data suggests that parallel activities played a supportive role in the maintenance of engagement with the interface.

The multidisciplinary team therapists at the Rehabilitation Centre reported several parameters of progress in a scale from one to five points as can be seen in the next chart:
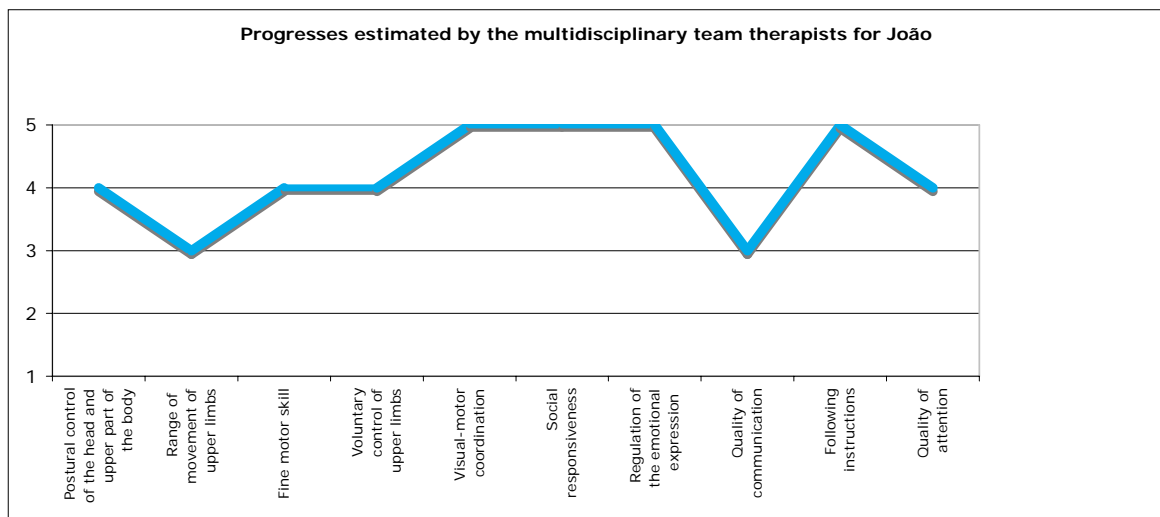
Figure 4 The multidisciplinary team therapists estimated progresses for various parameters in a scale ranging from one to five points

This report was answered bearing in mind not only the results obtained with the sessions but also the potential of the use of this interface for this child on a permanent basis. According to their estimates, progress was very satisfactory (5 points) for social responsiveness, visual-motor coordination, regulation of emotional expression and following instructions; quite satisfactory (4 points) for postural control of the head and upper part of the body, fine motor skill, voluntary control of upper limbs and quality of attention; satisfactory (3 points) for the range of movement of upper limbs and quality of communication.

4. Discussions and conclusions

In this study musical intentionality seems to be achieved and increasingly promoted with duration of participation: Brooks (2004) observed, "Longer interactions usual lead to a desire for subsequent interactions which stimulate, resulting in motivations of behaviour being generated" (p.18).

Since musical units were initially obtained with the support of graphical feedback, it can be stated that graphical intentionality is also involved in the child's activity. Preservation of previous motifs when graphics are removed suggests that image feedback is not necessary for maintaining musical structure. However, it may happen, in some cases, that the creation of original motifs requires graphical support. This hypothesis should be tested.

This interface was used with a child with low mobility of upper limbs that reduces his capability of drawing representative figures. Therefore, it would be interesting to compare the use of this system in a systematic way for children with different aptitudes and abilities.

It is possible to create systems more directed towards the artistic expression that each individual is able to express. This ability can be due to a natural aptitude or to the physical or cognitive impairments that the client may possess. Thus, for example, for a blind person it would be interesting to develop a mapping of space through events like sounds and smell, which happen in determined locations in space. This would provide a feedback that promotes space mapping through artistic expression, giving the visually impaired the acquisition of improved skills and the opportunity of doing so within the aesthetic experience.

In this study the intentional relates directly to the capacity for-, and the will to-, control the feedback. The will to control is due to the motivation the child feels in creating work of his own that gives him instantaneous fun and self-achievement. If in this child it is possible to improve his mobility, quality of attention and quality of life in general using such interface, it is possible to specify developments for people with other special needs.

To assist developing a broader span of mobility impairments, special interfaces can be built and other types of interaction used. For instance the use of non-intrusive technology for movement detection is one of the applications that could be used by a larger spectrum of people with disabilities. In order to meet the preferences and abilities of

the participant of this study the multidisciplinary team of therapists and family identified the use of computer mouse and keyboard as one of his favourite activities

Results suggest that enhancing artistic expression may improve motor and cognitive skills. The use of aesthetic resonant environments offers opportunities for artistic expression for people with disabilities. These opportunities must be considered as a means to improve quality of their life. The qualitative report that was composed by the multidisciplinary team of therapists state at the importance of the inclusion of this kind of activities in a permanent basis at the Centres of Rehabilitation in Portugal.

Acknowledgements

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MusiCam – an Instrument to Demonstrate Chromaphonic Synesthesia

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Abstract

Inspired by a type of synesthesia where colour typically induces musical notes the MusiCam project investigates this unusual condition, particularly the transition from colour to sound. MusiCam explores the potential benefits of this idiosyncrasy as a mode of Human Computer Interaction (HCI), providing a host of meaningful applications spanning control, communication and composition. Colour data is interpreted by means of an off-the-shelf webcam, and music is generated in real-time through regular speakers. By making colour based gestures users can actively control the parameters of sounds, compose melodies and motifs or mix multiple tracks on the fly. The system shows great potential as an interactive medium and as a musical controller. The trials conducted to date have produced encouraging results, and only hint at the new possibilities achievable by such a device.

Keywords: colour organ, audio synthesis, musical controller, synesthesia, HCI

1. Introduction

The term synesthesia (from the Greek, syn = together + aisthesis = perception) means 'joined sensation' and as such refers to an involuntary physical experience in which the stimulation of one sense causes an additional perception in a different sense or senses (Cytowic 2003). For example, a synesthete might feel, see or taste a person's voice as well as hearing it; might detect a scent on seeing a particular colour; or when looking at printed black numbers might see them in colour, each with a different hue. Synesthetes represent a group of otherwise 'normal' people who experience the ordinary world in extraordinary ways due to their senses of touch, taste, hearing, vision and smell becoming mixed up rather than remaining separate (Ramachandran 2003).

2. Aims and Rationale of the MusiCam Project

The MusiCam project aims to explore a particular type of synesthesia where colour will typically induce musical sound. Whilst it is impossible to replicate exactly different synesthetes' personal perceptual abilities, through the use of digital multimedia techniques we can create virtual synesthesia (MIT 2006) demonstrations that give a close approximation to what a person with synethesia might experience. In addition to studying the perceptions of synesthesia we explore the issues of colour sound combinations more generally with regard to using them as a computer based communication medium, for relaxation or rehabilitation purposes or as a static or interactive ambient display.

With these goals in mind, there are three intrinsic areas of interest which have influenced and inspired the development of the MusiCam system:

- The colour/sound phenomenon and audio/visual art.
- The synesthesia condition and chromaphonia in particular.
- Human Computer Interaction (HCI), musical controllers and Interconnected Musical Networks (IMN).

Colour/pitch scale systems were devised as early as the 16th century and 'colour organs' [note 1] developed by the 18th century (Moritz 1997). In these early systems the relationship between colour and pitch was normally determined by the inventor of the system using mathematical techniques. Even today's counterparts still use scales that are fundamentally drafted from assumption; but with computers frequently involved in producing arbitrary mappings between colour and sound (Abbado 1988). In chromaphonia (coloured hearing), a type of synesthesia (Cytowic 2003), those with the condition will naturally associate a particular colour with a corresponding musical note and in effect create their own colour scale; often this is unique for each synesthete.

