A COMPUTERIZED SYSTEM FOR NEUROLOGIC MUSIC THERAPY*

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ABSTRACT

Description of a web-based system using Neurologic Music Therapy (NMT), targeted to children with autism. This paper will describe the requirements and therapy curriculum, document the system specifications, and review the current state of implementation. At present, the system is at the concept demo stage and virtually ready for user testing.

INTRODUCTION

Throughout the United States, the number of children diagnosed with autism has more than doubled in the past decade and continues to grow at an alarming rate of 300% per year. Researchers are now calling this disorder—once considered rare—an epidemic (Mercola 1999). As a growing number of children and their families cope with the medical, psychological, economic, and social impacts of autism, the medical and therapeutic community struggles to identify promising therapies to address the most detrimental aspects of the disorder, which include severe communication deficiencies, inability to maintain focus and concentration, difficulty integrating sensory input, and a lack of physical coordination.

The unusual musical ability and responsiveness of autistic children make NMT a powerful therapeutic tool. Throughout history, there have been examples of autistic savants; individuals who have trouble performing many routine tasks but have extraordinary abilities in a specific field such as music (Thaut, 1988). A well-known

savant was Blind Tom Wiggins, who could recite any poem or play any piano piece after hearing it only once (National Public Radio, 2002). Leading experts recognize this unusual sensitivity to music and in addition advocate computer-based therapies for children with autism (Herskowitz, 2000). Dr. Temple Grandin, a Professor at Colorado State University who has autism, describes the autistic mind as "functioning like a computer" and highly recommends therapy and education with computer-based learning (Grandin 2000).

NMT, originally developed by the Center for Biomedical Research at Colorado State University (CSU, 1999) is described as the therapeutic use, based on research and scientific evidence, of musical tasks and techniques to help influence non-musical behavior. The web-based software system described in this paper has been designed to provide a selected subset of NMT to children with autism. Because the number of NMT therapists is limited and insurance companies generally do not cover music therapy, one-on-one therapy is impossible for most families to secure for their children. A web-based system makes the therapy universally available for little or no charge to families who would not otherwise have access.

A group of UTC master's project students built software (currently an amalgam of ASP.NET, Java, Visual Basic, and JavaScript) allowing parents or teachers to create accounts and lesson plans for their children. The children log in and play a series of games designed to implement specific NMT techniques. The first game of the curriculum is a warm-up activity using Auditory Perception Training. The second game utilizes Musical Attention Control Training as children perform different tasks based on hearing and recognizing a particular musical passage. The third game, still under development, will serve as a cool-down period following the lessons. As children play these games, the system records their response time in a database system. Parents and teachers have full control over the length of the lessons for their children and the choice of musical passages played during the lessons.

This paper first details the software requirements and inspiration for the project. Following will be an overview of the system design, after which the games implemented so far will be described and related to established NMT techniques. The current implementation of the project and future work are then described; the paper concludes by evaluating the suitability of this initiative as a master's project.

PROJECT GENESIS AND SOFTWARE REQUIREMENTS

Ms. Summa-Chadwick has provided one-on-one NMT sessions to children with autism for four years. During a typical therapy session, children perform various musical tasks involving sensorimotor, speech/language, and cognition skills such as playing musical instruments, moving in response to the music, and playing musical games assisting skills such as motor coordination, attention span, memory, and social abilities. Each child is typically seen three times per week, and video recordings document dramatic improvement in the attention and communication skills of the children after three months of therapy. Unfortunately, the treatment process is delivered primarily in one-on-one sessions which limit the amount of time the therapist can spend with each child and also limits the number of children who can receive the therapy. Therefore, the

idea was conceived to automate the delivery of NMT by developing a unique piece of software which would make cost effective in-home treatment possible. NMT emphasizes scientific monitoring of therapy effectiveness, so it is essential that the system provide objective measurements to track patient improvement.

In order to make the software as useful as possible to parents and teachers of autistic children, the authors hosted a user requirements session with representatives from four local agencies in the Chattanooga area who support autistic children as well as parents of autistic children. The current system does not yet meet all identified requirements but is designed with flexibility to allow functionality to be added as development continues. Following are the requirements generated from the initial session, some of which have been implemented and some of which will be added in the future:

Child Centric Interface. Ideally, the system would allow children to advance through the therapy program unattended. The system should support varying levels of difficulty to match the varying abilities of the children who use it. The software should be friendly and easy to use, and should include features to keep children's attention to the task at hand. It should support decision-making by the child and avoid making an incorrect response more "fun" than a correct response. Future requirements include a help system, printable reward certificates, and a "virtual buddy" to teach social skills.

Child Usability. The system should be challenging relative to each child's ability. It should be responsive and engaging yet not over-stimulating. It should feature multimedia elements including music and background animation. Eventually, the therapy will expand to encourage physical activity in conjunction with the computer activity.

