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MELOMICS

Contributions of computer science and biology to receptive music therapy

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Abstract

It is surprising the fact that while the personalized medicine model is more and more accepted, receptive music therapy is still applied collectively. Although, in some hospitals the subject (patient or health-medical staff) is allowed to select the genre or artist, with most published clinical studies reporting on concrete types of music (eg, relaxing or classical) that are applied to groups of patients.

Customizing songs to patient characteristics would make the study much more complex: on the one hand, a higher variability demands a larger sample and, on the other hand, it significantly increases the time and care dedicated to each patient. In any case, customization is a subjective element which strongly depends on individual preferences.

MELOMICS integrates computer technology that adapts music to the condition of the patient, in an automatic and objective way. This enables the future design of biofeedback devices, which in the long run results in being favorable for the therapeutic response of the patient.

Keywords: receptive music therapy, generative music, biofeedback

1. Introduction

Music therapy belongs to the field of complementary and alternative medicine. There are two types of music therapy. Active mode: requires participation of the patients. Passive mode: it only requires listening. Although, the use of music as a therapeutic remedy is very old, the first scientific clinical trials did not begin until 1944 in the United States. These trials focused on studying the effects of auditory stimuli and the relation between musical rhythms and biological processes. Since then, research has been done on the influence of music on the body, and the wide range of therapeutic options that it provides: post-traumatic stress (Hernández-Ruiz, 2005), dementia (Vink et al., 2004), depression (Guétin et al., 2009), autism (Whipple, 2004), insomnia (Yai et al., 1998, Ziv et al ., 2008), apnea (Smith et al., 2009), palliative medicine (Bradt et al., 2010, Brauer et al., 2010), reduction of stress and anxiety (Wong et al., 2001; Bringman et al ., 2009), infants with inconsolable crying and growth in preterm infants (Keith et al., 2009), reduction of pain after surgical procedures (Barnason et al., 1995, Nilsson et al., 2005, Nilsson et al., 2008) , reduction in drug administration (Nilsson et al., 2005; Bringman et al., 2009) and a wide range of other diseases: recovery of motor skills after stroke and trauma, improve motor skills in Parkinson's disease, attention deficit, cerebral palsy, hypertension, schizophrenia and Alzheimer.

Receptive music therapy is of particular interest for its low cost of implementation, and because it has demonstrated its effectiveness in treating many of the diseases we have discussed above. Nowadays, the current systems of passive music therapy are based on the selection of a set of songs for the therapy that depends on both patient's preferences and of environmental acoustics. These songs are recorded on a CD and can be played on a standard music player resulting in a one-way communication between the music player and the patient.

MELOMICS proposes a new standard for receptive music therapy: an online adaptation of a musical theme to the changes in the state of a patient and the environmental acoustics.

2. Background

2.1. Music Therapy

In the last few years, the experimentation with music therapy in health has grown much, as indicated by the increasing number of published papers shown in Figure 1. At the same time associations and international institutions have emerged. In the United States, music therapy is highly developed, pushed by music therapy research groups in leading universities, in addition to standardized music therapy units in many hospitals. In some other countries, music therapy units are being created, integrated into public hospitals.

