ENGAGEMENT WITH TECHNOLOGY IN SPECIAL EDUCATIONAL & DISABLED MUSIC SETTINGS

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YOUTH MUSIC

Music is Power

"IT IS...VITAL TO ENSURE THAT MUSIC EDUCATION TAKES PARTICULAR ACCOUNT OF CHILDREN WITH SPECIAL NEEDS, WHO HAVE DISABILITIES OR WHO ARE VULNERABLE IN OTHER WAYS. SUCH CHILDREN MAY FIND IT HARDER TO ACCESS MUSIC EDUCATION BUT THEY HAVE AS MUCH AS OTHER CHILDREN TO GAIN FROM IT."

Lord Adonis (speech given as Schools Minister to the Federation of Music Services, 2008)

EXECUTIVE SUMMARY

A RATIONALE FOR USING TECHNOLOGY IN THE DELIVERY OF MUSIC MAKING FOR SPECIAL EDUCATIONAL NEEDS/DISABLED CHILDREN AND YOUNG PEOPLE:

Contemporary musical technology makes it possible for musicians to use seemingly limitless libraries of musical instruments. It is also possible to create new, previously unheard sounds and timbres, with digital instruments such as synthesizers and effect units able to create new sounds and instruments. Such rich and diverse sonic palettes can help musicians to work towards expressing a musical voice that is truly their own, allowing cultural and genre specific music to find its way into the lives and compositions of musicians.

It is possible to control these sounds in a multitude of different ways, with expressive musical performances being facilitated through control interfaces that are varied enough to adapt to the physical and cognitive abilities of their musicians, not the other way round. For composers, software tools are available that provide new and exciting ways with which to create and perform musical content, reinventing the way that music can be notated and providing unique musical interfaces that can be accessed entirely through a computer.

The "visual reality" of contemporary musical instruments can be radically augmented with a flexibility that is simply not possible with more traditional musical instruments. Software programmers can radically alter the layout and complexity of software instruments and composition environments. Additionally video projectors and visualization software allow aesthetics to transcend the physical instrument, turning a whole room or wall into an audiovisual instrument. This can transform musical experiences into multisensory experiences, reinforcing cause and effect relationships and opening new routes of musical engagement.

Data transmitted between digital musical devices can also be used in other ways. This information can record the length, frequency and intensity of musical interactions for each musician in a session. It also can also be used to identify improvements in timing and musical articulation and may serve as a means of facilitating the personal choices of those musicians that may find such choices ordinarily quite challenging.

These examples articulate a clear and compelling rationale for making contemporary musical technologies available to those musicians that wish to use it. These musical technologies can be seen as both creative musical instruments and as tools capable of facilitating rich, creative musical expressions for musicians with a variety of SEN/D.

HOW TECHNOLOGY IS BEING USED IN SEN/ DISABLED MUSIC SETTINGS:

Both music technology and existing definitions of special educational need and disability are incredibly broad. For those whose barriers to participation are more physical than cognitive, the emphasis of provision, whilst primarily meeting the creative preferences of the musician, should aim to maximize individual physical abilities. For musicians that experience more pronounced cognitive barriers, the provision of musical tools and interfaces that are matched or adaptable to individual cognitive ability might warrant more primacy. It is also important that musicians who use contemporary music technology decide if they would like their technology to help facilitate computer based composition; to provide them with a contemporary musical instrument to play; or indeed both. These decisions will, in combination with the individual abilities and needs of the musician, ultimately dictate the types of music technology that are considered.

The audits of musical technology provision reviewed for this paper seem to indicate a prevalence of distance sensing equipment within the practices of music therapists and the resources of special schools within the UK. Unfortunately, identifying other levels of music technology provision has proved more difficult. There is a lack of defined categorization within the documentation reviewed, which consolidates many different types of technology. It was also difficult to source specific information pertaining to the distribution and consequent usage of computers and assistive technology to aid computer interactions. This lack of information is unfortunate when you consider the incredible breadth of relevant digital technology available to help musicians. The inclusion of detailed and current audits of provision would have helped to establish a more complete picture of the type and range of musical technologies that are currently being used.

The personal computer is an incredibly powerful tool for composition and performance. It is also incredibly adaptable, comprising three diverse determinants, namely: a method to represent information, a method to navigate through that information and a way to input information. Each of these determinants can be enhanced or replaced in a variety of different ways to help find a system that best addresses the individual barriers to participation experienced by some musicians.

Ultimately the accessibility and adaptability of music software will vary from product to product and in regard to the type or range of assistive technologies used to help provide access. There are several music programs that offer entry-level musical experiences for SEN/D musicians and complete control via assistive technologies such as switches. These options are often limited in their scope for expressive musical performance or composition and/or lack many of the features that are found in more mainstream musical software. Mainstream software, whilst rich in such functionality, is often not designed with accessibility in mind, something that can render some examples unusable to many musicians.

There are however some software environments with features that can improve accessibility to some musicians. The RNIB recommends two pieces of music software, Reaper and Sonar, accessible via screen reading technology. Composition and performance environments such as Ableton Live or Sibelius, which facilitate comprehensive and variable keyboard shortcuts, can provide some musicians with good levels of access using switches or enhanced computer control programs such as the Grid 2. Ableton Live also makes it possible to reduce and simplify certain elements of its interface using affordable third-party iPad software, something that many musicians may find useful.

In this example, the iPad is used as a musical control interface. There are several additional types of interface that can provide high degrees of musical expression and control. The most prevalent musical interface within context of this paper appears to be distance-sensing technology, with examples such as MIDIcreator and Soundbeam being used to track movement along a single dimensional plane, usually affecting the pitch of a sound. Traditional digital video cameras, coupled with motion tracking software, allow movement to be tracked along two-dimensional planes and emerging three-dimensional motion capture technology such as the Microsoft Kinect promises much more in regards to motion-to-sound interfacing. The physical joints of an individual can be tracked in three-dimensional space, which could allow three musical parameters to be controlled by the up/down, left/right, and forward/back motions of each joint. Clearly much more research and development is required to investigate the potential of this technology to surmount the barriers to access experienced by many SEN/D musicians.

There are other emergent technologies with promise for musicians in general and, in the context of this paper, SEN/D musicians in particular. Touch screen technologies, like those utilized in modern smart phones and tablet computers, have many facets making them ideal musical interface platforms for some. They respond to the slightest touch with a very high sensing resolution so that even subtle physical movements can be detected. The range of musical software available for these devices is increasing at an exponential rate, with graphical user interfaces that vary in their appearance and complexity. Software on these devices often cost very little compared to more traditional musical equipment. We may tentatively hypothesize that touch screen technology such as this will become more pervasive within the lives of many people with SEN/D, moving to replace the more traditional VOCA hardware as a means of communication. The ability to control a huge variety of affordable, diverse music software on the same, familiar device that assists an individual on a day-to-day basis may be something that appeals to many musicians.

There are several other types of musical control interfaces, designed either with SEN/D musicians in mind, or with features that have made them suitably accessible for musicians in the past to warrant inclusion. The Skoog, Banana keyboard and M.U.S.E are examples of alternative, tangible interfaces, designed specifically for musicians with SEN/D. They feature innovative, adaptable control surfaces that require musicians to press, squeeze or strike them to create and control music through corresponding musical software. Another interface, the Magic Flute, has also been design with features that improve its accessibility, however this interface is primarily controlled via breath. Whilst these musical interfaces have been specifically developed to address various participatory barriers, it is apparent that many SEN/D musicians use ‘regular’ musical instrument controllers within their work. Such devices, used by all manner of musicians, are far too numerous to be listed within this paper.

For individuals that face pronounced physical barriers to participation, a variety of biometric sensors exist that can provide suitable musical interfaces. EMG sensors record electrical activity in muscles and EOG sensors are fine tuned to measure only the muscles used to move the eyes, both can be used to facilitate a variety of musical interactions. Additionally, these sensors have been combined with the ability to measure some elements of a user’s alpha brainwave patterns using EEG in at least two examples; the iCube X Biowave and Brainfingers. These technologies define the cutting edge of assistive musical control; identifying the future potential for such equipment to provide meaningful musical interactions for the most marginalized of musicians.

BARRIERS TO ENGAGEMENT WITH TECHNOLOGY:

Whilst contemporary music technologies can help overcome some of the individual barriers to musical participation experienced by many musicians, several other barriers may prevent or restrict access. A strong finding is the huge range of musical technology available, implying a need for a variety of specialist training. There is evidence to suggest that music technologies currently present within schools are not being used, possibly owing to a lack of knowledge and training. This also appears to be a factor within the field of music therapy, with the majority of music therapists reporting that they were not aware of how to use music technology in their clinical work.

The financial cost of music technology is identified as a persistent barrier to the use of contemporary music technology for music therapists. This finding is all too apparent when the costs of assistive musical technologies are equated to comparable, mass-market alternatives. Another limited resource identified within schools was that of space, with a sizeable minority of schools lacking a dedicated music room. Two of the Youth Music reports submitted for review identified the multi-use nature of musical spaces, and this was identified as a detrimental factor in at least one project that utilized music technology.

A fear, dislike or indifference to technology is suggested as another barrier within some of the literature reviewed. Certainly a dislike of and indifference to technology has been identified as a factor for some music therapists. There is also anecdotal evidence contained within some of the Youth Music documentation submitted for review to suggest that this is also the case for other musical practitioners. If this very limited evidence does indeed point to a wider manifestation of personal reservation or dislike of contemporary music technology, there are perhaps grounds to speculate that this will reduce as technology becomes more pervasive and simpler to use.

