Converting Movements to Music
New Musical Exploration Opportunities for Children in Rehabilitation

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Rationale for the Movement to Music System

Music therapy is the creative use of music and its elements by an accredited music therapist to restore, maintain, and improve mental, physical, emotional, and spiritual health. Music's structural, nonverbal and stimulating nature is used to build a therapeutic relationship transcending ages, ability levels, and backgrounds. Music therapy practice includes observation, assessment, the establishment of goals and intermittent evaluation. A variety of clinical techniques and musical styles ranging from improvisation to precomposed music can be used, depending on our client's needs.

As music therapists, we strive to provide our clients with satisfying, positive, goal oriented musical experiences. This is often encouraged with a variety of instruments such our voices, piano, guitar, and percussive instruments. Some client populations are able to manipulate instruments by themselves, but others often require hand over hand assistance or modification of the instrument for independent use. This can include the use of string, velcro straps, gloves, and helmets, depending on the individual's abilities. This is time consuming and often creates new challenges for the client depending on the weight, and ease of use of the modification. Often, our clients endure quite a bit of poking and prodding in the process of rehabilitation. We must carefully consider any imposition that may be felt by the client when attempting to utilize modified instruments.

This is especially important when considering children in rehabilitation. Active exploration through intentional movement is critical to normal cognitive and physical development (Lewis, 1977). Specifically, children acquire knowledge such as an understanding of cause and effect by being able to control some physical aspects of their world (Brinker & Lewis, 1982). The concept of cause and effect can be reinforced in the musical environment through exploration of musical stimuli through active participation in instrument manipulation. Eckhouse et al. (1994) elaborate further, professing that continued access to the physical environment promotes social integration within the family and the community, and contributes to the development of a positive sense of self.

Children with severe challenges to their motor abilities are know to have fewer opportunities to physically interact with their environment in meaning ways (Glickman et al., 1995; Nakken et al., 1994; Lepage et al. 1998). Intellect, social skills, and a positive sense of self may be underdeveloped (Fromber & Bergen, 1998). When faced with limited ability to effect change in their environment, children with severe challenges often receive little to no reinforcement for their efforts. Passivity and dependence on others put these children at high risk for learned helplessness (Van Tatenhove, 1987) by the time they reach school age (Reeson & Ryan, 1988) and have been attributed to one of the risk factors in the development of learning disabilities (Turk, 1997).

Considering the limitation of conventional musical instruments and with today's technological advances, many music therapists have looked at the latest in electronic music

instruments for a solution. Although there are many products on the market, we are often challenged to find technology that is truly usable. Usability is "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (ISO, 1992). The definition of usability of an electronic instrument for a music therapist might include an instrument that is noninvasive, has the ability to produce a satisfying tone, adaptable to a client's individual needs, relatively inexpensive, portable, and success oriented.

The advancement of recent technology such as automatic movement recognition, a technology that enables a computer to recognize human movements (Cédras & Shah, 1995; Aggarwal & Cai, 1999), provides an noninvasive (noncontact) instrument. However, movement recognition technologies for children with developmental disabilities have been very limited. At Bloorview MacMillan Children's Centre, however, we have already explored motivating movement and encouraging creativity through the Soundbeam, an ultrasonic sensor that converts movement to music (Knox et al., 1998). The Soundbeam's ultrasonic ray is adjustable from 25 centimetres to 6 metres long. It tracks movement and converts it into MIDI (Musical Instrument Digital Interface) code, which controls an attached sound module or electronic keyboard. There are 10 modes of use including single tones, combined tones and various scales, as well as a transpose function.The Soundbeam is used especially in group settings in the Bloorview MacMillan School, for exploratory movement, body awareness, and control of sounds in connection with themes or stories. Various moods can be created, such as a harmonious mood using a pentatonic scale with harp, flute, and bird sounds, or a mysterious mood using the whole-tone scale with vibraphone and ocean waves.

In a study co-supervised by one of the authors, we observed an increase in exploratory movements by 2 children aged 5-6 with severe cerebral palsy who used it in individual sessions over a period of 6 weeks (Woo et al., 1997). In other studies involving the Soundbeam, Ellis (1995) reported more controlled and purposeful movements, shifting from gross to fine in a case study with a child with Leigh's disease who was encouraged free exploration of the Soundbeam over several months. However, the system is too expensive for most individuals and families (approximately $3,000.00 Canadian per system).

