

Personalized Music Therapy Information System Based on Algorithmic Composition in the Treatment of Autism Spectrum Disorder

Chaoguang Wang¹[0000-0002-1156-2637] and Lusha Huang²[0000-0001-5001-8039]

¹ Guangdong University of Finance and Economics, Guangzhou, China
Bournemouth University, Poole

² Guangzhou Academy of Fine Arts, Guangzhou, China
lusha.huang@connect.polyu.hk

Abstract. We utilize information technology, especially artificial intelligence algorithms and computer music techniques, to enhance the emotional understanding abilities of children with autism. The proposed information system includes a machine composition engine, a music therapy app, and a music database for coping with autism. First, we will develop a machine composition engine to provide the effective, economic, and personalized music therapy for autistic children. Music therapy has been validated as helpful for autism, and it is very suitable for children with limitations in physical activity and functional fitness. The music generated explicitly for recognizing and understanding certain emotions will have a much better curative effect by considering the preference and the situation of individuals. In addition, the usage of artificial intelligence will largely reduce the cost and time of music composition. Second, we plan to develop a musical therapy app that is child friendly. We will consider the special needs of the children, such as the size of the font, in mobile application design. It will provide a joyful and engaging way for children to relieve autism and benefit their psychological well-being and quality of life. Finally, we will build a large-scale music database for the free usage of the public and promote our service to the world. The research will provide an effective, low-cost, and personalized music therapy information system that directly benefits children with autism and their families by improving their emotional understanding, and informing the development of upcoming products and services, especially artificial intelligence technology.

Keywords: Algorithmic Composition, Autism Spectrum Disorder, Emotional Understanding.

1 Introduction

Autism Spectrum Disorder (ASD) is a disorder that is increasingly prevalent in children, with an estimated 1% suffering from the condition globally. With the advance-

ment of technology and the increased use of video games and the internet, ASD symptoms are increasing and leading to an increase in cases (Krishnan, Krishnakumar, Gireeshan, George, & Basheer, 2021). By using music therapy, algorithmic composition, and the internet as a tool for distribution, it is possible to utilize these new technologies in a positive way in the treatment of ASD and other disorders.

1.1 Autism Spectrum Disorder

It is reported that ASD currently affects approximately one out of 160 children across all ethnic and socioeconomic groups in the world (World Health Organization, 2017). As estimated, there were over 10 million people diagnosed with autism in China in 2018. However, it was pointed out that this number was extremely underestimated, and China already has the largest group of autistic individuals in the world. For instance, it is estimated there are around two million children under 14 persons with an autism spectrum disorder in China in 2018 (Wucailu Center for Children with Autism, 2018), and if we include their families, ASD is a part of daily life for a considerable population.

The main classes of treatment for ASD currently available are behavioral treatment, medication, and experimental treatment. Behavioral treatment usually consists of psychological therapy such as behavior therapy, family therapy, interpersonal therapy, and psychoeducational input (Ladd, 2008). Medication is usually in the form of stimulants such as methylphenidate or other chain-substituted amphetamines. Alternatively, non-stimulant medication in the form of antipsychotic drugs is also used for treatment. While stimulants increase the levels or effect of neurotransmitters such as dopamine, non-stimulants work counteractively by blocking dopamine receptors. Both forms of medication can prove effective, but adverse effects can come from both due to the addictive nature of stimulants and dopamine deficiency caused by non-stimulants (Ladd, 2008). Medication for ASD in either form may also be dangerous in the long term, although studies in this area are limited.

It is estimated that the medical costs of behavioral interventions for children with ASD are US\$40,000–60,000 per year per child (Centers for Disease Control and Prevention, USA, 2015). Applying these estimates to two million autistic children under 14 in China, only the behavioral intervention costs of caring for this population are between US\$80 billion-US\$120 billion per year. As aforementioned, the actual number of autistic people in China should be much higher. One report released by the Centers for Disease Control and Prevention (CDC) of the USA in 2020 stated that the rate of ASD rose again by ten per cent, with 1 in every 54 children in the USA diagnosed with autism. There will be an increased need for care staff, facilities and additional funding to support children with ASD, especially new innovative technologies (Mangafa, , Moody, Woodcock, & Woolner, 2016).