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1.0 **INTRODUCTION**

Since 1999, Youth Music has provided music making opportunities for over 30,000 children and young people with Special Educational Needs (SEN) across a range of settings. The musical abilities and needs of these children and young people vary greatly, as do the types of project and methods of delivery supported by Youth Music. In recent years, however, there has been a noticeable increase in projects using technology to engage with children and young people from these demographics.

This increase in the way that technology is being used has led Youth Music to commission research into the ways in which such technologies are being used for music making with these young people, the legacy of such approaches and the barriers to engagement with technology in these contexts. Specifically this document seeks to address the following research questions:

- To establish the rationale for using technology in the delivery of music making for SEN/Disabled children and young people i.e. what is the role of technology in these settings? Is technology used as a creative musical instrument or as a facilitating tool? How does technology facilitate creative expression?

- To establish how technology is being used in SEN/Disabled music settings i.e. what type and range of technologies are being used? Is technology suited to needs of children and young people?

- To identify barriers to engagement with technology i.e. do certain approaches require specialist training? Do non-specialist practitioners fear technology? Are there cost implications for establishing and maintaining delivery through technology?

1.1 **SPECIAL EDUCATIONAL NEEDS AND DISABILITIES**

The term Special Educational Needs (SEN) refers to "children who have learning difficulties and/or disabilities that make it harder for them to learn or access education than most children of the same age" (DirectGov 2011). This definition belies a range of different needs and abilities that are inadequately summarized by any of the acronyms or jargon in current usage. However, for the purposes of this paper the musical activities and technologies under review focus largely on young people labeled PMLD (Profound and Multiple Learning Difficulties – usually implying severe physical, learning and/or sensory impairments), SLD (Severe Learning Difficulties) and MLD (Moderate Learning Difficulties). Music technology provision for young people labeled EBD (Emotional and Behavioral difficulties) has been deemed outside of the scope for this paper. It is important to acknowledge that not all young people with SEN are necessarily disabled and, arguably, not all disabled young people have SEN. Therefore the term SEN/Disabled or SEN/D will be used throughout this document because the musical activities and technologies under scrutiny involve both 'groups'.

1.2 **LITERATURE REVIEWED**

This review was carried out in two stages; the first involved a systematic review of peer reviewed research findings and grey literature; the second a review of Youth Music program applications, evaluations and final reports.

1.2.1 PEER REVIEWED ARTICLES

The review of published peer reviewed articles and documents revealed there to be a dearth of research relating to this research area. A lack of robust, longitudinal studies was revealed, with the majority of articles citing very short periods of involvement. This was also highlighted by the disproportionate amount of research projects in the literature that are based on case studies or work with very small groups of SEN/D musicians. Whilst this does provide a valuable form of provisional data collection, the lack of studies that involved large numbers of participants, coupled with the prevalence of short project periods, does create issues when assessing the appropriateness or effectiveness of this or that technology to address barriers to participation. There is a far greater proportion of qualitative evidence in published papers, with very few reporting quantitative or longitudinal study designs, perhaps due to the pragmatic limitations of the latter.

The published documentation, though very limited, does reveal how complex and divergent the fields of reference are. Titles include: music therapy, clinical music therapy, learning disabilities, accessibility, popular music education, autism, physical disability, etc. This breadth of reference highlights the heterogeneity of the fields that this paper seeks to explore. When we talk of SEN/D musicians we use a blunt tool to describe an infinitely broad range of individual abilities. We are describing physical, cognitive, and/or sensory impairments, sometimes combined with an equally broad range of EBD. Each category summarizes a variety of learning difficulties or physical disabilities that are often combined, at varying degrees, with other categories.

Furthermore we identify the roles of several distinct music practitioners; music leaders, community musicians, music therapists and music teachers, each with differing constitutional goals; education in music, education through music, music therapy and music as a leisure activity.

Finally, whilst attempting to explore the role that new music technologies have within these distinct fields of music provision for young people, we must also acknowledge the breadth of existing assistive and musical technology that exists and the scope for near future technological innovations to change the landscape of musical provision.

1.1.2 YOUTH MUSIC APPLICATIONS, REPORTS AND EVALUATIONS

Initially twenty-two final reports were submitted in a digital format for review; a number that was consequently reduced to nine reports that contained any form of accreditation to the acquisition of music technology skills or any mention of the use of music technology. From these nine reports very little consequent information could be extracted regarding the individual barriers to participation faced by project participants, the type and range of music technology used within the projects, the way that these technologies were used and how effective they proved to be for different SEN/D musicians.

A look over the format for the Project Final Report form shows a categorical form of data collection that appears to be fairly crude when put against the diversity of barriers faced by SEN/D musicians. The categories tell us how many of the young people taking part have sensory impairments; it makes no indication as to what type of sensory impairment this may be and to what degree it is experienced by an individual. We see similarly broad definitions for learning disabilities and physical disabilities. We are left guessing if participants have a diagnosis of Downs Syndrome or Autism, Cerebral Palsy or Muscular Dystrophy, and to what degree such a diagnosis may, or may not, impact on an individual's music making. This form of data collection offers a very limited insight into the lives of the project participants. It also offers little scope for the fact that SEN/D musicians often experience multiple barriers to participation and that these barriers are experienced at varying degrees.

It has proved difficult to ascertain the different types of musical instruments, technology and equipment being used within many of the Youth Music reports submitted for review. Consequently it has also proved difficult to assess how effective different technologies proved to be within projects. Whilst the various genres and musical styles that best describe each project are documented, we see no formal request to record the types of musical instrument or equipment used within music workshops within the standard final report forms. Added to this we see no provision to record the effectiveness of any equipment or instruments that might happen to be mentioned qualitatively within the reports. This, when coupled with the crude categorization of individual need and ability, misses a good opportunity to demonstrate the potentials and failings of different types of musical apparatus to face the various barriers to participation experienced by SEN/D musicians.

There appears to be a lack of detail and some confusion as to what constitutes the development of 'music technology' skills. One project qualitatively recorded the use of music technology in the form of MIDICreator during the project's delivery and yet offered its participants no accreditation for the development of music technology skills. Another project appeared to offer switches and keyboards to SEN/D musicians and yet limited the accreditation of apparent technological skill development to "three expert music IT special needs music leaders". Conversely several projects did credit their project participants with music technology skills and yet gave little or no reference as to what they did to achieve this. Given the detail in which musical 'transfer effects' are quantitatively documented within the project evaluation forms (confidence & self esteem, enjoyment & motivation, achievement & pride, social interaction, concentration, attitude to education and numeracy & literacy skills) it is perhaps not unreasonable to expect more detailed data collection pertaining to the development of musical skills in general and, in the context of this paper, music technology skills in particular.

To accompany these final reports, Youth Music submitted a number of additional project evaluations that have been reviewed, some of which related to the Final Reports previously mentioned. These evaluations did provide us with good levels of information in regards to the types of technology being used and the effectiveness of those technologies, particularly when the evaluations had been conducted externally. Two evaluations in particular provided a wealth of information pertaining to the engagement of technology in SEN/D music settings with findings taken with mixed methodological approaches. One of these evaluations featured an initial audit of music making opportunities in special needs schools across three UK counties. This provided an insight into the provision of contemporary music technology in a relatively large sample of schools, something that has proved particularly useful.

2.0 **WHY MUSIC TECHNOLOGY?**

In this section we will provide a rationale for using new, digital technology as an appropriate musical medium for some young SEN/D musicians. We will see how contemporary music technology can trisect musical instrument design into three distinct, constituent parts; a division that allows each element to be altered according to individual ability and preference. Additionally we will look at the potential for music technology to provide a passive method for quantitative data collection and discuss why this may be appropriate.

2.1 **DESCRIBING MUSIC TECHNOLOGY**

One way to describe *technology* is as a 'use' of knowledge by means of tools, techniques, systems or organizations. The contemporary word technology originates from the Greek τεχνολογία – τέχνη (téchnē) often interpreted to mean variously, "art", "skill" or "craft"; and –λογία (logia) the study of something, or the branch of knowledge of a discipline.

In this context, where téchnē is a means of enacting knowledge, it would seem that music itself could be thought of as a form of technology. However, it is only relatively recently that a branch of musical practice has been specifically defined as such. In this instance, technology has been connected to music as a means of identifying music made by a particular, electronic, technology. The term Music Technology has found its way into common usage as a way of describing any electrical or digital instrument used to create, sequence, record or alter sound in some way.

Moog's (1988, pp.214–220) definition of contemporary music technology identifies *"three diverse determinants of musical instrument design and musical instrument structure. The first is the sound generator; the second is the interface between the musician and the sound generator; the third is the… visual reality of the instrument"*. This creates a modular system that allows each element to be modified, adapted or replaced depending on the individual needs of a musician. For musicians who face additional barriers to participation, a modular system such as this can offer significant benefits over more traditional, un-modifiable instrument systems. The following sections will explore each of these "three diverse determinants" in more detail.

2.2 **SOUND GENERATORS**

There are a variety of "sound generator" units available including synthesizers, samplers and sound modules. These contemporary musical technologies make it possible to create and manipulate a seemingly infinite pallet of music and sound. We see for example the General MIDI (Musical Instrument Digital Interface) protocol specifying the names of 128 individual instruments and sounds. This carries with it a variety of benefits for the deployment of varied and relevant musical experiences for any musician, including those with SEN/D.

Everyone experiences a unique relationship with music. Musical preferences are often influenced by an individual's cultural and social circumstances and heritage. New technologies enable the sounds being accessed by a musician to be easily altered, something that makes it easy to introduce musical materials that can be tailored to be culturally relevant and familiar. The sound of a sitar, djembe or flute can easily be sourced and switched between without the need to source expensive, often fragile, original musical instruments.

