The invisible keyboard in the air: An overview of the educational, therapeutic and creative applications of the EMS *Soundbeam™*

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ABSTRACT

Soundbeam is a 'virtual' musical instrument, an invisible, elastic keyboard in space which allows sound and music to be created without the need for physical contact with any equipment. The system utilises ultrasonic ranging technology coupled to a processor which converts distance and movement information into MIDI. Originally developed for dancers - giving them a redefined relationship with music - Soundbeam has proved to have dramatic significance in the field of disability and special education, because even those with profound levels of impairment are, even with the most minimal movements, able to compose and to instigate and shape interesting, exciting and beautiful sounds. Individuals who may be especially difficult to stimulate can benefit from what may for them be a first experience of initiation and control. A continuum of applications - ranging from the fundamentals of 'sound therapy' (posture, balance, cause-and-effect) through to more creative and experimental explorations in which disabled children and adults become the composers and performers of enthralling musical collaborations, and beyond to interactive installations and multimedia performance - can be described.

Soundbeam first appeared in prototype form in 1984 and was taken up in a serious way in special schools in the UK and subsequently in Scandinavia, the Netherlands and elsewhere following its launch in 1990. A totally redesigned version of the machine will be ready in the Autumn of 1998.

1. INTRODUCTION

Recent advances in movement sensor and other technology have utilised various electronic media to create human - machine interfaces with apparently significant but largely unexplored educational potential. Such systems have often been conceived and developed for purposes outside the sphere of formal school education or therapy (e.g. performance art, dance, electroacoustic composition, VR environments, video animation), yet preliminary research demonstrates that it is the educational and therapeutic environment in which such technology can contribute most dramatically; specifically to the educational experience of young children with severe disabilities who may have missed the foundation stones of early learning, and for whom a first experience of enjoyable control and initiation can be a crucial educational motivator.

Soundbeam™ is one example of such technology. It emits an ultrasonic beam of variable range. Movements within the beam generate data interpreted by any MIDI instrument. Described as 'an invisible, elastic keyboard in space', Soundbeam was first conceived by its originator - composer Edward Williams - as a tool for dancers. Soundbeam has proved to have dramatic significance in the disability field, because even with profound levels of impairment the most minimal movements can instigate and shape interesting sound effects, trigger rich and exotic aural textures, or perform soaring improvisations. Individuals especially difficult to stimulate can benefit from what may for them be a first experience of initiation and control.

The idea of a musical instrument which could be played without any physical contact was first developed by Leon Theremin, the Russian composer whose 'Thereminvox' astounded audiences in the 1920's, and which can be heard on the soundtracks of countless low-budget sci-fi movies. and famously on the Beach Boys' *Good Vibrations*. Most people have never heard of the Thereminvox, but nearly everyone has heard one played. In spite of its 'scary monster' associations, the Thereminvox (which is currently enjoying something of a comeback) is intended as a serious musical instrument. Repertoire exists for it, and the performances of Theremin virtuoso Clara Rockwell attest to the instrument's expressive power.

Soundbeam's development was inspired by the Thereminvox. There are, however, two essential differences between the two machines. Firstly, whereas the Theremin creates a fixed playing zone close to the device itself, Soundbeam (designed for large-scale performance) incorporates a variable ranging control which allows the invisible beam to be compressed into a few centimetres or stretched out to cover an entire stage area. In practice this means that the invisible instrument can be varied in size to accommodate the movements that the player wishes to perform, or is capable of performing. The second key difference is that whereas with the Theremin variations of timbre were not available (you were more or less stuck with the scary monster sound), Soundbeam - on its own - produces no sound at all. Instead, the machine functions as an information processor which translates distance and movement data into signals which are understood by electronic instruments, so that any sound which a given synthesiser or sampler generates can be 'played' with the beam.

Soundbeam works by emitting an invisible beam of high frequency sound (ultrasound) inaudible to human ears. The ultrasonic pulses are reflected back into the device's sensor by interruptions of and movements within the beam. Information about the speed and direction of this movement is translated into a digital code (MIDI) which is understood by a growing proliferation of electronic musical instruments, from relatively simple and inexpensive home keyboards to professional studio-quality synthesisers, samplers and expanders.