While ASD has been extensively studied, there is no singular cure for it, and it is considered a chronic disease, with up to 50 percent of children who are sufferers going on to express symptoms when they are adults. Because all autistic children have specific cognitive defects, methods of visual or spoken instruction that are used with normal children may not be suitable to the autistic child. It has been observed that what autistic children see is not as good as the apprehension of what they hear (Alvin, & Warwick,

1991). The early study indicated that individuals with ASD showed a preference for auditory stimuli presented in music over other stimuli. Studies revealed that adults with ASD have intact processing of musical emotions (Gebauer, Skewes, Westphael, Heaton, & Vuust, 2014), and many individuals with ASD can perceive emotion in music (Brown, 2016). Heaton discovered that individual with ASD have a unique attraction to music and may even have enhanced musical abilities (Heaton, 2009). It was demonstrated that there was no significant difference between the children with ASD and neurotypical groups in the identification of musical emotions (Whipple, Gfeller, Driscoll, Oleson, & McGregor, 2015). What's more, music therapy can factor in motivation, a key tool for helping ASD sufferers (especially children) concentrate on a specific task. Hence, it is pertinent to the use of music as a specific means towards the treatment of the autistic child, especially in inducing their emotional understanding.

1.2 Music Therapy for Autistic Child

Music therapy has been defined as the “clinical and evidence-based use of music interventions to accomplish individualized goals within a therapeutic relationship” (American Music Therapy Association, 2005). The World Federation of Music Therapy (WFMT) defines music therapy as “Music therapy is the professional use of music and its elements as an intervention in medical, educational, and everyday environments with individuals, groups, families, or communities who seek to optimize their quality of life and improve their physical, social, communicative, emotional, intellectual, and spiritual health and well-being. Research, practice, education, and clinical training in music therapy are based on professional standards according to cultural, social, and political contexts” (WFMT, 2011).

It is reported that more than forty percent of the population that music therapists serve today are individuals with ASD (Kern & Tague, 2017). Three main goal areas targeted by music therapy worldwide are Communication skills (79.2%), emotional skills (76.1%), and social skills (64.8%). Deficits in social skills lead to problems with friendships, romantic relationships, daily living, and vocational success (Barnhill, 2007). By contrast, communication deficits of autistic individuals are characterized by impairments regarding joint attention and social reciprocity, challenges with verbal language cues, and poor nonverbal communication skills.

The mechanism of musical stimuli is thought to be a unique accommodation for ASD, as rhythmic and structural components provide an external cue or anchor to help children with ASD to recognize, predict, and respond (LaGasse, 2017). Musical cues that facilitate emotional responses are embedded in music's tempo, sound level, timing, intonation, articulation, timbre, vibrato, tone attacks, tone decays, and pauses (Juslin, 2000). Music therapy interventions are highly effective in improving communication, social skills, and personal responsibility in children with ASD (Whipple, 2012). The unique stimulus provided by music can help engage children with ASD in meaningful social interaction and socio emotional reciprocity (LaGasse, 2017). Music therapy is believed to be a promising intervention for individuals with ASD, and most studies reported positive outcomes (Simpson, & Keen, 2011; Kern, & Tague, 2017; LaGasse, 2017).

A number of studies have explored music therapy as an intervention to develop emotional understanding in children with ASD. 43.1% of music therapy for individuals with ASD selected emotional skills or emotional regulation as the goal area (Kern, Rivera, Chandler, & Humpal, 2013). Katagiri (2009) reported that music therapy increased the decoding skills of emotions for children with ASD, in which pre-recorded improvised music was designed to reflect target emotions. They pointed out that music can be one highly effective intervention to enhance emotional understanding in children with autism. Brown demonstrated that facial emotion recognition in children with ASD is affected by emotionally congruent background music (Brown, 2016). Music therapy uses engaging musical experience to enhance emotional understanding, thus addressing one of the core problems of children with ASD.

As the music therapy market keeps growing, it also suffers high manpower input and high monetary costs. Music therapy today suffers high manpower input and high monetary costs. One individual session of music therapy mostly lasts 45 minutes, and a group session appropriately lasts 60 minutes, with an hourly charge from US\$30–59 to over US\$100 for individual and group sessions (Kern & Tague, 2017). And furthermore, the average treatment duration of music therapy may last 1-3 years or even 4-6 years. For example, there were only 54 registered music therapist in Hong Kong in 2018. The use of composing music was one predominant form of music intervention reported (Simpson & Keen, 2011), in which the music is composed prior to the intervention and implemented using a recording. However, the price of original composed music is very high. For instance, the industry standard (IS) rate for minutes of original music is US\$1,000-\$1,200 per minute. The high cost of music therapy is interpreted as leading to one primary concern of music therapists today for lack of funding (Kern & Tague, 2017). As pointed out by some researchers, computer-based music activities (e.g., making music videos or use of apps) have emerged as a new music therapy technique (Kern, Rivera, Chandler, & Humpal, 2013), and may improve the efficiency of music therapy and render its' cost competitively, especially in music composing.