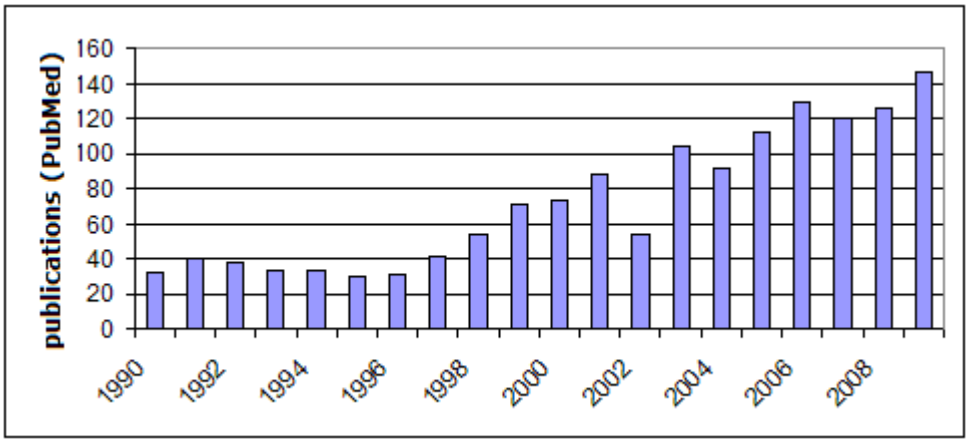

Figure 1. Number of publications indexed in PubMed under the ticker "music therapy" in the last 20 years (1990 to 2009). It shows a linear increase since the late nineties.

Recently, several institutions have been founded in Spain in order to regulate and promote music therapy, and they have implanted undergraduate and graduate studies. Moreover, there are initiatives to encourage the use of music therapy inside hospitals and clinics. This means a significant step forward, but the current equipment that this kind of care demands is very unsophisticated: musical instruments and common music players are used to apply the therapy, and sometimes the use of sensors are placed to capture the state, and assess the evolution, of the patient.

Despite the efforts to expand music therapy, both in Spain and many other occidental countries, most health centres still lack music therapy units. One of the main reasons may be the lack of standard products to satisfy the market’s demand.

Many review articles about music therapy on specific diseases point to the fact that, while it shows to be some preliminary evidence that its application improves patient's evolution, the lack

of rigor in current studies (according to the Jadad scale) avoids these results to be translated into medical indications. In fact, most of reported clinical trials are not fully reproducible, partly due to lack of data, and partly because the actual musical recordings are not cited, what is important in achieving the desire effect (Lin et al., 2010). The development of a standard system of music therapy will solve this problem, providing guidelines to design adequate devices to provide this treatment.

In this context, the products and services developed by MELOMICS aim to create a new standard in how music therapy is applied.

2.2. Musical Composition Technology

The musical composition technology, called *infinimels*, was developed by the research group in Biomimetics at Universidad de Málaga. This technology is based on bioinspired algorithms, and it allows the automatic generation of music content of a high compositional quality. Evolutionary computation is used to implement a natural selection context where compositions do evolve under particular constraints. In this scheme, the best-fitted compositions are expressed in a sort of artificial genome, that fully encodes the structure of a musical composition. The main advantages of this model are: (1) absence of human intervention in musical composition, (2) ability to customize the generation of songs, (3) optimum storage of these songs (<1KB for songs for several hours), (4) flexibility in handling and controlling the musical parameters (instrumentation, structural complexity, EQ, tempo, duration, and genre). The compositional level currently achieved by this generative algorithm is clearly higher than other algorithmic methods, which use repetitive rhythms, fixed formulas and combinations of preset melodies.

The evolutionary nature of the algorithm gives the composition a great variety and complexity. Another advantage of this model is the possibility of modifying the genetic operators to customize the music compositions. It also means that we can create a mutation of an original song by altering the genome of this song and, consequently, the mutated composition will have very similar characteristics to the original one. Any other type of music file would be damaged under this kind of manipulation. We have recorded several albums with some very interesting melodies; as a result, experts in the fields of music therapy and composition have shown much interest in this musical composition technology.

The content produced by *infinimels* show a common feature of relaxing music: they present a combination of expectative and simplicity that make them interesting, without getting to fill the listener's attention. It also makes them ideal for therapeutic purposes and to accompany other tasks. However, the reproduction of a song has a limited distractor effect (music therapy is mainly based on the phenomenon of auditory distraction) that we can enhance by adapting the composition to the state of the patient and his/her environment. For example, it is common to fall asleep with some kind of background music, but a bombastic note or a change in the song can wake the listener up. A much better strategy would be to attenuate overall volume as the subject starts to fall asleep. Besides volume, other parameters of musical reproduction might be modified to achieve this effect (e.g., *tempo,* complexity or instrumentation). Some of them have already been developed and can be applied to a standard music player. However, other parameters can only be modulated by reinterpreting musical composition. For example, changes in the instrumentation can only be achieved by interpreting it again using suitable tools and interpreters. In addition, changes in the complexity of a song can only be achieved with the help of a composer. *infinimels* allows the adaptation of any musical variable and synthesize new songs in few seconds through the use of a conventional computer.