Another example of this technology is the "Very Nervous System" (Rokeby, 1992) has been implemented by Doug Ramsey of the Wascana Rehabilitation Centre in Regina in his "Cool Moves" program. This system produces music when movement is detected optically. Due to the requirement of specialized hardware and software, it too is not affordable to the average music therapist in Canada.

Current Project

The Bloorview MacMillan Children's Centre is a world-renowned special rehabilitation and continuing care facility, which serves young people with disabilities, as well as their families. We include clients up to the age of 18 in Toronto, and thoughout Ontario, with acquired brain injuries, cerebral palsy, spina bifida, juvenile arthritis, muscular dystrophy and other disabilities. It is a focus of the Bloorview MacMillan Children's Centre to develop the abilities of children in rehabilitation in new and innovative ways. As a result, we are currently involved in the third and fourth phases of a usability study to test a new system with automatic movement recognition that is also more affordable. This system will incorporate the technology of automatic movement recognition to help encourage children with severe motor impairments to use their abilities by converting any physical motions, no matter how small, into music. The

research objectives are:

(1) To design and implement and adaptive and affordable, optical movement-to-music system for children with disabilities;

(2) To devise and administer a usability test for pediatric optical movement recognition, placing particular emphasis on establishing user requirements and attitudes; and

(3) To apply the usability test results in the development of recommendation for clinical evaluations of the cognitive, psychosocial and physical impacts of movement recognition technology on children.

For the first two trials we recruited Bloorview MacMillan Children's Centre School children with cerebral palsy aged 4-7 who had difficulty with gross and fine motor control. The session length was flexible, and the therapists encouraged the children to explore the different types of musical expression created by different movements.

In the third and fourth trials, we are including children as young as 2, with more diverse diagnosis, and who attend Bloorview MacMillan Children's Centre for outpatient occupational therapy services. More structured activities are offered to each child, such as a cued instrumental task (a structured task that requires the participant to complete a phrase of music sung by the music therapist with the appropriate instrumental sound as cued in the lyrics such as "If You're Happy and You Know It"), an opportunity to play a pre-composed song, or to improvise on a pentatonic scale to make up their own song. Again, session length continues to be flexible depending on the needs of each child.

Basic Technology

The hardware components of the movement-to music system are a standard PC running Windows with a multimedia soundcard and an inexpensive USB camera. The custom software was developed using a Microsoft vision software library and a MIDI software library. The basic operation for the system can be described as follows: the user sits in front of the computer, in the view of the camera. The user sees an image of him or herself on the computer screen or TV monitor. The camera captures the user's movements and sends images to the computer. Software then processes the images and produces the appropriate sounds. The overall effect from the user's standpoint is that by moving his or her body parts through space, he or she is creating audible sounds.

Design Iterations

Our initial design involved a simple on-off system. The computer displayed a black and white image of the user. There were two modes of operation. In the first mode, movement initiated random drum sounds that ceased when movement stopped. In the second mode, the user could play a chosen piece of MIDI music with movements. When the user stopped moving, the music would stop and would restart when the user began to move again. We tested this system with 7 able-bodied children aged 4-6. We found that the system's sensitivity had to be very flexible to accommodate different ranges of movements made by different children.

Our subsequent design involved a much more sophisticated music generation system and introduced a colour display. We interfaced the camera software with "Building Blocks", an object-oriented MIDI programming environment. Instead of playing random sounds, movement now initiated musical events. These events included arpeggios, licks, short musical phrases and chords. These events were not necessarily completely defined beforehand. The

software would generate the music within defined boundaries, such as specific rhythmic structure, using specific scale tones. A number of different musical scenarios were created. We tested this system with 5 children with cerebral palsy aged 4-6. We found that the generation of musical events by movements led to some confusion among children and clouded the distinction between cause and effect. As well, we found that the system's response was slow and required extensive customization and set-up time.

From a music and occupational therapy stand-point, the results from this phase of the study indicated that the MTM system had the potential to be used as a therapeutic activity to train cause-and-effect, and enhance the child's ability to affect their environment and to improve range of motion. Also, it presented the possibility of improving attention span, increasing self expression (expressive communication), increasing imitation skills (receptive communication), and most importantly, enhancing social skills. Children in this study also indicated that they enjoyed the experience with the MTM technology and found playing with the musical aspects of the system to be fun. They sustained the physical activity throughout the session, but expressed fatigue after a 20-minute session.