Aside from investigating the characteristics of the condition, we believe that discovering novel ways to interact with the personal computer will improve human creativity and in consequence improve communication and cooperation between humans. The benefits of sound and music in computer interaction are often forgotten even though auditory stimuli may leave longer lasting impressions than visual stimuli (Darwin 1972), better recall can be attained if information is received aurally as opposed to being read, and humans can react faster to auditory stimuli than to visual stimuli (Goose 1998). Music is one of the most highly structured auditory mediums and communicates through parallel streams, which can be effortlessly extracted and differentiated by our human cognition processes. Additionally, the inspirational qualities of music naturally spawn a multitude of research areas such as music in education, music therapy and more recently Interconnected Musical Networks (IMNs) which allow players to independently share and adapt each others music in real time (Weinberg 2001, Machover 1996).

3. The MusiCam system

The MusiCam system uses image processing techniques to extract colour data from a webcam. The colours that result from the extraction determine what note, track or instrument is played. Adding more colours can result in richer textures and increasing the level of a particular colour manipulates the dynamics of the system. Different banks of sound clips can be loaded into the system generating new sound/colour mappings, changing the character of the system and forcing different user interactions. For example, loading an ambient sound bank encourages minimal or moderate exchanges and suits therapeutic purposes whilst loading a DJ sequencer promotes more aggressive and complex interactions as user mix multiple tracks in real-time.

The test platform currently used is displayed in Figure 1 below. This particular arrangement is composed of a slowly rotating plinth on which coloured objects are placed and a mast which houses the webcam, positioned so as to allow a section of the disc to be examined.
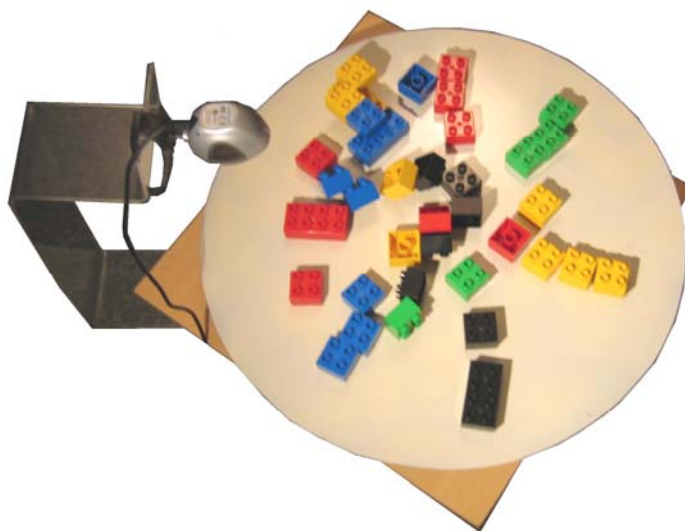

Figure 1 Test platform

In this configuration, users can carefully organise blocks in an orderly manner away from the webcams view. This can lead to structured and composed connections as clips are played in specific timing with one another. However, since the plate is continually spinning, even few or little interactions with the blocks can still result in continuous, highly textured music.

3.1 Colour Filtering and Performance
It is possible that the raw image from the webcam may contain a number of dark areas and shadows, and may lack overall definition. To address this, a series of tuning mechanisms have been implemented. This affords the user the ability to clean up the image on the fly. Any part of the image in the application can be selected for

processing, making it possible to eliminate the darker regions surrounding the edges as well as limiting the number of blocks examined at any one time. Additionally, the brightness and contrast can also be adjusted in real-time. The figure below shows a series of screen captures taken from the test application.

Figure 2 Screen taken before and after colour extraction

The idea of the colour filtering is to allocate pixels based on their RGB values into a discrete colour set. The method employed works by passing each RGB pixel value through a simple framework of logical operations, and after rational deduction, the system selects the colour to which it matches closest. At present, the system is able to distinguish between 10 different colours; the levels of these correspond to the volumes of the individual sound clips, and are illustrated on a dynamically changing bar chart on the interface. Adjusting the volume this way helps to make transitions smoother, between objects and areas with no objects.

3.2 Background masking

Currently MusiCam is programmed to nominate a single colour to ignore so that this can be used as the background mask. This allows the system to easily distinguish between moving or foreign objects. Without this mask, MusiCam would continue to play music with or without user interactions. Whilst this might be appropriate for a static ambient display it limits greatly the number of possible webcam arrangements. For this reason a further background masking module is introduced. The concept of this is to capture the image without the foreign objects present, and then subtract this image from all subsequent frames. By using this process it is possible to display all the pixels that have significant change (new objects in the frame) and to replace non-changing pixels with white respectively. This new image can then be processed and filtered for its levels of colour as before.

Since even the smallest changes of intensity could be detected, a thresholding equation similar to that developed in (Foyle 2004) was introduced. The values were tweaked accordingly so that only the larger changes will be displayed. The modified equation is presented below, where change in intensity is the difference in intensity between a pixel in the background mask and the corresponding pixel in the captured frame, and the new intensity refers to the intensity of the pixel in the captured fame.

$$Output = \begin{cases} DrawPixel, & if \ \dfrac{ChangeInIntensity^2}{(NewIntensity+1)} > 1.02 \\ \\ MakeWhite, & otherwise \end{cases} \tag{1}$$

Although this background removal technique works well with simple backgrounds, in more demanding and busier backgrounds the image resulting from the background removal process often does not exclusively contain the foreign blocks, it will also contain noise representing shadows, small changes in the scene and changes in lighting. The existing process is refined with the addition of another algorithm, which works on the principle that a pixel in a densely populated (non-white) row and column is more likely to belong to a group of pixels making up a foreign object than that of noise. Simply, the method works by firstly totalling the number of non-white pixels for each column and row, after this each suspect pixel is ranked by multiplying the corresponding column and row value. By using this method it is possible to eliminate some of the noise in the image. In Figure 3 a coloured block is introduced into the picture, the background is removed using the thresholding equation and then with the added noise filter to remove the light nuances.
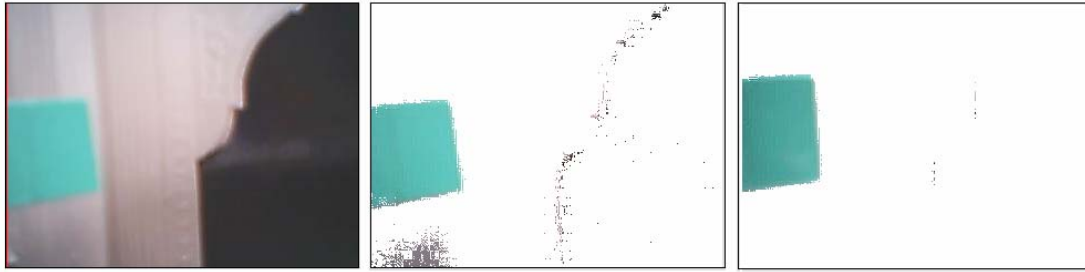
Figure 3 Background masking and noise filtering

3.3 Multiple voices

A straightforward way of achieving much richer and interesting sound from MusiCam is to increase the number of voices being used at a time. The image can be divided horizontally into equal parts according to the number of voices selected. Each of these segments can then be assigned to a different voice or sound bank, leading to multiple colour-to-sound mappings. For instance, if the picture were to be divided into two parts, it would be entirely possible to use the same colour to trigger off two independent sounds by moving it from one half of the image to the other.

