moosikMasheens: Music, Motion and Narrative with Young People who have Complex Needs

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ABSTRACT
We present moosikMasheens, a novel system for musical expression by young people who have physical impairments or complex needs, playing music in a mixed ability group context. moosikMasheens consists of three electro-mechanical musical instruments that can be controlled via simple tablet computer-based interfaces. An adapted glockenspiel, guitar and a set of electro-mechanical drumsticks have the potential to provide feedback through many perceptual channels including sonic, visual, vibro-tactile and kinsaethetic. Through the use of both *a priori* theory and an extended participatory requirements analysis, the system has been designed for use by both teachers/workshop leaders and students, as this has previously been found to be the most common form of group musical interaction. The technical implementation of the system is outlined with an initial evaluation.

Categories and Subject Descriptors
J.5 [**Arts and Humanities**]: Music

K3.1[**Computers in Education**]: Collaborative Learning

General Terms
Design; Human Factors.

Keywords
Music Technology; Special Education; Novel interfaces; Adapted musical instruments

1. INTRODUCTION
Group musical interaction is a key part of both playing and learning musically expressive skills and has also been shown to benefit young people with cognitive and physical impairments in developing self-confidence, personal identities and social skills [24]. Additionally, using music technologies such as alternative input devices in music therapy with people who have complex needs can reduce feelings of isolation and increase those of self-accomplishment [27]. In the partnership special educational needs and disability (SEN/D) institution for this project, group activities have been observed to be the most common form in which students have access to creative musical expression. Despite this, there has been a significant lack of both design research and publicly available tools that are undertaken or created specifically for the purpose of group musical activity. There is also a lack of evaluation discourse surrounding novel sonically expressive technologies in general [11] [33]. As a result, we present a novel system informed by both empirical, qualitative participatory research and deep theoretical study aimed specifically for the purpose of delivering group musical workshops to young people with complex needs in a mixed ability environment. The system comprises of three electro-mechanical musical instruments, narrative-based software and tablet interfaces with which to facilitate sonic expression.

Relevant literature relating to the theoretical underpinnings of this research regarding movement, sound and narrative are primarily outlined in the background section. The related work section subsequently details technologies and design literature that have informed this work. Furthermore, the extended participatory requirements analysis phase is outlined in order to situate the work within the scope of the wider research project. The details and functionality of the system itself are then presented showing how both theoretical and empirical study have infused the design. This is followed by an initial evaluation of one part of the system. Finally, conclusions and further work are provided.

2. Background
There has been significant recent work exploring the fundamental links between movement, sound production and sound perception which has informed the design of the system. Rolf Inge Godøy [14] posits a model of sound-action chunking which is a way of conceptualising the link between perception, movement and sound. Godøy separates the action-perception link between sound-producing gesture and sonic outcome into three distinct categories of chunk: sub-chunk, for any event that occurs within 0.5 seconds of the action; chunk, which is any outcome in the 0.5 - 5 second period immediately following an action; and supra-chunk, that can be over 5 seconds and up to hours, including the perception of structural contours within the sound and music. Leman [22] also gives a detailed examination of how music and technology fit with Embodied Cognition theory and develops the concept of behavioural resonances, in which humans articulate motor-mimetic movements to particular styles of music. Indeed, Vines et al [34] describe a study in which perception of emotional expression proved to be greater when performers' bodies could be

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seen during the musical act. Schogler and Trevarthen [31] also note that a number of empirical studies in the 1970s linked expressive movement with fundamental communicative behaviours. They further assert that “Music is the product of bodies moving with perceptual control of the quality or `e-motion' of moving” [31]. The body also plays a role by which sound in the environment is perceived through the Head Related Transfer Function (HRTF) [29]. This function pertains to the ability of the human perceptual apparatus to measure minute differences in the arrival of waves to the inner ear relating to the size, shape and spatial position of the head and pinna of the outer ear. This fundamental link between music, movement and the physicality of human auditory cognition underpins one of the major attributes of the system presented in this paper: physical moving objects producing sound in response to users' actions.

Welch et al. [36] state in their research that children with profound and multiple learning difficulties (PMLD) are comparable to infants and therefore the related discipline of developmental psychology is important to consider. Malloch [28] has noted that narrative is in fact one of three key elements in communicative musicality between infants and mothers. The other two elements being pulse (relating to periodicity) and quality (relating to pitch and timbre). Gratier and Trevarthen [15] further explore how narrative constructions form the basis of musical understanding in vocal communication between mothers and infants. In a detailed study focusing on both whole body and acoustic signal analysis, Gratier and Trevarthen [15] demonstrate how mothers and infants co-create musical narratives that have distinct form. This research indicates that designing the possibility for narrative structures into future systems could help to enforce timing and event based understanding from students with complex needs in group musical activity. When discussing the use of storytelling in the support of people with special needs, Nicola Grove defines narrative “as the conveying of a sequence of events that are linked in time (*temporality*) and by consequence (*causality)*”[16]. This definition will be used when narrative is referred to below.