Schedule. In future versions, software should depict (both graphically and via text) a schedule of tasks to perform, completed tasks, and the current task.

Curriculum. The software will use musical tasks to influence nonmusical behavior. It should include a warm-up phase, a main activity phase, and a cool-down period, and will implement NMT (as described later). The metronomic rate of music should be dynamically tailored to the child being treated, and the music samples should eventually encompass a wide variety of musical styles.

Data Collection and Measurement. The system should support different classes of users; parents can establish lesson plans for their own children; teachers can establish lesson plans for their students; administrators can access all the information to evaluate the effectiveness of the therapy. An important element of NMT is the scientific measurement of the effectiveness of the therapy, so as the system evolves it should identify and measure various metrics of performance. In future versions, the system should adjust the difficulty of tasks based on the history of performance.

Parent/Teacher Supervision. Parents should have access to information relating to their own children, and teachers/therapists should have access to information for their students. This means that the software needs to have a separate, user-friendly interface for these users. Desirable extra features include support for a discussion forum for parents of autistic children, a cut-and-paste method allowing the easy creation of similar but not identical programs for multiple children, and a mechanism to keep arbitrary notes on child performance.

Tutorial and Documentation. When completed, the system should support ample tutorials including video explanations, context-sensitive online help. Help should be provided not just for children performing the appropriate tasks for the therapy, but also for parents and teachers designing a schedule of tasks for their children.

Platform-Specific Issues. The software should support as wide a variety as possible of client computers. It should allow dial-up access, broadband access, and even offline access. The software should allow parents to upload graphics and/or music files for use by the system, and it should be easy to for parents to upgrade the client software.

Legal and Licensing Issues. The system should be web-based allowing for easy access. Where feasible the program should link with existing therapy programs and other software. The system definitely needs to be secure and use encrypted communication.

Universal Accessibility. The system should be low- or no-cost for parents to use. It should support users with varying physical and cognitive abilities (some children can not type on a conventional keyboard; some can not use a conventional mouse; etc). Future requirements include vocalizations for tool tips and screen text; support for MIDI devices, alternate keyboards, or voice recognition as input devices; support for various types of scanning or single switch devices used by handicapped patients.

SYSTEM DESIGN

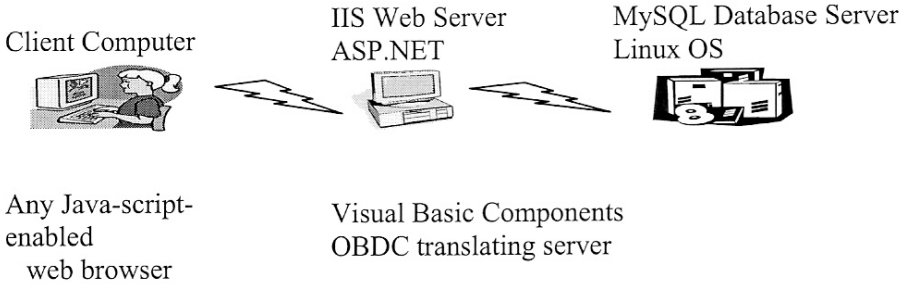
The system uses a three-tier architecture shown in Figure 1. A web browser connects to the server which retrieves and stores pertinent data from a database engine (needed for storing the measurements documented in the initial requirements). The decision to make the application webenabled was reached 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 pages are easy to update and do not require any complicated software installs to access.

The authors had prior experience with the popular MySQL database engine, which offers the security and ease of maintenance needed by the system. The machine runs the Debian flavor of the Linux operating system. It was decided not to “force-fit” the new application into the existing web server; a graduate-level project team decided to initiate development on an unconfigured machine to evaluate the best web-based technology to use.

Macromedia Cold Fusion was evaluated at the project onset based on its support for creating visually appealing websites as well as easy integration with multimedia formats including Flash animations. Ultimately, Cold Fusion was rejected mainly due to licensing expense. The team recommended Microsoft’s ASP.NET programming language as readily available and familiar to our students, making it easier to hand-off the project from semester to semester. Thus, the bulk of the software is a combination of JavaScript, ASP.NET, and Visual Basic code running on IIS 6.0 on a Windows 2003 server. Since Microsoft components use OBDC to communicate with databases, the server also runs internally an OBDC server which acts as a translator and proxy for the MySQL database

server. A current project team is evaluating Microsoft's Active Data Objects (ADO) component software.

Figure 1: Three Tier System Architecture



DATABASE DESIGN

The project team also designed the database structure needed for the software, including entities needed for account generation, measurement storage, and the first game's attributes. Administrator accounts are placed in the database directly by the DBAs. Administrators can then use a web interface to create accounts for parents and teachers of autistic children. Supervisors can then use a very similar interface to create an account 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 library information on all available musical passages and stores the complexity of the passage (three levels, but not necessarily corresponding to the difficulty of the game), the musical instrument used, whether the passage is ascending or descending, and a link used to form a URL for the client computer to play the passage.

