Interaction with shapes and sounds as a therapy for special needs and rehabilitation

T Brooks[1], A Camurri[2], N Canagarajah[3] and S Hasselblad[4]

[1]Kulturcentrum Skaane, Box 1237, S-221 05 Lund, Sweden

[2]Laboratorio di Informatica Musicale, Universita Degli Studi di Genova (DIST)
Via Opera Pia 13, 16145 Genova, Italy

[3]Department of Electrical and Electronic Engineering, University of Bristol, Bristol, UK

[4]Emaljskolan, Emaljgatan 1C, S-26143 Landskrona, Sweden

tonybrooks@soundscapes.dk, *music@dist.unige.it*, *Nishan.Canagarajah@bristol.ac.uk*, *stefan.hasselblad@mila.landskrona.se*

http://www.kulturcentrumskane.com, *http://www.infomus.dist.unige.it*, *http://www.bris.ac.uk*, *http://www.emaljskolan.se*

ABSTRACT

Causal interactive audio and visual feedback sourced from whatever faculty is available from children with severe disability and utilised within an adaptable user-friendly interactive environment that encourages, motivates, and is "fun" to participate within has proved to be a rich resource within which to research towards possibilities for the children to reach their fullest potential. This paper details the practical implementation of further (related to earlier work) various visual media; virtual reality; and associated technologies so as to further enhance the study and to verify the feasibility towards a commercial system product.

1. INTRODUCTION

1.1 Who and what?

The authors were previously involved in earlier research projects within the special needs field. One was a recent EU funded project that solely focused on the sonic aspects of interacting with sensor appliances to children of various ability and disability; another project has a longer history of researching applications of synchronous audio and visual interactions within adaptive interactive multimedia environments as applied in special needs and rehabilitation. These two projects are subsequently referenced as background below.

Our paper reports on the use, within the field of special needs and rehabilitation, of interactive feedback in the form of Virtual Reality objects, shapes, and sounds to encourage movement. The approach centers upon a novel concept/observation termed 'aesthetic resonance' - referring 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. In the past, such repetitive movements/exercises have been either tedious (in the rehabilitation field) or indeed impossible to achieve by previous means (in the special needs field with severely handicapped children). The potential for such a system, concept and methodology which is able to adapt to an individual user profile, in all aspects, is shown to be of great value for further academic research, commercial opportunities, and more importantly, the opportunity for an improvement in quality of life possibilities, applications in new therapy, and usage as a supplementary aid towards general well being for the participants. These potentials are further explored in our segued EU funded IST project titled CARE HERE. Results confirming the potential of this fresh approach are given.

1.2 Background – Sound (EU CARESS Project) – Sound/Visuals (HANDI-MIDI/SOUNDSCAPES)

Some severely handicapped children are denied to a large extent the experience of movement. This includes a denial of all that follows from this including the ability to approach, reach out, discover, manipulate and

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make sense of the world around us. The world of sound, fortunately, is as accessible and available to these children as to anyone else, which enabled the EU CARESS (Creating Aesthetically Resonant EnvironmentS in Sound) Project to explore the enjoyment and benefits those children can derive from immersion in a *sonic* environment. The authors[3,4] were key researchers in the CARESS project and a reference to this work can be accessed through the web site http://www.bris.ac.uk/caress

One of the authors[1] established HANDI-MIDI/Soundscapes in 1987 – (initially titled HANDI-MIDI, later changing and referred hereafter as Soundscapes) – as a self-funded research and development project originating from experiences and interactions with family members with a disability. The concepts and methodologies of utilising multimedia, within his self termed Virtual Interactive Space (Brooks, A. L. 1999) as an interactive play environment to aid in quality of life, therapy and other 'special needs' issues developed through years of sessions in which he palpably witnessed the influencing effect that was possible within his applied 'user-created' interactive audio visual environments. The work has been termed as an aid to augmented and alternative communication. The desire for optimising the potential for participants' experiences within the environments, as well as the creation of a system that could satisfy the prerequisites, drove the project to its current status as a continuing pioneering and open structured innovation.