3. Related Work

Druin's original framework [5] around the four roles children have played in design projects is built upon by Guha and Druin [17] where the design process is directly linked to children with disability. The *Inclusionary Model* begins with Druins standard model but additional layers of *Nature and Severity of the Disability* and *Availability and Intensity of Support* are folded in [17]. Similarly, Kärnä et al [20] suggest a participatory process that involves the children, their teachers and their families. The *Children in the Centre Framework* (CiC) aims at conducting workshops with the people who perhaps know the children the best and will potentially be able to communicate more complex ideas that are suited to them. While both these frameworks seem to appoint the highest level of participation as the most effective, Larsson and Hedvall [21] make the point that when working with children without speech or other effective communication skills, there is the potential to focus on deficiencies as opposed to abilities. Additionally, only the CiC framework begins to acknowledge the role that the adults play in the children's lives. Other examples of participatory work with young people who have complex needs includes that of the ECHOESII project [12] in which a system was created for students with autism, using feedback from a variety of participatory workshop sessions. The students in this case had the abilities to communicate ideas through drawing and to some extent through speech, thus information was gathered in these forms. Hornof [18] describes working with young people who have complex physical needs that prevent them from communicating through conventional means. One of the recommendations from Hornof's research is “Interact with as many different caregivers as you can” [18], something that this project implements.

This research has used an applied participatory requirements analysis technique in combination with the use of extant theory to inform the design intervention. This is because a substantial amount of students at whom the work is aimed have difficulties communicating through conventional means such as speech, text or images. However, they do possess the skills to express themselves creatively through other means such as sound and music. Thus, the primary phase of the project was undertaken to elucidate a detailed understanding of the group music workshop context, in order to distill requirements for any subsequent design interventions. This was done by using an existing piece of music technology with teachers and teaching assistants who normally mediate the interactions and can help to interpret students' responses.

Music technologies are used with young people who have complex needs in disciplines such as Music Therapy [26] Special Education [10] and Sound Therapy [6] [7]. However it has been shown that in fact, uptake in practice is generally quite low in the UK [25] [10] and in 2003, Ockleford et al [30] suggested that only 2% of students with complex needs received any sort of music therapy. The most common piece of music technology was found to be the *Soundbeam*[10] [25]. The *Soundbeam* [43] is a piece of hardware that converts input from ultrasonic sensors and mechanical switches into digital information in order to produce electronic sound. It has inputs for a number of ultrasonic sensors whose range can be scaled between 0.56m and 6.00m, thus it is described as “the invisible, expanding keyboard in space” [43]. Up to four sensors and eight switches can be attached at the same time to provide input for triggering and controlling sounds built into the device itself. Finally, the *Soundbeam* can also send out control signals via the Musical Instrument Digital Interface (MIDI) protocol that can be used to control separate sound generating devices. The *Soundbeam* was used in the primary phase of this research to examine how music technologies are used in contemporary group musical activity in the partnership school. The reasoning for this was that traditional participatory methods such as low-tech prototyping and group discussion sessions would be difficult to implement with students who cannot communicate in conventional ways, so an applied study was therefore needed to understand usage in context.

There are also a large number of commercially available tools and research projects that can be classed as accessible music technologies. *MIDIGrid* [19] is a system developed as a purely software interface that allows musicians to select from a grid of square buttons, each of which can contain a variety of musical information. These can be notes, chords, sequences or rhythmic sections and the user can choose when and how long each of these are played back. Like *Soundbeam*, this information can be sent via MIDI to an external sound generation device. *MIDICreator* [41] is another commercially available product that is used for interfacing with computers and sound generators that has a number of different attachments such as squeeze switches and floor pads.

The R.H.Y.M.E.S project [3] is focused specifically on creating novel tangible technologies for “musicking” by young people with complex needs and their families. They have demonstrated that embedding technologies such as speakers inside tangible music systems can facilitate engagement from participants.

The Deep Listening Institute have developed a tool which can track the head movements, utilising webcams, of a single user that can then be translated into sound [1]. Another similar, but more complex implementation of a head track system was created by Boulanger [2] using infrared camera tracking and connecting the input data to the *Hyperscore* [9] software that allows the system to become a tool for composition and performance. Further input device and software systems include the *Skoog* [42], which is a soft tactile sensor unit connected to a laptop computer running physical modelling software that creates sound. Crucially, with all of the systems detailed above, an interface is provided for a single user to create electronic sounds amplified through loudspeakers. The key difference between these interactive technologies and the one presented in this paper is that multiple interfaces are provided to produce acoustic sounds from physical instruments with the intention of facilitating group musical expression.

Currently, all the commercially available products and publicly available research implement the method of one interface to control electronically generated sound. This is with the exception of smartLab who created an Eye Gaze system using electro-mechanical bells [39].

In summary, salient work from developmental psychology and embodied music cognition literature has been detailed with a view to providing a theoretical underpinning to explain why crucial design decisions have been made. Previous research into processes for designing novel technologies for and with young people who have disability have also been examined to elicit relevant comparisons. Finally, a review of available contemporary music technologies designed for musical expression by people with disability has been given showing that emphasis has to date been on enabling access to control electronic sounds through single-user interfaces. This has been done in order to situate this work within the context of accessible music technologies and also to outline the current gap in research in this area.

