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Brooks, Anthony Lewis

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Active and Non-Active Volumetric Information Spaces to Supplement Traditional Rehabilitation

Anthony L. Brooks
Aalborg University, Denmark
Email: tb@create.aau.dk

The purpose of this paper is to inform on findings from a mature body of research titled SoundScapes. The goal was to define, create and question sensor-based ICT systems, techniques and methods to supplement traditional rehabilitation. Following initial biofeedback/sensorimotor tests, a non-invasive (non-wearable/gesture-based) motion-sensitive sensor system enabling human performance control of computer-generated multimedia was originated. Digital music making via motion data was originally investigated as a strategy to train physical impairment. Gesture-control of painting, robot control, and video games followed. Commonly referred to as Virtual Reality therapy, the work was applied within wide arrays of participants marginalized by their disability. Outcomes point to an optimal solution as an adaptive flexible system that could be mixed and matched to an individual's profile coupled with an intervention approach to maximize a participant's development. Emergent are models toward establishing valid and replicable techniques and methods to evolve new digital test batteries to assess clinical evidence. Human-machine, human-human interactions, and information exchange are core of the research. Published patents resulted from the work. Conclusions summarize how accessibility, inclusion and rehabilitation have been influenced by such non-invasive sensor-based gesture-control of multimedia. Another main conclusion is the need for new strategies of staff training with ICT due to their key role in the rehabilitation process. Contemporary adoptions of gesture-controlled video games and creative recreation in rehabilitation indicate ongoing potentials and influence.

ACM Classification: J.4, J.5, K4.2

Introduction and Background

A mature body of research that began in the mid-eighties is presented titled SoundScapes. Preliminary research explored various causal sensorimotor solutions based on biofeedback (worn and touch-based). Subsequently, the author originated bespoke, non-invasive sensor technologies created to empower unencumbered physical movement to control elements of a virtual environment. The responsive components of the interactive environments were initially auditory but later selectable multimedia. Thus, the fun multi-modal user-experience is of making music, digitally painting, playing video games, or controlling robotic devices via gesture. Challenges are incremented as abilities progress so as to engage, achieve and maintain as long as possible 'a flow state' (Csikszentmihalyi, 1991). Stimulated by the selected 'feedback' response to the 'feedforward' motion, the participant iteratively becomes motivated to input further with subsequent movement. In this situation, it is a goal to subvert the participant's conscious attachment to the primary

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feedback (e.g. a hand motion) via the created/evolved feedback stimulus that is selected according to the participant's profile. Thus, the inter-subjective feedforward/feedback information interaction mediated by the responsive computer-generated environment becomes an intra-subjective channel that can be used to stimulate participant 'NeuralAesthetic Resonance' where micro-development in non-traditional rehabilitation is targeted. 'NeuralAesthetic Resonance' questions a participant's response to media that 'dynamically mirrors' the participant's input (Brooks, 1999; 2012). This dynamic biofeedback concept extends traditional Neuroaesthetics where static media are mostly studied (e.g. Changeux, 1994; Zeci, 1995; 2001; Nalbantian, 2008; Salah and Salah, 2008).

Whilst arrays of sensors have been trial mapped to a variety of multimedia feedback, this paper focuses on informing of the mature body of research that originated an intervention strategy using mix'n'match techniques exploring volumetric 3D information spaces created by infrared sensors; linear information spaces via ultrasound sensors, and/or planar information spaces sensed via camera sensing.

Integrated designs of these three sensing technologies mapped to dynamic software (image processing etc) and multimedia content were drafted and proposed by the author at the end of the nineties and start of 21st Century (Brooks 1999; 2002; 2004). However, the design was not taken seriously by the business team associated with the research … and the hardware was subsequently superseded by the Nintendo Wii, Sony Move, and (closest to the proposed device) the Microsoft Kinect.

Emergent over the life of the research behind the SoundScapes concept are the related registered entities 'ArtAbilitation', 'GameAbilitation', and 'Ludic Engagement Designs for All (LEDA)'. These entities collectively comprise the evolving collaborative transdisciplinary research platform where primarily focus is on unencumbered gesture control of specific multimedia (respectively – art, games, and play) as a means of supplementing traditional therapeutic intervention where the situation, end-users, and system components vary.

Notably, the same author-created system was used in the author's stage performance art and interactive installations/exhibitions at Museums of Modern Art (etc) where the research was enhanced through first and third person experiencing and observations of responsive human behaviours. Such experiences uniquely influenced design in a transdisciplinary fashion between the art and healthcare fields.

Method models for in-action intervention and on-action evaluation have emerged in the form of a family of international published patents titled 'Communication Method and Apparatus' originally filed in 2000 (Brooks and Sorensen, 2005). Commercial products, additional patents, national and internationally funded research projects, and a spin-out company resulted from the SoundScapes research.

Specifically, in line with the context of this publication, a focus of this paper is the active and non-active information spaces that are core of the intervention approach. Making music, digitally painting, playing video games, or controlling robotic devices via unencumbered gesture within programmable active data spaces is empowered in SoundScapes.

Non-active spaces are either outside of the active space, via sensor positioning, or programmed to be null-response data. This offers an option of using a unique 'stillness' channel of communication in the intervention that is crucial to understand their usage (Brooks and Petersson, 2007b).

Efficacy of the non-active/stillness spaces was questioned. Conclusions are positive in that they complement the active zones by making available an effective channel of communication with which to interpret end-user's progress, in-action preferences, and state. Clinical evidence is posited through such evaluation by emergent models from Brooks (2010).

