様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９　（共通）

科学研究費助成事業　　研究成果報告書

令和　２ 年　 ６ 月 ２１ 日現在

機関番号：３２６８９
研究種目：若手研究(B)
研究期間：2017～2019
課題番号：１７Ｋ１８１７８

研究課題名（和文）Robot music therapy for effective social training of ASD children

研究課題名（英文）Robot music therapy for effective social training of ASD children

研究代表者
ＣＯＳＥＮＴＩＮＯ　ＳＡＲＡＨ（COSENTINO, SARAH）

早稲田大学・理工学術院・准教授（任期付）

研究者番号：８０７７０７２６

交付決定額（研究期間全体）：（直接経費）　　3,200,000円

研究成果の概要（和文）：このプロジェクトの目的は、ASDの子供たちの音楽社会療法に音楽ロボットを使用することの実現可能性と有効性を調査することだった。 開発されたトレーニングプロトコルとシステムの有効性と使いやすさを確認するために障害のないと障害のある若い成人と子供を対象にテストされて、効果的で使いやすいことが証明できた。ASDの子供たちの社会的訓練に音楽ロボットを使用することは、非常に費用効果が高く、長期的には個々の社会的治療のロジスティックおよび経済的負担を軽減する可能性がある。 トレーニングデータをロボットに保存し、療法士がアクセスして、トレーニングの介入に対するASD被験者の進化を評価することもできる。

研究成果の学術的意義や社会的意義
The results are very important: automated, adaptive systems for individual ASD therapy would reduce the stress of the therapeutic sessions, and also enable therapists to follow more patients.

研究成果の概要（英文）：This project objective was to explore the feasibility and effectiveness of using a musical robot for music social therapy for ASD children. The training protocols and systems have been developed and tested with non-disabled and disabled young adults and children, to confirm their effectiveness and usability. The developed systems and protocols proved to be effective and easy-to-use. The use of a musical robot for social training of ASD children might be very cost-effective and reduce the logistic and financial burdens of individual social therapy, in the long term. Training data can also be stored in the robot, then accessed by a professional therapist to evaluate the evolution of the ASD subject over a training intervention.

研究分野：assistive robotics

キーワード：music therapy　child psychology　autism

様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９（共通）

１．研究開始当初の背景

Japan, with >2% of the population, is among the countries with the highest rates of autism in the world.

Autistic Spectrum Disorders (ASD) are developmental disorders that sets up at an early age, impeding mostly the correct development of social and behavioral skills, and causing the affected subject to avoid or ignore interaction with others, eventually resulting in severe cognitive and developmental handicap over time, as the subjects cannot follow societal learning patterns. Albeit in some cases ASD is present together with mental disorders and retardation, clinically reported data show that 46% of ASD children have above average intelligence, are strong learners, and usually excel in technical subjects, such as math, science, music, or art. ASD children could, in fact, live a normal life, be independent and contribute to society if they would be able to develop basic social competence.

Early intervention and effective treatment can reduce the effects of ASD, soften its symptoms, and improve the subjects' behavior and social skills.

Robots have been successfully used in ASD therapeutic interventions as non-human interactional agents [2]. The advantages of using robots are essentially three:

- subjects are less intimidated and anxious during interaction, compared to interactions with human therapists
- robots represent novelty, and new situations have been shown to have a greater effect on children with ASD than on typically developing children
- robots can be used also as automatic monitoring devices as they can use sensors to monitor children and can store monitored data for later retrieval, analysis, and comparison.

Music therapy has also been successfully used in the treatment of children with ASD, motor or cognitive disabilities.

Music therapy is used to help patients improve in several domains: motor skills, cognitive functioning, emotional development and control, and social skills. The benefits of music therapy have been well documented in a large body of both qualitative and quantitative research literature. There are two types of music therapy:

- Active: the patient actively plays a musical instrument. This method consists in ad-hoc exercises to improve motor skills and coordination, but also cognitive, emotional, social and communication functions.
- Receptive: the patients listen to music. Music has calming and soothing properties, and can trigger physiological changes in body parameters, such as pulse and respiration rate, blood pressure, and muscle tension. This method is primarily used for emotional support, but also for social and communication skills improvement, with tailored interaction exercises.