4. Participatory Requirements Analysis

In the previous phase of this project, a detailed evaluation of the use of *Soundbeam* in practise was undertaken with a mixed ability class in a Three Ways School in Bath, UK. As discussed above, this differed from previous participatory methods in that it used an existing device as a tool to examine how such technologies could be used in contemporary practice. The study was conducted with one class of reception-age (4-6 years old) students with varying abilities, three female and five male. The class had one teacher and up to five teaching assistants who worked with them. The abilities of the students included those who were able bodied with moderate learning difficulties; Autistic Spectrum Condition (ASC); Profound and Multiple Learning Difficulties (PMLD); and those with physical and sensory impairments.

This study involved an extended observation period of approximately three months with visits lasting one or two days per week. This was followed by a six-week project with the aim of creating a structured musical performance that the students had helped to co-create. The researcher in this project (the first author) acted as a teaching assistant during the observation period which helped to garner understanding of student abilities, and then as technological facilitator in the performance phase. It is important to note that this latter phase was led by the teacher who decided to structure the sessions using a narrative co-created by the students in the class with stronger cognitive abilities. The researcher helped to develop a system using two *Soundbeams* with a combination of two sensors and sixteen trigger switches that triggered and controlled both musical (tonal) sounds and sound effects. The school's interaction designer developed two audiovisual animations which could be triggered by the *Soundbeam* switches.

Data collection was from detailed notes of in-session observations as well as audio-recorded semi-structured interviews with staff after the sessions which were subsequently transcribed. The first part of the analysis was conducted by drawing out salient themes from the observations. The second part was analysed using a combination of constructivist Grounded Theory methods [4] (from the work of [13]) and Activity Theory [35] [23] [8]. Grounded Theory methods such as open, selective and theoretical coding and memo writing were used to elucidate emergent themes regarding staff perceptions of technology and student interactions within the sessions. Activity Systems [8] were created pertaining to each of the main stakeholders related to the sessions, to garner higher level understanding of the wider context and systematic issues in a similar method to that undertaken by Welch [37]. This is in line with the work of Seaman [32] who posits that the two approaches can indeed be used effectively together.

One of the key outcomes was that music technologies were rarely used due to a number of issues such as lack of effective training, and negative perceptions of technology. This correlates with the findings of Magee [26] and Farrimond et al [10] who have conducted work from a survey and document analysis method. Another outcome was the initial lack of strategies for using such technologies available to the teacher, and subsequently the fact that the teacher successfully used narrative as a tool to underpin both student contribution and session structure.

A set of categories were distilled into the main implications for the design of new technologies for group musical interaction for young people with varying needs:

- Enabling student contribution.
- Design for both sonic exploration and narrative structure.
- Design for usability by teachers/ workshop leader.
- Provide effective knowledge transfer resources and strategies.
- Include movement and multi-sensory feedback.
- Design with compatibility in mind.

This final point relates to the fact that with such a variable ability range present in the classroom context, there will be no one design that will meet the needs of all students. Thus any design intervention will be part of a wider tool set that can be called upon when required within such a dynamic environment.

Two key parts of the development process of moosikMasheens are pertinent to note: the first was the integration of both *a priori* theory and grounded, participatory research into the design. The second was the inclusion of staff in the participatory research process itself. This was deemed essential for gaining understanding of real-world use situations as nearly all observed technologically-mediated group musical interaction was in turn further mediated by teachers or teaching assistants. Thus, designing for the workshop leaders as well as the students themselves has become a fundamental part of the process. Both students and teachers acted in the role of informants according to Druin's categories [5].

5. Movement and Sound

The literature around the fundamental link between movement and sound [28] [15] was integral in informing the design of moosikMasheens. This link subsequently led to the design taking a physical, moving form in that of electro-mechanical musical instruments. It is also connected to the design implications from the previous phase in that these instruments provide sonic, visual, kinaesthetic and vibro-tactile feedback. This multi-sensory information is arguably greater on those perceptual channels than electronically generated sound from loudspeakers which generally involves less perceived physical movement to generate the sound. Additionally, using individual instruments provides a single point source for the localisation of sound thus increasing the potential for understanding the cause-effect link. It was also found in the participatory requirements analysis phase that it was difficult to discern who was doing what when in a group musical situation with all the sound coming from a single set of loudspeakers.

Finally, in choosing to adapt common musical instruments found in western SEN/D schools, the project is working to build on current practices. This also applies to the use of iPad interfaces that are becoming increasingly prevalent.

6. Narrative Structure

Both contemporary literature and the empirical work undertaken as part of this research project have narrative as a common theme. Narrative, as defined by Grove [16], was used in teaching practice in the requirements gathering phase as a tool for structuring and timing the delivery of the musical workshop. This has led to the development of narrative-structuring software that allows the possibility of utilising a framework around which to base the theme, context and musical ideas of a workshop or teaching session.