That being said, the provision of relevant sound material need not always be based on digital reproductions of existing, conventional musical instrument sounds. Indeed new musical technologies contribute a distinct sonic pallet of their own, with contemporary music being filled with the sounds of synthesizers, effects units and processors. As Nagler (1993, p7) states, "the vernacular of these children is often digital, electronically produced music" which suggests that the wood blocks and tambourines forming the staple of every day musical interventions for many young people with SEN/D (Welch, Ockelford and Zimmerman, 2001) may not be representative of the musical aspirations or identities of some individuals.

2.3 MUSICAL INSTRUMENT INTERFACES

The appeal and prevalence of percussive instruments within special schools can be attributed in part to their intuitive and rugged control interface, an interface that exploits a clear cause and effect relationship between the instrument being struck and an ensuing sound being created. Music technology can provide the same cause and effect relationship between actions and sound, however it also provides musicians with a variety of different ways in which to trigger and manipulate sound and music.

Until the advent of Control Voltage and Gate (an analogue method of controlling synthesizers, drum machines and other similar equipment with external music sequencers) the ways in which you manipulated an instrument, its valves, keyboard, strings or skin, were inseparable from the ways that the instrument made noise. Musicians needed to physically adapt to a method of play dictated by how these instruments were constructed. New musical technologies allow musicians to play the sounds of many different instruments from a single, separate interface, often taking the form of a MIDI controller keyboard. This enables a musician to experiment with an array of different instrument sounds without an intrinsic need to master a new, unfamiliar interface.

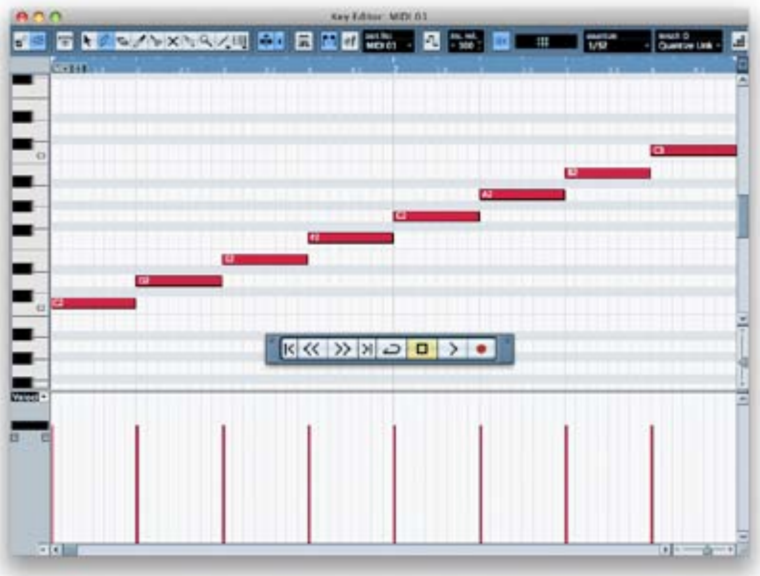
For many young people with SEN/D the MIDI controller keyboard is itself a fairly unsatisfactory interface demanding as it does high levels of finger dexterity. Owing to the modularity of new music technology systems however, a MIDI controller keyboard can be substituted for an interface better suited to the physical, sensory or cognitive abilities and needs of an individual. In this sense music technology can be viewed as a facilitator; enabling the musical explorations of an individual according to their individual abilities and needs, with musical interfaces serving the physical attributes and requirements of the musician, not the other way around.

We will explore the multiplicity of musical instrument interface methods in section 3.4 in this paper; methods that are available to translate any physical action into information that can be used to trigger and manipulate music and sound without the need for specialist skills in fingering, bowing, plucking etc.

2.3.1 SOFTWARE INTERFACES

When manipulated, musical instrument interfaces output tiny packets of information (normally MIDI events), which are sent to the various samplers, synthesizers or sound modules that they are plugged into. These packets of information are used (amongst other things) to define which notes or sounds are to be played and how quiet or loud these sounds should be. It is also possible for a computer to produce messages such as these from within a Digital Audio Workstation (DAW).

Figure 1: A MIDI step sequencer in Cubase SX displaying a C Major scale



What was once performed by traditional musical notation (with all of its idiosyncrasies and inherent complexities) can now be approximated through the use of a DAW sub-program known as a 'step sequencer'. A step sequencer offers a musician a visual representation of MIDI information, usually in the form of graphical 'blocks' (as seen in Fig 1. below), with vertical alignment ordinarily representing pitch and the length of blocks representing note duration.

Such a representation is for many musicians (from the SEN/D community or otherwise) far more intuitive than the complex array of dots, ties, sharps and flats that define more conventional musical notation. Within the step sequencer, notes can be recorded, deleted, transposed, moved or duplicated; amplitudes can be increased of attenuated and the resulting music can be heard on a multitude of different instruments; with each process of composition being executed at a regularity defined by the musician, something that can be very liberating for some musicians with SEN/D.

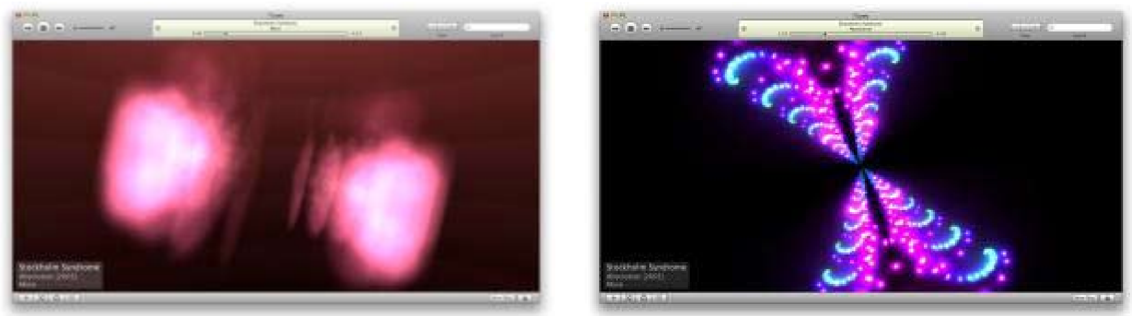
In this sense a MIDI step sequencer can be regarded as a musical interface in its own right, an interface that encourages the musician to compose content using incremental steps to achieve what can be incredibly complex results; results that might never be realized on more traditional musical instruments that demand very high levels of dexterity and coordination to create even simple musical outcomes.

It should be noted that the accessibility of many existing DAW's are questionable for some SEN/D musicians, being both complex, and not adequately supporting technological interventions such as screen readers for musicians with visual impairments. This being said, the potential of these musical tools should not be overlooked when we consider the agency that they may provide many musicians with SEN/D.

2.3.2 VISUAL REALITIES

Step sequencers help to create music in response to graphical representations, however it is also possible to create rich visual realities directly in response to music and sound. An example of this technology is built into many computer based media players like iTunes or Winamp. Media players such as this can generate and render graphics to music and sound in real time, synchronizing the movements of animations to the amplitude and frequency spectrum of the music used to generate them.

Figure 2: iTunes is an audiovisual media player.



In this context, visualisations are responding to prerecorded music; more interesting potentials may arise when these visualisations directly respond to musicians. Whilst such programs generally restrict their graphics to a computer monitor, the addition of projectors and bespoke visualisation software allows huge, immersive musical environments to be designed that expand the visual reality of music and musical instrument design.

Whilst well documented, longitudinal studies involving SEN/D populations and audiovisual music systems appear thin on the ground; there are several possible benefits that might provide a good rationale for further exploration. It is apparent that visualization software such as this can provide musicians with hearing impairments a forum with which to experience and compose sound and music if they wish. To this end software such as Lumisonic has been designed specifically to create visual representations of music and sound, with concentric rings that expand and contract in response to pitch and volume. Unfortunately no studies could be found to underline the effectiveness of this system. Hunt, Kirk and Neighbour (2004) indicated that multi sensory stimulation might be of benefit to musicians with a variety of SEN/D's (notably Autistic Spectrum Condition / ASC) to engage with musical activities. Gumtau et al. (2004) also utilized a multi-sensory environment to facilitate creative expression and exploration in young people with ASC. More research is required to ascertain the benefits and hindrances of audiovisual systems as experienced by SEN/D musicians and to explore potentially useful creative contexts.

2.4 **DATA COLLECTION**

Data derived from a user's interactivities can be routed to sound generation units and visualisation software to vary and enrich musical experiences. This data can also be collected and used to provide quantitative data sets that can help prove the effectiveness of equipment and practice, and help some young people with SEN/D make creative choices.

Parker and Graham (1972, pp.147-155) implied a need for the development of an "information retrieval system" for music therapy as far back as 1972, pointing out that "Scholars in the arts and humanities ha[d] made relatively little use of the storage and retrieval capacities of the computer". Hunt, Kirk and Neighbour (2004, pp 56-57) also identify a need for music therapists to encourage quantitative analysis of their work through MIDI event data collection systems such as CAMTAS (Computer Aided Music Therapy Analysis System).

> *"CAMTAS captures all MIDI data supplied to it and displays it as a piano-roll–like display...The musical data produced by the therapist appears in horizontal bars of one color, while that produced by the client appears in another color. Color intensity indicates how loud or soft the therapist and client were playing at any point, giving a visual indication of the energy of performance. The therapist can then use the stored data to analyze musical interaction using the CAMTAS display after the session is finished. Controls to fast-forward and rewind the data let the therapist scan for significant musical events. The system also includes controls for a video camcorder, which CAMTAS keeps synchronized with the MIDI data. Thus if the therapist fast-forwards through the data to a certain point, CAMTAS will fast-forward the video to the corresponding point. The video display (and its soundtrack) provides a useful record of events not otherwise captured in the MIDI data. Users can watch the video display in one corner of the computer screen. This system greatly reduces the time needed for session analysis and has already been found useful by music therapists engaged in research."*

Whilst systems such as CAMTAS were designed to provide therapists with quantitative data, it could be argued that data such as this is also an applicable resource within the musical education of young people with SEN/D, despite the two disciplines working towards different musical outcomes.