These multidimensional dynamic data spaces are key aspects in this contemporary form of intervention using ICT in rehabilitation where virtual reality/interactions are the core. In other words, this is where both feedforward (sensing) and feedback (computer-generated content) can be created and manipulated in real-time to tailor-fit each individual's profile and the intervention goal. The creation of these information spaces involves artistic vision, ICT experience, and engineering know-how. This is in line with contemporary opinions reflecting the on-going strength of scientific, philosophical, aesthetic and artistic research that makes digital art perhaps the defining medium of the 21st Century (Adams *et al*, 2008).

Concept

The work overall questions the requirements for an optimal ICT system for supplementing traditional rehabilitation and therapy using an alternative approach where data sourced from human motion is used to treat the same human via mirrored activities by a responsive interactive environment.

The participant's perceived experience should be of fun, creative expression, and playful interactions. Designing the intervention involves foreseeing how to achieve ludic engagement, flow state and afferent-efferent neural feedback loop closure according to the abilities, preferences and desires of the participant and the session/treatment goal. The building of alternative sensitizing channels to stimulate and evoke brain plasticity is the catalyst of the concept. Collaborative research and development around the concept is an aim of the ongoing work. Whilst initial design parameters of the interactive environment are based upon personas, over time, knowledge of each individual's profile is core to tailoring the design of system, environment experiences and intervention strategy, which are optimized for each participant.

Building upon the author's prior research studying Aesthetic Resonance (Brooks, 1999; 2002; Camurri *at al*, 2003), involving questioning Neuroaesthetics (Zeki, 1995; Zeki and Stutters, 2012), Neuroeducation and Microdevelopment (e.g. Battro, Fischer and Léna, 2008), the concept of Neuroaesthetic Resonance (Brooks, 2011; 2012) has evolved to currently be investigated. Furthering this is – as in SoundScapes – where the participant is empowered to input to create mirrored stimuli with which to express, explore and play through gesture. Thus, rather than solely the viewer being the subject it is possible to query the creator at the same time. This approach satisfies that requested by Skov and Vartanian (2009, pp 3–4) i.e. "Historically, it has proved easier to study aesthetic processes in the viewer rather than in the creator of objects, which has guided researchers in their focus, although everyone realizes that ultimately both sides of the coin need to be understood" (Fitch, von Graevenitz, and Nicolas, in Skov and Vartanian, 2009, pp. 59–102)

In SoundScapes, the feedback acts as a dynamic digital mirror for the brain to seek alternative channels of stimuli. However, it is speculated that the complexity of interpretations of the 'double-sided coin' could be beyond scanning techniques and the hard-science fact seeking mechanisms and rather rely on a philosophical approach where each researcher is needing to experience being creator and active viewer so as to determine acquaintance. From such an approach the philosophical aesthetic principle of acquaintance (Hopkins, 2006; Sibley, 1959; 1965; Wollheim, 1980; 2003), a viable theory may emerge. For the time being this author hangs his hat on Neuroaesthetic Resonance which is the subject of further writings outside of this paper.

The next section introduces Aesthetic Resonance/Resonant Environments that are created in various contexts, both formal (e.g. hospital, institute, clinic and school) and informal (e.g. home, club, etc.). At the turn of the century, SoundScapes' research led to a European project titled Creating Aesthetic Resonant Environments for Handicapped, Elderly, and Rehabilitation (CAREHERE[i]).

Aesthetic Resonance

Aesthetic Resonance is a term used across various disciplines (Table 1). Table 2 presents definitions from research with disabled people starting with 'Aesthetic Resonation' (Ellis, 1997, p. 175). This definition originated from working with children empowered to control sound through motion that resulted in their "aesthetic motivation" and "internal resonance" (Ellis, 1995, p. 77). The author's text in Table 2 differs by denoting the situation, i.e. the created installation, as an Aesthetic Resonant Environment (Brooks *et al*. 2002). Additionally, in SoundScapes Aesthetic Resonance is investigated beyond solely auditory stimulus as in Ellis' research.

A multimodal definition describing Aesthetic Resonance/Resonant Environments thus originated and evolved from the author-led European funded 'future probe' titled 'Twi-aysi'vi (The World Is As You See It). This directly led to the full European project CAREHERE (Creating Aesthetically

- In Sound Therapy for the profoundly disabled (Ellis, 1997; 2004a)
- In rehabilitation with audiovisual stimulus (Camurri *et al*, 2003; 2004)
- In internet performance art (Broeckmann, 2004)
- In reflecting artist experiences (Hagman, 2005a)
- In questioning music, creative process and self-experience (Hagman, 2005b)
- In sculpture art (Collins, 2005)

Table 1: Examples of use of the term "Aesthetic Resonance"

- Ellis, 1997: *special moments experienced by individuals described as having profound and multiple learning difficulties, in which they achieve total control and expression in sound after a period of intense exploration, discovery and creation.*
- Brooks *et al*, 2002: *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.*
- Camurri *et al*, 2003: *an environment giving patients a visual and acoustic feedback depending on a qualitative analysis of their (full-body) movement, in order to evoke lucid aspects (and consequently introduce emotional-motivational elements).*
- Ellis, 2004a: *special moments when a child achieves real control and experession after a period of intense exploration, discovery and creation – moments which can be seen to be both 'endearing' and 'touching'.*

Table 2: Definitions specific to research with disabled participants

i http://www.bristol.ac.uk/carehere/

Resonant Environments for the Handicapped, Elderly and Rehabilitation). Table 2 extract (labeled *Brooks et al*, 2002) is from this definition (also see Brooks and Hasselblad, 2004). Table 2 also presents a definition that emerged from the CARE HERE project consortium Italian academic partners subsequent to the project start that is based on the author's work (Camurri *et al*, 2003). This definition clearly links to the earlier multimodal definition (Brooks *et al*, 2002). Ellis' (2004a; 2004b) subtle text reformulation in Table 2 suggests acknowledgement of Aesthetic Resonance occurring beyond solely auditory feedback stimulus and beyond solely participants with profound and multiple learning difficulties.