7. moosikMasheens

moosikMasheens is currently made up of three electro-mechanical musical instruments. They each implement physical constructions around the instrument itself that comprise of solenoid (electro-magnetic linear actuators) driven, spring-return electro-mechanical strikers, pluckers or fretters. The instruments have wired USB or wireless WiFi connectivity and receive the OpenSoundControl (OSC) protocol which allows expansion and compatibility with other interfaces. Each instrument is controlled by an iPad interface created using the touchOSC [45] application with bespoke layouts. Each instrument contains a micro-controller such as Arduino [38] or Teensy [44] that receive messages from either a central computer or the iPad interfaces via the above methods, translating the digital commands into analogue signals that control the electro-magnetic actuation of the mechanisms.

There is, additionally, central narrative-theme software that allows workshop leaders and students alike, to compose their own music and embed narrative meaning into their sessions through images. The instruments can be used with the software or just with an iPad controlling them directly. The moosikMasheens system is aimed at students with PMLD and/or complex physical impairments undertaking musical activity in a mixed ability group music workshop, but this modular approach to the design of the system is intended to reflect part of the findings from the participatory requirements analysis: the fact that moosikMasheens is just one tool available of many and as such will not meet all the needs of student abilities. The key is that it can be used in conjunction with other instruments, technologies and workshop strategies if that is what teachers and students require, as it is unlikely one system will be able to cater for all abilities in a typical class in a special school.

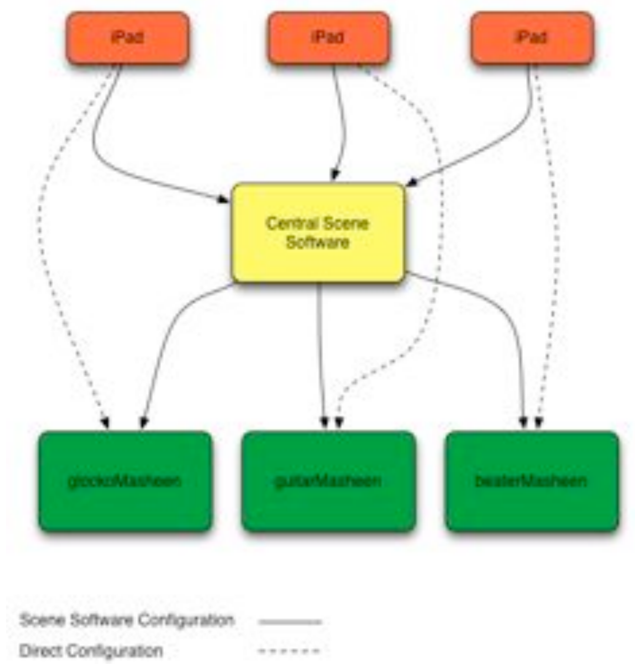

Figure 1. Communication configurations.

7.1 Scene Software

Within the software a teacher or workshop leader can sequence images and musical compositions, changing them at the required point in the workshop. This allows themes to be embedded within the structure of the session itself as well as providing contextual information to students. Each "scene" in the software comprises of two main elements: an image page and a composition page. While there are a number of basic narratives provided as examples to teachers as part of the knowledge transfer resources, users can also build up their own narratives by importing images and interacting with the composition graphical user interface. Providing this possibility of situating musical expression and learning within a narrative structure could help students' abilities of recall and help with general meaning making throughout extended workshop sessions as with the communicative musicality between infants and mothers [28] [15].

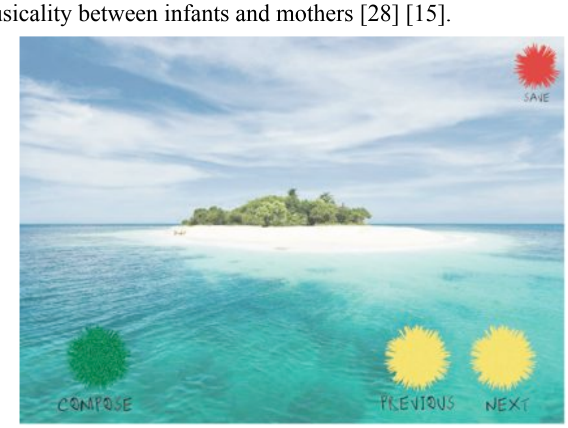

Figure 2. Scene software with desert island scene being displayed

7.2 glockoMasheen

This instrument is a glockenspiel that has been adapted with electro-mechanical hammers that strike the bars, which in turn create sound. The chromatic glockenspiel was chosen to allow for as much flexibility with musical playing as possible. There are seventeen beater arms, one for each bar of the instrument, and the heads of the beater arms are made out of wood which was found to produce the most the best results when testing different materials.