However, music therapy presents strict requirements for therapists, hindering its practicality and effectiveness:

- knowledge of an instrument and use of several different instrument for different activities
- interpreting actual psychological signals from the patients and choosing the appropriate exercise and melody for both active and receptive therapy, which requires a specialized psychology background.
- establishing the correct level of interaction with a child with developmental delays or with psychological disorders, which is very difficult and changes depending on therapy evolution but also on daily mood swings.
- continuous supervision and presence of a therapist for each intervention, for monitoring and assessment purposes

In this research, we plan to combine the benefits of robot and music therapy in the treatment of children with ASD, using our interactive humanoid saxophonist robot WAS-4. Using our interactive musical robot for social therapy will bring all the benefits of robot-mediated social interaction, and at the same time fulfill the current music therapy requirements, combining the effects of active and receptive music therapy, and allowing for an adaptive individually tailored therapy program. The use of the WAS-4 robot, which can also monitor and save physiological and interaction data for later assessment and trend analysis, will allow therapy sessions to last longer and be less invasive, maximizing the effectiveness and feasibility of continuous therapy.

２．研究の目的

The purpose of this research was to adapt and use our interactive Waseda Anthropomorphic Saxophonist (WAS) robot for music therapy for social training in the long

term treatment of Autistic Spectrum Disorder (ASD) subjects, to reduce the effects of these psychological disorders, soften their symptoms, improve the subjects' behavior and social skills and eventually help them to conduct a normal, constructive and independent life.

３．研究の方法

In this research project, we plan to use our saxophonist robot, WAS-4, for music therapy intervention with ASD children.

WAS specifications

Body Parts	DoF
Lips	2
Oral Cavity	1
Tongue	1
Lung	2
Fingers	19
Waist	1
Gaze	2
Eyebrows	1
Eyelids	2
Total	**31**

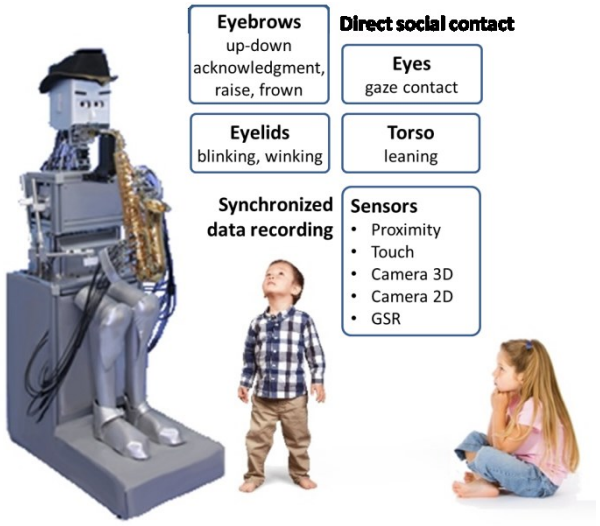

Fig. 1: Music therapy scenario with WAS-4

The use of a robot has several advantages over traditional music therapy:

- The compact nature of the robot, its stability (no bipedal standing), and its humanoid but very robotic appearance, makes it an ideal non-threatening companion for initial contact and sustained social interaction training, without the necessity of close guidance and the sometimes stressful strict supervision by a human caretaker. This will reduce stress and anxiety in the children and allow for longer therapy sessions.
- From the analysis of body movement and gaze direction, as well as, if present, facial expression, the robot can recognize basic interactive behaviors and emotional patterns of the child, and adapt it performance consequently. In this way, also the effects of both active and receptive music therapy can be combined, as the robot can choose appropriate melodies and music tunes according to the current needs of the child under therapy.
- The robot can also be used in "Wizard of Oz" mode, controlled remotely by a therapist to perform specific exercises.
- The robot can continuously record objective data during therapy, which can be analyzed at a later time by therapists for therapy evaluation. We plan also to equip our robot with several other traditional sensors for close interaction, such as proximity, touch, and galvanic skin response (GSR) sensors, to collect as many data on the interacting subject as possible.

3) Scientific characteristics, originality and expected achievements and significance of the research in the area

Originality: Robot and music therapy have been successfully used for the treatment of ASD subjects, but the benefits of a joint use have never been explored. This research aims at combine these methods to reach a faster improvement of subjects' psychological state and social skills. Using the robot will allow for longer and less stressful therapy sessions. Moreover, the robot can automatically record subjects' data during interactions, for later analysis and trend profiling.