Magee (2006) observes that the primary focus of music therapy is the evolving therapeutic process, and that whilst any therapeutic intervention is important, outcomes may not necessarily be the primary focus. This differentiates music therapy from music education or other music activities where performance, product or skill acquisition is the primary goal. Whilst music therapists can use this data to plot an individual's progress, it can also be used to help young people make creative and compositional decisions that they might not otherwise be able to iterate.

Some young people with SEN/D find it challenging to make conscious decisions in certain situations, something that has partially led to the development of communication systems such as PECS (Picture Exchange Communication System, Bondy & Frost 1994). Making conscious decisions regarding personal preference is important when deciding on musical genres, instrument sounds and many other elements essential to realising individual musical expression. Without the provision of systems to aid and promote personal choice, many musicians with SEN/D may find themselves using music technology tools and instrument sounds that have not been explicitly chosen by them. Collecting data from a music session can help musical practitioners to establish personal choices with very little outside coercion. For example it can provide a record of how many times different musical sounds are used; something that can identify and so facilitate clear creative decisions.

Now that we have established a rationale for the use of music technology within the context of this paper, we will attempt to present the reader with an overview of the various music technologies that are currently available. We will explore in some detail the variety of assistive tools used by many musicians to create music on computers. Additionally we will discuss musical software environments that some may find appropriate. Finally we will investigate the multitude of musical control interfaces that have been developed specifically with SEN/D musicians in mind.

3.0 A SUMMARY OF MUSICAL TECHNOLOGIES USED IN SPECIAL EDUCATION

> *"One effective example of a modification is moulding a new rubber grip around the handle of a drum beater to facilitate better beating by a patient physically unable to beat the drum without the grip."*
> Nagler 1993.

This is a good example of how musical equipment can be adapted to increase accessibility and usefulness by making simple and proportional contributions to an existing musical tool. Contemporary music technology can also benefit from this type of augmentation, with many assistive aids being simple and affordable alterations. These alterations can open up a myriad of composition and performance opportunities to many SEN/D musicians who might otherwise find themselves at a disadvantage. Many of these solutions are easy to implement; however solutions that address the more profound barriers to participation experienced by young people labeled 'PMLD' (Profound and Multiple Learning Difficulties) can be accompanied by increased levels of complexity, requirement of specialist knowledge and/or high levels of cost; potential barriers that will be discussed in greater detail in section 4.0 of this paper.

3.1 MATCHING TECHNOLOGY TO NEED

Picking a contemporary digital musical instrument is, in much the same way as one might pick a traditional musical instrument, an act of self-expression in itself. It is often difficult to know which technologies might be best suited for recommendation to an individual without in-depth specialist knowledge of both the musician and the available technology. Ultimately, the most appropriate solutions will be highly dependent on the needs, abilities and personal musical preferences of each individual musician with no single method being suitable for everyone.

Bott (2010) identifies that a key issue to consider when determining musical possibilities for individual musicians is to try and distinguish between: "a) Access Needs, and b) Learning Needs. Although the two are often interrelated, making such a distinction can begin the process of cutting through what might otherwise seem to be impenetrable complexities". For those whose barriers to participation are more physical than cognitive, the emphasis of provision, whilst primarily meeting the creative preferences of the musician, should aim to maximize individual physical abilities. For musicians that experience more pronounced cognitive barriers, with an emphasis on meeting creative preferences still being paramount, a need to provide musical tools and interfaces that are matched or adaptable to individual cognitive ability might warrant more primacy.

It is also important that musicians who use contemporary music technology decide if they would like their technology to help facilitate computer based composition; to provide them with a contemporary musical instrument to play; or indeed both. These decisions will, in combination with the individual abilities and needs of the musician, ultimately dictate the types of music technology that are considered. We shall explore the broad range of music technology tools that are currently available within the following sections.

3.1.1 AUDITS OF MUSIC PROVISION

As we shall see, there is an incredible range of access opportunities and musical instrument interfaces available for SEN/D musicians. Given this range, it should be possible to provide individually tailored music systems that address personal preference and ability, however it is not clear if this is being achieved. Two audits of musical provision within special needs schools that used sufficiently large sample sizes do shed some light on the range of equipment and the human resources available to facilitate their use.

The London Institute of Education and the Royal National Institute for Blind People conducted a comprehensive audit- the Provision of Music in Special Education (PROMISE) (Welch, Ockelford & Zimmermann, 2001) project. The project used data from a total of 52 randomly selected schools that catered for individuals with PMLD and SLD, 13% of national special need schools at that time. Whilst this was a very comprehensive report, it should be noted that it does not reflect the current distribution of music technology; technology that has become far more sophisticated and prevalent within the ten years since the report was published.

A more recent project, funded by Youth Music, undertook its own audit in 2006. This audit gathered information about the range and types of music making in a sample of 22 special need schools across three counties. Whilst this audit provided us with a more recent snap shot of music technology provision within special schools, its sample of schools was geographically narrow. Ultimately such an audit can only provide us with a national picture of distribution, provision and use by generalising the project findings.

3.1.2 DISTRIBUTION OF MUSIC TECHNOLOGY

Both reports clearly identified a prevalence of distance sensing and switch equipment such as Soundbeam or MIDICreator within schools, technology that will be discussed in section 3.4.1 below. The PROMISE report showed that 80% of schools owned the technology compared to 50% identified by the Youth Music projects audit. This prevalence is also demonstrated in a survey of 113 music therapists (Magee, 2006), which, despite reporting very low numbers of practitioners using music technology, established that distance-sensing technology was the most frequently used music technology tool. 30% of those music therapists surveyed stated that they had used electronic music technologies at some point in their career; of which 76% reported using Soundbeam and over 35% had used MIDICreator.

The range and provision of other musical technologies within the schools is not as clearly established. The Youth Music project audit does demonstrate a high presence of other music technologies, with over 95% of schools surveyed owning some form of "computer, keyboard or MIDI system". However there is no information regarding what types of keyboard or MIDI system this includes, which supportive technologies are in place to assist pupils to use computers, and what music software packages are being used.

Magee reports that of the music therapists that used technology in their practice, 35% used software with specialist input devices, 35% electronic hardware or software and 26% electronic or MIDI instruments. Whilst slightly more explicit, these categories still offer little detail regarding the specific types of equipment being used. Indeed these categories encompass disproportionately broad ranges of music and assistive technology when compared to the precise records of distance-sensing equipment.

3.2 COMPUTERS

Arguably the most prevalent and powerful music technology tool is the personal computer. There are numerous musical computer applications available to facilitate playback, composition and performance. Whilst some of these computer applications have been specifically designed for SEN/D musicians, most are aimed at the mass-market. Such mass-market music applications benefit from substantial developmental budgets to provide high quality musical production and composition tools to their users; however many make little or no specific provision for SEN/D accessibility in the form that they are sold.

Assistive technologies are available however that try and bridge the barriers-to-access presented by much mainstream software. These tools provide access for many individuals on a range of computer applications, facilitating increased access to illustration, reading, writing and music alike. The effectiveness of any assistive technology however is ultimately dictated by the design decisions, limitations, complexities and appropriateness of the software or hardware that it is seeking to augment; factors that can result in varying degrees of facilitation.

Human-computer interactions are most commonly achieved by employing a combination of interactive tools. These tools, in much the same way as other contemporary musical instruments, comprise three diverse determinants, namely: a method to represent information, a method to navigate through that information and a way to input information. Each of these determinants can be enhanced or replaced in a myriad of different ways to find systems that best address the individual barriers to participation experienced when using music software tools.

3.2.1 REPRESENTING INFORMATION

A computer monitor is simply a way of representing information and can be replaced with a variety of alternatives or enhanced in a number of different ways to make it more accessible to blind and partially sighted people or other individuals with SEN/D that require it.

Altering the contrast of a computer display so that text, buttons and other details become more defined can significantly increase visual accessibility. Other simple alterations include setting a display to be composed exclusively of shades of grey (i.e. 'grey-scale') or changing a display's colour system to 'negative' so that black becomes white and vice-versa. These alterations are just some of the simple ways that computers can be modified to cater for individual need with nothing more than standard system preference settings.

Using additional hardware or software products, the visual output of a computer can be augmented in many more ways to improve access to individuals who experience additional barriers to technology. Screen magnifiers are one such solution, magnifying the screen area around a mouse cursor to make conventional computer monitors more accessible to some partially sighted people.

Such modifications can be used in conjunction with screen readers; technological aids that attempt to identify and interpret the information being sent to a computer screen for presentation either in the form of text-to-speech or a digital Braille output device. There are a number of screen reading software solutions available that vary widely in their levels of functionality and consequent expense. Microsoft Windows have included the Microsoft Narrator light-duty screen reader as part of the Windows Operating System (OS) since Windows 2000 and Macintosh have implemented the screen reading software 'VoiceOver' as standard since their OS version 10.4 with additional implementation for the iPhone and iPad iOS.

Other examples, produced and developed as independent commercial products, include Window Eyes from GW Micro and JAWS from Freedom Scientific. The compatibility of individual pieces of software with screen readers varies greatly and unfortunately it is still the case that much music composition software remains relatively inaccessible to many blind and partially sighted musicians.