1.3 Foreground – Virtual Reality (EU TWI-AYSI probe)

The European organization i3net funded future probe Twi-aysi (The World Is – As You See It) emerged from the CARESS Project to answer the question:

> Can immersion in a *visual* environment hold similar potential for such children in terms of the aesthetic resonance they might derive from *movement* within such a visual space?

Our paper reports on the technical approach and results achieved in answering this question and the fresh applications that have arisen out of its successful completion. It details our technical approach, the experiments we conducted, and the results achieved from the various multimedia environments. The evidence of technical soundness and relevance of results is supported by the photos and on-line video mentioned in the appendix.

2. EQUIPMENT, TECHNICAL APPROACH AND METHODOLOGY

2.1 Equipment

The Soundscapes system was used in Twi-aysi. Soundscapes refers to a concept and methodology. However, when referenced as a system, it refers to a conglomeration of equipment, assembled according to the authors' prerequisites from prior experiences which, when incorporated as a whole, is capable of capturing body function data information (for example, movement data, breath pressure, biofeedback) which can then be used as a source for real-time interactive manipulation and control with multimedia. The capturing of the body function data information can be sourced from a selection (or a combination) from a variety of equipment: for example, sensors, cameras, biofeedback and other peripherals.

The most often chosen capture device utilised in Soundscapes has been infrared beams where movement within a single or multiple pseudo 3 dimensional area(s) which is emitted in the form of an 'egg shaped' infrared beam of light can capture data. The sensitivity of the areas can be easily programmed according to each individual participant. The range of the Virtual Interactive Space can be selected and created according to the desires of the participants from a mere few centimetres up to around fifteen meters by using high reflection panels. In this way small body part movements, such as a finger twitch, or full body movement, such as a standing balance rotation exercise, can be sourced for processing to affect the selected multimedia feedback.

Available visual feedback depends on the software and hardware configuration of the system. Music programs are readily available that accept the system protocol signal of MIDI. "Video Jockey" programs are becoming increasingly available; they enable a selection of triggering a basic assigned image to more sophisticated programs that enable real-time manipulation of an image – even three dimensional images & environments. The ability for the program to enable the user/therapist/family member to select images and to even scan in photographs that are personal is a prerequisite. Sound output from the Music program can also be used as an input to the readily available visualization programs via the line input to the computer. In the sessions in both Sweden and Denmark we used a basic paint program that accepted MIDI.

2.2 Technical approach

For the Twi-aysi sessions it was decided to begin with synchronized digital sounds with digital colouring of image sequences through mapped gestural data sourced from users movements within single and multiple infrared beams. In the Swedish sessions, a retail product called Dbeam by Interactive Light from Santa Monica, USA was utilised. This is an infrared sensor box with the above attributes. In the Danish sessions however, two prototype sensor boxes were used. The first prototype was created, designed and constructed by the author (1). The second prototype was an adaptation from three Dbeams to the authors' design assembled into a 19¨rack flight case. Both prototypes consist of a three-headed infrared sensor array with each having the emitter and receiver mounted at the end of an easy flex miniature gooseneck. This was to enable minimum intervention and ease of set-up and adjustment of the interactive areas. Both prototypes are capable of capturing the movement data information that is assigned, via an easy user interface, to similar or different channels of operation within the MIDI protocol. The three channels can each be selected to transmit on either channel 1, 2, 3,…or 16, and a choice of data information can be selected (for example; note on, control change, pitch bend etc.,). The range of the data information can be programmed to suit the user profile of the individual participant. The three signals are collected into one output cable to be further routed downstream to a computer via a MIDI interface.

2.3 Methodology

The collaboration between the prime researchers provided a wealth of experience within which to explore the application of visual media, solely beyond the sonic, within the field of special needs and specifically, with the children with severe disability. Both researchers have many years of experience with these and other similar children. To make the children comfortable, previous tried and tested technologies, user preferences (where known and applicable), and user limitations were integrated and initiated at both test locations. Thereafter, new explorations with the available technologies were selected for the user to experience such that an immersive visual experience was created to encourage the desired expression through movement that would give an indication of an aesthetic resonant achievement.