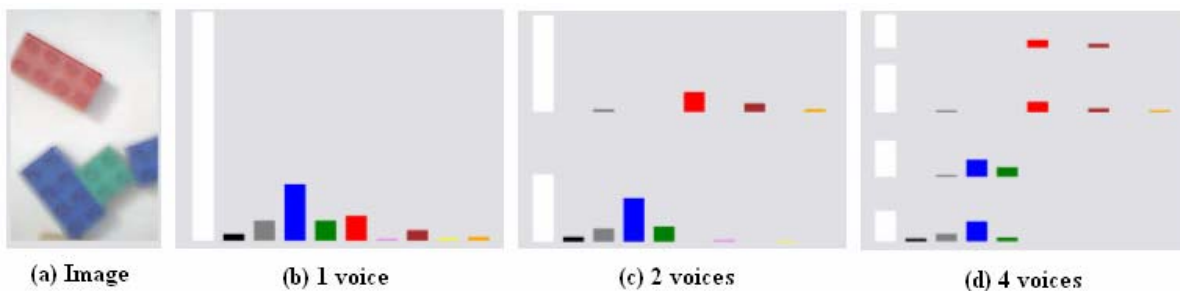(a) Image (b) 1 voice (c) 2 voices (d) 4 voices

Figure 4 A demonstration of image segmentation

By using this function it is not only possible to increase the number of different instruments, but also to extend the range of a single instrument, for example by having a higher register of notes in the upper segments and vice versa.

3.3 User modes

For demonstrative purposes there are three modes which aim to exploit the diversity of the system. Each mode encourages a different type of interaction and consequently has different application potential. Demonstrations of these modes can be found in (Yau 2006).

In the first mode, collections of ambient sounds are used. This encourages minimal or moderate exchanges and suits therapeutic purposes. It is also attuned to other ambient based applications, for example by positioning the webcam in a hallway or lobby it could serve as an ambient device, playing music to people passing by.

Much different to the ambient mode is that of the synthesiser. Funky drum, guitar and bass loops make up this mode, and it promotes almost aggressive interactions as users cope with mixing multiple tracks in real-time. It is much preferred to have the platform stationary in this mode and not continuously rotating. Areas of interest can be set up in different parts of the circle and activated by spinning the plate manually, the action similar to that of a DJ spinning a turntable deck. A user can also wave the webcam like a stylus over the areas of interest, zooming in and out to gain expression.

A collection of musical notes make up the sound-banks in the last mode. Aiming to play virtual instruments much like a keyboard would, this mode has as much appeal as a toy xylophone, and thus benefits as an introductory music aid or educational toy.

4. User Feedback and Further Plans

To date, more than a dozen users have experimented informally with MusiCam and feedback has been very encouraging. As well as giving users an insight into synesthesia, users have frequently remarked on the quirky originality of the concept, and have positively given ideas, prompting the future implementation of extra features and functionality, which could heighten the user experience. An idea currently under consideration is to include sound panning. So if an object was to enter the frame on the left and leave on the right, the system would emulate this by panning the sound from left to right accordingly. The rate of object movement could also be studied and used to influence the pitch of a sound. However, both of these new additions require some form of object tracking, and hence the system would need to take into account previous states.

Indeed the novelty of using colour as a musical controller is not restricted to it being an ambient, interactive musical platform. MusiCam also has considerable scope for developing into a tool for music education, much like the Hyperscore system (Farbood 2004); a graphical compositional software utility which interprets gestures and strokes as musical ideas.

There has also been much interest in the area of therapy and assistive technology for children with special needs. One expert who specialises in building interactive rooms and spaces for children who are disabled or have sensory impairments wishes to use the technology to enhance the experience in these spaces. They consider the technology could be extremely rewarding especially for children that suffer from blindness, as colour based gestures could be used to manipulate appropriate sounds, for example blues would indicate water based clips and greens associated with fauna and meadows, and a fun interaction would encourage those previously unable to distinguish or see the beauty in natural colour. Also, studies have shown that music therapy is especially of value for pupils who through differing forms of autism find it difficult to communicate in more traditional ways (Alvin 1991). Another area of research therefore is to establish whether this type of HCI serves as a useful interaction mechanism for these individuals, as well as an interactive toy

Modern music artists nowadays use computers to create and manipulate sound. It is not unusual for a band to bring on the stage a laptop as a supporting musician. Triggering these sound clips and tracks can be to the audience visually dull and un-stimulating however using the MusiCam software as a real-time musical controller instead of the typical keyboard would allow more freedom and expression to the performer and also enhance the live music experience for the audience.

5. Conclusions

"The sound of colour is so definite that is would be hard to find anyone who would express yellow as a bass note or dark lake with treble…"   - Wassily Kandinsky – Artist & Synesthete

The system developed during this project has given the chance for others to experience something quite unique. Aside from effectively demonstrating virtual synesthesia, testing and evaluation the system has demonstrated the realistic potential of MusiCam as an adaptable musical controller, that could easily grasped and learnt by a child as well as having the technical specifications required of such a controller by a professional musician.

A major benefit of the system developed is that it is easily accessible by others. Since the system is software based, and only requires the additional support of an off-the-shelf webcam and regular computer speakers, potentially any personal computer can take on the identity of an interactive musical device.

Just as Hyperscore (Farbood 2004) allows children to leap over the obstacle of musical notation and technique in order to express their compositional creativity, the MusiCam software also hopes to give people the opportunity to make instrumental music before they have achieved the mastery of the techniques of a conventional instrument.

Note 1: Colour organs are interactive musical controllers capable of creating abstract audio/visual compositions in real-time. A phrase coined by Rimington in 1893 (Peacock 1991) the earlier machines looked like typical instruments and when played controlled coloured gas lamps or coloured paper strips lit by candles.

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Unintentional Therapy, Unexpected Results: My artistic life to this point

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Abstract

This autobiographical paper explores the varied and intricate relationships between the creation of visual art (through painting, drawing and sculpting) and the improvement of cognitive functions. It expresses the point of view of the "patient" as this author shares her own personal experience with using art elements (colour, line and shape) as a neurological stimulus. These creative and expressive therapies (though unintentional, in this case) were instrumental in restoring her cognitive abilities after surviving a massive childhood stroke. She goes on to relate how she applies this learning to working with children, adults and others with varying degrees of cognitive/neurological dysfunction today.

Keywords: sensory perception, neural pathways, visual stimuli, motor co-ordination, foundational elements

1. Introduction

This author may be an unlikely candidate for writing this type of paper on this particular topic for an international audience. I am a self-taught artist without any official credentials (although it is my wish to someday earn my Masters in Art Therapy). But years of independent study and my personal experiences with brain trauma and recovery have combined to give me insights into this field. Unlike an academic who may only be able to claim knowledge of this subject from relevant writings, my views are largely supplemented by a unique experiential knowledge.

2. Background

I grew up on the rugged west coast of the island of Newfoundland (off Canada's eastern coast). My family lived in a very small community, with few amenities that a larger city would have (i.e. – public transportation, paved roads, etc.) I now realize that I had a distinct advantage with growing up in this environment – my father was a graphic artist, so I can't remember a time when paint, pencils, clay and other assorted art materials were not in abundance around our home. My brother and I were always drawing, painting, sculpting or otherwise creating something. This creative background would help spark ideas on which I was to base my life's work.

I suffered a massive ischemic[1] stroke when I was eight years old. At the time, doctors were not quite sure what caused it – over 25 years ago in rural Newfoundland, they did not have access to the technology that hospitals take for granted today. We had never heard of magnetic resonance imaging, and there was no CT scanner on the island. A cerebral angiogram was performed a week after suffering the stroke, and this ruled out possible causes (for example, cerebral tumor). Doctors theorized that the cause was probably an accident that I suffered the day before at a grade three "Education Week" winter party, at which we were sliding down hills of snow as part of the celebration. I was struck in the head by a tobaggan, and I possibly suffered a concussion. Because of lack of technology and delays in diagnostic treatment (the only treatment facility for stroke patients was in our capital city of St. John's on the other side of the island - about 8 hours away by car), they could not pinpoint a definitive cause.

The stroke damaged my brain's left hemisphere. This resulted in right-sided hemiplegia[2], anomic aphasia[3], problem solving, mathematical and memory difficulties. Not much was known about pediatric strokes at the time, and the presiding doctors warned my parents not to be too optimistic about my recovery. Due to its severity, they were not sure how much I would recover of my cognitive and physical abilities. I would need to learn how to walk, talk (overcoming facial paralysis as well as using nouns, verbs and other grammatical rules correctly) and overcome more basic difficulties associated with the stroke (dressing, feeding myself . . .) Doctors were also concerned with behavioural and learning difficulties that I might possibly exhibit as a result of the damage to my brain.