These facts raise several questions: can this technology be used to create a music player that could be sensitive to the patient’s condition and environment, and that would be able to adapt the music

to these conditions? Is it possible that a song could reduce its *tempo*, volume and pitch, or even that it becomes simpler, as an insomniac patient begins to fall asleep?, could a song be adapted to our current state and divert our attention from a painful process? We will show next how this can be achieved.

3. Proposed system for receptive music therapy

The MELOMICS project aims to adapt *infinimels* content to fit the evolution in patient's state (Figure 2). It allows the creation of new products and services for the health sector, which, until now, were not technologically feasible. MELOMICS allows the design of biofeedback devices that optimize the therapeutic response of the patients. These devices will be validated in hospitals by means of rigorous clinical trials and can be used to prevent and treat several diseases and traumatic processes. In addition, the use of these biofeedback devices in health centres might improve the efficiency of treatment, and reduce the use of drugs, saving both, money for the security system, as well as unwanted side effects for the patients.

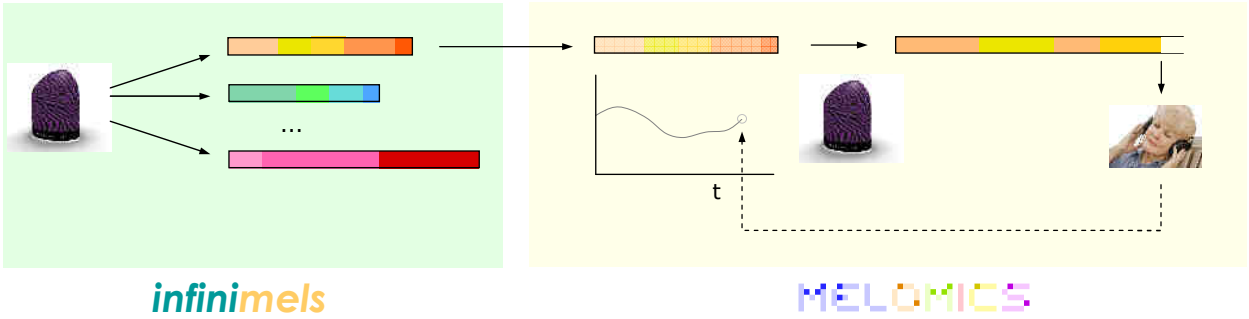

Figure 2. *infinimels* technology allows to generate unlimited musical compositions. MELOMICS exploit this capability by adapting the compositions to the evolution in patient's state.

In order to adapt a song to the patient's evolutionary state, it is necessary to characterize some bio-signals (pulse rate, phase of sleep, brain activity, respiratory rate, etc.). To achieve this purpose we are using several technologies, such as pulse oximetry, respiratory band, measuring of brain activity and sleep characterization techniques. These technologies have been adapted for use in clinical trials that we are currently performing to validate MELOMICS technology.

The results of these rigorous clinical trials will be submitted to high-impact journals in order to demonstrate MELOMICS' technology and products. The development of a website (*infinimels.com*) allows the creation of a repository of musical content, which will be used in these clinical trials. In addition, this repository provides the music therapist with a powerful tool to use in their sessions. This functionality cannot be achieved without this technology, due to the copyright of commercial music.

MELOMICS aims to create a new standard system for receptive music therapy setting out the differences from the traditional system which uses a one-way communication between the music player and the patient (Figure 3).