Evaluation was through Multiple Camera Analysis (MCA – Brooks, A.L. 1999) technique that entails two or more cameras set up so as to capture various views of the interaction. These cameras can matrix feed between: monitors and a switch box for live monitoring and switching, separate videocassette recorders, or directly into a video capture facility on the computer. The archived videos are synchronized so as to enable multiple view analysis for observation of all qualitative movement and other signs from the session that may be an aid towards a quantitative evaluation. MCA also enables options for camera angle switching selection in post session presentations.

3. DESCRIPTION AND RESULTS

3.1 Sessions description - Sweden

The sessions in the special needs school in Landskrona were with eight children of mixed gender and various ages between six and seventeen, with various levels of disability. The sensor space was created with three separate sensor heads as detailed above assigned to MIDI channels 1, 2, and 3 on the hardware interface display. The signals fed a 3 to 1 merge box and subsequently the output was fed into a computer running Opcode Max. The simple patch in Max allowed the mapping of the gesture data information to a MIDI input paint program and to be output externally to a MIDI sound module and MIDI sound effect unit.

Due to delays in setting up on the first day and the user falling asleep, the sounds and images were preset before the user entered. The sensors (A, B, C) were mapped externally to 1, 2, or 3 different patches/instruments in the sound module and effect combination, and internally to the paint program to colour filters in the colour synthesizer window. This affected the Red, Green and Blue parameters so as to open the colours to input to the (black driven) sequence created by the author prior to the session. Various real-time changes were undertaken within the sessions depending on user reaction. These changes ranged from mapping all three channels to a single channel and thus instrument patch and colour, to extreme visual interactive causal sensitivity swings (varying the amount the movement caused the response).

Six cameras (1 – 6) were implemented so as to archive the sessions. Four of these cameras, which were each focused on the various expected interactive body parts fed a quad splitter and subsequently, a videocassette recorder. One camera was set up so as to record close facial expressions and another was set up to record the whole scene. A workstation set up controlled all parameters of the session downstream of the programmed sensors.