'Aesthetic' derives from the Greek 'aisthesthai', to 'perceive'. In this research it refers to a participant's external representation of what is internally perceived. The externalization of the perceived experience is an intuitive response to the interactions. It signifies a 'communication', a linkage, to an innate 'inner quality' that has relationship to self-achievement, self-empowerment and self-agency. This complex communication is mediated by the interactive system and its affordances, thus directly reflecting intra-subjective and causal system attributes.

In SoundScapes, 'Resonance' refers to the above-mentioned 'inner quality' resulting from the interactive system-mediated experience. This known quality of the motor system refers to how it responds during the observation of an action. This is where higher order motor action plans are coded so that an internal copying of the interactions is not repeated but is, rather, used as the basis for the next motivated action (Rizzolatti and Arbib, 1999). Links are to the mirror neuron system (MNS) and how it is capable of processing animate stimuli with social relevance (Oberman, Pineda and Ramachandran, 2006), and the innate learning from imitation (Rizzolatti and Craighero, 2004) that are raising questions and theories arising within disability (e.g. Oberman *et al*, 2005). The 'observed action' in this case is not of a specific motor action. It is rather the observation of the reaction of the feedback content to the controlling motor action.

Aesthetic Resonance is thus directly associated to afferent-efferent neural feedback loop closure, which is tentatively suggested as a reason why interactive multimedia such as making music, digital painting and robotic control and video games control by intuitive gesture is so effective with disabled people.

Evaluation of the use of the system (i.e. apparatus and method), the potential meaning and efficacy for the end-users – participant and facilitator, is primarily via the participant's body movement/motivated actions alongside verbal utterances, facial expressions, and other non-verbal behavior/communication.

Whilst a researcher has insight and experiences to draw on in such assessment the final evaluation in this work has been with expert therapist/carers who are close to their charge through extended professional relationships (e.g. see Falkenberg, 1999 – available by request). The work presents evidence that is often lacking such expert's knowledge, competence and comprehension of the technical system to optimize intervention via parameter changes according to affect and response of participants. Advances in video games and corresponding peripheral controllers, i.e. natural user interfaces, also referred to as NUI, or Natural Interfaces, have attracted much attention that has resulted in positive transdisciplinary actions. Games innately have motivating content and transmedia story lines that evoke interactions resulting in competition (both social- and self-) that can drive participant/player engagement. Such ludic engagement has been evident leading to activity beyond that otherwise limited by impairment. Resulting from SoundScapes' concept is the strategy titled 'GameAbilitation', which is presented next.

GameAbilitation

Game systems are increasingly being adopted within healthcare contexts such as therapy, rehabilitation and other treatment situations to supplement traditional strategies by a community of multidisciplinary professionals, staff, and patient/client families.

Use is across disease, age, and ability as well as across disciplines, for example, physio- and occupational therapists for training, by anesthetists before an operation, and by nursing staff for patient pain distraction. This adoption has been responsible for new paradigms of intervention, empirical research, and programs of treatment.

This adoption of games as 'Virtual Reality healthcare' is timely as it brings new perspectives to the use of the term Virtual Reality wherein so much has been promised over the last quarter century. Thus, many see healthcare as the omnipotent application of how Virtual Reality can directly be of benefit to society. These safe interactive experience environments more than ever, can be designed, created and adapted according to personalized needs of use. This tailoring of input (feed forward) and content (feedback) enables new paradigms of intervention as well as assessment. This use of games is impacting welfare society, lifelong learning, and strategies for the future according to future demographics and predictions of associated service needs' shortcomings where technology will be required to support.

GameAbilitation has resulted as an international conference/symposium that was recognized by the European Alliance for Innovation (EAI). In 2011 it was hosted alongside ArtAbilitation, which was author-conceived in 2006.

ArtAbilitation

As GameAbilitation, ArtAbilitation is an entity responsible for an international conference recognized by EAI. ArtAbilitation and GameAbilitation, together under the umbrella of SoundScapes and the evolved concept of Ludic Engagement Designs for All (LEDA), offer a platform for dissemination where art, creative expression and/or playful activity are the catalyst. A common goal is the empowerment of people with disabilities, without restriction to ability, age, race, gender or creed. Both rehabilitation and 'habilitation' issues are pertinent for presentation in ArtAbilitation.

Rehabilitation of people with disabilities is a process aimed at enabling them to reach and maintain their optimal physical, sensory, intellectual, psychological and social functional levels. Rehabilitation provides disabled people with the tools they need to attain independence and self-determination. The term habilitation refers to the process of enabling people with disabilities to develop skills and participate as fully as possible in the community, and as such it is an ongoing process which enhances the quality of life of people with disabilities and empowers them towards self-determination. The concept is based on the developmental principle which holds that all people have the capacity to grow and learn in their own way.

