

Identifying Neurologic Music Therapy Techniques Amenable to Automation

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Abstract - *Neurologic Music Therapy (NMT) can improve deficiencies in speech, motor, and cognitive skills. This paper introduces the field to computer scientists by explaining the rationale behind NMT techniques and identifies aspects suitable for automation. UTC has developed a web-based system implementing a subset of the NMT therapy.*

Keywords: Autism, NMT, music therapy

1 Introduction

An increasing number of American children are diagnosed with autism. The condition, once considered rare, is now reaching epidemic proportions [1]. A growing number of children and their families are struggling with the disorder; specific problems include communication deficiencies, difficulty maintaining focus and concentration, and a lack of physical coordination.

Fairly recently, music-based therapy has emerged as an effective method for rehabilitating patients with neurologic problems such as strokes, cerebral palsy, and autism [2]. The emerging field of neurological music therapy offers quantitative evidence to support the long-held intuitive notion that people (savants) who may have great difficulty with normal tasks can excel in a particular field such as music.

This paper summarizes the development of NMT, and lists the specific therapies with an emphasis on the relevance for autism children. The goal is to attempt to automate therapy delivery—ideally suitable for home-based use. Each of the approaches used by NMT is summarized with its suitability for automation. Some methods are extremely easy to automate; these can be incorporated into a web-based application and are ideally suited for our goal of home-based therapy. A second class of methods can be automated, but require either substantial computing resources or special hardware (such as a data glove, motion analysis software, etc). A therapy center may benefit from an automated system, but it is not suitable for free home-based use for cash-strapped parents. Lastly, we identify therapy techniques that can not be effectively automated with current technology. Advances in AI or substantial

algorithm development will be needed before these can be effectively automated.

2 Neurologic Music Therapy

This section summarizes the development of the field of neurologic music therapy, leading to the specific NMT techniques analyzed in the next section. This summary of the field is based on Thaut's Rhythm, Music, and The Brain. [3].

Music has been recognized as part of human culture for thousands of years. Therefore, rehabilitation therapy often included music based on general notions of "wellness," "culture," or "social enrichment." But even early research suggested that music had more specific benefits; a 1975 survey [4] found extensive use of music improved speech and language defects, though the author noted a lack of rigorous methodology. Intriguingly, case studies documented individuals who were unable to speak but were able to sing [5]. Another study showed that memory improved (both for normal children and those with a learning disability) when music-based mnemonics were used [6]. A recent case study documents a violinist with advanced Alzheimer's disease who not only was able to continue playing the violin but also was able to learn new music pieces [7].

However it was not until the invention of non-invasive brain imaging techniques such as CAT scans and PET scans that the specific neurological effects of music could be documented. As a gross indicator, individuals with professional music training have different brain structures (due to placidity) than non-musicians [8], [9]. Studies on finger-tapping exercises showed complex brain behavior; when the frequency of the stimulus signal changed, from one to three different portions of the brain activated depending on the magnitude of the change [10].

Music-based cues have been used to improve the gait of stroke victims; often surpassing the results of non-music therapy [11]. Music-based gait training has also been shown effective for victims of Parkinson's disease [12]. A study of the arm movements of stroke victims showed that rhythmic cuing reduced not just the temporal variance of motion (as might be expected from a temporal cue) but also reduced the spatial variance of motion [13].

With the ability to objectively measure the effects of music therapy, Thaut proposed the Rational-Scientific Mediating Model (R-SMM) of music therapy [14]. R-SMM proposes that researchers first document the effects (neurological, physiological, and/or psychological) of a particular music activity. Next, researchers should identify a similar nonmusic activity that uses the same brain structures, similar behavior, or is otherwise analogous to the music activity. Researchers should form a specific theory for how music will influence the non-music behavior. Only after these preliminary steps are complete should a researcher attempt to design a specific therapy.

The Transformational Design Model is a closely related model also developed by Thaut targeted to therapists rather than researchers. The TDM advises therapists to begin (as always) with an assessment of the patient. Realistic therapeutic goals are developed, and a series of exercises (therapy) is designed. Step four of TDM introduces music; the designed activities are now translated into musical activities shown (by R-SMM) to have therapeutic value. The last step of TDM is to transfer the music learning into functional, non-musical applications.

3 Specific NMT Techniques

This section describes some specific and commonly used applications of NMT ideas. Each method has a description of the therapy, followed by a brief analysis of the extent to which therapy results can be automatically monitored.

3.1 Auditory Perception Training

Auditory Perception Training (APT) attempts to improve speech skills distinguishing related sounds (such as identifying which tone is a higher pitch, distinguishing speech phonemes from background sounds and similar tasks). This type of therapy improves the ability to recognize phonemes and gives some improvement in spoken language skills; tests have not shown improvement in reading skills [15].

This technique is extremely amenable to automation and computer control; for example, <http://www.audiva.org/> sells a kit for home-based training.

3.2 Musical Mnemonics

A mnemonic is a method (such as a pithy saying) that aids in factual recall; a musical mnemonic is a mnemonic that is sung or rhythmically chanted. Musical mnemonics have been developed for a wide variety of cognitive tasks; for example “ $6 \times 7 = 42$; Sticks in heaven with a warty shoe.” These give dramatic skills improvement for the specific tasks involved [16].

Computers are very patient in drills and practice and can repeat mnemonics, so once a series of mnemonics have been developed, computers can automate the delivery.

There is a danger that too much automation introduces a tendency to passively listen rather than actively participate; however, if a human teacher supervises the initial learning of a mnemonic, assessment and repeat drills are readily automated.