3.2.2 NAVIGATION

When interacting with a computer display, whether its information is being relayed visually, audibly or tangibly, some form of navigation is required to enable a user to specify which section they wish to interact with. Anything designed to facilitate this must be able to detect two-dimensional motion and make provision for some form of selection procedure; functions normally met by a standard computer mouse.

Track-pads and touch-screens are other, increasingly pervasive, examples of navigational technology that offer unique and increased levels of functionality and control for a user. Touch screens might be of particular benefit when building a cognitive relationship between onscreen objects (for example buttons or faders) and physical interactions, as they allow a user to directly touch the area of the screen that they wish to select or control. Additionally touch-screens and track-pads can sometimes incorporate multi-touch sensing, allowing the user to touch and control multiple points of the display simultaneously. This function offers software designers the opportunity to create computer applications that interpret more elaborate physical gestures than a conventional mouse can offer.

Clearly such devices are not suited to every individual, demanding as they do, significant levels of hand dexterity and motor coordination. Fortunately, there are a wide variety of adapted and alternative mouse products available that can meet individual requirements. Joysticks and trackballs are examples of familiar physical computer technologies that many SEN/D users can find more accommodating than a conventional computer mouse or track-pad. Musicians that have more control over their head than their hand can use various combinations of software and hardware to translate these physical movements into mouse actions. Systems such as Headmouse or SmartNav 4 allow head movements to be translated into those of the onscreen mouse cursor.

To aid computer users who face more pronounced physical barriers to the use of computers, software solutions such as Cross-Scanner exist that can automate mouse movements on screen with output coordinates controlled by a single on/off switch. This process is executed in two stages; firstly a line passes vertically up and down the monitor until the user confirms it to be in the right place by activating a switch, the line's movement is then repeated horizontally with the next click completing the required on screen coordinates and signaling a mouse click.

Other systems that cater for people with significant physical impairments take advantage of a user's eye movement as a means of computer navigation. Systems such as Eyegaze track on the computer monitor where the user is looking, adjusting the mouse cursor's position accordingly. Whist this system is compatible with one or more physical on/off switches to action a mouse click, they can also be used in conjunction with a concept known as 'dwell clicking'. Dwell clicking, through software extensions such as Autoclick and Dragger, allows users to produce a variety of mouse clicks simply by keeping the mouse cursor stationary in an area of the screen for a predetermined period of time.

Software tools are available that enable mouse clicks to execute complex computer commands. This can transform a computer mouse into an extremely powerful tool for computer-based music making opportunities. The Grid 2 is a software package that contains multiple tools to assist communication, access and enhanced computer control. Using the Grid 2 a user can create an array of user-defined buttons that execute various program specific keyboard shortcuts. For certain music applications this process affords very good levels of creative access. Programs such as Sibelius, a music notation program, allow musicians to enter classical musical notation using only a computer keyboard. Such a comprehensive integration of keyboard shortcuts allows users of the Grid 2 to create correspondingly comprehensive arrangements of onscreen buttons. This dramatically increases the speed at which some composers with SEN/D can create music.

3.2.3 INPUTTING INFORMATION - SWITCHES

Dwell clicking demonstrates an effective form of on/off switching used to benefit individuals who face considerable physical barriers to music making. It should be noted that the vast majority of human-computer interactions make use of switch technologies; from the clicking of a mouse to the use of a computer keyboard, which is itself comprised entirely of on/off switches.

Computer keyboards come in a wide variety of different forms, from physical, tangible objects of numerous shapes and sizes; to graphical, onscreen representations accessible though the variety of mouse and navigation iterations outlined previously. They are incredibly important for computer-based music making, with keyboard shortcuts reducing long, laborious activities to single, easily actioned events.

Keyboard shortcuts are often highly configurable from within a DAW, for example the key combination that saves a musical composition to disk could be changed from the preset "Alt + S" key combination to almost any single or combined key press that the user likes. And it is not only rudimentary functions such as "open file" or "save file" that can be actioned in this way, many DAWs allow users to trigger samples, open mixer channels and insert software instruments, all with a single click of a physical or screen based switch.

There are many adapted keyboard products available to suit the individual needs of a wide variety of computer users. Keyboard guards for example are low technology assistive devices that fit over standard QWERTY keyboards and allow a user to lean on the keyboard without triggering a barrage of key presses. Keyboards can have their physical dimensions and attributes varied to suit, making keys larger or smaller depending on dexterity or implementing Braille symbols to assist navigation for partially sighted or blind people. Keyboards such as Intellikeys allows a user or practitioner to alter the look and functionality of a keyboard by creating graphical overlays that replace the standard alphabetical symbols we normally associate with keyboard interfaces. The images shown on these overlays can vary in size and number and can feature any design, shape or pattern that best meets the physical or cognitive abilities of the user. When pressed, each image functions in much the same way as a conventional keyboard key would, sending out a single instruction that the computer interprets as a regular key-press.

Indeed a computer cares little for the aesthetic appearance of the various switches that it finds connected to it; they are able to take a variety of different forms to suit the individual needs of the user. If a user has control over a single physical gesture, no matter how subtle or broad that gesture may be, then technology is able to provide a switching mechanism to offer control over a computer system and so the opportunity to compose and perform music. Switches are available in a variety of different shapes and sizes, with varying degrees of contact being required to determine a key-press. Users are able to activate switches by pressing mechanical switches, activating tilt sensors or breaking infrared beams. For individuals that have good command over their mouths, bite or sip/puff switches can be employed, and for individuals who face more pronounced physical barriers, Electromyography (EMG) switches can be utilized as a means of harnessing the subtle flexing of a muscle.

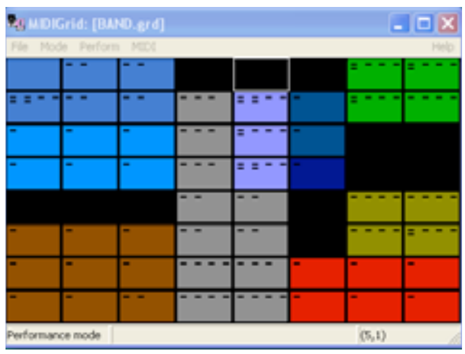
3.3 **AN OVERVIEW OF MUSICAL SOFTWARE USED BY SEN/D MUSICIANS**

The potential of switches as a means of creative musical expression is, for the most part, dictated by the musical software that receives them. Swingler (2002) observes that musicians who utilize switches as their sole method of musical control, particularly musicians that are just starting to experiment with music in this way, can experience fatigue, frustration and de-motivation owing to the high demand for precise and numerous mouse operations that many DAW's make.

3.3.1 MUSIC SOFTWARE DEVELOPED SPECIFICALLY FOR SEN/D MUSICIANS

The accessibility and adaptability of a DAW to individual abilities varies from product to product and in regard to the type or range of assistive technologies being used to access them. There are several computer programs that offer entry-level musical experiences controlled fully via single or multiple switches. These applications, including the Widget Music Factory, Switch Jam and Super Switch Ensemble, allow musicians to control and arrange pre-made musical elements including loops, drum fills, melodies, riffs or chords. These examples do demonstrate a good level of integration in regard to their employment of switching technology, however they are rather rudimentary in terms of musical variety and can be very limited in their scope for expressive musical performance and composition.

Figure 3 MIDIGrids virtual containers



MIDIGrid provides another example of music software designed with SEN/D musicians in mind (Hunt & Ross, 2003). In this instance, musical materials comprising notes, chords and musical phrases, are composed via MIDI and stored in virtual containers that are graphically represented on a grid (see fig. 3). The size of the grid can be defined and varied by the musician to contain anything from 1–200 cells, with stored musical data being activated by moving a mouse over the cell containing the musical information you wish to trigger and clicking. This provides an effective method of composing, storing and accessing musical data.

E-Scape is an example of musical software that has been developed to offer musicians a more comprehensive but equally accessible platform for musical composition and performance. Like previous software examples, it can be accessed entirely using single or multiple switches, the various iterations of computer keyboard or mouse, touch-screen technologies and crucially with any equipment capable of sending MIDI information. E-Scape is controlled through a series of large, guided menus that can also be spoken by the computer. This makes the process of composition much more interactive than that of most DAW's. At every stage E-Scape asks the user what they want to do and offers a range of options depending upon which level of complexity the user has chosen to work at.

Unlike most DAW's, E-Scape has two modes of operation: Composition and Performance. In performance mode, the same hardware that has been used to create a composition (e.g. 2 switches) can then be used to perform the piece in a variety of different ways. All of E-Scape's menus and alert boxes can be identified by screen reading software, onscreen text can have its size increased and both text and background colours can be altered according to preference. E-Scape can output MIDI data to any hardware or software sound module or sampler, although the guided menus assume that the user will be using the General MIDI sound set, which is now fairly out-dated. While E-Scape's accessible features are extremely comprehensive, they also make it time-consuming to use. Even the simplest of tasks, such as placing one note on the step sequencer, must be preceded by a series of questions from the guided menu. Until the early 2000's E-Scape provided the only real option for severely physically disabled people to use a DAW independently. But now, software such as The Grid 2 can enable access to almost any (Windows) software meaning that there is the potential for disabled musicians to use the same, up to date, software as their non-disabled peers.