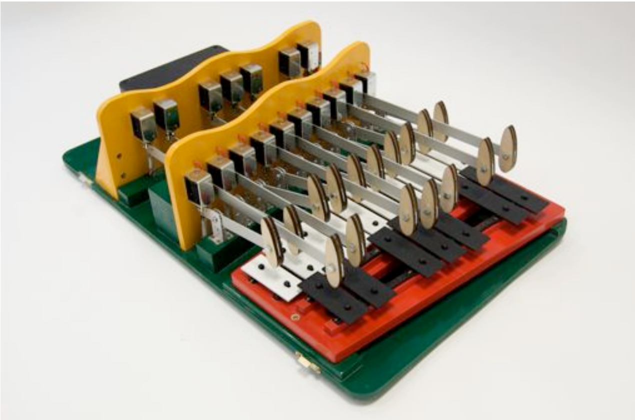

Figure 3. glockoMasheen

7.3 guitarMasheen

This instrument is a classical acoustic guitar, similar to those found in the store cupboard in the music room of the school, that has been adapted to be electro-mechanically actuated. Throughout the extended observation period as part of this project, it had been noted that when guitars were used by students in group musical activities, they had been open-tuned by the workshop leader to a particular chord. This means that students are able to strum the guitar and still be in the same key as all the other musical activities happening at the same time, preventing undesired dissonance according to the western tempered scale. This fact was used as a point of departure for the creation of the guitar mechanism and functionality: using an open tuned guitar with a simple fretting action to bar across the strings thus changing chord.

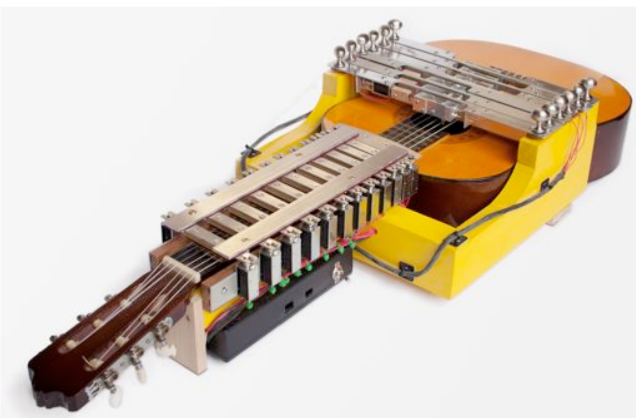

Figure 4. guitarMasheen

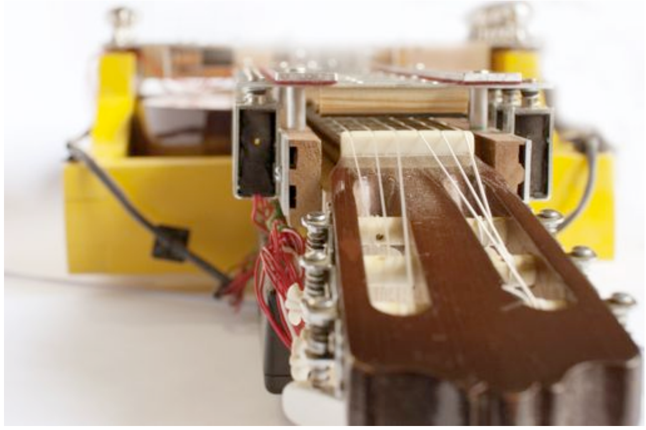

Figure 5. guitarMasheen fretting mechanism

This does musically constrain the possible output of the guitar, but this constraint provides a simpler set of interactions which both students and teachers can learn quickly. Each string can be plucked individually however which means that melodies can be picked out, and chords can be strummed such that there is still a high level of musical possibilities. The picking action uses the solenoid driver to push a guitar pick across the string thus plucking it to generate the sound. The pick itself is mounted on a uni-directional pivot so that as the solenoid stops being charged, the spring return pulls the pick back over the string but the pick flips up thus not actually plucking the string on its return journey. Pulse-width modulation (PWM) control over the power of actuation enables variable velocity of movement of the pickers. This facilitates dynamic expressive capabilities of playing quietly or loudly.

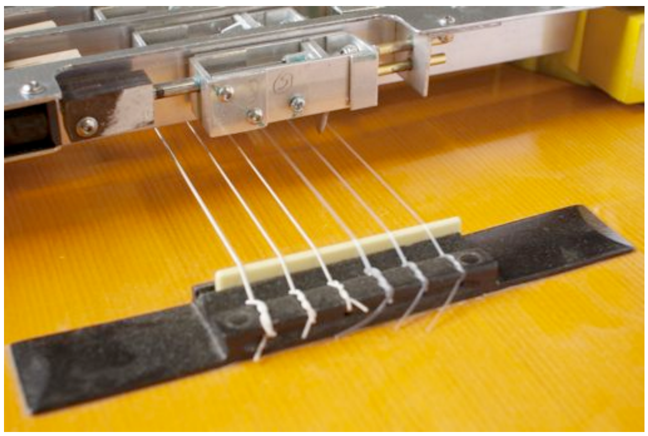

Figure 6. guitarMasheen picking mechanism

Aluminium was used as the main construction material for the mechanism itself due to its strength and relatively lightweight.

7.4 beaterMasheen

This general purpose beating device is designed to beat an instrument such as a drum. In keeping with building upon as much equipment already found in UK SEN/D schools, it is designed to fit to a microphone stand so that it can be positioned to play various percussive instruments. It consists of two electro-mechanically actuated drum beaters whose position can be rotated around two axes thus making it possible to obtain the optimum placement for beating the percussive surface. Unlike glockMasheen and guitarMasheen, the sound output of beaterMasheen is variable thus allowing students to choose a sound that they particularly like.