3.3 Musical Attention Control Training

Music Attention Control Training (MACT) has children suffering from autism or other attention deficit disorders performing tasks in response to musical tunes. For example, song may correspond to musical instruments; the child should switch instruments as the songs change. The tasks use memory skills, and develop attention spans. An important aspect of MACT is to stop activity at the appropriate time.

Traditionally, the activities performed in MACT have been physical, music-based activities. If this is abstracted away, the cognitive features of MACT (such as remembering the mapping of cue to action) can be automated. MACT appears readily automatable provided that the activities performed remain engaging.

3.4 Rhythmic Auditory Stimulation

Rhythmic Auditory Stimulation (RAS) uses a metronome or music with a very strong, regular rhythm to improve motor skills, such as finger tapping or walking. This therapy has shown significant improvement in the stride length and walking speed of stroke victims [17] and Parkinson's disease [18]. A related technique known as Rhythmic Cuing uses rhythm to cue the start, pacing, and termination of other types of movement.

For effective therapy, the RAS tempo needs to be adjusted based on the gait of the therapy recipient, and thus a home computer can not by itself automate this type of therapy. However, a lab equipped with motion-capture equipment can determine the appropriate tempo automatically. Thus, this type of therapy can be automated in a lab environment rather than a (typical) home environment.

3.5 Melodic Intonation Therapy

Some stroke victims who are unable to speak can still sing. Melodic Intonation Therapy (MIT) uses therapeutic singing to allow stroke (or other aphasia victims) the ability to communicate their thoughts and feelings. In many but not all cases, after repeated singing sessions, non-musical speech improves as well. Computers can aid in this process with song libraries, Karaoke-style accompaniments, and lyric displays.

Computer voice recognition software continues to improve, and can be very useful for high-functioning patients. But for some therapy clients, the responses are not close enough to normal speech to be understandable by general-purpose speech recognition systems. Currently, only humans are able to first learn how to understand the

patients and second guide them to improved speech. This area seems ripe for technology improvement, but such improvement would be research in language understanding rather than research in Neurologic Music Therapy.

4 An Initial Automated NMT System

The University of Tennessee at Chattanooga, in collaboration with the non-profit organization Music Therapy Gateway in Communication, is developing a web-based system implementing Neurologic Music Therapy; the design of the system is described in further detail in [19].

The system uses a three-tier architecture; a web browser connects to the server which retrieves and stores pertinent data from a database engine. The current system uses the same server for the web application and database engine. The decision to make the application web-enabled was reached for several reasons. First, most web protocols are platform-agnostic thus fulfilling the requirement of making the software accessible to users of a wide variety of operating systems. In addition, much of the existing accessibility hardware includes drivers interfacing with web browsers; thus, these devices can be used to interact with the server without additional programming. As a final consideration, web applications make it easy to ensure that all users are accessing the current version.

Project administrators create accounts for parents and teachers, who use a web interface to create accounts for their children. Each child has a separate set of defined games initialized to default values. Parents have full control of the duration of the games, the difficulty of the games, and even the specific musical passages played for the game. The database maintains information on which songs are available as well as the chosen game parameters for each child. During game play, the database records the timestamp of each mouse click and whether it corresponds to a correct or incorrect response. From this raw information, a plethora of derived calculations follow including an accuracy percentage, time needed to complete the game, performance improvement over time, and so forth.

The first game implements APT. The child must identify whether a single passage (the library includes a variety of musical instruments) is ascending or descending. The game also has an intermediate level in which the computer plays two passages in sequence; the child must identify whether the sequence was first ascending then descending or first descending then ascending.

The game itself begins with a demonstration; one of the rounds is played and the correct response highlights. As the child plays the game, the system records the response time for each attempt in the database. A correct response moves the child to the next round (or to Game 2 after all rounds are complete); an incorrect response plays the music

again and gives the child another chance to select the correct response.

The second game implements MACT. Parents or teachers create associations between music passages and animated graphic icons; after a demonstration round of the mapping, the child must click the correct image corresponding to the music passage being played.

The system has received favorable reviews from area autism treatment centers and is gathering data from local children. The next objective is to identify and compare the benefits of NMT for children who receive both computer-based and therapist-based NMT to children who receive only computer-based NMT. Determination of whether NMT can, in fact, be successfully automated is a critical step in the long term goal of creating and disseminating an innovative web-based software program that can be used by parents and teachers of children with autism.

The research results attained from the testing will lead to changes in the program and database structure once a better understanding of “what’s important” is achieved and additional NMT technique modules are incorporated into the software. Once suitable metrics are determined, the database structure will be altered to store only relevant information rather than detailed data for every mouse click.

5 Conclusions/Research Opportunities

This paper reviewed current ideas in Neurologic Music Therapy, and gave an initial analysis of their suitability for automation. A system that implementing two of the ideas (APT and MACT) was summarized.

This is an area ripe for cross-disciplinary research. First, additional NMT ideas (particularly RAS) seem readily automatable. These techniques can be combined with other autistic therapies, such as agent-based approaches to improving social interaction, for a synergistic approach. AI research and research into computer-based education systems continue to expand the ability of computers to understand the speech and intentions of humans and with suitable lab equipment can further expand suitable therapeutic techniques.

The UTC/MTGIC project is focused on the short term on usability issues, documentation, and data analysis. However, we hope in the future to expand the system to incorporate other therapies, particularly RAS. AI music generation can be incorporated the project to provide a more engaging sound than a metronome while still having a prescribed tempo. In short, this area can and has proven a fruitful area for research.

6 References

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