The residing neurologist gave us one glimmer of hope – he said that, like many stroke patients, the information that was already stored in my brain as well as my capacity to learn were not gone. Rather, the

"bridges" were "burned", or the neural pathways were disconnected. (For example, if shown a picture of an object, I could not tell what it was unless given a choice. The object's name was still in my vocabulary, but I could not retrieve it unless assisted.) If I were to resume anything approaching a "normal" life, I would have to "rebuild" those "bridges" from scratch. The neurologist stated that this would be a long, arduous process – there would be no guarantee as to how much I would recover of my abilities.

Despite this somewhat bleak outlook, my family encouraged me to continue creating art. They thought it would help me with my motor co-ordination and my left-handed writing skills, since I was right-handed before the accident. I began by simply making marks on paper with a pencil. Over time, I added colour to my art by colouring simple, pre-drawn images. At the time, I was most strongly attracted to bright and neon colours (I would only make a connection between my first colour choices and neurological "healing" years later). I experimented with clay and began to complete unfinished drawings and, later, to draw simple objects and face shapes of my own. (Figure 1)
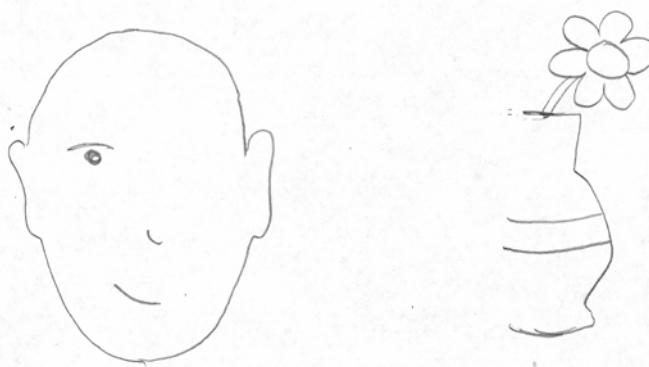

Figure 1 Samples of unfinished drawings that I was to complete

Figures 2 and 3 show my artwork as I was progressing through school. Figure 2 is a pen and ink work that I completed in grade 7 (12 years old). Figure 3 is a figure drawing (two knights) that was completed in grade 11 (16 years old).
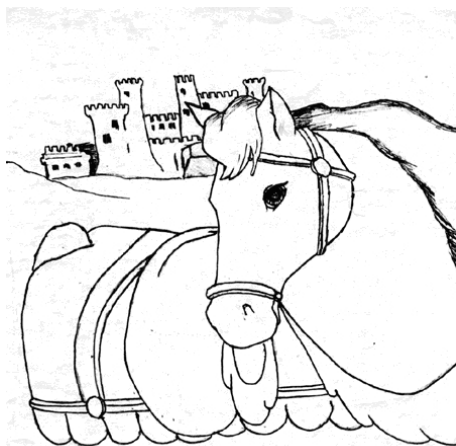

Figure 2 Pen and ink on bristol, 1983   Figure 3 graphite on cartridge paper, 1988

In the years that followed, I surpassed the expectations of the resident neurologists and stroke specialists. I did not experience many of the cognitive or behavioural problems that they had predicted. Contrary to their opinions, I also did very well (with the exception of mathematics) academically – although I struggled through elementary school, I graduated high school with honours. During this time, I continued with my creation of art works, and I was noted among my peers as an "amazing artist". I was also becoming more aware of other stories of neurological improvements in survivors of brain trauma when using visual art as

therapy. From that point, I began to suspect that creating art had played a bigger role in my recovery than previously realized.

From authors like Betty Edwards and Shirley Riley, I learned that our brains are most active in the first three years of life. The right hemisphere plays a dominant role in these formative "non-verbal" beginnings. At that time, we have not yet achieved a mature concept of words, symbols or linear constructions. We try and make sense of our enviornment by studying the colours, lines and shapes that it contains. This is why many of us were so prolific at creating art in our early years. When drawing, colouring and sculpting, we were making our first attempts at processing visual information. These sensory perceptions fuel our higher thought functions, and stimulate dendrite growth in the brain. As we grow older and become more proficient at symbolic and language oriented tasks (or left hemisphere specialities), many of us rely less and less on shape, line and colour for stimulating our mental processing. With few exceptions, the left hemisphere becomes the dominant side of the brain. As the brain becomes more efficient (as suggested in the University of California's study of the inverse relationship between glucose metabolic rates and intelligence in *Intelligence and changes in regional cerebral glucose metabolic rate* – see full reference in the 'References' section.), areas in the right hemisphere that were once used for such tasks as shape formation and visual-spatial orientation are ignored in favour of the faster symbolic mechanisms of the left hemisphere.

At eight years, I was possibly at an ideal age (if there is ever an "ideal" age to suffer a massive stroke!) to undergo a cerebral vascular accident. My brain was at peak performance in both the left and right hemispheres. Although a left hemisphere (or the dominant brain half) stroke is still widely regarded as more damaging in terms of day-to-day living, my right hemisphere was still sufficiently active to eventually compensate for most of my damaged cerebral areas. I cannot help but think that this was supplemented by manipulating art elements (for example – line, colour and shape) through the years.

When I first began to draw and paint after the stroke, I reverted back to my "non-verbal" beginnings to try and make sense of environmental sensory stimuli. As in my formative years, this manipulation stimulated dendrite growth, strengthened and possibly even rerouted neural connections between the right and left hemispheres. An increased number of dendrites and strengthened pathways led to improved mental processing speed and thought function. Tactile media (for example, clay, and finger paint) improved my fine motor control and the connections between my pre-frontal motor cortex as well as my muscles in my left arm and hand. My creation of artwork also strengthened blood vessels leading to the brain, thus leading to re-development in a more oxygen and nutrient-rich environment than otherwise would have been possible. This must have been what the neurologist was referring to when he stated that I was going to have to "build my bridges" all over again. However, I sincerely doubt that, at the time, he knew about the neurological benefits of creating art.

Presently, I have an art studio - I sell art supplies, original paintings and teach private art classes. I initially became an art instructor to supplement my income. I did not make a connection between my recovery through art and the needs of my students until a few years after I started teaching.

At one of my drawing classes, a student was highly frustrated with her sketch. She reported that she was having no problem "seeing" the object in her mind, and she could understand my instructions, but she was unable to translate that image to the paper. I suddenly realized that my students had a left / right hemisphere problem of their own with which to contend.

Because most of us rely more heavily on the left hemisphere as we become older, areas in the right hemisphere are dismissed as being irrelevant for efficient performance. Over time, unused dendrites seem to atrophy and finally, the neural pathways leading to these right hemisphere areas begin to close down. Therefore, these students (who had no prior brain trauma) were just as "cerebrally disabled" as I once was – though possibly through disuse and not damage. Presented with an object, they had no problem seeing the object, visualizing the object in their mind's eye and understanding the object, (as I had no difficulty understanding these things after the damage to my brain).

They had no problems with verbally describing the object (as I could not at the time of my accident, caused by damage to my left hemisphere). However, their brains lacked the capacity to retrieve stored information and make sense of it in terms of line, orientation, shape, etc. In order to teach them to draw, paint and become spatially aware, I was going to have to help them rebuild their own neural "bridges" from scratch.
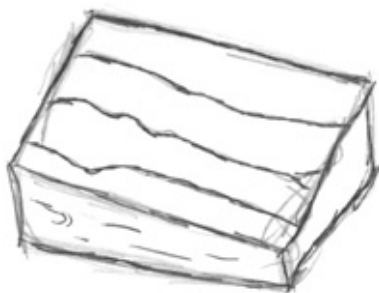
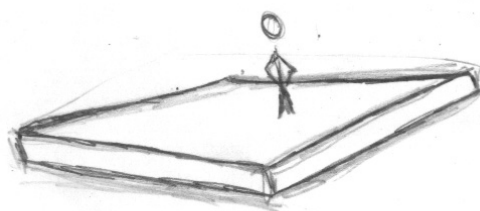Figure 4   Figure 5

Figures 4 and 5 are examples of wharf sketches. In this particular class, I made the mistake of telling my students to think of the wharf as "diamond-shaped". Many beginners used their logical left hemisphere to draw a diamond symbol (as in Figure 4), instead of actually drawing the shapes presented (as in Figure 5).