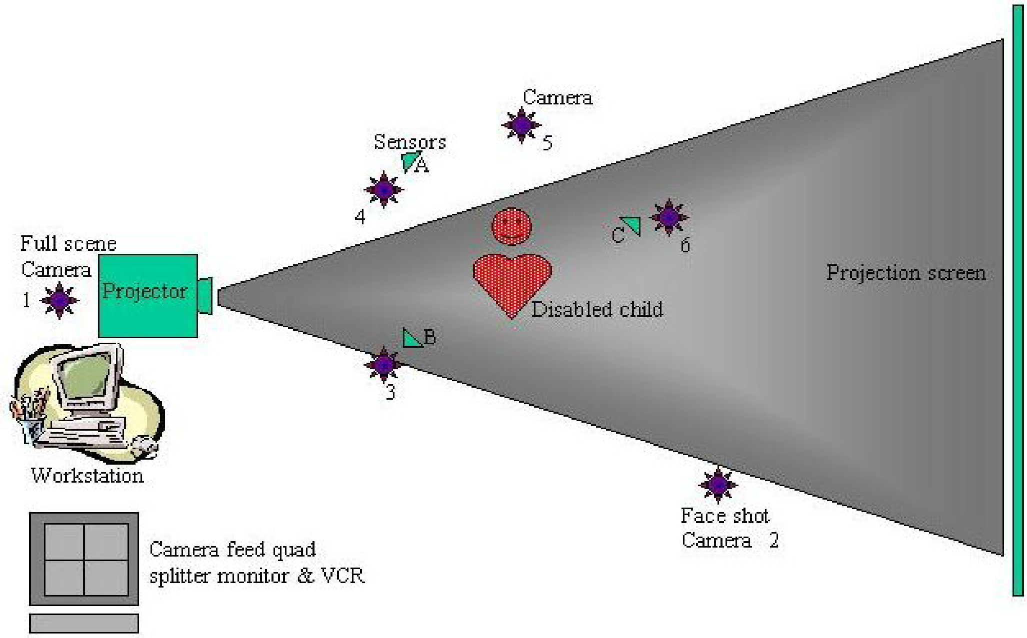

Figure 1. *Camera/sensor set up.*

3.2 Sessions description - Denmark

The sessions in Denmark were with four male children with severe disability ranging in age from three to five years of age. The sessions began with three days in the Experimentarium, a large empty space, and then two days in the Panorama Virtual Reality room; both are located within the Center for Advanced Visualisation and Interactivity in Aarhus. MCA was again used with two cameras set up to archive the sessions: one camera was set for close facial expression while the other camera was set up to record the whole scene. On the first day the prototype sensors (as described above) were used in the Danish sessions in a similar manner similar to that method used in the Swedish sessions. On the second day, a further implementation enabled gesture data information to be mapped to control "intelligent lighting". Therefore, in addition to being able to colour the image sequence, the user was able to control the X axis, Y axis and gobo pattern/colour of the robotic light from his gesture. The success of the three days of sessions encouraged the author to initiate a session on the fourth day in the Virtual Reality Panorama room for the children. This decision was confidently taken as a result of the author's previous investigations. It resulted in the prototype sensor assembly being able to control a simple Virtual Reality environment (QuickTime VR) such that each sensor achieved a functional role similar to the usual interface - a standard mouse. Thus, the prototype in this instance became a non-tangible mouse emulator so that navigation within a 2-dimension or 3-dimension environment was possible with the added bonus of being able to dwell click on certain objects to get a predetermined simple response. It was also possible to manipulate 3D objects in a similar manner.

The VR Panorama is a room with a large parabola screen onto which is (multi) projected a stereoscopic computer-generated three-dimensional image and/or environment that can be interacted with by the use of a navigational aid (usually an assembly resembling hard –wired jointed sticks or pins which the user moves to affect the assigned parameters of the projected image). Shuttered glasses are used to view the stereo image that appears blurred to the naked eye.

The programmers at CAVI adapted an existing Virtual Reality program that enabled the prototype sensor to control a projected spacecraft that was visible in strong contrasting colours on the screen. In the individual sessions, the prototype sensor was positioned behind each child's wheelchair. Two sensor heads, which were optimally adjusted and positioned each side to the child's head, were required to capture his small gestures that we were told were his best form of movement.

All children responded favourably to the visual environments. Whilst all indicated individual characteristics through their interactions by their limited body movements they all at some time achieved a level of 'aesthetic resonance'. The evaluation of the synchronized videos from the Multiple Camera Analysis technique proved an invaluable aid: it enabled us to observe that certain movements or facial expressions which otherwise may have been overlooked allowed us to correlate the specific causal chain effect.

3.3 Results – Sweden

A negative aspect about the sessions in Sweden was the intervention that had to be initiated by the authors so as to set up the interactive space to the desirable sensitivity and position. This was further hindered by the size of the sensor boxes (30cm x 16 cm x 3cm) and the many wires that encumbered the working area. It was also observed by the author that often the child would lose focus on the interactive feedback due to the distraction of a small movement in the room. Future research has been planned within two rooms divided by a two-way mirror so that the child can be alone in the virtual interactive space yet still closely monitored for any signs of discomfort with related ethical rules abided by.

However, despite the negative issues raised in the paragraph above, the sessions were classified as a success: once an optimum feedback was achieved, it was obvious through the child's facial expression that a higher nuance of concentration was attained.

Our observations led us to conclude there was an overall distinct increase in motivational intent in the children. We witnessed instances where an initial subconscious (unintentional) efferent (motor) action by the child led to a definable cognitive experience (through the manipulation of the feedback as a result of the action). We would suggest that this afferant (sensory) stimulation led to an intentional (conscious) reaction resulting in the causal interactive motivation that would suggest a closure of the neural afferant/efferant loop.