The system incorporates a number of control parameters. Variations in the send/receive switching speed of the transducer allows variation of the beam’s range from a minimum of 25 centimetres to a maximum of 9 metres. Shorter beams concentrate note information into a relatively small space, a set-up which has proved to be of significant value in special education where the player's ability to move expansively may be limited by disability. Longer beams allow a complete performance space to be 'live' with sounds. *Transpose* settings allow semitonal modulation of the scales contained within the beam, useful where the beam is played alongside other electronic or acoustic instruments. *Mode* settings govern the realisation of note information contained in the beam. Each of the Mode presets comprises four variables: the number of notes potentiated (between one and sixty-four), the relationship of those notes to one another (scales, chords and arpeggios), the articulation required to activate the note (the dynamics of the movement in relation to the sensor), and secondary information such as velocity, pitchbend and modulation depth. In addition to the resident Soundbeam 'memories' it is also possible to load several user-defined sequences of notes and chords into the beam. This has the benefit of enabling a considerable degree of compositional exploration without the necessity for a commensurate level of keyboard skill: an idea can be programmed in at the user's pace and then performed in real time with dance or simple movement. Theme-based note strings and chord progressions can also be entered into the machine’s memory for subsequent real-time improvisations in the beam. Up to four sensors can be attached to the controller, making possible the creation of a three-dimensional playing space, with beams each of different length, each angled in a different plane, and each with its own sound or 'voice'. Alternatively one or more of the sensors can be used to operate MIDI controllers such as volume, panning, modulation wheel, pitchbend etc.

2. SOUND THERAPY

In traditional music therapy, the less the client is able to say something with sound because of a physical or cognitive disability, the heavier becomes the therapist's responsibility for empathy and interpretation . The main focus and engine for the mood and meaning of the music which is happening is on the therapist, and this creative and interpretative role is increasingly shifted away from the child with more profound levels of disability. Consequently, as the liberating potential of musical expression increases, it becomes correspondingly less achievable. This allocation of creative 'power' may have no clinical or therapeutic rationale, it may simply result from what is physically possible. New evidence suggests that technology like Soundbeam can provide answers to this problem.

The experience of *initiation* is central to the success of this approach, especially for individuals with profound disabilities. If one’s overall experience of life is essentially passive, it may be difficult to develop any concept of 'selfhood', of oneself as a separate individual. What devices such as Soundbeam offer, perhaps for the first time and regardless of the individual's degree of immobility, is the power to *make something happen*. This is the vital experience of "that was me!", which can function as the foundation stone for further learning and interaction. This use of sound as the source of motivation is an extremely simple but crucially important application of the technology; it is impossible to overstate its value.

‘Aesthetic resonation’ is a term coined by Dr Phil Ellis (‘96, ‘97) to describe 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. Enjoyment and self-motivation are key aspects of this work, which Ellis describes as *Sound Therapy.*

Ellis’ work has provided the first systematic long-term evaluation of Soundbeam's potential for children and adults with disabilities. The beam is positioned so that as soon as the child begins to move an interesting sound is triggered, motivating further movement and, eventually, radically enhanced posture, balance and trunk control. All of this is accomplished in parallel with a strong sense of fun and achievement. For the child, the therapeutic dimension of what is happening is irrelevant. Ellis also discusses some of the broader aesthetic issues connected with his approach:

> “There are differences between sound and music, but the term ‘music’ may now encompass a broader sound spectrum due to the possibilities which have emerged during this century through the increasing use of electricity in music.... Furthermore, through sound synthesis electricity has made it possible to discover and create sounds which have never before been heard, and which could not be created any other way. In addition, we can simulate... a range of acoustic environments - concert halls, rooms, cathedrals or other large spaces for example, or may create acoustic environments which are impossible to encounter in the external physical world. This aural richness and variety provides the internal motivation which lies at the heart of this approach. In addition the technology also provides physical access for the disabled.
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> ....Sound itself is the medium of interchange... This approach contrasts with traditional models of music therapy, with its emphasis on ‘treatment’, direct intervention and imposition of external stimuli determined by an outside agent. Even where a music therapist may claim to be ‘responding’ to a patient’s music, this is a personal response on the part of the therapist. Often the therapist uses, or moves towards, a traditionally based musical language comprised of melody, harmony and rhythm, so limiting the soundscape and genre of ‘musical’ discourse. The ‘patient’ or ‘client’ is viewed in a clinical way, with a condition which needs to be treated or ameliorated. There are clearly defined goals with these treatments, with success measured according to how effective the treatment has been in terms of the clinical or medical condition. The *modus operandi* of these approaches is essentially from the outside -in, with an emphasis on clinical intervention rather than independent learning.
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> In Sound Therapy a different, contrasting approach is taken. Whilst progression and development remain a key focus, the essence lies in the internal motivation of the child, in working from the inside - out. This internal motivation is produced through the use of sound within a carefully controlled environment. At all times the child is given the opportunity to independently take control of the situation as far as possible. Certain aspects are controlled externally - notably the sonic environment - but the essence lies in allowing the child freedom to act as she or he chooses within available parameters which remain as open as possible. In this way, learning occurs incidentally. As a result we can see progression and development in a variety of ways across a range of disabilities. Such progression is not prescribed in advance, but happens as a natural and additional part of activity, all stemming from the internal motivation of the child - a phenomenon referred to as *aesthetic resonation*. This is made possible through a particular use of sound as the primary medium of interaction, and through giving access through the use of technology, so enabling even profoundly handicapped children the opportunity for expression and control - in other words the encounter with and development of communication skills - through sound.”