3.3.2 MAINSTREAM MUSIC SOFTWARE

Unlike previous examples, Ableton is an example of software not designed to specifically accommodate SEN/D musicians. It does however provide a fairly intuitive musical environment that supports various modes of interactivity; something that can be useful to musicians with SEN/D. Rather like E-Scape, Ableton offers a musician two principle sections with which to make music; one designed for musical composition and arrangement; the other aimed primarily at improvisation and performance. The latter section demonstrates conceptual similarities with MIDIGrid, allowing a user to compose or load musical phrases, samples or loops into discrete graphical holders. This musical content can then be triggered in a variety of different ways, including mouse clicks, MIDI data or via numerous and highly configurable keyboard shortcuts; something that makes this program fairly accessible to SEN/D musicians using switch technology. It is also possible to trigger content within Ableton wirelessly via an iPod or iPad running either LiveControl (see Fig. 5) or Griid - both applications baring a striking resemblance to MIDIGrid visually and operationally (at least in part). Musicians are able to trigger audio playback by touching the graphical container that contains the desired note, chord, musical sequence or audio file. They also provide the user with the facility to control a wide variety of additional musical parameters within Ableton Live including audio effect controls, panning, volume and the ability to initiate track record/mute/solo functions. Many SEN/D musicians might find such a system inaccessible owing to the significant level of manual dexterity required to interface with Ableton in this way. However, the highly responsive nature of contemporary touch screen technology, coupled with the simplified graphical representations of Ableton provided by LiveControl or Griid, can make this a suitable option for some.

Figure 4 E-Scape

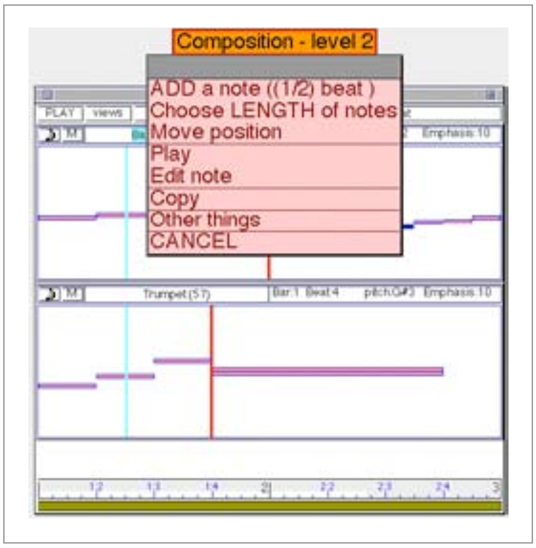
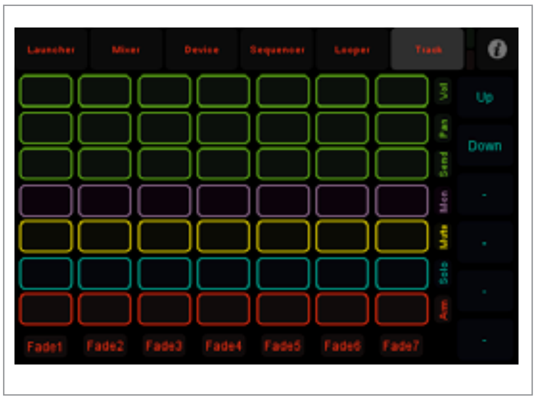


Figure 5 LiveControl - an iOS application used to control Ableton Live



Unfortunately, whilst many SEN/D musicians can find Ableton to be an accessible and useful musical instrument and compositional tool, to some it does still present various barriers to participation. Without augmentation from control software such as LiveControl or Griid the application can be very complex - the price paid for the plethora of musical tools that the application provides. This can consequently make it very difficult to use for musicians with learning difficulties without varying degrees of additional support. The complexity of the application is also apparent in the various display windows that are associated with the program, littered with small buttons and number boxes, hard to interpret with assistive devices such as screen readers and requiring significant levels of manual dexterity and coordination to target with a mouse cursor. Ableton Live is not alone in this; many commercial DAWs remain fairly inaccessible owing to a number of recognized design issues for many SEN/D users (Magnusson, 2006). Cubase, Logic and Pro-tools are three examples of prevalent DAW platforms that do not work well with screen reading software and do not provide many options to increase their overall accessibility.

The RNIB website currently recommends two DAWs that provide good levels of support for users of screen-reading software. Both examples provide high-end musical composition packages that facilitate the recording, editing and manipulation of both MIDI and audio data and include or support numerous effect unit formats and software instruments. Owing to these high levels of creative functionality, both pieces of software are fairly complex and consequently many musicians might find them challenging. The first (and reportedly the most) accessible application to screen reader technology is Sonar by Cakewalk, available for Windows. Sonar version 8 can be made accessible to the screen reader JAWS via the use of two different types of user script: CakeTalking, which requires a commercially available license and also via JSonar, a community-driven project that is supported via donations. The second RNIB recommended software package is Reaper, an affordable DAW that has been in rapid development since 2005 for both Windows and OSX. Reaper boasts a user interface that is highly customizable by its users through the application of additional themes and also good integration with a variety of Windows based screen-readers, namely JAWS, Window-Eyes, NVDA, and System Access, through an accessibility bridge called ReaAccess.

3.3.3 MUSIC SOFTWARE DEVELOPMENT PACKAGES

It has already been suggested that it is the modular nature of contemporary music technology that helps it to address the various additional support needs of many SEN/D musicians. One strand of music software takes the principles of modularity and bespoke DAW design to such an extreme that it results in a system that most people find utterly incomprehensible in its composite form.

Whilst this type of software is in many ways not well suited to most musicians in terms of instant musical access or gratification; offers little or no initial support for screen-reading software; and demands long periods of study just to grasp the fundamental concepts that underpin its use, it does provide one of the most versatile and powerful tools available to develop and augment musical software for users with SEN/D.

Software programs such as Max/MSP, Reaktor and Pure Data provide software developers with a versatile, graphical programming environment that allow unprecedented levels of bespoke musical software design and the manipulation and conversion of various data protocols. With such software it is possible to convert keystrokes or mouse movements into MIDI messages, design synthesizers that can be controlled exclusively with a microphone and perform video motion tracking with the latest depth sensitive cameras to turn three-dimensional movement into a vehicle for sound control.

The strength of this type of music software is the promise of being able to mould it into or onto any musical system conceivable; an ability that enables software designers to create bespoke musical solutions that are adapted or adaptable to a SEN/D musician’s individual needs and preferences.

3.4 MUSICAL CONTROL INTERFACES

So far we have explored computer accessibility through methods that help physically and sensory disabled musicians use keyboards and mouse alternatives. Additionally we have summarized and described a selection of music software in use today, suggested examples that some SEN/D musicians might find useful for composition or performance and touched on music development software available to creators of bespoke music systems. Now we will move our attention to the vast array of interfaces available to help musicians control and manipulate music or sound.

Whilst the computer keyboard and mouse are certainly examples of musical control interfaces (being capable of high degrees of musical expression) they are by no means the only examples. Most people would be familiar with the most pervasive musical control technologies, the MIDI controller keyboard and microphone, technologies that are commonly used to translate human intervention into musical or sonic material. It is important that we briefly look at some of the scope for these two interfaces as methods of interpreting human gesture into musical control.

In the case of a MIDI keyboard, ordinarily two modes of interaction are mapped to two distinct musical parameters: 1) the key you play dictates the pitch of the sound 2) the harder you play the key the louder the sound will be. This familiar way of doing things can easily be altered so that the pitch of the note changes depending on how hard a key is played or that the volume of the sound increases with each key from left to right. In regards to the microphone, ordinarily it amplifies your voice or the sound of an instrument, perhaps with the application of reverb or some other sound effect to augment and distort it. It is relatively easy to extract pitch and amplitude information from the sound source using software such as Max/MSP that can then be used in various different ways. The louder the sound the faster the drum loop might play; the higher the perceived pitch coming into the microphone the brighter a computer monitor might glow. By presenting these examples of how digital information can be re-appropriated, it is hoped that the reader will see some of the inherent potential and variability of musical control interfaces in terms of what physical gesture can be mapped to what musical or visual parameter. The gestural interfaces that follow do not have to be used solely for increasing or decreasing pitch; they can control tempo, amplitude, visuals or effects parameters.

3.4.1 DISTANCE SENSING & MOTION TRACKING TECHNOLOGY

We have seen that the most common musical control interface used by SEN/D musicians appear to be the distance sensor. The interface can take a variety of different forms and is used broadly in music education (Welch & Ockelford 2010) and music therapy (Magee, 2006). Modern iterations of distance sensing technology include the Soundbeam, MIDICreator, Musii and Benemin. Such interfaces sometimes allow their measuring range to be varied for movements over very short (50cm) or very long (6m) distances, which consequently allows the movements of a head or foot to control the same note range as running across a room. It is also possible to specify the musical content available for control with an unabbreviated range of musical scales being easily applied. Additionally the number of notes can be varied and 'cyclic triggering' can be used to allow pre-recorded musical passages to be played, note-by-note, by sequential interruptions of the distance sensor's beam.

Clearly distance-sensing equipment brings with it huge musical potential and provides an appropriate musical control interface for many SEN/D musicians. The technology is an accessible, adaptable and expressive instrument used by many musicians, something that has been longitudinally documented (Ellis 1995, 1997, Swingler 1998, Ellis & Leeuwen 2000, Swingler 2002, Swingler & Brockhouse 2009).

A video camera can, in combination with a computer, also be used to translate physical movement into a musical interface. Whilst conventional distance-sensing technologies such as Soundbeam or

MIDICreator can only extract information from one-dimensional linear movement (that is to say you move towards or away from the sensor), single lens cameras, combined with motion tracking software, can identify movement on two planes. This system has been used in the development of at least one product for SEN/D musicians, De-Coda's Dancing Squares. By suspending a video camera from above, the movements of those below are tracked. Any motion detected within pre-assigned hot spots is consequently used to trigger pre-assigned musical content.