Figure 7. beaterMasheen

7.5 Interface

The iPad interface, currently at prototype stage using the touchOSC app [45], consists of a series of buttons and an XY slider on separate pages. This allows rapid adaptation to students' abilities: one can change from a single full-screen switch, useful for users with severely limited motion, to the XY fader or multiple buttons with a single touch. Students activating the interface can explore the musical sequences embedded within the narrative software or, if playing without the software, with preset sequences on the instrument itself.

There are six primary interaction styles initially created, which will be developed further through evaluation workshops with students and teachers. All the interaction styles produce an immediate response from the instruments, this is in line with Godøy's [14] the sound-action sub-chunking and chunk in that each response falls well within those designated time periods:

- Single note
- Single chord
- Stepping through a note sequence
- Stepping through a chord sequence
- Triggered playback of a note sequence
- Triggered playback of a chord sequence

The final two interaction styles result in the automatic playback of a musical sequence when an action is made and sustained by a student using the iPad interface. This range in output from the system has the potential to produce simple cause and effect responses for students with complex needs and the ability to compose and playback more developed musical forms for students who have higher cognitive functionality.

Figure 8. Interface with glockoMasheen

Due to pragmatic constraints regarding the amount of power needed to drive the solenoid actuators, the instruments currently require mains power which means that there is a wire running to them. However, when they are switched on, they can be seen on a wireless network and thus connected to via the central software or iPad. A series of training workshops and online tutorials will be given to staff in order to provide detailed understanding about the functionality of the system such that they can choose to integrate it into their practice for the full evaluation. Additionally, a set of four preset narratives have been created to enable quick use of the system. This should help staff members use the system in a more immediate way without having to learn all of the functionality. It is intended that these parts of the system design and implementation will address the implications of the design in terms of effective knowledge transfer.

8. Initial Evaluation

An initial evaluation has taken place using just the glockoMasheen and iPad interface over four sessions in the partnership school. Each class from the school came to use the instrument twice over a two week period. Other music technologies such as *Soundbeam*, Korg *Kaosilators*[40] and a bespoke system created by the school's interaction designer were also available to the students. This was mainly to test the functionality of the system in a typical SEN/D environment and also to introduce staff and students to the system incrementally, before the full evaluation takes place. Ages of students ranged from Key Stage 1 (ages 5-7) to lower sixth form (ages 16-17). Student abilities ranged from able-bodied with moderate learning difficulties to those with PMLD and complex physical and sensory impairments. Data were collected through detailed notes made regarding observations and direct feedback from students and staff throughout the sessions.

8.1 glockoMasheen

The visual, sonic and vibro-tactile feedback were observed to give students with more complex needs understanding of the cause-effect relationship between their actions and the responses from the instrument. Some students did however want to bend the beater arms of the glockMasheen and had to be stopped by the member of staff attending to them. Whilst the instrument is robust, it is possible that some more encapsulation of the mechanism would help increase its stability.

The general sound volume of the instrument was observed to be slightly shocking for some students who flinched when it first sprung into action. It should noted that there was quite a substantial amount of noise in the room due to the other musical activities such that if the instrument had been any quieter, it may not have been audible. The immediacy of the response from the instrument was also observed to be effective in engendering student attention and fascination. Upon the first touch of the interface, the students could clearly engage with the instrument and control various aspects of what it was playing. For some of the older students however, they preferred the sound of the *Kaosilators* as it had sounds such as drum loops and synthesised bass.

8.2 Interface

The adaptivity of the iPad interface was also found to be useful in terms of providing a range of interaction possibilities to suit students' abilities: from certain students with very limited movement using a large button, to other more able bodied students using eight buttons controlling sequences. One student was able to play the glockoMasheen with his chin with the interface set a one single switch. Whereas when the interface was on a setting with more buttons, other students engaged with how it actually worked, explored the musical sequences and how they related to the coloured buttons.

There did seem to be a lack of sustained interest however, partly due to the fact that there was only one sequence available to play through and explore during the sessions. Additionally, as there was only one interface available at this time, students had to take it in turns to play with the instrument which led to some students losing concentration. This situation differs from that of the full evaluation which will subsequently happen as there will be other instruments and interfaces available. Further strategies for this situation will need to be developed with staff to enable quick, direct use of the instruments. When not given instruction by the researcher or a member of staff, a considerable number of students played the buttons as fast as they could. This certainly increased the general volume of the instrument however students would often look away as if they were not concentrating.

There were some instances where the interface was not as successful with the students. Of particular note was a blind student with PMLD who could not feel where the button was thus did not engage with the instrument at all. This was converse to the same student interacting with a set of low profile switches that are part of the *Soundbeam* where he could feel the action of the switch mechanically closing.