From systematic analysis of videotape session records, Dr. Ellis has identified nine criteria of progression and development:

1. from involuntary to voluntary
2. from accidental to intended
3. from indifference to interest
4. from confined to expressive
5. from random to purposeful
6. from gross to fine
7. from exploratory to preconceived
8. from isolated to integrated
9. from solitary to individual

He notes that even profoundly disabled children respond to Sound Therapy by:

- performing, listening, verbalising, 'composing' with sound;
- often showing 'aesthetic resonance' through most telling facial expressions;
- being actively involved for extended periods of time;
- revealing an ability for concentration not apparent elsewhere;
- beginning to discover, explore, give expression to and communicate their own feelings;
- making significant physical responses - movements and gestures which hitherto have not been seen, or have not previously been made independently.

> "...in addition, a change has been seen in behaviour patterns beyond the immediate environment of Sound Therapy. Some children are now more self-aware and are interacting...Other children show more tolerance and a growing awareness of other people, moving towards interpersonal skills."

Kathryn Russell (Russell '96), working in Australia has also identified a number of areas of development with the special students she involves with Soundbeam, including:

- AESTHETIC AWARENESS (includes the capacity to make choices and judgements as to what sounds or movements to select and manipulate)
- IMAGINATION (anticipating sounds and movements well ahead of time - perhaps in the week between classes)
- LISTENING SKILLS (listening to the effects of moving or standing still)
- CHOICE-MAKING SKILLS (will I choose Soundbeam? which sound will I choose? which part of my body will I move? where will I move?)
- CONCEPTUAL SKILLS (especially 'beginning, middle and end' - how will I begin? what will I do then? how will I make an ending? specific musical concepts such as high, low, fast, slow, variation; the concepts of linkage - words with movement, feeling with tone colour...)
- MOTOR PLANNING SKILLS (which movement will I make now to produce...?)
- REFLECTIVE COGNITION (how did I feel about the piece I just invented? what could I have done differently? What did it remind me of?)
- MEMORY SKILLS (can I remember which sound I liked last time? do I want to use it again?)
- SPATIAL ORIENTATION (where in space is that dog barking sound?)
- LANGUAGE SKILLS (describing what I did and how I felt, giving a title to my work).
- EXPLORING A HYPOTHESIS (I remember that if I move this way, that sound happens. If I move the same way, will I get the same sound?)
- SOCIAL SKILLS (waiting for a solo turn, sharing the beam to produce joint improvisations).
- CONFIDENCE (this is something that I *can* do).

> "Bearing in mind the extremely short attention span of many children with special needs, students have demonstrated a remarkable capacity to focus on their improvisations for long periods of time, thought previously to be beyond their abilities.....Those using Soundbeam for music education have discovered that children who are able to take control of their music making develop not only expressive and practical movement capabilities, but also create improvisatory music which has relevance and validity"

Aural stimulation - the use of sound as a motivator - lies at the heart of this kind of application of the technology. However it is possible to extend the experience by including visual stimuli, and by using *vibration*. Originally developed to allow individuals with hearing-impairment to use Soundbeam, *Soundbox*, *Soundchair* and the larger *Soundbed*, are vibro-acoustic resonators upon which the user may stand, sit or lie, thereby *feeling* the physical vibrations of the music generated by the beam. The addition of a graphic equaliser allows specific frequency ranges to be enhanced or diminished. Although first envisaged as a recreational resource (its use by no means exclusively restricted to deaf users) the various clinical and therapeutic benefits of this kind of vibration are increasingly well-documented (Wigram, 199).

The concept of *Snoezelen* pioneered by Ad Verheul at the Hartenberg Institute in the Netherlands (Verheul, 1987) has been highly influential in the provision of resources in schools and other centres for people with disabilities. Typically installed as a multi-sensory room (MSR), such environments incorporate a range of equipment designed to stimulate the primary senses in a pleasing and relaxing way. Projectors, bubble columns, fans, mirror balls, soft play, ball pools, coloured lights and sound-light floors are all characteristic. Traditionally, these environments have been used with a strong emphasis on relaxation, though there is now a growing awareness of the potential of MSRs as a tool for learning and control. Bradford-based company SpaceKraft have been in the vanguard of the design and manufacture of systems which allow users of this equipment to effect direct control over the various stimuli in the environment, rather than being passively subjected to experiences chosen by carers, by using pressure mats, tracker balls, squeeze and paddle switches, etc. The Soundbeam *Switcher* applies this principle by allowing the sensitivity of the beam to be used for switching. The beam can be divided into eight, four, two or a single portion, each corresponding to a particular effect in the room.