ArtAbilitation targets educating and training of staff and associated service industry personnel to the potentials from new ICT techniques and creative/play experiences. Training is in-situ (i.e. at the place of work) as well as at a specialist training retreat in Denmark where time is given for specific learning in line with contemporary Welfare Society and Lifelong Learning strategies.

As an open-ended transdisciplinary entity SoundScapes in the guise of GameAbilitation, ArtAbilitation and LEDA has a goal to encourage collaboration across fields of disciplines. Thus, for example, researchers, academics and inventors present alongside carers, artists, and families at the events.

Non-formal and informal reside alongside traditional formal intervention in SoundScapes. Idiosyncratically tailored and adaptive/improvised approaches where new advances in technology and creative thinking are applied towards quality of life issues are a focused core of the work.

Method

Summing up so far one can reflect that an end-user experience of play, fun, and social interaction is targeted alongside the complex determining of meaning from generated data. Main topics include improved strategies in rehabilitation/habilitation and therapy; accessibility and inclusion; healthcare and quality of life. Alongside, learning, play and social interactions are key motivators innovating new apparatus and methods for advancing intervention and evaluation (especially valid and replicable clinical evidence potentially through realizing the potential of new digital test batteries).

The research catalyst and outcome goals target feeding next-generation healthcare professionals, trainers/educators, and related disciplines. The informing of families, friends and end-users reflects contemporary strategies in empowerment and responsibility to promote home-based activities.

End-user residual abilities rather than impairments that handicap are focused upon in this research having a mission to augment life quality through evolving new apparatus and method to supplement traditional approaches in healthcare intervention.

Systems and sub-systems comprising optimization algorithms capable of adapting to the end-user profile needs, requirements and preferences according to intervention goal is a goal of the created environments, e.g. AI, Dynamic Difficulty Adjustment (e.g. Hunicke and Chapman, 2004). The environment is used for rehabilitation training i.e. physiological learning, for people with profound disabilities, and often no verbal competence.

Movement of the human body is sourced as feed-forward kinetic data and empowered to control multimedia feedback content, e.g. audio, visual, or robotic feedback. It is delivered to be as a direct and immediate feedback so as to optimize user-awareness and association.

The feedback is selectable as either figurative or abstract in form and can be art or game based. Inherent to the programming design of the data collection is the creation of stillness zones which generate null data.

The non-active or 'stillness' zones have been found significant for participant augmented communication. The uses of these stillness zones for this targeted community have been subject to limited exposure. The next section describes how these zones are used in rehabilitation training. Findings are presented from the established SoundScapes body of research.

Technique

There is a plethora of sensing devices available to source data from human participants. As well as empowering experiences that motivate interactions such devices, and the data they deliver, act as a means to evaluate each case study. A need is to further evolve and verify from the studies such that clinical evidence and new test batteries result alongside replicable intervention techniques to enable widespread use and more generic applications.

Non-intrusive digital interface technologies that do not require any worn devices on the body to source movement information are central to the focus of the SoundScapes concept. These devices are selected from a 'library' of input interfaces based upon various sensor technologies that operate beyond human visible range. Such 'invisible interfaces' have been found optimal to promote uninhabited and intuitive natural kinetic expression from activity zones that were coined as Virtual Interactive Space (VIS) (Brooks, 1999).

The sourced feedforward kinetic data is mapped to a computer workstation. The digital signal protocol was originally MIDI (Musical Instrument Digital Interface), which is a standard open protocol designed for communication between musical devices. This digital signal has for many years been used as core in DSP mapping software to control more than solely digital music. More recently alternative digital signal protocols have become available to enhance mapping options.

In SoundScapes the digital signal is mapped to control various multimedia content feedback that make up the personalized interactive environment. The environment is a room sized space. Whilst the latency issues of MIDI have been debated and speedier alternatives are available this is still considered as a viable solution for the needs of this work.

The personalization of the feedback content is designed according to an individual profile that originated from knowledge of the individual and evolves throughout a treatment program of monitored training.

A computer database tracks progression of the participant using the profile as a baseline. Feedback content can be music making, digital painting or game playing, all responding to the same kinetic information.

The technique of utilizing active and non-active zones is exemplified in Figures 1 and 2.

Figure 1 illustrates a single participant head and upper torso with two 3D sensor activity zones set up either side of the head.

The participant in the intervention training becomes aware of the proprioception connected to activating the feedback content, e.g. sounds.

The stillness zone is the area between the sensors which is usually established in the neutral position, in other words, the position where the head comes to rest when the participant is in neutral posture and not involved in "doing" anything.

The intent in use of the active zones combined with the stillness zones by people with profound disability augments participant communication with facilitator. Apart from this set up there is the

Figure 1: A Participant with two active kinetic information zones either side of the head.

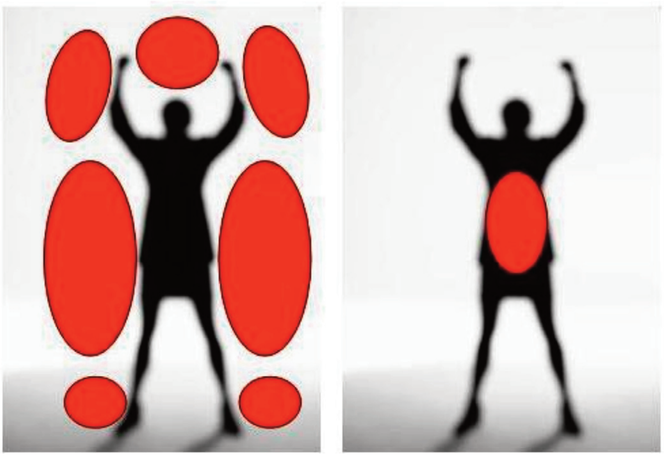

Figure 2 (a – left) and (b): Illustrates options of an extended 3D infrared sensor system.

opportunity for programming the stillness zone inside of the active zone so that activity transmits a "null" signal.