At the next few classes, I introduced exercises involving only line, abstract shape and colour – exercises not entirely unlike those I completed after suffering the stroke (Figure 6). After independently studying relevant material by such authors as Dr. Vernon Mark and Rudolph Arnheim, I knew that this would be an excellent way to "wake up" the right hemisphere. Over time, these exercises had the desired effect in that the students now could understand basic art elements more completely. They seemed to be making connections between visual stimuli, image recalling, shape formation and motor function. Several students remarked upon other unexpected benefits as well. Some older students claimed a diminished ability to perceive colours of similar hues when they first began to attend my classes. After a couple of months, however, they could differentiate between hues that are close to each other on the colour wheel (i.e. red and orange). Some claimed to "think" better after attending my classes. Many commented on the increase in energy they experienced, as well as their improved ability to cope with stress. In my humble opinion, these improvements seem consistent with neurological improvements that I experienced after suffering my brain trauma ordeal. Increased dendrite formation and stronger neural pathways would explain improved colour recognition, visual-spatial orientation and thought function, as well as improved coping ability. An increase in blood supply to the brain (therefore, an increase in oxygen and nutrients as well) would explain the energy increase.

I find it fascinating that, in all my reading on the subject on art as a therapy, most material will overlook persons with no experience of brain trauma – it is assumed that these people are at their peak in terms of neurological performance. But, in my own experience, that is not the case. Perhaps what is needed is a person whose personal expertise in brain dysfunction gives her the authority to point this out! I first volunteered my time and ability at the Bay St. George Long Term Care Centre in June 2004. This facility is the only government-funded geriatric care institution in the Bay St. George region. I contacted Lisa Henley, the resident recreation specialist, and told her about my ideas for an art program there. With her help and using my knowledge, I tailored these classes to meet the residents' needs and abilities. Since the art program was launched, I have had experience with teaching people having such impairments as arthritis, motor skills limitations, mobility problems, Alzheimer's disease, stroke, other neurological impairments and types of brain trauma.
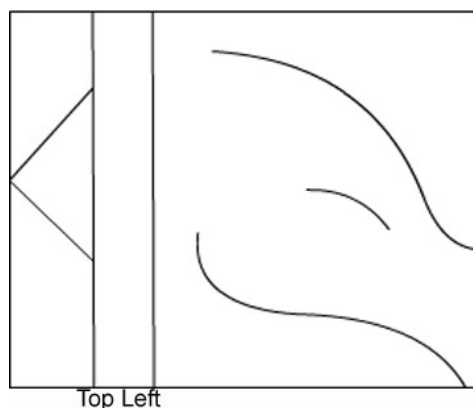

Figure 6

Figure 6 shows an example of a drawing exercise. In this particular exercise, I instruct students to divide their drawing paper into 4 squares. Then students are to draw exactly what they see in the prescribed square.

Between June of 2004 and December of 2005, I spent a few hours a week with these residents as we created with paint, oil pastel and clay. I choose colours for our paint and oil pastel projects very carefully. In my research, I discovered that bright colours stimulate the brain, and dark colours relax the brain. I did not want to over-stimulate the neurological processes of the residents, so I choose pictures that would not tax them psychologically. These pictures were mostly of Newfoundland landscapes and scenes that they would remember from their lives in the community (with neutral colours and very few bright colours). This would encourage them to talk about their youth and their memories, which, according to Dr. Vija Lusenbrink in his 2004 paper *Art therapy and the brain: An attempt to understand the underlying processes of art expression in therapy* stimulated the formation of new sensory pathways by itself. When the residents started to paint, I could direct them to paint a particular shape, rather than referring to the picture as a whole, in order to activate parts of the right hemisphere.

Over time, Lisa and I began to notice several things. The use of tactile media (such as clay and drawing materials) aided in maintaining and strengthening motor skills as well as eye / hand co-ordination. Clay was especially important for stimulating the sensory system. Its three dimensional nature also improved their visual-spatial awareness. Over time, residents who came to these sessions on a regular basis finished their projects much more quickly than they did at their first few sessions. Their stamina within the program seemed to be improving as well (that is to say that they did not seem as tired when completing a project). This indicated improved (or more efficient) brain functioning and faster mental processing speed. At this point, I was expecting these results because of past experience. However, I was surprised to see improvements in other aspects of their lives, which may be unique to the geriatric age group. Many residents experienced heightened self-esteem when completing an art project. Unlike programs that focused on something that they may have once been good at (for example – knitting, woodworking), every improvement was one that they could be proud of. Residents who had never participated in other programs offered by the facility took part in the art program, thus diminishing their isolation from their social group. A resident art show was put off in September 2004, with great success and accolades from the community and our local Artists' Association. (Figures 7 and 8). Overall, the program was a huge success.

Figure 7   Figure 8

It was with great sadness that, in January of 2006, I moved from the Bay St. George region to the neighbouring city of Corner Brook. However, it seems that my reputation preceded me because I am currently in charge of another volunteer geriatric art program here. I have also set up another art studio, where I am teaching people using the same curriculum as in my Stephenville classes. I am seeing improvements in my students here that are consistent with improvements witnessed in my Stephenville students. This cannot be dismissed as coincidence. Rather, I feel confident in saying that the creation of art is a powerful tool when used to improve brain connectivity. Art components such as line, colour and shape can be seen as foundational elements in our structure of mental processing. If recognition and manipulation of these elements weaken, it seems to handicap our higher thought functions over time. This can prove to be a serious stumbling block as we grow older, especially if we suffer some sort of brain trauma and we do not have the luxury of right hemisphere function to fall back on. The above evidence suggests that, to keep the brain at peak performance, we need to incorporate activities that strengthen the right hemisphere, as well as the left.

The geriatric art program has been attracting a lot of attention from people and organizations in the area including the Honourable Minister of Health of our provincial government. As this paper is being written, the research board at Western Health (our local health care organization) is considering this program as a possible pilot research project. With my experience and an abundance of articles, books and other relevant writings by such authors as Rick Garner (among the first to suggest a possible model for neuropsychological art therapy) and Dr. Maureen Del Giacco (American Creative Art Therapy Institute) as support, I feel validated in stating that such a program is needed.

Explanatory notes
[1]ischemic – stroke caused by the interruption of blood flow to the brain, most commonly due to a clot
[2]hemiplegia – paralysis
[3]anomic aphasia – speech disorder in which I found it very hard to express myself verbally, using nouns, verbs or other grammatical rules

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Flying Cities: building a 3D world from vocal input

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Abstract

The Flying Cities artistic installation brings to life imaginary cities made from the speech input of visitors. In this article we describe the original interactive process generating real time 3D graphics from spectators' vocal inputs. This example of cross-modal interaction has the nice property of providing a tangible correspondence between the two spaces. This interaction mean has proved to suit the artistic expression well but it also aims at providing anyone with a pleasant and stimulating feedback from speech activity, a new medium for creativity and a way to visually perceive a vocal performance. As the feedback we have received when presenting Flying Cities was very positive, our objective now is to cross the bridge between art and the potential applications to the rehabilitation of people with reduced mobility or for the treatment of language impairments.

Keywords: speech processing, interactive art, artificial reality, cross-modal, rehabilitation.