The recent commercial release of the X-Box Kinect has provided us with the addition of visual depth perception for such systems, allowing data to be extracted from the three dimensional movements of objects. This paves the way for systems that perform complex three-dimensional motion capture within a variety of spatial contexts. A relatively small area of movement could be used to control musical material, perhaps the movements of a musician's thumb or the movements of their head. These movements could ultimately be measured within three-dimensions which could potentially allow more complex gestures to be mapped to musical actions. This may be of particular benefit to musicians who may find moving along a single dimensional plane challenging. Alternatively much larger areas could be analyzed, perhaps recording the three dimensional movements of several individuals as they move around within an entire room.

The Kinect is a relatively emergent technology but it has already been exploited for use within a variety of programming languages and environments for musical applications, notably Max/MSP and its visual counterpart Jitter. More research and development is required to explore and demonstrate the potential benefits and failings of this emerging technology as a method of musical control for SEN/D musicians who might wish to use it.

3.4.2 TOUCH SCREEN TECHNOLOGY

Video camera motion-capture, in much the same way as more conventional distance sensing technology, does lack the intrinsic tangible, visual control interface that many musicians find useful. Tangible two-dimensional touch detection has been utilized by SEN/D musicians in a variety of different forms. Products including the Korg Kaoss Pad (Welch, Purves & Himonides 2006) and the Tenori-on (Watson, 2010) have been used to create, control or perform musical material on visually rich touch sensitive interfaces.

It is worth noting that both these products have been consequently influenced by the advent of widespread and affordable touch screen technologies in the form of smart-phones and tablet computers. Korg have sought to take advantage of the iPad's touch screen technology by creating the worlds first dedicated iPad based musical instrument, the iElectribe and affordable iOS applications like the Aurora Sound Studio HD are able recreate at least some of the functionality of the Tenori-on at around one-hundredth of the price (excluding the cost of the iPad itself). Indeed devices such as the iPad can run a variety of very affordable musical software applications and instruments. These applications make use of user interfaces that can vary in complexity, using multi-touch screen technology that requires very little pressure from the user to activate and control. These features might help address some of the barriers to access experienced by many SEN/D musicians.

Devices like this sometimes contain a variety of different internal sensors, often including 3-axis accelerometers to report the orientation of the device, digital compasses to identify alignment to the poles, microphones and also cameras. These sensors provide software developers with a lot of information about the device, including how fast it is moving, which direction it is pointing, which way up it is and what it is seeing or hearing. It will take several years to fully realize the scope of these devices in terms of musical software development, but it is clear that the embodiment of so many gesturally sensitive devices in one device will bring about revolutions in the way music can be made; particularly if it is being used as an assistive device by an individual on a day to day basis.

Many people that have difficulties speaking use Voice Output Communication Aids (VOCA) to provide them with a voice to speak (Westrup, 2010) or sing. Systems such as the PowerBox, FuturePad, and Vantage etc. incorporate graphical or text based variable overlays that allow users to piece together sentences and statements to be spoken by the VOCA. Proloquo2Go is a software VOCA that has been designed to run natively on iOS devices such as the iPad. Given the enormous expense of many dedicated VOCA devices in comparison to this emergent system, it is not unreasonable to predict that software VOCAs on these affordable tablet computers will become more widespread. The ability to control a huge variety of affordable, diverse music software on the same, familiar device that assists an individual on a day-to-day basis may be something that appeals to many musicians.

3.4.3 TANGIBLE INTERFACES

Whilst the iPad and its equivalents provide a tactile interface (which is to say you touch something when you use them), for many musicians this is not comparable to experiencing the tangibility of a physical musical instrument. There are several musical control interfaces, designed with SEN/D musicians in mind, which seek to offer this type of tangible experience. One notable piece of recent music technology is the Skoog. The instrument comprises a 'soft, squeezable object' that is variably sensitive to touch, responding to a light touch or the total compression of its malleable interface. The object is multi-touch sensitive with five colour-coded responsive zones. Each zone can have a particular note or sound allocated to it and these are variable from within accompanying software. The instrument does not simply trigger samples when pressed. Using a sophisticated synthesis method known as physical modeling developed within Max/MSP, it is possible to dynamically manipulate the various instrument sounds though 'pressing, squeezing, rubbing, stroking, tilting or manipulating the Skoog'. The company's website provides six case studies with accompanying qualitative data sets (Watson, 2010), iterating some positive experiences of six SEN/D musicians who used the Skoog. The data was collected from a total of 60 participants of different ages and abilities with the case studies seeming to demonstrate that the Skoog has the potential to benefit a range of service users with a variety of disabilities. It is noted that of the 60 participants who took part in the study, none acted adversely to the Skoog.

Another tangible control interface design for SEN/D musicians, closely resembling a standard MIDI keyboard controller, is the Banana Keyboard. The device, which is part of the Soundhouse Special Access Kit™, has sixteen keys configured in much the same way as an oversized piano, but curved to suit the radial movement of an arm. The interface boasts additional ports that allow the connection of up to eight external switches for alternate activation of the keys on the keyboard. It is bright yellow in colour in an apparent effort to make the device more accessible to users with visual impairments. The size of the device means that it can be comfortably mounted onto the arms of a musician's wheel chair. The large keys are designed to be very sensitive, requiring a limited amount of pressure to activate each key, aimed at helping individuals with limited hand dexterity. The device is accompanied by software that is able to create visual feedback relating to the keys being pressed, so called "Banana Vision". It is a device that may provide a suitable control interface for some SEN/D musicians, however at over £1200 it might be considered expensive.

The MUSE (Multimedia Used in Special Education) Project has developed several prototype tangible control interfaces for use by SEN/D musicians. One interface, like the Banana Keyboard, is based on a conventional MIDI keyboard controller. The interface differs in that it can have the number of keys on it varied from one through to twelve in relation to the level of dexterity and cognitive ability of the musician. The keys are individually coloured and are numerically labeled in a break away from the layout of a traditional musical keyboard. The interface is used in conjunction with the company's DAW environment that allows the instrument to control a variety of different instrument sounds. Longitudinal studies of the equipment are not available but initial records taken from music workshops that have used the equipment appear to indicate that it may be a useful interface for some SEN/D musicians. This seems especially the case for young people who have moderate to severe learning difficulties, yet have learned some early number and/or colour concepts.

3.4.5 WIND CONTROLLERS

Clearly the devices listed previously within this section are not suited to all SEN/D musicians. Each of the control interfaces described so far requires that a musician is able to move or physically manipulate an interface in ways that require varying degrees of motor control. There are however other ways in which a musician is able to control musical material.

Breath has been a staple and persevering form of physical control over musical instruments for a very long time. Breath can also be used to control contemporary music technologies, something that can be of benefit to some SEN/D musicians. There are several digital musical instruments that have been designed to respond dynamically to the amount of pressure applied through a musician's breath. Wel (2011) has qualitatively documented two MIDI wind controllers used by SEN/D musicians, namely the Yamaha WX11 and WX5. The two controllers do vary in functionality with the WX5 identified as more appropriate for single hand manipulation than the WX11. Both the WX11 and WX5 are no longer available, however several commercial wind controllers are.

The Magic Flute provides another example of a wind controlled musical instrument, which has been uniquely conceived to be played without the use of hands, something that makes it practical for some SEN/D musicians. The "flute" can be mounted onto a tripod that allows it to be easily tilted up and down with the musician's head movements. This action selects which note will be played while blowing into the flute and the amount of air pressure controls the instruments amplitude. The company's website provides several videos and case studies that seem to indicate the effectiveness of the device for the SEN/D musicians featured. It is noted that the instrument reduces the physical and cognitive challenges inherent within conventional wind instruments. One musician, with very limited lung volume, is nonetheless able to realize the full dynamic range of the instrument. The video evidence provided on the site leaves little doubt that this instrument has proved to be an expressive and versatile wind instrument that addresses many barriers experienced by the featured SEN/D musicians.

3.4.6 BIOMETRICS

> *"Any sufficiently advanced technology is indistinguishable from magic."*
> Sir Arthur C. Clarke

Some SEN/D musicians have very limited control over physical movement and devices that respond to breath pressure might not provide a suitable interface to facilitate their musical expression for a variety of reasons. SEN/D musicians have used a variety of technologies that offer them the ability to control musical parameters with muscle tension and brain waves.

Electromyography (EMG) is a technique for evaluating and recording electrical activity by detecting the electrical potential generated by muscle cells when they are neurologically activated. These signals can be analyzed to detect the 'activation level' or amount of muscle activity, information that can then be translated into data for switching and the dynamic control of various musical parameters. EMG sensors can be placed on any muscle or muscle group that the musician has a reasonable level of control over. This technology has been incorporated into a variety of products produced by iCube X. The BioFlex v1.2 sensor responds directly to muscle tension within a musician's arm or legs using EMG sensors to convert this information into usable MIDI data. Additionally, and with more functionality, the Biowave v1.2 is able to combine EMG sensors with the ability to measure some elements of a user's brainwave patterns, providing Electroencephalograph (EEG) data that can be used to control music.

Another system that uses a combination of EMG and EEG technologies to extract information from muscular and alpha brainwaves is a product known as Brainfingers. The system features in a case study documented by Drake Music Scotland recording the progress of a young composer and musician with Cerebral Palsy who achieves an A in a Standard Grade Intermediate 1 Music examination after the

SQA (Scottish Qualification Authority) agreed to accept the Brainfingers interface as his chosen musical instrument.

Technologies such as these are helping musicians overcome the substantial barriers to access and participation that they experience on a daily basis. There are however a variety of barriers, additional to the subjective barriers faced by SEN/D musicians, that exist between the potential of music technology to meet the needs of SEN/D musicians and the success of its provision. We shall explore those barriers in the next section.