The database currently stores all data concerning child response to the software; specifically it stores the number of attempts needed to obtain the correct answer for each round of each game played, and the specific time taken for each child's response on every attempt. 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.

SOFTWARE DESIGN

NMT endorses techniques to aid and improve sensorimotor, speech/language, and cognitive functions (CSU 1999). The software under development provides support for two NMT techniques: Auditory Perception Training (APT) is utilized and implemented in the first game, and Musical Attention Control Training (MACT) is utilized and implemented in the second game.

The APT technique uses musical exercises to discriminate and identify different components of musical sound such as pitch, timbre, tempo, or rhythmic patterns (CSU, 1999). To facilitate the game development, a digital library of various instrumental recordings was created and sorted by the musical complexity of the passages (two notes, simple scale, and complex scale). In addition to adjusting the musical complexity, parents

can adjust the task difficulty of the game. At the easiest level, a child must correctly identify whether a single passage is ascending or descending. In the intermediate level, the computer plays two passages in sequence, one of which is ascending and one of which is descending. The child must identify whether the sequence (possibly of different instruments) was first ascending then descending or first descending then ascending. At the third and highest level of difficulty, two passages are played and the child must identify the correct combination of ascending and descending for the passages (four possible choices). In all cases, the supervisor can view and modify the specific passages selected for the game.

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. Note that the web server can accumulate data to send in a single burst and need not transact with the database server on each mouse click.

The second game uses the MACT technique in which musical elements cue different musical responses. In one-on-one therapy, the tasks performed are normally musical tasks and involve the playing of musical instruments. Since the web-based system can not evaluate physical activity, the MACT technique is adapted to have the child click an animated icon associated with the song; if the child clicks the correct icon, he or she may play a simple animated game for the remaining duration of the song (typically a minute or two).

The MACT technique emphasizes not just the initiating of a correct activity, but also recognition of the need to stop the activity at the appropriate time. For this reason, the game launched in response to a correct click does not immediately end with the completion of the song. An auditory cue indicates to the child that it is time to stop the subgame. It is hoped that the child will voluntarily close the subgame and return to the main Game 2 screen. If not, after a suitable timeout, the system itself will end the subgame, remind the child of the audible cue, and record in the database the lack of response to the cuing.

Implementation of Game 2 is currently in progress, so the database schema and supervisory interface have not been finalized. The requirements state that the supervisor will be allowed to specify the total number of rounds for Game 2 as well as the initial and maximum number of musical associations used in the game. The supervisor will also determine whether the associations are randomized at the start of each therapy session or fixed for all sessions. Response time between the start of the song and the click on an icon will be measured as well as whether or not the click was on the correct icon. Additionally, the system will track whether or not the subgame was voluntarily exited at the appropriate time.

Game 3 is still in design and will involve an entertaining musical cool-down at the end of each session; one possibility is to allow for freeform music to be played on the computer keyboard.

IMPLEMENTATION STATUS AND FUTURE WORK

The project is presently in the prototype phase and rapidly approaching the point where it will be suitable for user testing. It is anticipated that the program will provide many years of fruitful research in NMT techniques and novel therapy ideas for children with autism.

Upon finalization of Games 2 and 3, and with the user interface designed to suit the target audience, the project will be ready for beta testing and initial data analysis. The first objective is to identify and compare the benefits of NMT for children who receive both computer-based and therapistbased 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 innovated 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.

SUITABILITY FOR A CAPSTONE CLASS

This project has provided four master's students and one undergraduate with interesting and relevant capstone experiences. Assigning this type of project as a capstone project allows the students to gain research experience without committing to the time and hassle of a thesis. In addition, this structure has provided the authors with assistants that funding would not otherwise permit.

Since the project spans multiple semesters, each team (which works for only one semester) is keenly aware of the importance of proper documentation. The knowledge that another team will continue to build upon their work has led to awareness of the importance of documentation. In addition, students who work on this project seem to appreciate the fact that their work will endure and qualitatively seem to take more effort to "do the right thing" compared to one-semester projects which place a premium on expediency.

There are a few drawbacks to this approach to the capstone project as well. The authors took care in matching this project with suitable students who had an interest in a research-oriented project. There is a strong danger, particularly if this approach is used for all capstone projects, that students will feel like unpaid employees and not contribute adequately to the high-quality research expected. In addition, instructors must monitor the project teams much more carefully in multi-semester research-oriented projects. In the current project, the paper authors met with the initial project team weekly for detailed study of design issues; the entire process was much more collaborative than typical capstone projects.

All in all, this was a very positive experience both for the authors and the project members.

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