1. Introduction

In the same way as Myron Krueger defined his work on VIDEOPLACE (Krueger et al. 1985), we would say Flying Cities "is not so much a solution to existing problems, as an effort to stretch our thinking about the human-machine interface" (p. 40). The underlying objective of this artistic experiment was to determine if speech could be transposed into a visual 3D representation in an interactive, meaningful and creative way. By "transposed", we really mean transferred from one modality to another through an artificial conversion process. The idea behind is to provide people with the ability to have an active and creative experience in a virtual environment in a different way than usually done (body tracking, buttons, data gloves...), thus potentially extending the target group of these systems to people having a physical handicap or a language impairment.

A particular implementation of this principle was made and experimented with an artistic context in order to validate the feasibility and the effectiveness of such interface. In particular, we have developed computer programs producing the images of 3D shapes created from the analysis of users' speech in real time and we have built an immersive multimedia installation to open our work to the general public. The theme of architecture was used for this materialization of voice as a metaphor of civilization's expressions into architectural forms of their linguistic cultural evolution.

The first part of this document will present our motivations and particularly emphasize the possible use of such system in the field of rehabilitation. We will then describe in details the principles of our speech-to-3D transformation in order to explain how the interaction can cross modalities while remaining consistent and allowing control of the generated output. Finally, after a short presentation of our implementation and of the exhibition context, we will analyze the feedback from questionnaires and discuss our observations.

2. Related works and motivations

Speech therapists have found since the nineties that a real time visualization of the vocal tract during pronunciation exercises could improve the learning efficiency (Hutchins 1992). The display is used to show how the tongue and the mouth should be placed to achieve the correct pronunciation as soon as the sound is identified, thus providing the missing auditory feedback for patients with hearing impairments (Park et al. 1994). With a friendly multimedia interface, such speech therapy is particularly well adapted to children with small to severe hearing impairments thanks to the motivation gained by playing (Vicsi and Váry 2002). Overall, it is clear that a visual feedback of the vocal performance is generally stimulating for the therapy of various language disorders (Georgopoulos 1999).

To the opposite, speech interfaces are also used to help people with full vocal communication abilities but suffering from another kind of handicaps, generally by providing a vocal control of electronic devices (computer, robot, etc.).

This is reinforced by the current evolution of the information society where impaired people could take an active part since the access to Internet, computer games, or virtual reality (VR) can be supported by appropriate multimodal interfaces (Nijholt et al. 2000). Jaron Lanier already mentioned in a conference on VR and disabilities the parallel between the development of interface for disabled people and the research in virtual reality; "Let's look at the human being closely. Let's see how people perceive the world or how they act. Let's design a computer to fit very closely around them, like a glove, you might say. Let's match up the technology to exactly what people are good at"(Lanier 1992). This definition of virtual reality shows the evident similarities with the experimentation with interfaces for rehabilitation and summarizes quite well our approach.

The integration of speech in VR multimodal interfaces did not change much since the original experiments done in the early eighties in MIT (Bolt 1980); some technological limitations encountered at the time (amount of words in the speech database, reliability of the recognition) have been overcome since, but the combination of key words with pointing gestures is still the common way how to envisage multimodal interaction. Even in the multimodal communication with virtual humans (Thalmann 2000), the combination of speech with other modalities remains essentially based on their complementarities. However, we consider that voice could be combined with other modalities in a different way. Some experiments on cross modal feedback have already confirmed the possibility to influence the perceptions of our haptic actions with visual clues (Lecuyer et al. 2000). We did not find any equivalent with speech; in fact, the only systems which we found to be close to a cross modal feedback with speech is the one mentioned above for the rehabilitation of speech impairments.

The absence of similar works was taken more as a motivation for experimenting than as a argument for changing direction. The research work of (Brooks and Hasselblad 2004) on the use of reactive interfaces for the rehabilitation of people with severe physical or brain disabilities did also encourage our perseverance in the use of non-invasive interfaces: "This freedom is a catalyst of the concept – especially in respect of when the effort in the achieving of a goal means the overcoming of a pain."(p.192): The artistic component of their work is also an important factor of the success of such therapeutic tools where patients should be rewarded for their efforts by the aesthetics and the satisfaction of creating. As such, the interactive poem generation proposed by (Tosa et al. 1998) could be used for therapy as it could in principle reward a speech performance by producing a pleasing poetry.

Finally, according to the categorization of artistic installations proposed by (Edmonds et al. 2004), we intended to design Flying Cities as a *varying dynamic interactive* system. This means that "the 'viewer' has an active role in influencing the changes in the art object" and that "the performance of the art object varies […] according to the history of its experiences."(p.114): What we targeted was an immersive virtual reality installation where the voice would play the central role and would allow visitors to continuously aliment the 3D content.

3. Principle of the speech-to-3D transformation in Flying Cities

3.1 Original idea: the 'phonemons'
Some physic theories rely on the analogy with elementary particles to explain complex phenomenons; there are photons in theory of light and phonons in quantum mechanical vibrations. We basically extended this idea to 'phonemons' in language; the principle is that every phoneme could be represented by a particle and that humans would emit 'phonemons' while speaking. Extending this analogy further, we propose to describe how these "particles" evolve in space according to their initial energy (amplitude, frequency) and how they interact between them according to the prosodic and grammatical properties of the speech (attraction and repulsion corresponding to the original linguistic structure).

3.2 Detection of phonemes in live speech
The detection of phonemes in users' speech is the first step in the transformation process. Our system has to be user and language independent, has to identify phonemes on-the-fly as they are pronounced and has to extract vocal attributes such as the amplitude and pitch (but not the words and their meanings).

While looking for solutions to this problem we were aware of the existence of the commercial or open source speech recognition software (Microsoft® Speech 2006), (IBM® WebSphere Voice 2006), (Dragon Natural Speaking 2006), (Carnegie Mellon University 2006), (Open Mind Speech 2006). However these applications rely on a dictionary of words in one language and require a training phase with the user to achieve the full accuracy.

Speech interaction is also an active research area which we have investigated. However, as clearly emphasized in (Rosenfeld et al. 2001), the goal is to create "interactive systems as mechanisms for humans to express needs to and obtain services from machines."(p. 36): Typically, speech interfaces in the Speech Graffiti project (Tomko et al.

2005) or the Voice Code system (Désilets et al. 2006); rely on a database to establish an interview-style dialog between the user(s) and the machine.

We have rather wanted a generic identification of phonemes independently from the language. This may be controversial from the linguistic point of view as it is usually established that each language is based on its own set of phonemes (e.g. 62 in English, 32 in French or 28 in Italian) but the idea found its validation in the work of Marcel Locquin; in his study of the apparition of articulated language in human history (Locquin 2002) he defines twenty archetypal phonemes which would have formed the root of every current language (Locquin 2006). These twenty phonemes could be found in elementary sounds of baby talk and in 80 extinct and 50 living languages. Our approach differs from Locquin at this point as we did not need to investigate further into their meaning or their impact on the structure of languages; we only kept the principle of a global classification of human 'emitable' sounds into a limited number of classes.

Finally, we have adopted a strategy based on a low level signal processing and a simplified but versatile prosodic analysis of the vocal input. An FFT analysis of the signal is applied to the phonemes to provide a spectral signature for each of them. This allows us to determine the type of each phoneme by using a K-Means classifier trained on a large database of human voices. The final output of the sound processing is a set of parameters attributed to each phoneme: duration, amplitude, phoneme class (or *type*), and the time since last phoneme was detected.

3.3 Visualization of phonemes

When a phoneme is recognized, a particle ("phonemon") is sent into the 3D space with its corresponding attributes: its speed is attributed according to the amplitude of the voice, its mass is given according to the duration of the phoneme, its life time is given according to the delay after the previous phoneme, and its type represents the class in the phoneme recognition.

The louder the voice is, the faster the particles go. The slower the speech is, the longer the transformation will take and the heavier the particles will be. Visually, we chose to represent particles by bright points (contrasting with the dark environment) with different color and size (according to their type and mass respectively).