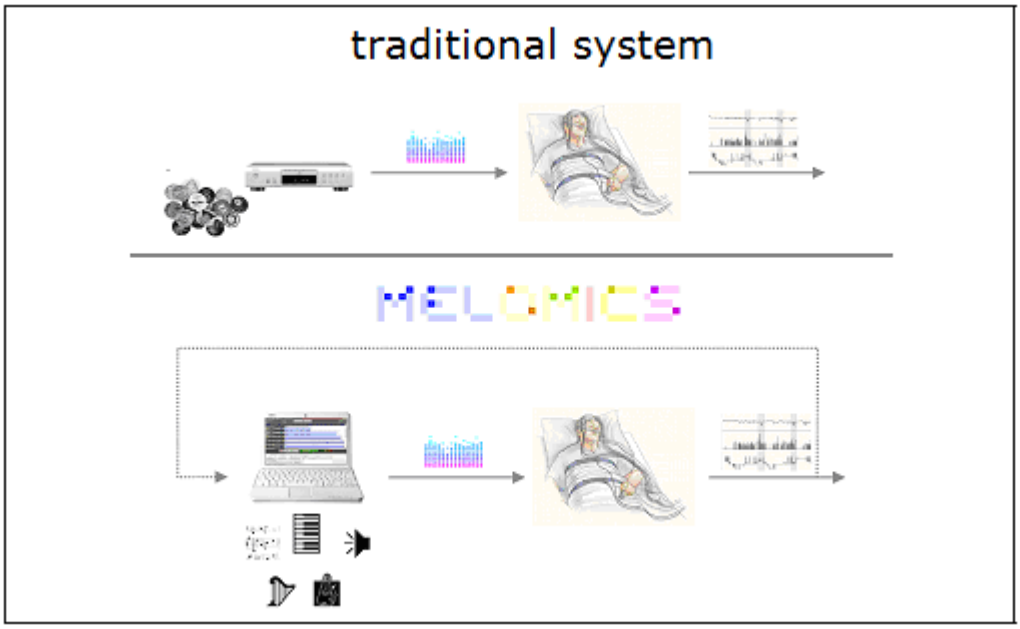

Figure 3. Difference between the traditional system of passive music therapy and the new feedback system proposed by MELOMICS.

The new proposed system works as follows: firstly, the therapist creates a patient's history by introducing information such as age, genre, origin, previous conditions or current disease. Then, during therapy sessions, the system automatically customizes the musical composition depending on the patient's state, so the patient receives a real-time adapted auditory stimulus. The aim is to create a more efficient therapy by providing stimulus adapted to the evolution of the patient. In addition, this system has the advantage that it operates automatically and its maintenance cost is very low.

A multi-computer architecture named Pink Noise (Figure 4) has been designed and configured to attain a high level of complexity in music composition. Pink Noise implements artificial development and evolution to approach the creative process of music composition. A web platform to distribute music contents is also being developed.

Figure 4. Pink Noise is able to generate compositions of variable duration and instrumentation

MELOMICS project is funded by the Spanish Ministry of Science and Innovation. This project involves major companies, research organizations, foundations and research centers, with the participation of Universidad de Málaga led by the research group has developed the technology *infinimels*. Therefore, this project involves a multidisciplinary team of engineers, mathematicians, physicians, therapists and composers belonging to the areas of computational intelligence, biotechnology, neuroscience, biomedicine and therapy.

4. Applications derived from MELOMICS

As it has been pointed out before, MELOMICS technology focuses on the design of a range of products and services to implant the proposed system for receptive music therapy. The production phase will be short and low risk because the technology will have been validated by end users and real scenarios. Moreover, the manufacturing of this range of products and services will be simple since it consists of a technological integration of computer equipment and music players, which are of low cost and are mass-produced by companies around the world.

Before the start of MELOMICS project we did an extensive market research to ensure that the health product suits the customer's need. It has been determined that MELOMICS products and services can have a great success in the health sector due to low competition for the new proposed system for receptive music therapy.

We have identified three types of products or services addressed to the health sector, which are illustrated in Figure 5.