4.0 **BARRIERS TO PARTICIPATION**

Contemporary music technology can provide a variety of tools to help musicians challenge many of the obstacles to involvement that they face. We have looked at the broad range of tools available to assist musicians to use computers for composition and performance and we have introduced and discussed the variety of music software environments currently available. Finally we have seen that versatile, adaptive control interfaces can be, in principle, well suited to many SEN/D musicians. Given such an intimidating range of equipment, we might tentatively assume that such equipment would be most effective if the staff and music practitioners who may consequently provide it are themselves well trained in its use.

4.1 **A NEED FOR SPECIALIST TRAINING**

> *"Training for music therapists on how to use electronic technologies would influence both the initial clinical decision as to whether it is appropriate in a given clinical situation, and also the continued use of electronic technologies within the clinical setting. Quite simply, therapists are not aware of what electronic technologies have to offer the client in therapy, nor of how the therapist might use it to meet their clinical aims."*
> (Magee, 2006, p144)

Both the PROMISE report (Welch et al., 2001, p22) and a Youth Music project funded in 2006, demonstrated that a high percentage of schools had a dedicated music coordinator or music specialist. However the PROMISE report also indicated that over half of the music coordinators within its sample of schools had no qualifications in music. The report also stated that of the 80% of schools with access to some form of distance-sensing equipment, only 11% used it on a weekly basis, something that the author suggest might be because "staff were unsure of how best to use such technology" (Welch & Ockelford 2010, p44). Additionally Magee (2006) established that 65% of music therapists were not aware of how to use music technology in their clinical work. Magee's (2006) report also provided some qualitative evidence to suggest that electronic technology equipment was being kept 'in a box in the cupboard'. It should be noted that Magee's study relates to a relatively small sample of music therapists and that the PROMISE report was conducted in 2001. However both reports imply that training might constitute a significant barrier to the provision of music technology to SEN/D musicians.

An in-house skill deficit was also identified for staff in at least one school visited by another Youth Music Project funded in 2006. The project's research evaluation paper (Welch et al., 2006): recorded that a lack of music technology expertise within the school had apparently left computers poorly configured and the school's music software uninstalled. The task of setting up these facilities consequently fell on the project team, a task that they were reportedly unprepared for owing to the extent of the problems encountered and the lack of in house support. Subsequently a great deal of time and resources were expended setting up the systems in a sustainable way. The paper consequently recorded that the lead tutor perceived a lack of music technology expertise within the school meant that little project-related music making could take place when the project team were not present.

We can tentatively infer from these findings that the range and potential of music technology and assistive technology in musical contexts is not always realized by music therapists, or within special schools. If this is true, then there is a possibility that the musical technologies deployed might not always be best suited to the needs of all individuals or indeed used appropriately. More research is needed to ascertain current levels of technological competency within all forms of musical provision for SEN/D musicians.

4.2 RESOURCES

The cost of equipment has been hailed as a persistent additional barrier to the use of music technology tools. Nagler (1993) suggested that an important factor preventing music therapists from engaging with music technology is the high cost of new equipment. This appears to have remained a factor for music therapists with Magee (2006) identifying that 40% of those questioned in her survey agreeing that music technology is too expensive to buy.

It is true that owing to economies of scale, music technology specifically developed for SEN/D musicians is often expensive, especially when compared to mainstream equivalents. The Banana Keyboard for example retails at around £1200 pounds. Whilst it is true that the keyboard offers additional functionality in relation to other keyboards, including an enlarged interface and high sensitivity to touch, when you compare it to the price of a more conventional keyboard such as the Korg NanoKey (available on 1/1/11 for £31.49 from Amazon.co.uk), the additional expense of assistive musical equipment becomes all too apparent. With the recent economic downturn and consequent government savings, it is unlikely that large periods of investment in expensive music technology equipment will be forthcoming from special schools that have had their funding budgets frozen. The expense of much assistive music technology, combined with a suspected prevalent lack of music technology training within special schools, may well become a substantial barrier to a school investing in new equipment.

Money is just one of several limited resources identified. Having a dedicated space of musical practice is another problematic issue highlighted within several sources of documentation. The PROMISE report (Welch, Ockelford & Zimmermann, 2001, p38) indicated that just under half of the schools surveyed had made provision of a dedicated music room. Additionally around two-thirds of schools had a multisensory room in which sound and music activities took place or another area that was seen to contain musical instruments. This is also apparent in an audit conducted by a Youth Music project in 2006 with just over 36% of school respondents identifying a school hall or classrooms as suitable spaces for music making. These findings seem to indicate that music making is being conducted in multi-use spaces. This is something that was seen as a detrimental factor in a least one school visited by another Youth Music project from 2006. In the project's research evaluation it is reported that problems with computers used for music making within a school were exacerbated owing to the multi use nature of the music block meaning that equipment could not be left in situ from week to week.

4.3 A FEAR, DISLIKE OR INDIFFERENCE OF TECHNOLOGY

> *I'd like to bring you up to date with the project that strikes fear into the very soul of the traditional musician – Music Technology."*
> Music and the Deaf – Issue No 21, 2005.

Technology is in a constant state of change and development. Computing and modern music technology has grown out of ground strewn with complexity, jargon and convolution. This may have contributed to the negative impressions of complexity apparently formed about contemporary music technology by some music therapists (Streeter 2007). It is certainly the case that 18% of therapists in Magee's (2006) survey stated that they did not like technology and that additionally 4% did not think that music technology was appropriate/relevant for music therapy work in general. Whilst this does indicate that a majority of music therapists show a willingness and positive attitude towards using electronic music technologies in their work, it does still indicate that a sizable minority remains unconvinced.

There is perhaps much that software and hardware developers can do to reduce the potentials for anxiety and frustration that may or may not be expressed by users and providers new to such equipment. It is not unreasonable to expect the language used to describe technological processes to be relatively short and free of the technical jargon, something that might make an incredibly effective musical tool unwelcoming to someone not experienced in music technology. Streeter (2007) identifies MIDICreator as being one such source of unnecessary complexity, it is suggested that the 78-page manual might present a significant disincentive to some. Streeter goes on to suggest that the requirement for a user to install 'configuration builder software' prior to using MIDICreator could suggest that considerable work will need to be done before a user can even begin to create a configuration. It is also noted that the inclusion of a 'configuration tutorial' may further convince the reader that the technology may be beyond them.

> *This is not like going up to a xylophone and quickly changing the bars to make a pentatonic scale; first one has to learn what a MIDICreator is, what it is supposed to do, how it should be 'set up', how to operate it and what to do if it goes wrong.*
> (Streeter, 2007, p8)

It has been difficult to source accurate information pertaining to the opinions of wider music practitioners and indeed SEN/D musicians to music technology. There is some anecdotal evidence to suggest that a discomfort around music technology still exists for some musical practitioners, however whilst mentioned in some the literature reviewed, it is apparently not substantiated though any sizable surveys. Technology is certainly becoming more pervasive in people's homes. The proportion of households owning a home computer rose from 72 per cent to 75 per cent between 2008 and 2009; up from 70 per cent in 2007 and just 33% in 1998/99 (Office of National Statistics, 2010). Considering this fact, it does not seem unreasonable to assume that such an apparent acceptance of conventional technology might positively influence any negative perceptions of music technology over time. This assumption, if true, will become more pronounced as digital media becomes ever more pervasive through the widespread distribution of smart phones and tablet computers. It might be pertinent, as Swingler (2002) suggests, to look at any negative perceptions of contemporary music technology in the historic context of the hostility encountered by Theobald Boehm when he introduced his redesigned fingering system for the flute in the early 1800's; a system that is now universally accepted and much revered.

5.0 FUTURE WORK

It is recognized that whilst this paper chose not to draw focus on music technology in relation to social, emotional and/or behavioral difficulties (SEBD), music technology does still have much to offer young people categorized as such. Whilst SEBD constitutes an additional barrier for many of the young musicians this paper has sought to represent, it was decided that the representation of PMLD, SLD, and MLD had already established incredibly broad research boundaries and that the inclusion of SEBD would substantially dilute this paper's focus. Given that SEBD carries with it a breadth of definition at least as broad as the barriers already included within this paper, it may prove appropriate for Youth Music and other organizations with an agenda to invest in accessible music technology for young people to consider commissioning a further, separate review of literature to establish the current state of music provision for young people with additional needs that are primarily understood as SEBD.

A priority for near-future work may be the implementation of training programs by highly trained and specialized musicians and music technologists to build the competence and confidence of parents and/or school-based professionals in using adaptive music technologies. There are several benefits to this kind of model. Primarily it will help organizations to realise the potential of the music technology resources that they may already possess by giving teachers and/or parents the skills required to use them. This in turn will help these institutions cement a legacy for future musical provision.

Research and development pertaining to new and diverse technologies will help ensure access, enjoyment and learning for all young people who wish to make music. It has been established that new touch screen technologies may be of advantage to some SEN/D musicians. Tablet computers and smart-phones are affordable, pervasive and offer unprecedented levels of interactivity for some musicians. Software for these devices is often relatively affordable and human resources are abundant to facilitate software development. More research is required to ascertain how effective the existing musical software packages on these platforms are for SEN/D musicians and more development is required to meet the additional needs consequently identified. Research and development for this technology will additionally create findings transferable to the music making of young people not labeled SEN/D, something that may provide scope for future collaborations between different 'demographics' of musician on a single contemporary platform. Similar transferable benefits will come from possible investment in the research and development of three-dimensional motion tracking using systems such as the Xbox Kinect.

Owing to the diversity of music technology, coupled with its tendency to develop and evolve so quickly, the development of an online wiki (a website that allows the easy creation and editing of any number of interlinked web pages) might be established to record the multitude of different music technologies currently being used by SEN/D musicians. Such a resource could provide a hub that would encourage an exchange of knowledge between SEN/D musicians, music practitioners and other interested parties.

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