Then, the "phonemons" start to interact with each other in a spring-mass particle system. In our simplified physical model implementing Newtonian gravity, viscosity and Hooks springs law, we have fine tuned the parameters in order to guarantee a convergence in a relatively short time (according to particles life time). Eventually, the particles would converge to a 3D shape representing the pronounced word/sentence. For instance, a word of three phonemes would lead to a triangle, and word of four phonemes to a tetrahedron.

3.4 Creation of 3D structures

The last phase of the transformation consists of applying forces to guarantee that the organization of "phonemons" in space corresponds to the original organization of the phonemes in speech. The idea is to use the type attribute of phonemes to influence the relative distance between particles. This is achieved by forcing the convergence of the particles to a static equilibrium where the 'springs' between particles would be at their rest-length (i.e. the length of the 'spring' between two particles is the sum of the lengths for each side).

1. Every phonemes detected by the speech analysis are converted to particles interacting with each other a spring-mass system.

2. The chain of "phonemon" particles of a sentence builds a 3D mesh made of triangles striped and folded together

3. The shape converges to a posture where the relative distance between two vertex i and j is the sum of the types T_i and T_j.
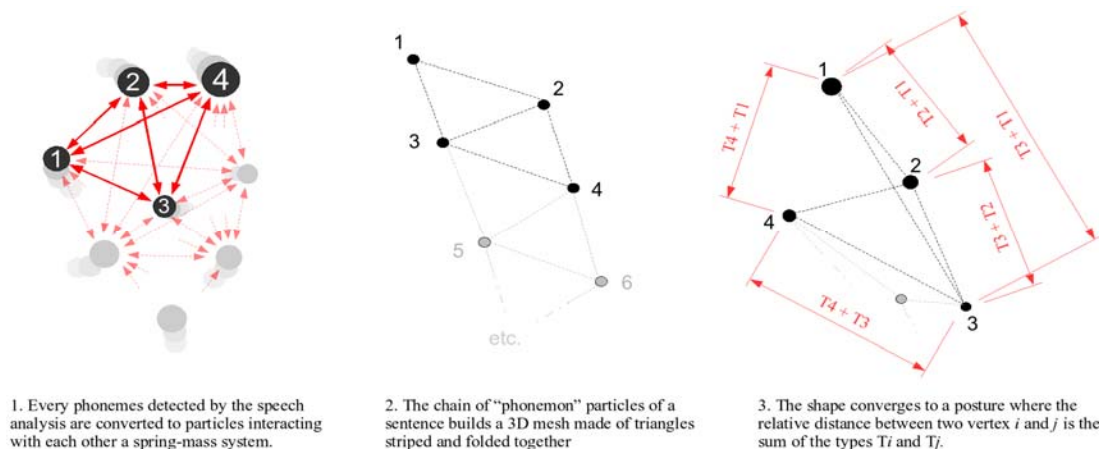
Figure 1 Elaboration of a 3D structure from a "phonemon" particle

However, the geometric construction of shapes from a fixed distance between vertices is not mathematically generalizable with five or more points. Therefore, the geometric constraints were applied sequentially on each particle by taking into account only the three previous ones. From the graphical point of view, this leads to the construction of tetrahedrons (four particles) with common faces (three former particles) and shaped according to the distance between vertices (types of phonemes). Like this, two different words of the same length become two different shapes with the same topology. At this stage, the processing of a sentence (speech between two silences) generates a 3D mesh made of triangles striped and folded together. In order to ensure that they would not be folded inside each other, we added repulsion forces in the direction of the normal to the triangles. Figure 1 illustrates the three steps of the elaboration of a 3D meshes from "phonemon" particles.

It is important to notice that, at the end of the speech-to-3D transformation, phonemes' duration and type have been conserved and integrated in the geometric structure (as mass and distance). To the opposite, voice amplitude has been transformed into dynamic factors (the speed of each particle being transferred to the shape as kinetic energy). The reason for this choice is that the duration and the type of the phonemes are part of the linguistic structure identifying the words, whereas the voice amplitude does not affects the message but is related to its strength.

4. Implementation and experiments
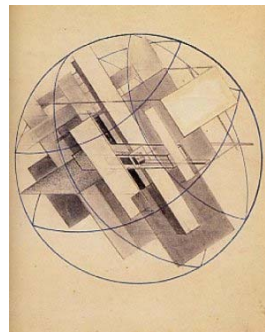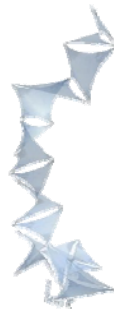
4.1 Software implementation
The interactive process was computed and rendered in real time. The real time 3D graphics was developed using OpenGL with the Open Scene Graph library. The audio and graphic processing was performed by two dedicated machines. The communication between them was done using the UDP-based Open Sound Control protocol.

4.2 Cultural context and inspirations for visuals
The artistic background of this project stands in various implicit and explicit references to the European vanguards of the XXth century. First, the interactive process was designed as a metaphor of the artistic creation process of the Russian Constructivism. The political context in Russia at the beginning of the century notwithstanding, artists like Tatlin, Rotchencko, Klutsis or Malevich intended to use pictorial and architectural elements for the design of a utopian vision of the society. Similarly, we intended to let the visitors sketch the imaginary architecture of futuristic cities with their words. The use of speech for this process also corresponds to the work of a constructivist artist: Klebnikov. In his experiments with his poetic language 'zaum', he elaborated the 'stellar language' based on elementary phonetic structures which resemble very much our "phonemon" particles (Khlebnikov 1986).

    a. *A.M. Rodchenko,* Architectural composition, ~1920.   b. *G. Klutsis,* Construction, 1921.
       vs. Visualization of a sentence in Flying Cities   vs. Representation of a building in Flying cities
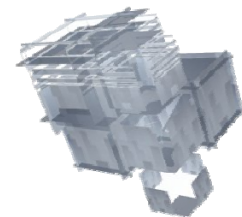
Figure 2: Graphical inspirations in Russian Constructivism

Second, the graphical choices were also inspired by Russian artists. Typically, the elaboration of sentences relies on basic geometric shapes, integrates the dynamics of points and lines into the structure, and results in abstract models of architectural composition (Fig. 2.a). Moreover, we have extended the visual transformation to resemble buildings more concretely; cubes of variable size (function of the mass) are placed at each vertex in the structure of a sentence. The superposition and apposition of blocks should provide the illusion of a construction (Fig. 2.b).
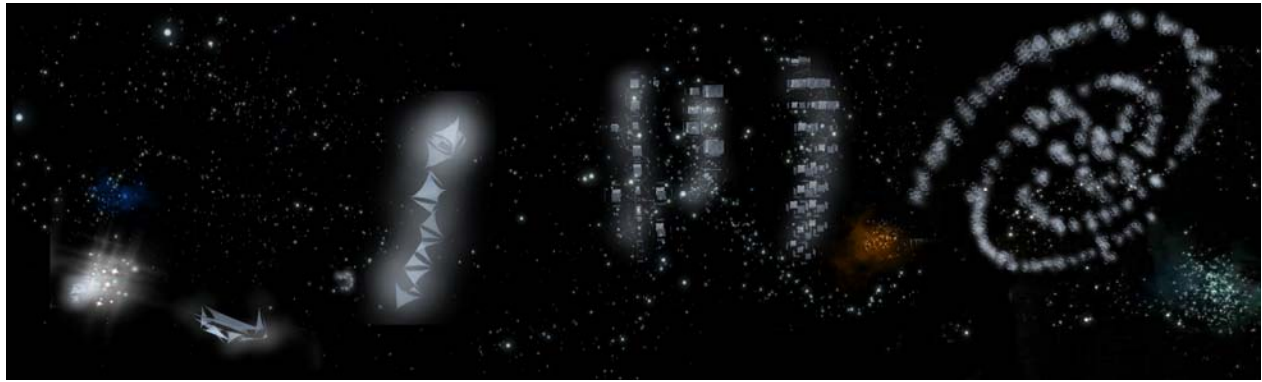
Figure 3: Strip of the transformation of particles into geometrical structures, buildings and finally flying cities.