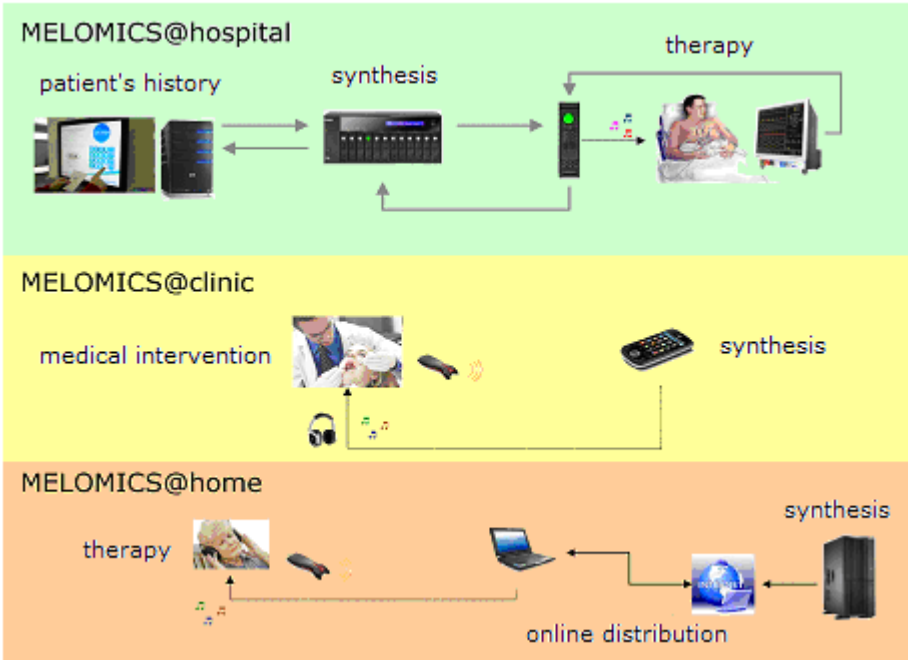

Figure 5. Products and services proposed for generating musical compositions applied to music therapy.

4.1. MELOMICS@*hospital*

MELOMIC@*hospital* aims to provide a complementary medical system in the prevention, treatment and rehabilitation of several diseases and traumatic processes in hospitals. The use of this biofeedback system in health centres will improve the efficiency of treatments as well as

savings in the use of drugs, both in costs for hospitals and unwanted side effects for the patient. This system is composed of two modules:

Central node

The *central node* is the main module, and it manages the therapy system. This module is connected to several units where it is possible to charge the batteries of the *mobile dispensing devices* when they are not in use and load and download data to and from the central node. This *central node* stores medical records, songs and statistics. Moreover, it includes a computational unit to run the composition algorithm and some learning algorithms; as well as a user interface device. This interface device is touch-type and provides the therapist with access to system data and therapy settings.

Mobile dispensing devices

This module is a portable device that provides patients with music therapy. It includes an interface with sensors to capture the patient's bio-signals and environment features (light, noise, etc); a computing unit for real-time signals processing, real-time characterization of the patient's condition, real-time manipulation of the development of musical genes and real-time synthesis of the adapted musical stimulus. It also includes a unit to store the initial musical genes for the session, data from the current session and synthesized musical contents. Moreover, depending on the therapy type it could have playback controls used by the patient, small speakers or headphones; units for powering devices and changing batteries; and an interface for uploading and downloading data on the device.

4.2. MELOMICS@*clinic*

MELOMIC@*clinic* is aimed to be used in medical clinics such as dental clinics, ophthalmic clinics or dermatologic clinics, where medical procedures generally cause a state of anxiety or stress in patients.

MELOMICS@*clinic* provides patients with auditory stimulus depending on their state of anxiety. It allows the patient to be addressed in a greater state of relaxation. The system can also capture the environmental noise level and adapt the music volume to completely isolate the patient from the intervention of which he/she is being subjected to. This system allows an improved service quality and patient´s comfort. It can also be used in waiting rooms of clinics, or in hospitals lacking of MELOMICS@*hospital*.