2 Methodology

2.1 Algorithmic Composition

Algorithmic composition enables the computer to generate music like human composers via intelligent algorithms (Cope, 1992; Van Der Merwe, & Schulze, 2011), which can provide a large number with low-cost and personalized music as a solution for children with autism. Algorithmic composition fascinates researchers in different fields because it intends to approximate artistic creation, the most charming and mysterious part of human intelligence (Holland et al. 2016, Jaques et al., 2017). Additionally, the machine-composed music has shown significant commercial potential in entertainment, game, health, and education (Chen, Liu, Zhong, & Zhang, 2018). Algorithmic composition is believed to be a promising technology to provide effective, low-cost, and personalized music therapy urgently needed by the autistic children community.

The new technology of algorithmic composition promotes and benefits all-round music therapy progress, mainly in three aspects. First, the App can provide easy-access, low-cost music therapy with a wide variety of music generated by algorithmic composition. The algorithmic composition can improve the effectiveness of music therapy by generating the music automatically. Second, the music can be specially designed for both good musicality and the purpose of therapy. Autistic children are rarely treated with music they enjoy, but most music therapists choose existing music for their patients. The key to music therapy is that the music should be selected according to the target listener's preferences. This will make it easier for them to listen to the music they need rather than caregivers putting music they do not like on the stereo. The algorithmic composition can generate numerous individualized and preferred music for the persons (Hu, Liu, Chen, & Liu, 2020). The music generated explicitly for recognizing and understanding specific emotions will have a much better curative effect by considering the preference and the situation of individuals. Third, the cost of music composition can be largely reduced, which now is over US\$ 1000 per minute for the original human-composed music. The usage of artificial intelligence will largely reduce the cost and time of music composition.

2.2 Music Therapy App and Implication

It aims to investigate the use of algorithmic composition music therapy to treat children with autism and to develop related software tools. The goal of our music therapy intervention is to help children with ASD gain a deeper understanding of four basic emotions (happiness, sadness, anger, and fear). Our objectives include: 1) Develop a musical therapy App based on algorithmic composition; 2) Pilot the music therapy software among a sample of children with autism; 3) Promote and train health professionals or parents to use the software and related material.

Our plan of action consists of 3 separate parts: the development of music therapy App, the pilot study among children with ASD, and training and promotion for using of the App (Fig 1).

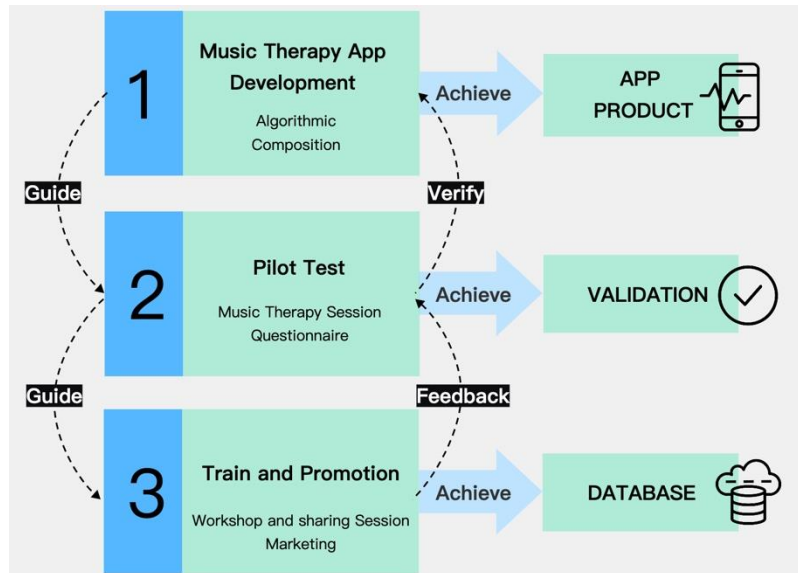


Fig. 1. Research roadmap

Music Therapy App Development. An App for music therapy will be developed based on algorithmic composition and aims to induce four emotions of happiness, sadness, anger, and fear. These emotions are thought to be four basic human emotions described by psychology research (Ekman & Friesen, 1971), and cover both the negative emotions (i.e. sadness, anger and fear) as well as positive emotion (happiness) as classified by the dimensional mode of emotion (Watson & Tellegen, 1985).

These four emotions have been used as target emotions by music therapists to be elicited in music and communicated to listeners (Juslin, 2000; Katagiri, 2009). Especially, it was reported that autistic children have more difficulties in the recognition of negative emotions than positive emotions (Ashwin, Chapman, & Baron-Cohen, 2006; Katagiri, 2009, Brown, 2016). For instance, their understanding of the emotions of sadness, fear, and anger improved significantly more than their understanding of happiness.