8.3 Discussion

The key points related to the instrument part of the system were that students could hear and feel the sound, see the movement and were engaged in the short term. While the sound level was shocking to some students, with a large amount of ambient noise from a full class of mixed ability students, the audio level was necessary in order for the instrument to be heard. The constraint of an acoustic instrument is such that its sound palette is limited by its physical properties. In this case a glockenspiel makes percussive, metallic, tonal sound which was not to the taste of all of the students. Once the other instruments are introduced there will be more choice, however this is a clear limitation of using electro-mechanically adapted acoustic musical instruments. Electronic means of producing sound through loudspeakers have a substantially larger set of sonic possibilities. Finally, students with more physical ability displayed their fascination in part through touching, bending and grappling with the instrument using their hands. While this is positive as they could feel the mechanism moving and the vibrations of glockenspiel bars, any such hardware designs need to take into account withstanding the physical explorations that students will inevitably go on when such an object is placed in front of them.

The interface showed great adaptability but was not useable to all students. There is the possibility of implementing features of tablet computers such as haptic feedback however this may distract the student from the feedback provided by the instrument itself, and would still not suffice for some visually and cognitively impaired students without taking on the physical form of a switch. Due to the modular design of moosikMasheens however, the fact that all the instruments respond to the OSC protocol means that other interfaces more suitable to particular students' abilities can be quickly adapted to control them.

The incremental approach to introducing the system to staff and students in the school did certainly raise the profile of the glockoMasheen so that now staff are aware that they have access to such technologies. This should prove useful when conducting the full evaluation as staff will be in a better position to assess whether the technologies are appropriate for members of their class. This initial evaluation did show the variety and range of abilities across the school however, and this is obviously a major consideration when undertaking the more longitudinal evaluation period. Students playing the buttons as fast as they could for extended periods without showing signs of concentration suggests that it is important for the full evaluation that staff are able to instruct and supervise student interaction successfully. This should consequently allow such time for free play and for developing musical and social skills.

9. Further Work and Conclusions

The process and design of a novel system for group musical workshops with young people who have complex needs has been outlined. Both extant theory and empirical field work have been shown to permeate the design thus creating an adaptable and accessible tool that provides high levels of multi-sensory feedback. Some preliminary evaluation work has been undertaken, however at the time of writing the full evaluation is just beginning. It is intended that the system be evaluated in-context at the same SEN/D school in Bath, UK using the information generated from the participatory requirements gathering phase as an evaluation framework. There will however, be scope to incorporate new iterations on the design throughout the evaluation period as teachers and students will be working with the system for a period of approximately one school term (three months).

The initial evaluation shows that the instrument can engender engagement through enhanced perceptual channel feedback, however this engagement is only currently in the short term. The iPad interface created with touchOSC [45] has also proved to be adaptable for varying student abilities but clearly will not be able to cater for all students. The issue of the limited sound palette, an affordance of working with a physical acoustic instrument, was also shown to be an issue with older students.

Once these further iterations and evaluation has taken place, the system will be used in different schools to test how the evaluation framework can be applied within a wider context. The aim is that this system, in conjunction with the framework, can be used to explore further how novel music technologies can be developed in-context to produce effective and sensitive outcomes for group music making by young people with complex needs.

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11. REFERENCES

[1] Adaptive Use Musical Instruments: 2011. *http://deeplistening.org/site/adaptiveuse*. Accessed: 2011.

[2] Boulanger, A. 2008. Expressive Gesture Controller for an Individual with Quadriplegia. *Proceedings of the 10th ACM Conference UbiComp '08*. (2008).

[3] Cappelen, B. 2012. Musicking Tangibles for Empowerment. *Computers Helping People with Special Needs* (2012).

[4] Charmaz, C. 2006. *Constructing Grounded Theory: A Practical Guide through Qualitative Analysis*. Sage Publications.

[5] Druin, A. 2002. The role of children in the design of new technology. *Behaviour and Information Technology*. 21, 1 (2002), 1–25.

[6] Ellis, P. 1995. Incidental Music: a case study in the development of sound therapy. *British Journal of Music Education*. 12, (1995), 59–70.

[7] Ellis, P. 1997. The Music of Sound: a new approach for children with severe and profound and multiple learning difficulties. *British Journal of Music Education*. 14, (1997), 173–168.

[8] Engeström, Y. 2006. Activity theory and expansive design. *Theories and practice of interaction design*. (2006).

[9] Farbood, M. et al. 2004. Hyperscore: a graphical sketchpad for novice composers. *Computer Graphics and Applications, IEEE*. 24, 1 (2004), 50–54.

[10] Farrimond, B. et al. 2011. Engagement with Technology in Special Educational & Disabled Music Settings. *Youth Music Report*. (Dec. 2011), 1–40.

[11] Fels, S. 2004. Designing for Intimacy: Creating New Interfaces for Musical Expression. *Proceedings of the IEEE*. 92, 4 (Apr. 2004), 672–685.

[12] Frauenberger, C. et al. 2011. Designing technology for children with special needs: bridging perspectives through participatory design. *CoDesign*. 7, 1 (Mar. 2011), 1–28.

[13] Glaser, B. and Strauss, A. 1967. *Discovery of Grounded Theory. Strategies for Qualitative Research*. Sociology Press.

