When Music, Information Technology, and Medicine Meet

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ABSTRACT
From Napster to YouTube and iTunes, music has always been a major driving force of Internet technologies. A huge amount of music content is now accessible to the public. Organizing and categorizing this content to support an effective recommendation system has become a significant challenge. The primary goal of our lab is to develop new technologies to address this challenge in the field of healthcare. We seek to harness the synergy of sound and music computing (SMC), mobile computing, and cloud computing technologies to promote healthy lifestyles and to facilitate disease prevention, diagnosis, and treatment in both developed countries and resource-poor developing countries. In this talk, I present a collaborative research project between the SMC lab at National University of Singapore and the Music, Neuroimaging, and Stroke Recovery Lab at Beth Israel Deaconess Medical Center (BIDMC) / Harvard Medical School. We are developing a cloud-based therapy delivery system that uses music to enhance limb function and speech in patients with neurological impairments using smart devices such as iPhone. Our focus is to develop high-tech, low-cost solutions that aim to (1) facilitate recovery in patients with post-stroke speech and motor impairments, (2) improve gait and mobility and reduce fall risk in patients with Parkinson's disease (PD), and thereby, improve Quality of Life (QoL) for both patients and caregivers.

Categories and Subject Descriptors
H.5.2 [User Interfaces]: User-centered design; H.5.5 [Sound and Music Computing]: Signal analysis, synthesis, and processing; K.4.2 [Social Issues]: Assistive technologies for persons with disabilities

Keywords
Music Retrieval and Recommendation, Information Technology, Healthcare.

1. INTRODUCTION
It is estimated that by 2015, 602 million people will be over the age of 65, and by 2025 that figure is expected to rise to more than 840 million [1]. Age is an independent risk factor for multiple neurological conditions, among them, stroke and progressive movement disorders (e.g., Parkinson's Disease, (PD)). As a result, there is growing international concern over the cost and availability of high-quality healthcare for the projected numbers of patients with such long-term disabilities [2].

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In parallel, cloud computing is rapidly changing the face of communication on a global level, and the development of smart mobile devices has made this technology widely available. According to market intelligence [3], more than 916 million smart devices (including laptops/desktops, media tablets, and smart phones) were shipped worldwide in 2011. That number is predicted to reach 1.84 billion by 2016 [3].

Our collaborative research project seeks to address problems in healthcare and rehabilitation, making use of mobile and cloud computing.

2. PROBLEM FORMULATION
We focus on two neurological problems for which auditory-motor interventions have been shown to be an effective avenue for treatment. Using cloud-based architecture, we plan to develop high-tech, low-cost solutions that aim to (1) facilitate recovery in patients with post-stroke speech and motor impairments, (2) improve gait and mobility and reduce fall risk in patients with PD, and thereby, improve Quality of Life (QoL) for both patients and caregivers.

- Aphasia/Speech-Motor Disorders. Stroke is the number two cause of death worldwide and the leading cause of long-term disability in adults. Of the fifteen million strokes that occur each year, five million patients (half of all survivors) are left with a permanent disability [10]. Aphasia is a common and devastating complication of stroke characterized by the loss of ability to produce and/or comprehend language. It has been estimated that, at six months post-stroke, at least 25% of those who initially had an aphasic syndrome and survived the stroke are still left with significant speech-language impairments [4]. Research has shown that intoning (singing) words/phrases can help facilitate speech output in aphasic patients, particularly those with severe nonfluent aphasia [7]. In response to the clinical observation that patients with nonfluent aphasia can often sing the lyrics of a song better than they can speak the same words, a technique called Melodic Intonation Therapy (MIT) was designed to capitalize on this preserved ability [5]. Over the course of treatment, patients learn to use (1) simple, 2-pitch melodies that follow the natural contour of speech, and (2) rhythmic hand-tapping to accompany each syllable and facilitate speech production [9]. MIT has been shown to produce improvements in expressive language beyond the limitations of either natural recovery or traditional non-intonation-based speech therapies [4][5][6][7][8]. In addition to use with aphasia, cloud-based delivery of such an intervention may also be useful for other neurological disorders that present with a significant speech-motor impairment such as stuttering, pallilalia in PD, and nonverbal forms of autism.
- Gait disorders. Like stroke and all other age-related health issues, there is a rapidly increasing number of people with gait

disorders that both limit their ability to function safely and independently, and significantly impact their quality of life (QoL). Such limitations in mobility increase with age and ultimately, affect 1 in 5 non-institutionalized older individuals who will require either the assistance of another person or special equipment to walk. Gait disorders and balance impairments are two defining features of Parkinson's disease that not only affect the 6.3 million people who currently suffer from this debilitating illness [10] but also appear as a consequence of other neuro-degenerative diseases and stroke. Medications are often ineffective in the management of gait and balance problems, in particular when a "jump start" is needed to initiate walking. By contrast, recent work with Rhythmic Auditory Stimulation (RAS), an intervention that aims to help patients initiate movement and regulate gait through synchronization with a steady beat, has consistently shown immediate improvement in multiple outcome measures [11][12]. However, there are currently no home-based, interactive, and portable delivery methods for RAS.

3. OUR PROPOSED SOLUTION

Thus, we propose the following interconnected solutions for addressing the devastating consequences of stroke and neurodegenerative movement disorders (e.g., PD) through innovative technology and evidence-based medicine:

- To develop a cloud-based, smart device delivery system for auditory-motor-based therapies designed to enhance speech production, limb-motor, and speech-motor functions for patients suffering from disabilities due to stroke or neurodegenerative disorders, and
- To develop two clinical applications (Sing2Speak and Music2Walk) that can be used independently by patients/caregivers to provide therapeutic support when supervision by a trained therapist is not possible.

Sing2Speak will be a cloud-based, smart device delivery system for Melodic Intonation Therapy (MIT) that first assesses the patient's level of impairment (e.g., time needed to initiate speech sounds, mean length of utterance, intelligibility, fluency, etc.), then, based on the assessment results, delivers the appropriate training material. Through the use of adaptive technology, this interactive program will respond by increasing the complexity of the target words/phrases in accordance with patients' improvement.

Music2Walk will be a cloud-based, smart device delivery system for RAS/gait training that first assesses patients' gait using in-shoe sensors. Based on the patients' current level of ability, our context-aware music recommender [13] will then help patients/caregivers/therapists create their own gait-training music playlist. To track and measure progress, we will use in-shoe sensors to monitor gait parameters such as stride time and stride length.

Both applications will be tested in proof-of-concept clinical trials in Harvard Medical School Teaching Hospitals (e.g., BIDMC). Furthermore, several major hospitals in Singapore (e.g., SGH, TTSH, NUHS) have already expressed the desire to test and use this technology as soon as it becomes available.

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