On the left, in Figure 2 (a), seven sensors are set up to surround the body with active zones (oval symbols). The non-active/stillness zone is predetermined as a central neutral position from where selected activity, e.g. hand, arm, hip or foot movement moves into an active zone in order to trigger (or control) the selected feedback content.

Figure 2(b) illustrates a single sensor that is used in the extended set up (>1metre <14 metres) but the body size is positioned to block the infrared light.

In this second scenario the stillness zone is where the body is situated to block the infrared light beam in line with a purposeful occlusion technique. As the beam is invisible this can only be determined by a sonic or visual feedback.

To activate the mapped media, e.g. sound, in the second scenario the participant moves laterally so as to permit the infrared light to pass the body and in this way the participant can listen to his or her body movement in space as a result of the generated kinetic data being sensed.

In comparison to state of the art Figure 2 (a) looks similar to common computer vision techniques in camera based interaction where active matrix zones, blob tracking, or pixel differentiation scenarios are established that generate data according to inhabitation of zones, recognition of an object, or change of pixel color.

The use of an infrared sensor instead of a standard camera means that it can operate in complete darkness and that the sensor used is able to collect 3D data from close proximity. Figure 2 (b) illustrates the scenario set up where transfer from stillness to active generation of kinetic data can be as a "felt" dynamic interaction through body change of position that is intuitive and suitable for rehabilitation training.

Amongst the many studies undertaken in the research in rehabilitation training work with acquired brain injured patients, exercises were conducted where the patient closed their eyes when in the neutral still position. Notably, closing of the eyes while standing was a traumatic experience for this group as fear of falling was evident.

Body movement training was initially along an approximately perpendicular plane (to sensor/body alignment) away from the original upright still position and back again. As the participant moved they were able to "listen" to their body motion in space (the mapped sonic feedback) as a linear sonic scale so as to train direct proprioception association and body dynamic awareness. Thus, an alternative channel of brain/body sensing was achieved. In other words from no sound (the stillness zone) then rising linear scale tones depending on movement away from the stillness zone, and then falling linear scale tones as the body was returned to start position in the stillness zone.

Individual limb movement gave similar training opportunities (also in non-perpendicular motion exercises) and the basic technique of moving to permit the passing of infrared light from emitter to reflector to receiver was easily learnt and intuitively associated and understood. Dynamic movements, both torso e.g. rotation, raise/lower, and limb/head is available depending on intervention design.

Positive response from participants supported observations of a self-motivated pushing of limitations as confidence grew so that each increment of sonic scalar feedback was an indicated matched achievement of quantified progress in their movement training. The flexibility of the system to be able to change sound patches (also parameters such as octave, resolution, trigger/control etc.,) also gave opportunities for change (alleviating boredom/repetition) and development of system-mediated social-cultural interaction between the facilitator and participant. In addition, system flexibility and adaptability enabled the tailoring to each participant's preferences, desires and needs. This was exemplified by a participant who was a visual artist who had no inclination for music or sonic experiences. He brought in a catalogue of his art from a recent exhibition as a gift when he informed the study. In this case the author created a visual simulation of one of the art pieces and mapped three sensors to control filters where gesture controlled red, green and blue colors. Thus, the artist could interact by painting in real-time a simulation of his art via movements training his acquired unilateral neglect. Engagement was increased and training motivation increased substantially.

Discussion

Aesthetic Resonance has been associated to the phrase "where the expression is the art and the art is the expression". In SoundScapes, the 'art' aspect of the work is often misconceived as the interactive content feedback created from participant movement, i.e. the perceived 'product' by the unacquainted; however, this is incorrect as the true art lies in the perceived effect on the participant, thus the therapeutic aspects attributed to the system.

This experienced phenomenon is optimized through the tailoring of the design of the environment and the interaction to it so as to be immersive and engaging such that a state of flow and related autotelic experience (Csikszentmihalyi, 1991) is achieved. This has been termed as Aesthetic Resonance and has multiple interpretations, for example, Swingler (1998) quotes Ellis' (1996; 1997) original coining of the term as referring to "special moments experienced by individuals described as having profound and multiple learning difficulties, in which they achieve total control and expression in sound after a period of intense exploration, discovery and creation".

Whereas Camurri *et al* (2003) states that it is defined as giving "patients a visual and acoustic feedback depending on a qualitative analysis of their (full-body) movement, in order to evoke ludic aspects (and consequently introduce emotional-motivational elements) …" (p. 269). Ellis further refers to facial expressions of children with a disability that are indicators of aesthetic resonance (Ellis, 1996; 1997; 2004; Swingler, 1998). In our earlier work we have augmented Ellis' definition by suggesting it refers to "a situation when the response to 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). With this document we redefine the meaning as special moments that are experienced as control with intent within a responsive environment where a direct association between body movement and audiovisual feedback content (including games) acts as a stimulus that evokes joyful discovery, intense exploration, and expressive creativity that results in, and from, optimized and motivated ludic engagement. This phenomenon is such that the response to the 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.