Finally, the buildings resulting from the speech-to-3D transformation keep floating into space and eventually agglomerate in larger structures: the so called flying cities. The elaboration of cities also follows some architectural rules supporting the idea that they are built to allow the navigation between buildings while still being capable to grow indefinitely (like human cities). The shape of Fermat's parabolic double spiral was used for its nice geometric properties and for the analogy with Tatlin's Monument to the Third International (1920). Figure 3 illustrates the complete transformation process once integrated with a space background.

4.3 Other elements of the installation and exhibition
The display of the 3D content was accompanied by an electronic music specially developed by the German composer Georg Hajdu to evoke various atmospheres reacting in real time to the detection of phonemes.

Physically, the installation (Fig 4) could host up to ten people at a time, the spatial sound was produced by six speakers placed on the perimeter, and images of the 3D world were projected on a glass to make them 'float' in front of a background projection. We shall also mention that the installation was accessible to people in wheelchair.

Here is the scenario of a visit into the Flying Cities installation: "People enter a large structure which transports them into space. An ambient music surrounds them and they can see through windows (portholes) the cosmos outside. They can feel they are floating in space and moving slowly among fantastic architectural spaceships. When approaching a window, they eventually realize that their voice generates visual events. Each word they pronounce is sent into space in the form of bright particles which gather together into geometrical shapes. Progressively, they understand that the architectures floating in space are the visual representations of the past sentences; this is how the flying cities are built".
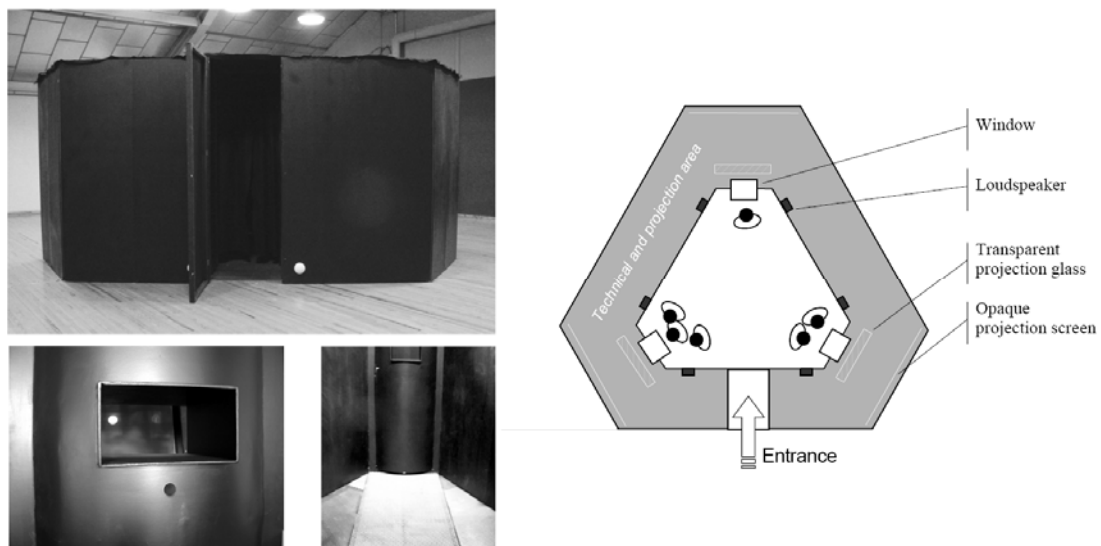

Figure 4: Scenography for the Flying Cities project

The Flying Cities installation was presented during two weeks in an art exhibition in France (Zurlo and Herbelin 2003). It was open for two week and visits were organized every morning for primary and secondary schools. A short written description at the entrance explained the artistic background and the need to speak in the installation.

5. Results and discussions

First, we could observe that the interaction by voice allowed everybody to act within the system. We were glad to see how well children enjoyed it, coming several times to sing or say poems. Moreover, it seemed that people familiar with speaking or singing particularly enjoyed the experience (e.g. a group of lyric singers played with it for a long time). Of course, some people were more hesitant or even shy at the beginning, but since the discussions between them were triggering visual events, people generally started to test the interface by successive trials (onomatopoeia; interjections; words) and continued by saying longer sentences. Overall, although the interaction process was unusual and not obvious, the effect of voice was clear enough to be understood and the visual results stimulating.

Once people understood the principle of the transformation of speech into flying cities, they started to appropriate the shapes they have generated ("Look! This is my name!"). The fact that people knew that what they have created in the environment is persistent and that what they have seen has been made by people before them gave more impact to the virtual content and stimulated their curiosity. From the artistic point of view, we achieved our objective to explain to people that they can be part of an artistic creation process by their own performance.

For the same reasons presence questionnaires are used in virtual reality systems to estimate if the subjects had the feeling of "being there" (Slater 1999), we designed a small questionnaire to report how visitors perceived our interactive installation. It was made of a short section on subject's profile (gender, age, usage of new technologies), three questions related to the different aspects of presence (temporal, spatial and dynamic), and three more questions to correlate the former with "the possible causes of presence" (Kalawsky 2000). Although it was not easy to obtain spontaneous reactions during the exhibition, we could collect 42 answers covering an acceptable sample of the population (well balanced profiles). The amount of data was not sufficient to lead to a strong statistical validation but could provide us with interesting observations. Regarding presence, 80% of people reported a feeling of forgetting about their real location (low temporal and dynamic feelings though). The answers to the last questions gave the visual feedback as being more important than staging and music to achieve this feeling (in more than 75% of the cases), and showed that people evaluated very highly the importance of the vocal interaction (>80%). It is safe to conclude from the questionnaires that the combination of visuals feedback with vocal interaction was well accepted and fulfilled our objective to offer a virtual voyage in an imaginary space.

Conclusion

Our objective was to show the imaginary phenomenon of "phonemons" as if it was real so people could actually visualize the particles getting out of their mouth. To simulate this interactive process we have developed programs transforming speech data into particles floating in 3D space and have built an installation which allows spectators to experience architectural creation in an interactive and poetic way. According to the observations made during the presentation to a large public, we could conclude that the transformation of speech into 3D structures was easily understood and helped visitors to feel involved and immersed in the installation. From the artistic point of view, most of our expectations were satisfied: breaking the rule of silence in museums, involving visitors in the realization of the artistic work, and showing language as a material for building mental architectures. We only regret the installation could not be shown in multiple countries to build and compare the databases of Flying Cities in various languages.

Based on the experience gained, we think that our implementation of the speech-to-3D interaction has been successful because it could provide a tangible correspondence between the two spaces: the reaction was immediate and obviously consistently influenced by the voice, the transformation was understood and well accepted because it was fully shown and simulated simple physics laws, and finally the resulting visual outcome could reflect all the richness of the speech input because it resulted in the application of geometric transformations, not in the use of arbitrary logical rules. The specific choices made for our implementation (visual aspect of particles, shape of the 3D structures, etc.) were made according to an artistic context, but could very well be adapted to another application as far as they remain consistent with the control of the generated output. However, the setup used to display and interact was made to receive many visitors and did not allow them to experiment fully with the system. We have been working during the development on individual interfaces and the speech processing was obviously better when the microphone could capture the voice in good conditions. Moreover, it appeared that allowing the control of the viewpoint could be more appropriate to follow the transformation process.

Finally, this experiment has shown that speech processing could be used in another context than for dialog with the machine and was a rich interface for producing events in a 3D simulation. A system like Flying Cities therefore combines two qualities for speech therapy: it gives a visual and reproducible representation of the speech performance (like the guides for pronunciation) and it provides the user with a stimulating and valuable feedback for his performance. As we could see during the exhibition, such approach may be very well appropriate for children. In a more general context, we have shown that the use of speech for interaction in a virtual environment does not necessarily have to reproduce human communication in order to be meaningful; people or children with important physical or mental handicaps, even with limited speaking capabilities, could benefit from such interface for their rehabilitation.

Acknowledgements

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