Currently, we have constructed a third prototype that also uses a colour display but simplifies the musical output. In light of our experiences with the first two prototypes, our objectives were to create something more akin to a musical instrument, where specific movements were associated with specific sounds. In the present prototype, regions of space are identified around a child. Each region is assigned certain musical properties, such as the tone, the volume and the timbre. As well, the sensitivity and response time of the region can also be adjusted. Each region is represented on the visual display by a coloured shape or as a picture of a musical instrument. When the computer detects motion within one of the identified regions, it creates a sound according to the designated musical properties. At the time of writing, we are in the process of testing this system with 7 children with various disabilities.

The third phase of sessions have been progressing well. The matching of the specific sound with a movement has helped to encourage the concept of cause and effect. This is reinforced with the pairing of colours or pictures of instruments on the projected image on the screen. Once this association appears to be formed and is practiced, the child is engaged in a cued instrumental task (as described earlier). This appears to be a satisfying experience for approximately half of the children while the other half seem to enjoy the more advanced task of playing a song with provision of a scale. Each solfege has been matched with a colour (e.g. Do = blue, Re = yellow, etc.). The occupational therapist either instructs the child as to the sequence of colours, or the child reads the colours off of a score. In addition, the child has the option of performing the piece as a solo, or having the music therapist sing along. The third, and most recent musical option made to each child is free improvisation. A pentatonic scale is established on the screen using the coloured dots and the child is encouraged to make up their own song. Again, there is an option for solo work or a duet with the music therapist. This last option more closely matches the measure of playfulness of the system.

Multi-Disciplinary Team Approach to the Trials

Working with a multi disciplinary team has been beneficial to this study. It has been productive and valuable to integrate the knowledge of music therapy, occupational therapy and rehabilitation engineering in the second and third trials of the study. The most important similarity between occupational therapy and music therapy is that engagement in satisfying musical activity has benefit to the client in and of itself. In addition, a client-centered approach

to treatment is a common philosophy of the two professions.

Of course, goals may vary somewhat depending on the approach of the profession. Music therapists may use this system for a variety of reasons. The benefits of the cause and effect aspect of the system are limited without the benefits of social interaction within a musical paradigm, which is encouraged by the therapist. Expressive communication can be increased with the use of an alternate voice, especially for those children who are considered nonverbal. This form of self-expression can also be beneficial for psycho social goals such as anger management for children who are unable to express themselves in a satisfying manner. Receptive communication and memory can be developed through the encouragement of imitation of musical concepts such as rhythm and sequencing.

Occupational therapists may use the MTM technology in two ways. One focus of a session may be centered around a specific therapeutic goal such as improving range of movement, sequencing, exercise, basic cause-and-effect and problem solving. Another focus may be centered around the goal of enhancing the client's ability to interact with his/her environment for play and enjoyment of music. The ability to impact or interact with the environment to produce musical sounds is valuable and enjoyable to the client, has prescience over the actual musical performance.

The three professions complement each other in the implementation of MTM technology. Occupational therapists bring to the session the knowledge of the client's physical, cognitive and perceptual abilities and therefore provide insight into how the clients will access the system and in what position they can best do this. The music therapist brings the knowledge of music and its elements (structure, dynamics, tempo, etc.), the motivational characteristics of music, and an understanding of the process required to come to a positive success-oriented end. Rehabilitation Engineers not only provided the technology itself, but are required to make the necessary adjustments to the system between sessions. They provide the opportunity to make essential changes to the system thereby increasing the chances of providing a satisfying experience to the participants in the study. The combination of these three perspectives is necessary to produce a successful process and outcome with the MTM technology.

Future of the Technology

Upon completion we will be able to make recommendations for anyone who wishes to use the system. Although this project is for young children the technology and materials can easily be adapted to older populations. Information derived from this project will be useful for occupational and music therapists working with different populations with physical disabilities.

Where do we go from here? It is important to understand that there are constant modifications being made to the system to improve its effectiveness. We face important issues surrounding the technology. Is it too difficult for the child to understand their proprioceptive abilities in a computer screen? The USB camera is inexpensive and easy to use, but does make it difficult for individuals with visual challenges to use the system effectively. Is the system flexible enough for a variety of diagnoses? Although dynamics can be adjusted for each field, this cannot be manipulated while the system is running. Is there a way to allow each child to play in an expressive manner? Although this technology is relatively new, it appears to have provided children with severe challenges to their motor abilities a satisfying musical experience. The technology was fairly inexpensive and easy for the music therapist to manipulate. It can be installed into a therapist's or family's computer with a software program and provision of the USB camera. Most importantly, the technology is non-contact; essential to the children who

have faced many invasive procedures in their rehabilitation.

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