This system can be used by the smartphone technology. These mobile devices incorporate large computational power and memory, standard connection interfaces, well-known application programming interfaces, and friendly user interfaces. The application installed on these devices can determine the patient's condition by using a peripheral plugged into it (eg, heart rate sensor). It can also manage the patient's history and provide a graphic-touch interface to record and manage patient's data; as well as playback controls that allow the patient to discard the least favourite songs.

MELOMICS@*clinic* will be distributed in a package that includes the therapy application installed on the smartphone device, music genes stored in a memory card inserted in the device (the current solid-state memories can easily reach up to 32GB, enough to store tens of millions of musical genes), headset, sensor device and instructions for use.

The clinic staff will configure the mobile device by selecting the patient's history and provide him with the mobile device and peripherals. The patient may use the mobile system both in the

waiting room and during the medical intervention. The patient will only have access to the playback controls without access to other patients' records, or any other unauthorized data.

MELOMICS web platform will have a customer area of the mobile system that allows the download of new music genes and collect usage statistics.

4.3. MELOMICS@*home*

MELOMIC@*home* provides home users with the proposed system for receptive music therapy. It includes an online version of MELOMIC@*hospital* system and two versions of the MELOMIC@*clinic* mobile system. A new area will be created in MELOMICS website for home customers, where they can buy products and get other services.

The home system will have the following variants:

Home therapy

A music therapy system will be developed for users who want to receive preventive therapies, treatment and rehabilitation, similar to those provided by MELOMICS@*hospital*.

The user can access and configure the therapy system through a web interface and the therapy will be held online. The user can subscribe to the service and receive at home the sensor device, depending on the chosen therapy. The therapy instructions are provided on the website and the therapy will be applied through recommended headphones.

Home mobile system

This variant of MELOMICS@*home* is designed for users who want to receive music therapy to treat stress and anxiety problems at home. Two alternatives are proposed for this system. The first one is designed for users who already own a smartphone device. They would receive the sensor device to connect it to their smartphone. In addition, they can access the client area on the website to download the application and the musical genes, as well as instructions for installing the application and setting therapies. The second one is similar to MELOMICS@*clinic* mobile system. This new system simplifies the user interface to adapt it to the home needs and to facilitate the use of the device for the elderly. The system will not require internet connection to work.

5. Conclusions and discussions

MELOMICS propose a new system for receptive music therapy. There are four features that differentiate this proposal:

1. Real-time automatic generation of music content adapted to the evolution in the patient's state by using biofeedback devices, which demands dedicated hardware and bio-inspired models. The proposed model differs from traditional systems of music therapy in which there is a one-way communication between the device and patient.
2. This technology focuses on the design of a range of products and services addressed to hospitals, clinics and the home.
3. This technology allows the reduction of costs associated with the use of music therapy due to the reduction of production costs (mainly copyright and distribution costs).

4. This technology is designed for the use of music therapy in hospitals and clinics, thus, it is able to be used in performing clinical trials with patients supervised by specialists, which greatly promotes clinical research.

MELOMICS technology is based on computational intelligence modelling, which is providing, through various techniques, new solutions to solve a wide range of problems. Here we have presented the application of MELOMICS technology to create a new paradigm of receptive music therapy. However, its application could be extended to areas as diverse as digital entertainment, tourism, sports or musical composition.

Acknowledgments

MELOMICS project is funded by the Spanish Ministry of Science and Innovation and the following companies: iSOFT Sanidad SA, Brain Dynamics SL, Grupo Viamed and CITIC. We also want to acknowledge the cooperation of Universidad de Granada, Fundación IDIBAPS, Universidad de Cádiz, Conservatorio Superior de Música del País Vasco, Fundación del Hospital Ramón y Cajal, Hospital Montecanal and Fundación MD Anderson.

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