The dilemma facing many carers, especially where the exigencies of timetables and staffing make long periods of 'wait and see' activity impractical, is that for the more 'unreachable' students, the 'that was me!' moment of realisation - the revelatory experience of making something happen (perhaps for the first time) - may take hours, weeks or even months to happen. It is extremely difficult if not impossible to make an accurate assessment as to how long it will be worth persisting with activity which involves such opportunities for control. Yet these are the very students for whom the benefit of such an experience will be most profound.

One solution which this kind of configuration makes possible is to create a sensory world which can be enjoyed passively, but which is also permanently ready for interaction and control as soon as the student begins to investigate it by moving. Two sensors are used, angled in such a way as to intersect. Used in this way, the machine independently creates complex rhythmic and melodic structures without the need for any human intervention. These intersecting beams are positioned horizontally about 0.5m above the surface of the Soundbox resonator. A bank of eight coloured pinspots connected to the Switcher are positioned nearby. Lying on the resonator, the user feels and hears the sound structures generated by the beams and at the same time sees projected above patterns of coloured light which change in parallel with the sound. Hand or arm movement effects changes in these stimuli. For example, movement of the right hand will alter the pattern of notes and rhythms, whereas movement of the left hand changes the switching of the lights. This configuration of equipment is of value in three main ways:

- It allows for an optimal level of sensory input, providing auditory, visual, and tactile stimulation, combined in a dynamic and aesthetically pleasing manner.
- The experience is available to users who are unable or disinclined to exploit it in an interactive way, because the intersecting beams create the changing patterns of sound, light and vibration autonomously, without the need for human intervention. However the option of interaction and control is ever present. The idea is to create a stimulating environment which can be used passively, but in which interaction and control are totally accessible at a point when the user wants to or is able to respond. Relaxation/interaction ceases to be an either/or dichotomy.
- As learning develops, users are able to exercise increasingly sophisticated levels of choice, moving to trigger favoured colours, sounds and frequency ranges.

3. FROM THERAPY TO PERFORMANCE

Russel's findings, like those of Ellis, provide a systematic assessment of physical and affective responses, giving quantifiable data about Soundbeam's clinical possibilities. In parallel with this approach, many projects in the disability field are exploring the creative performance-based paths opened up by this new technology. At 'The Ark' in Bracknell, a multi-arts project for people with learning difficulties, dancer Penny Sanderson and musician David Jackson's workshops always involve a narrative theme, and include live music, dance and drama, providing an excellent example of the way in which technology can be used to complement and enhance a successful established activity (rather than a sterile 'technology-led' approach) in a way which allows participants a fuller involvement. The sounds and tunes triggered by the students' movements in the beam have a place in the story and are tailored to the personalities and moods of the individual students. Dinosaurs, waterfalls, butterflies, monsters, princesses, lions, explosions - this aural dimension is all controlled and modulated by the students', and this in turn reinforces and remotivates their involvement.

Fransisco Borges da Souza, a music therapist working in Portugal, has formed a rock band with Soundbeam as one of the key instruments. The astounding expressiveness of the disabled Soundbeam player clearly reveals a talent that has been unlocked.

Special schools in England are now starting to collaborate with so-called 'mainstream' schools on music projects involving Soundbeam. As the children are able to learn and perform on an equal basis, the disabled/non-disabled barriers can be broken down. English special schools are often isolated and the arts can clearly give a strong focus for integration where this can be enabled by appropriate technology. Meldreth Manor School in Hertfordshire and the Ormerod School in Oxford are outstanding examples.

We are taught that 'serious' musicianship demands years of dedication. So what are we to make of devices which allow musical expression to happen almost immediately, and how can the musical 'validity' of what we hear be assessed? With conventional instruments, designed for those with average or above-average physical, mental and sensory functioning, the time gap between musical imagination and musical realisation takes years to develop. Good technology radically shortens this gap. It extends the limits of selected-scale or percussion based work, and it asks the player to learn not the technical skills of the traditional instrumentalist but the freedoms and disciplines of improvisation. This kind of music is difficult to evaluate because there are no right or wrong ways of playing it - no performance of a piece of music played with Soundbeam will ever sound the same twice; but it is possible to assess the extent to which the student enjoys it and gets a feeling of achievement from it, and some of the work reviewed here indicates strongly that the attainment of significant milestones in the physical, cognitive and social development of individuals with a range of disabilities can be radically assisted by the use of such technology.

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