[14] Godøy, R. 2011. Sound-Action Chunks in Music. *Musical Robots and Interactive Multimodal Systems*. (2011).

[15] Gratier, M. and Trevarthen, C. 2010. *Musical narrative and motives for culture in mother-infant vocal interaction*. Journal of Consciousness Studies.

[16] Grove, N. 2012. *Using Storytelling to Support Children and Adults with Special Needs*. Routledge.

[17] Guha, M. and Druin, A. 2008. Designing with and for children with special needs: an inclusionary model. *In Proc. of Interaction Design and Children 2008*. (2008).

[18] Hornof, A.J. 2009. Designing with children with severe motor impairments. *Proceedings of the 27th international conference on Human factors in computing systems*. (2009), 2177–2180.

[19] Hunt, A. and Kirk, R. 2003. MidiGrid: Past, Present and Future. (2003), 135–139.

[20] Kärnä, E. et al. 2010. Designing technologies with children with special needs: Children in the Centre (CiC) framework. *IDC '10: Proceedings of the 9th International Conference on Interaction Design and Children*. (Jun. 2010).

[21] Larsen, H.S. and Hedvall, P.-O. 2012. Ideation and ability: when actions speak louder than words. *Proceedings of the 12th Participatory Design Conference: Exploratory Papers, Workshop Descriptions, Industry Cases - Volume 2*. (Jul. 2012), 37–40.

[22] Leman, M. 2008. *Embodied Music Cognition and Mediation Technology*. MIT Press.

[23] Leontjev, A.N. 1978. *Activity. Consciousness. Personality*.

[24] MacDonald, R.A.R. and Miel, D. 2002. Music for individuals with special needs: a catalyst for developments in identity, communication and musical ability. *Musical Identities*. M.R.A.R.M. D, ed. Oxford University Press.

[25] Magee, W. 2006. Electronic technologies in clinical music therapy: A survey of practice and attitudes. *Technology and Disability*. 18, 3 (2006), 139–146.

[26] Magee, W.L. and Burland, K. 2008. Using electronic music technologies in music therapy: opportunities, limitations and clinical indicators. *British Journal of Music Therapy*. 22, 1 (Sep. 2008), 1–13.

[27] Magee, W.L. et al. 2011. Using Music Technology in Music Therapy With Populations Across the Life Span in Medical and Educational Programs. *Music and Medicine*. (Apr. 2011).

[28] Malloch, S.N. 2000. Mothers and infants and communicative musicality. *Musicae scientiae*. 2, 2; SPI (2000), 29–58.

[29] Møller, H. et al. 1995. Head-Related Transfer Functions of Human Subjects. *Journal of the Audio Engineering Society*. (1995).

[30] Ockelford, A. et al. 2003. Focus of Practice: Music Education for Pupils with Severe or Profound and Multiple Difficulties - Current Provision and Future Need. *British Journal of Special Education*. 29, 4 (May. 2003), 178–182.

[31] Schögler, B. and Trevarthen, C. 2007. To sing and dance together. *On being moved: From mirror neurons to empathy (Advances in Consciousness Research)*. (2007).

[32] Seaman, J. 2008. Adopting a Grounded Theory Approach to Cultural-Historical Research: Conflicting Methodologies or Complementary Methods? *International Journal of Qualitative Methods*. 7, 1 (2008), 1–17.

[33] Stowell, D. et al. 2009. Evaluation of live human–computer music-making: Quantitative and qualitative approaches. *International Journal of Human-Computer Studies*. 67, 11 (Nov. 2009), 960–975.

[34] Vines, B.W. et al. 2011. Music to my eyes: Cross-modal interactions in the perception of emotions in musical performance. *Cognition*. 118, 2 (Feb. 2011), 157–170.

[35] Vygotsky, L.S. 1978. *Mind and society: The development of higher mental processes*.

[36] Welch, G. et al. 2009. `Sounds of Intent': mapping musical behaviour and development in children and young people with complex needs. *Psychology of Music*. 37, 3 (Jul. 2009), 348–370.

[37] Welch, G.F. 2007. Addressing the multifaceted nature of music education: An activity theory research perspective. *Research Studies in Music Education*. 28, 1 (May. 2007), 23–37.

[38] “Arduino”: 2013. *http://www.arduino.cc*. Accessed: 2013-01.

[39] “BECTA”: 2011. *http://dera.ioe.ac.uk/1565/*. Accessed: 2011-05.

[40] “Kaosilator”: 2013. *http://www.korg.co.uk/products /dance_dj/kaossilator/kaossilator.asp*. Accessed: 2013-01.

[41] “MIDICreator”: 2013. Accessed: 2013-01.

[42] “Skoog Music”: 2013. Accessed: 2013-01.

[43] “Soundbeam”: 2013. Accessed: 2013-01.

[44] “Teensy”: 2013. *http://www.pjrc.com/teensy/*. Accessed: 2013-01.

[45] “touchOSC”: 2013. *http://hexler.net/software/touchosc*. Accessed: 2013-01.