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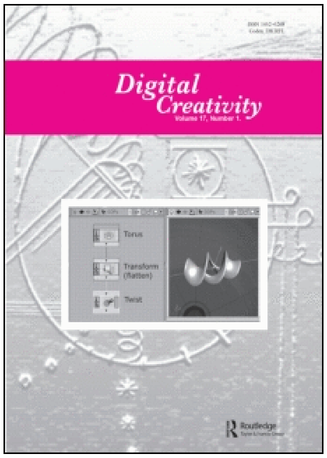
Published in:
Digital Creativity

Publication date:
2007

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



Digital Creativity
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t714576173

The **Picturing Sound** multisensory environment: an overview as entity of phenomenon

Digital Creativity
2007, Vol. 18, No. 2, pp. 106–114

The *Picturing Sound* multisensory environment: an overview as entity of phenomenon

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Abstract

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 stimuli 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 multisensory environments in special schools and institutes as a supplemental tool for traditional methods.

Keywords: communication, contingency awareness, empowerment, interaction, therapy

1 Introduction

The use of interactive causal multisensory environments are 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

1462-6268/07/1802-0106$20.00 Routledge Taylor & Francis Group

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 and 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). 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) (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 or peer or, in terms of 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). It would appear then 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 (Brooks et al. 2002; Reid 2002) 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 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 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 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. a system of this sort 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) analyse 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. Permission 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 considerations 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 behaviour. Four sessions took place in the exploratory study. Each session involved a non-intrusive means to empower the child to be in control of manipulating digital audio-visual 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.

3.1 System design

Eyesweb© is the name given to a graphical programming software environment developed at the University of Genoa. 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

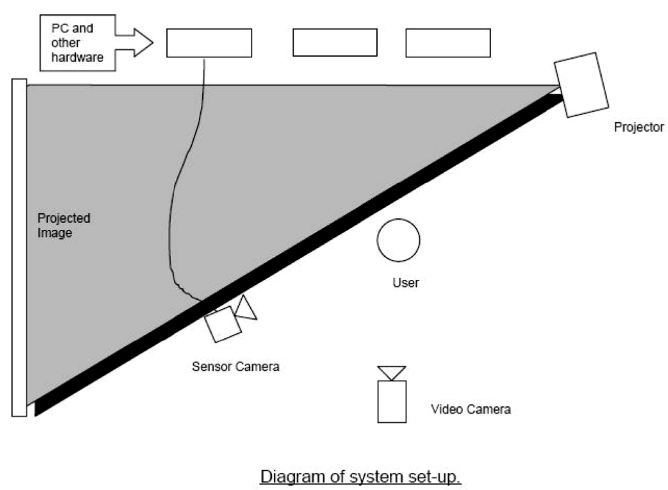

Figure 1. The system set-up.

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 and/or heard via a sound system.

4 Method of analysis.

The method of video analysis was qualitative, based in part on layered analysis (Ellis 1996) and the body of work that has evolved into what has been termed 'recursive reflection' (Brooks and Petersson 2005).

Layered analysis (Ellis 1996) 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 hermaneutic 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.

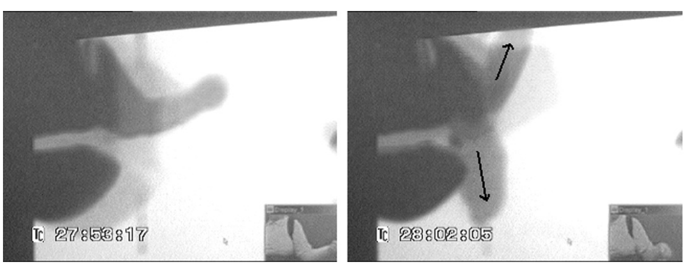

Figure 2. Images 1 and 2, © Ceri Williams.

4.1 Case study 1

Case study one was a female 13 years old 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. 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 first session the *Eyesweb*©-processed image was switched on for a period of 5 minutes and she began 'painting' using her 'unused' right arm almost immediately; 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.

In Image 1 the inset image (lower right corner) shows the source image whilst the large image shows the processed *Eyesweb* algorithm of the source. The dark area in the centre of image 1 indicates the initial area occupied by the child's arm; image 2 shows two clear indications of her arm movement both up and down. Note her arm position is different in the inset, this is due to inherent latency 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!"

4.2 Case study 2

Case study two was a 15-year-old 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 third session, and based on his vocal responses in his first session, the addition of a lapel microphone processed through an effect unit to produce a pronounced echo provided him with an additional expressive channel. On recognising that his vocalisations were being echoed back to him, his sound-making increased.

Figure 3 shows case study 2 in his final session. The scene shows his image inverted so he can see himself the right way up. This was the session where the TA said she had never heard him be so vocal, and the picture

Figure 3. Case study 2 on floor with inverted image: helper (left), author 1 (right), © Ceri Williams.

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 eye 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 at 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.

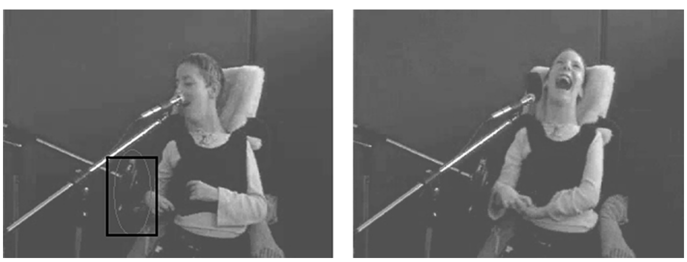

Figure 4. Case study 3, images 1 & 2, © Ceri Williams.

4.3 Case study 3

Case study 3 was a 15 years-of-age, non-verbal, non-ambulant female with cerebral palsy. In her first 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, they continuously 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 . The sensor area was placed within reach of her right arm (Figure 4 image 1). The tone produced a swooping harsh sound which 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.

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 indicated 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 first image in Figure 4 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 gleeful reaction when she causes the device to make a radical change in sound.

The third session had both *MIDI* sounds generated from the *Eyesweb* patch and the

Alesis device, 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 fourth 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 to suggest a positive communication.

5 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 indicate the potentials of bringing such systems into the mainstream curriculum for special schools.

6 Conclusions

The aims of this study were to evaluate the effect of an 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 they 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 3, 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. Implications in education of such non-formal learning potentials (e.g. Petersson 2006) for people with different abilities must be accounted for alongside current traditional methods. On reflection, available tools could in future be adapted to supplement the method used in the reported study so as to satisfy the 'hard science' sector e.g. *The Geneva appraisal questionnaire* (GAQ) and *Geneva emotion analyst* tool, 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 may be adapted. Inter-coder annotation is planned for future work utilising the *Anvil* software tool so that a clear indication of progression between and over a series of sessions is monitored. The use of such tools is envisaged 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 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 and effect via the stimulus-response chain—see Scherer). The emotion and communication theories of the Geneva Emotion Research Group provide an inspiration for the study's future development.

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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