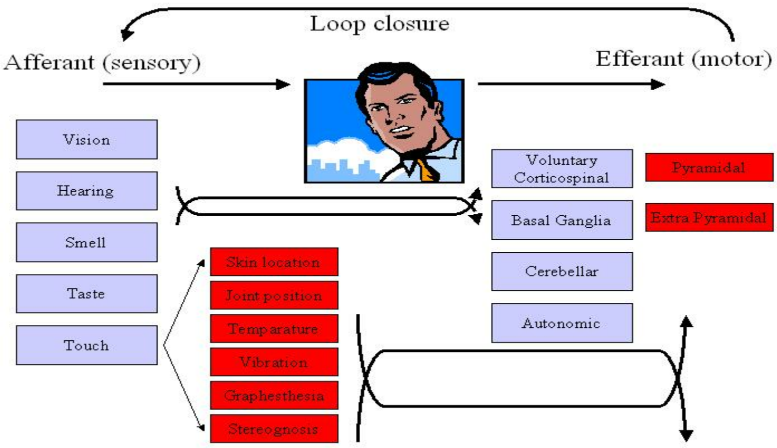

Figure 2. *The afferant/efferant loop.*

3.4 Results - Denmark

As stated above the three days in the Experimentarium were a success and the extended prototype sensor control to 'robotic intelligent lights' from the author's earlier work again highlighted the point that a feedback of physical movement relative to physical movement proved to be a strong stimulating feedback for the users.

Three of the four children were very comfortable in the Virtual Reality Panorama environment. However, the fourth had a problem with achieving a comfortable position in the sensor space (his preferred position was on his back) that was further hindered by his feeling under the weather on both days according to the helper.

As expected, all refused to wear the shuttered glasses required for viewing the Virtual Reality projected image. This may be alleviated over time with more tries and probably – more importantly – the requirement for an adaptable fitting would be an aid as the shuttered glasses available were one size only and thus too large for the children. As a result, the projected image was driven in mono.

One session in particular resulted in an extended aesthetical resonant response from a child who very quickly demonstrated an understanding for the virtual interactive space. The recordings from this specific session were subsequently synchronized into a blended video file by the author and are accessible via url *http://media.nis.sdu.dk/video/twi-aysi.html.*

This video shows a five-year-old multi-handicapped boy who depends entirely upon his wheelchair. He can hear and has very limited vision but notices strong colours and is able to follow images with his eyes. He is unable to communicate verbally, but his helper told us that the sounds he is capable of making are indicative of enjoyment in the task in which he is involved. This is the first time he tried to control the spacecraft.

With a small gesture to the right, the rocket ship points to the right; a movement left and the rocket ship points left; a head movement down and the ship's nose tips down as if to dive; and a head movement backwards and the ship's nose tips up as if to climb. In the video an obvious conscious vigorous shake of the head from side to side is reciprocated by the spacecraft's corresponding response. The young disabled boy was only able to express himself through a single verbal expression (a sort of repeated "AYYE" phrase). While in the session and immersed in the 'aesthetic resonant' interaction, (as can be appreciated on the video), he could clearly be heard making his sounds that when interpreted by his helper as an expression of a joyful experience.

In a following experimental session the two infrared sensors were set up and programmed at long distance. They still were sending MIDI data through the same mapping network to control the VR spacecraft. With this space it was possible to still move the spacecraft but without the fixation of location of sensor head as in the short range detailed above with the five year old child. This then became a further exploration of the two sensor spaces through the interactive feedback (i.e. manipulation of the spacecraft). It was discovered to be a much more intuitive experience as body gesture, weight shift and rotation (for example) made a corresponding change to the spacecraft. Thus, a form of 2D and/or 3D navigation in Virtual Reality with non-wearable equipment at long distance, using just a small movement in the interactive space similar to the QuickTime Virtual Reality described earlier, was achievable. A possible improvement for the interaction would have been from a pilots' view.

In Sweden there were many positive responses given by both staff and families who witnessed the sessions. In Denmark, the children's helpers were positive and especially remarked upon an improved vocal communication over the following weeks by the children. A subsequent session provided further proof as a stronger verbal expression could be detected and it is proposed to utilise this as a quantitative measurable in the future research. The reactions of the child in the video provided the most obvious proof of 'aesthetic resonance' through VR visuals, matching the experience with sound we had observed in our earlier work. Virtual Environments combining sound and visual stimuli were an obvious next step.