Pilot Test of the App. This part will investigate the influence of music therapy Apps on children with ASD's ability to recognize four basic emotions (happiness, sadness, anger, and fear) depicted in facial photographs and their response time. The researchers from psychology, music therapy and computer science will co-design a set of experiments to assess the effectiveness of App and investigate its long-term impact on the children with autism.

Participants aged 0-18 years with a type of ASD will be recruited for the pilot of the APP. Individual Music therapy can be conducted in schools, homes, music therapy clinics, or hospitals. Participants will listen to musical excerpts conveying emotions and be required to rate expressions of happiness, sad, joy and anger in pictures under four

music listening conditions (happy music, sad music, anger music, and fear music). We will measure participants' abilities to recognize facial expressions and corresponding emotions themselves pre and post music therapy.

Several standardized scales or published observational scales will be used as the secondary outcome measures to determine the efficiency of the music therapy App. Parent questionnaires, such as the Autism Treatment Evaluation Checklist, the Functional Emotional Assessment Scale, and the Vineland Social–Emotional Early Childhood Scales, will be distributed to determine the impact of music therapy treatment on children with ASD. Parental questionnaires are commonly used in music therapy research because the participants in the studies are often children who may not have verbal or cognitive skills to report on their own perceptions of their abilities.

Training and Promotion. Parents and health professionals working with children affected by ASD will be trained to use the App as an aid to therapies. We plan to develop an online course for parents and health professionals that is designed to prepare them to use the music therapy App for children with ASD. This course will contain 3-7 topic-specific e-learning modules, covering essential topics, including the theory and background of music therapy, emotional understanding skills, guideline of App, and monitoring progressing. These modules will be designed such that they can be taken independently or as a structured sequence. We then employ new media, such as Facebook, Twitter, WhatsApp, WeChat, to distribute and promote this online course to audiences. We also propose a set of workshops, seminars, and sharing sessions on training and promotion of using the App as an aid to therapies. Some workshops/seminars will be given by our colleagues, and we will invite external guests, including school teachers and music therapists, for others. Interested parents and professionals can enroll in workshops/seminars based on their needs, and can then propose their intended music therapy sessions. It will directly benefit the autistic children and their families, especially by enhancing emotional understanding.

As ASD occurs primarily in children, the target group is the patients' parents/guardians. Also targeted will be endorsements, as well as societies and treatment groups. By targeting existing treatment groups and societies, we can offer them an alternate mode of therapy in an already established community with many of the target audience already present. Marketing may also be applicable to schools, where ASD is prevalent and usually the first establishment of detection.

3 Conclusion

Music therapy has been demonstrated to be highly effective in improving social interaction and socio-emotional reciprocity. The mechanism of musical stimuli is thought to be a unique accommodation for ASD, as rhythmic and structural components provide an external cue or anchor to help children with ASD to recognize, predict, and respond. It is reported that more than 40% of the population that music therapists serve today are individuals with ASD. As far as we know, this is the first project that aims to study and develop algorithmic composition therapy for the treatment of children with ASD.

This research will provide effective, easy-access, and low-cost intervention for ASD suffering using algorithmic composition technology.

This project will allow us to produce a music therapy App and related database, which will enable the practitioners to provide both individual and group music therapy for autistic people. The App will be available to all to download free of charge for non-commercial use, and the results, in turn, will expand our database with more participants' data. The database will document music therapy practices from participants for reference, e.g., participants' background, duration and intensity, quality elements, and best practices. It is anticipated that this database will support parents and professionals in conducting their own music therapy sessions for autistic children.

Autistic children, parents and health professionals will form a community that provides support for treatment, where they can share examples and discuss related topics, such as problems and challenges encountered, engaging and assessing children in music therapy, the impact of the App on autistic children. Users will also be able to join a music therapy club, whereby rewards and prizes will be used as an incentive for joining. An online community and support for ASD and music therapy will then be set up in order for guardians and patients to share feedback and communicate with other ASD sufferers. Feedback can be gained following their practice which may help other patients overcome their symptoms, and the prospect of building an online community for ASD to share their experiences through the music therapy will help create a network of support which patients or guardians can use to manage the disorder more effectively. Acting on the side effects of the traditional treatment of ASD the method helps to drastically reduce the costs of health services.

The proposed App will facilitate the well-being of autistic children and their families by improving their emotional understanding, communication, and social skills. We are confident that this research will be a beneficial success for children with ASD, their parents, and health providers in China and worldwide.

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