The approach is such that it encourages the participant to disassociate toward incremental higher engagement and the inherent motivation of the play. This disassociation could for example be from pain that may otherwise be present as a result of the physical movement involved in the conveying of intention in interacting with the system. The aesthetic resonance paradigm can offer a potential in training where physical functionality limitations may be exceeded through motivated play.

The state of Aesthetic Resonance happens when there is a balance between a person's skills and the challenge at hand. This can be compared to the state of flow (Csikszentmihalyi, 1991) which associates to autotelic activity (ibid).

Play in this context is similar to the autotelic experience as it is characterized as being carried out for its own sake by inner goals generating the state of flow. This is similar to the way the "doings" or actions function as prerequisites to playful engagement and how the technical system intends to awake and develop enjoyment and curiosity among the participants resulting in an optimized motivation to train, play and learn. Being engaged is in this case closely related to "having fun" (Brooks and Petersson, 2005a; 2005b; 2007a; 2007b).

Building upon this view and in line with Gadamer (1989), the author agrees to the transformational power of real aesthetic experience. However, whilst in agreement with the above suggested inferences, it is a belief that once an experience phenomenon such as aesthetic resonance, or the performing of an art, is attempted to be described in detail it immediately becomes something else, and thus a reference back to the acquaintance principle that states the need for that being referenced to be experienced so as to be evaluated (see the Acquaintance principle from aesthetic theory as detailed elsewhere in this document).

Designing for Kinetic Data Mapping

The research has evolved to be a vehicle for multi, interdisciplinary exploration. A concept, apparatus and method models have emerged from the work that substantiate non-formal rehabilitation as an intervention towards improved opportunities in quality of life for certain people. The designers and creators of these works are digital artists collaborating with others. Processing decisions in much of the research to date in respect of the kinetic data mapping, both pre/post sessions (designer assigned – therapist advised) as well as in session (facilitator intervention), has continued to be via a computer graphical programming language called Max produced by Cycling74. This has been extended over recent years via improved software across modalities. Feedforward data is now more efficiently mapped to an array of multimedia feedback so as to enable the facilitator to address participant preferences and profile as exemplified earlier in this text.

The bespoke and commercial 3D infrared sensor devices and the Soundbeam[ii] ultrasonic sensor that were used mostly in SoundScapes sessions in the 1990s were easily programmed pre-session and changeable via designed presets in sessions so that parameters could match participant progress. In-session changes are available either directly at the infrared sensor head; at the control box that the ultrasound sensing head plugs into; or in the computer software where DSP is designed. This is in line with contemporary use of cameras and computer vision algorithms as exemplified by advances in game peripherals such as the Microsoft Kinect, Sony MOVE, and Nintendo Wii. A weakness in camera-based systems is that the interface for a facilitator to increment through parameter presets in line with the ZONE in-action model (Brooks, 2010) is arguably not optimized at this time. In this way the functional ability progression of the participant, for example sensitivity, range or resolution of the active source zone according to dexterity or other physiological dynamic targeted by the therapist is not optimally addressed and there is room for improvements.

Another weakness of camera-based games in this context is the lack of access to program adaptability into the game content and interface. For example, game content rarely matches the quality of graphics and motion as the blockbuster leading titles.

Dynamic Difficulty Adjustment (DDA) is a related strategy to enable such auto-matching of interactive content to the player's game input (e.g. Hunicke & Chapman, 2004).

More recently, the inclusion of video game sensor-based perceptual controllers expand the range of selectable perceptual controllers.

The latest addition to the array of devices is the laser-based music controller Beamz[iii]. However, this system is limited to the end-user having a level of hand dexterity to operate. A Beamz system limitation is highlighted when one wishes to involve a player who does not have the required functionality as, despite the 'playability' of the musical content where correct melody notes are generated to play along with songs, it is only the Beamz that can be mapped to the software. In other words, alternative sensor devices that enable increased access cannot be used alongside the Beamz units.

Beyond Rehabilitation

The SoundScapes concept is applicable beyond solely rehabilitation for persons with disability and can address all ages, across situations, and across different functional abilities.

The infrared sensor systems have been the core of art exhibitions at Museums of Modern Art and stage performances. Such contextual research in installation and performance art took place parallel to the healthcare studies.

From this early work across fields emerged the concept coined as Virtual Interactive Space (VIS) (Brooks, 1999). VIS has been referred to as an inhabited information space (Brooks, 2004) and it is through active use, (and non-use) of this dynamic volumetric data space that a level of non-verbal communication between a person with profound and multiple disability and a SoundScapes

ii www.soundbeam.co.uk
iii http://beamzcommunity.com/

facilitator is achieved so as to arrive at a non-linguistic meaning from the intended action by the participant with disability. VIS is also questioned in respect of art audience wherein much has been learnt that carries over to healthcare.

Interpretation meaning in the research is achieved through the intention of a participant in use of these active/non-active/stillness zones during facilitator intervention in a rehabilitation session. It is thus important to incorporate stillness zones into the design of interactive information spaces when used in rehabilitation. This is because this community is often lacking in opportunities for artistic or playful expression through being limited by their dysfunction. Thus, participants may be restricted from full exploring and experiencing to their fullest potentials communication and interpretation channels when the design is weak and all parameters are not comprehended.

Creatively applied technology aligned with contemporary training to optimize interventions such as outlined in this document can augment such limitations.

Non-formal/Informal Rehabilitation and the Facilitator

Controlled operation of the system and dynamic use of the stillness zones, which are spaces that do not generate data from inhabitation, indicate user progression in sessions. However, of great importance to a successful non-formal rehabilitation session is the facilitator intervention. This intervention is successful when interpreted meaning from the intent of the participant is achieved.