4. CONCLUSIONS

The main conclusions we have drawn from the Twi-aysi work are as follows:

- Immersion in a visual environment *can* hold similar potential to immersion in an audible environment for such children. Indeed, we were ourselves surprised how readily aesthetic resonance could be observed in such children moving within the quite crude (and sometimes silent) visual spaces we assembled.
- The attraction and advantages of using neither wearable not touchable sensors but merely exploiting the childrens' unencumbered movement through space was readily apparent. The need for cumbersome virtual reality headsets or indeed *any* physical attachments would seem at this stage both undesirable and unnecessary for achieving satisfactory states of aesthetic resonance (see for example the video *http://media.nis.sdu.dk/video/twi-aysi.html* and pictures below).
- It was apparent that when the individual feedback was singular, certain users were more perceptible to audio while others were more perceptible to visual stimuli. When the two elements were simultaneously available and triggered through interactive captured movement, a greater degree of immersion was observed.
- Virtual Reality in its current state is not an answer because of the head/eye equipment needed to view it. However, the researchers believe that a cave environment would add to the immersive experience and as such be an aid towards 'aesthetic resonance.' The non-tangible navigation in the 2D & 3D environment that was achieved will also be implemented in further research where appropriate.

Acknowledgements. Ron Laborde, Bristol University, UK; Staff and children involved at both research locations in Sweden and Denmark.

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APPENDIX

Extracts from the Swedish Sessions

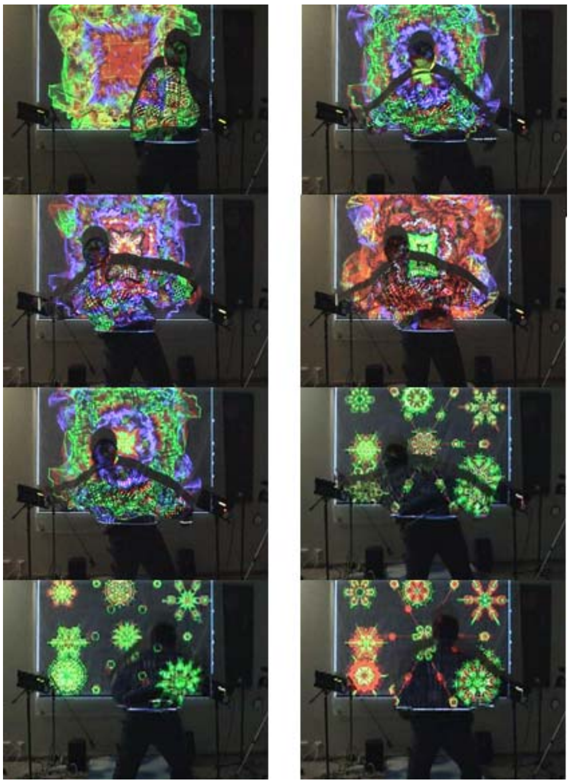

Figure 3. *A cerebral palsy child achieving Aesthetic Resonance within his virtual environment as a result of responding to colour feedback to his own movement in space. The motivation that was achieved through the immersion in a visual interactive space is obvious as the variation in colour indicates a dynamic movement in all three zones and as the pictures progress down the page an increase in body movement can be observed. This session in Sweden resulted in the child pushing his physical limits without realising until afterwards when he said that he was so tired, and still he returned to the space for further interaction.*

Figure 4. *The images above show a wheelchair bound disabled child photographed from behind. The child sits in an interactive space created from three infrared sensors and in close proximity in front of a screen because of his poor eyesight. A speaker is positioned close to him for his monitoring of the audio sounds that he is manipulating through movement. He is also manipulating the colours of the "Doughnut" through moving into the interactive area of the each sensor (each designated 1 = Red, 2 = Green & 3 = Blue). The progression from upper left to bottom right in the series of photographs illustrates a progressive increase in movement that can be seen by the increase in "doughnut rings" and the colour references indicate which area/sensor is being activated. In the sessions the three different sounds being triggered were further indication.*

Extracts from the Danish Sessions

Figure 5. *The upper image shows the disabled child from Denmark viewed from the front camera (large image), with rear camera showing the spacecraft that he was controlling with his head gestures, (inset lowerright). A video of this session is available on-line. (http://media.nis.sdu.dk/video/twi-aysi.html).*

Figure 6. *The lower shot is a reverse image of the Virtual Reality set-up at the Panorama room CAVI (Center for Advanced Visualisation and Interactivity) in Denmark with the child in a wheelchair (centre) with two sensors (over/behind = the thin lines;) the helper is sat beside him (centre right). A camera with night vision was set up so as to capture his facial expressions and the spacecraft was projected onto the panorama screen. A second camera was set up behind to capture the total scene.*