Central to gaining the interpreted meaning is an intimate knowledge of the participant such that space is given for non-linguistic communication.

Exemplifying this form of communication is the interaction between the involved parties through the stillness zones acting as a mediator of intentional and unintentional action. It is often in this phase of intervention that misunderstandings are realized through facilitator 'need or desire' to reach a goal.

In other words, time needs to be given where the facilitator steps back and permits the participant a breathing space in the session interaction so as to indicate through the mediating stillness zone his or her desire. This could be an indicated preference for the next phase, for example, if bored with a choice of content to move forward to another; it could just as well be a defined pause to reflect upon what had been happening; or it could also be an indication of exhaustion and a desire to stop the session.

Often these moments can be wrongly interpreted by the facilitator and in most cases the participant would enforce their desire through response to the experienced facilitator verbal questioning so as to reach agreement and mutual understanding. However, the stillness zone offers an increased independence for the participant in that they can indicate informed choice rather than have a secondary role and thereby contribute to a fun and playful experience.

Pros and Cons of a Non-invasive Invisible Interface

Each sensor interface from the SoundScapes input device library has pros and cons that have to be evaluated so as to make a conscious choice, according and adaptive to the end-user and treatment intervention goal. This choice is thus based upon knowledge of the available device (i.e. hardware), the opportunities available via computer software, and the participant (i.e. a personal profile developed with those closest to him or her and including the therapist).

In SoundScapes three forms of invisible sensor technology are used where the data retrieval is achieved from: linear, planar, or volumetric space.

Sensor devices can be applied in multiples as the technologies are mixable. However, care must be taken to prevent undesirable system cross-talk artifacts that can occur, e.g. with multiple ultrasound devices. The camera-based planar sensors require a minimal lumen of light (not necessarily visible light, e.g. infrared) and when working with image feedback content it can have a tendency to pixel corruption and subsequently mis-triggering. Other camera-based sensors (e.g. Kinect) are problematic when used in sunlight due to the wide range and strength of IR at 830 nm corrupting the light sensor. As well as the situation/environment (e.g. lighting) the choice of sensing device can also be determined by range (e.g. the Kinect operational range is 0.8-3.5 metres) and resolution (e.g. the Kinect resolution at 2 metres is 3 mm in X/Y and 1 cm in Z i.e. depth).

Although improvements have been evident in the field of linear sensors they are still often overly-sensitive to hard surfaces. Such surfaces result in false signaling. They also operate with an annoying perceivable audible click that represents each cycle of the 'send-receive' frequency of the sensor head.

A negative attribute of the infrared volumetric sensor is that it has a limited data retrieval hierarchy which is either incremental from 'skin to core' or from 'core-to-skin' (the invisible volumetric space can be imagined as a virtual onion skin where each layer is a level of data) however, this can be programmed otherwise and saved as user presets in the software so that each participant has specific patches to work with. This latter sensor is the one commonly used in SoundScapes as it can source data from natural three dimensional gestures and is operational from close range (Figure 1) or up to around 14 metres as illustrated in Figure 2. Resolution is variable through a wide range with the minimal calibration at millimetre size.

Being invisible there is limited reference for guided operation thus the interactive space becomes 'tangible' through the mapping of the data to selected content, i.e. the feedback stimuli.

In this way the autonomous intuitive link between user and system is such that a direct and immediate feedback, e.g. auditory or visual, is achieved and recognized which gives the interface its 'tangible' attributes for the user. This attribute relates to the concept of 'reafferentation training' that has emerged from the research as outlined in Brooks (2010).

Conclusions

There is increasing evidence of potentials emergent in accessibility, inclusion, and rehabilitation through adoption of ICT when a different way of thinking about technology issues is adopted. SoundScapes exemplifies such thinking.

SoundScapes is a mature body of research investigating ICT across functional diversity of ability. It originated from preliminary research starting in the mid-eighties. Creative expression and play resulting in fun interactive experiences for the end-user is the catalyst from which Cybertherapy system requirements are questioned. Thus, 'art' in the form of making 'music', digital 'painting', controlling robotics as well as playing video games were explored as cyber-content. Requirements for apparatus and method to supplement traditional intervention whilst planning ahead to address societal demographic predictions of increased aged and disabled persons was explored.

Conceived via creating and exploring bespoke apparatus with various disabled people, the work progressed through studies of various worn biofeedback systems. It was advanced by innovating bespoke apparatus to achieve unencumbered biofeedback through gesture-control of cyber-content.

The research platform emerged from investigations of how contemporary computer-generated data environments can be created to be accessible and inclusive whilst being programmed to respond to human control data sourced from a range of different abilities in order to manipulate the same human's subsequent interactions.

Programming decisions relate to feedforward (i.e. means of control) and feedback (e.g. audio visual content) as well as the mapping choices. Ideally, in the context of this research, the human participant experiences the system as intuitive and fun.

This is where challenges can be assigned, achieved and success rewarded. In such immersive environments the interactive stimulus influences the participant's efferent-afferent neural feedback loop closure. Thus, actions can be intentional as well as subliminally driven by the information exchange between innate systems. In this way interventions can be designed according to the participant's profile and the healthcare goal for a program of treatment. However, participant profiles differ as does development and progression as a result of intervention.

Another significant variable is the session facilitator who has a range of responsibilities including changing system parameters during in-action intervention to prevent mismatches between player ability and the interactive environment. This is needed as systems able to automatically adapt to match the participant's nuance of ability progress by automatically incrementing to maintain challenge and engagement, thus achieving a flow state, are rarely used in this context. However, predictions of service industry overloading from increased aged and disabled suggest that automated artificial intelligent technology solutions such as Dynamic Difficulty Adjustment (DDA) are required to empower such complex balancing between the human and the system. Such is discussed in GameAbilitation and ArtAbilitation.

Considering unencumbered motion (kinesthetic and proprioception feedback), manipulation via programing of the Virtual Interaction Space (or information space of action) (Brooks, 1999) it is posited that human traits can be manipulated to respond in such a way to influence progressions in development.

Alternative channels of stimulus are targeted to bypass limitations caused by impairment. The brain's plasticity is thus questioned from a real-time perspective. Related to this is how Neuroaesthetics is delimited to being a primarily non-auditory concept.

Because the complex human is addressed, achievement and successes are important facets of the design that resources upon the field of biofeedback research. Thus, artificial Intelligence (AI), where issues to achieve issues such as reflecting design incorporating Dynamic Difficulty Adjustment (DDA) programming, is seen as a significant player to optimize potentials from the designed interactive environment.

In line with this, the diverse utilization of ICT (Information and Communication Technologies) is herein focused to the field of people with impairment. Ludic Engagement Designs for All (LEDA) also investigates potentials of ICT across functional diversity of ability through collaborative trans-disciplinary research.

The platform has evolved from applied research based upon designing a system for a persona (a non-detailed sketch) and subsequently getting acquainted with a person and their detailed profile (abilities, preferences, likes/dislikes/diversity etc) to refine the design.

Outcomes are evaluated with the original healthcare professionals in order to further refine the design of the interactive environment.

Investigations of ICT use in healthcare are increasing as advances in apparatus and methods are being adopted into education and practices. This bears questioning of the approaches and strategies to train the next-generation of therapists, carers and other healthcare professionals. In line with this the author has a private practice and consultancy based at a studio complex for such training (in context to welfare society and lifelong learning rather than medical oriented).

This article is about the increasing evidence of potentials emergent in accessibility, inclusion, and rehabilitation through adoption of ICT when a different way of thinking about technology issues is adopted.

However, it is evident that the game industry and arrival of advanced perceptual controllers made affordable by the size of the video game market have a significant role to play in this field.

Perceptual controllers/Natural User Interfaces (NUIs) are also increasingly able to be adapted to uses other than those they were originally designed for via increasing numbers of open-source hackers!

In this work a bias is towards exploring the empowering of a person to create and manipulate abstract form. More specifically where advanced sensor-based noninvasive ICT is used to enable human motion to manipulate kinetic, color, and other attributes of a form. The form can be anything – the aesthetic in question is the human internal entity rather than an entity that is referred to within a framework of 'beauty' etc., as is common with the term. Thus any stimuli e.g. visual and/or auditory and/or others can be used.

Active and non-active information spaces are core of this intervention approach using a system that evolved within a mature body of work titled SoundScapes that started in the mid-eighties. Making music, digitally painting, playing video games, or controlling robotic devices via programmable active data spaces is empowered. Non-active spaces are either outside of the active space, via sensor positioning, or programmed to be null-response data (i.e. not mapped). Efficacy of the non-active spaces was questioned.

Conclusions are how non-active spaces complement the active zones by making available a channel of communication for end-user's to inform their wellbeing, in-action preferences, and state. These data spaces are key components in this form of contemporary intervention using ICT in (re)habilitation.

Models for intervention and evaluation emerged from the work. In line with this, and the author's domestic situation with severe disability, a personal investment in the form of a training and consultation company with studio complex is made committing to the belief of the need for supporting for future service industry ICT use – i.e. welfare society, lifelong learning, as well as families.

This segment of care workers is predicted to have shortfalls due to increased demographics of aged, disabled, and infirm, and a lack of personnel to address need. Currently, on-job training is limited by time and money, under this body of work support from infrastructures in welfare society, traditional education, and life-long learning is being proposed. Interested parties are welcome to make contact regarding this initiative on Active and Non-Active Volumetric Information Spaces to Supplement Traditional Rehabilitation.

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Biographical Notes


Anthony L Brooks

Acknowledged as a third-culture thinker[1]*, Associate Professor Dr Anthony Lewis (aka Tony) Brooks was born in Wales, UK, into a family having members with profound disability. A background as an engineer, musician and digital artist combine with his tacit knowledge gained from experiences with disabled relatives to evolve his pioneering work in the field. He is active as an international keynote speaker and has over 170 publications. His doctoral dissertation titled 'Soundscapes: The Evolution of a Concept, Apparatus and Method where Lucid Engagement in Virtual Interactive Space is a Supplemental Tool for the Therapeutic Motivation' reported the evolution of his body of research titled SoundScapes that resulted in a family of international patents, product, and a spin out training/consultancy company called SoundScapes. The research was the catalyst of national and European funded projects (1997–2002) investigating potentials of SoundScapes' gesture-control of video games and creative expression as an alternative therapeutic intervention to supplement traditional rehabilitation. In 2002, he was headhunted to be a leading member of the team that originated the Medialogy education at Aalborg University where he has since been coordinator, study board member, lecturer, international representative, and is now Director of the SensoramaLab.*

1 John Brockman (1991) "…third-culture thinkers tend to avoid the middleman and endeavor to express their deepest thoughts in a manner accessible to the intelligent reading public." An artist "rendering visible the deeper meanings of lives". http://www.edge.org/3rd_culture/