Achievements: Various physiological and physical signals will be automatically recorded and analyzed with the help of the robot, to establish correlates with changes in emotional and social patterns and reduce the analysis and assessment effort by therapists, leading to more effective individually tailored therapy and possibly faster improvements of the subjects' behavior.

Significance: The significance of this research is extremely high, as ASD children are a

wide percentage of the population, especially in Japan, that could potentially live a normal life after successful treatment. The use of a robot for music therapy and social training will help in establishing and maintaining social contact, profiling with automatic collected data, adapt the intervention to the particular individual and improve therapy effectiveness.

４．研究成果

The WAS robotic system was integrated with user interaction interfaces: two vision-based system to recognize the user posture and to detect the user gaze direction, a facial expression display, and a simple button interface to receive simple inputs from the user.

Two main training protocols have been developed, under the guidance of child psychologists:

1) a tempo-training therapy protocol

2) a face expression recognition therapy protocol.

These two protocols focus on two main difficulties ASD children have during social interactions: understanding and correctly reacting to the actions and expressions of the people they interact with. This gives the impression that they are not empathetic and creates unpleasant social situations, making social integration difficult. In particular, time is a critical component of social interactions. A correct timing understanding is important not only in verbal conversations but also when performing joint physical activities, such as walking, dancing, or playing with other people. Moreover, differentiating the facial expression of the individuals they interact with is essential in social interactions.

During the tempo-training session, the robot played a melody with specific tempo patterns, and the user was instructed to move according to the music tempo. The robot used the vision-based user posture recognition system to detect the user movements, compute the movement tempo, and compare it with the music tempo. The session was divided in several phases with different tempos, to measure if and how fast the user adapted their movement to the new tempo.

During the face expression recognition session, the robot played different melodies associated with different displayed facial expression, and the user was instructed to press different buttons depending on different robot actions. The session was divided in 3 main phases:

P1 is the verification phase where WAS-5 will play a specific music cue used in a music therapy previously attended by the ASD subject. Different music cues in the music therapy triggers different taught movements. This phase is to verify if the subject reacts properly to the music cue as learnt in their music therapy with their therapist.

P2 is the training phase of the experiment, where WAS-5 will play the same music cue as in P1 and simultaneously create a predetermined expression for the music cue. Before WAS-5 executes any action in P2, the accompanying therapist will give instruction or command to the subject to look at the expression of WAS-5. If a positive eye contact is registered between the subject and the expression module of WAS-5 with the use of the gaze tracking camera, WAS-5 will then perform the music cue and corresponding expression.

P3 is the evaluation phase, of which the effect of P2 is being tested to see if the training has been effective to help the subject to perform the specific action triggered by the music to now also be triggered by the corresponding expression. If reaction is not as expected, P3 will revert to P2 to continue training the subject and ends if desired reaction is shown.

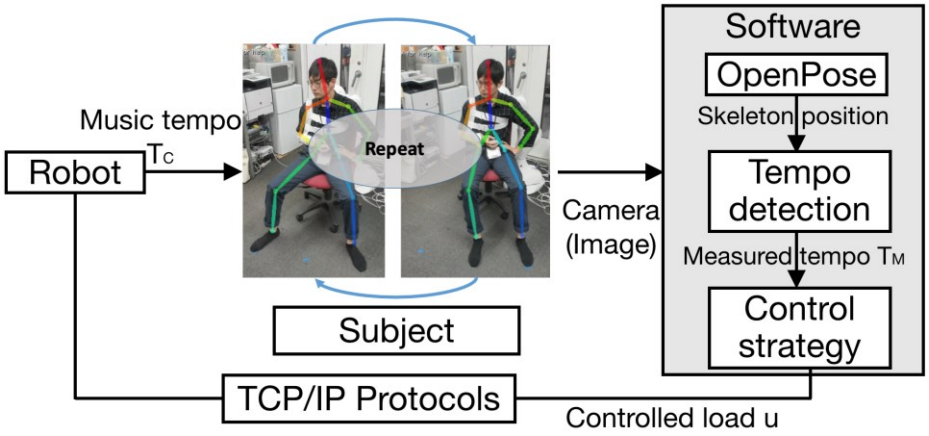

Fig. 2 Tempo-training protocol diagram

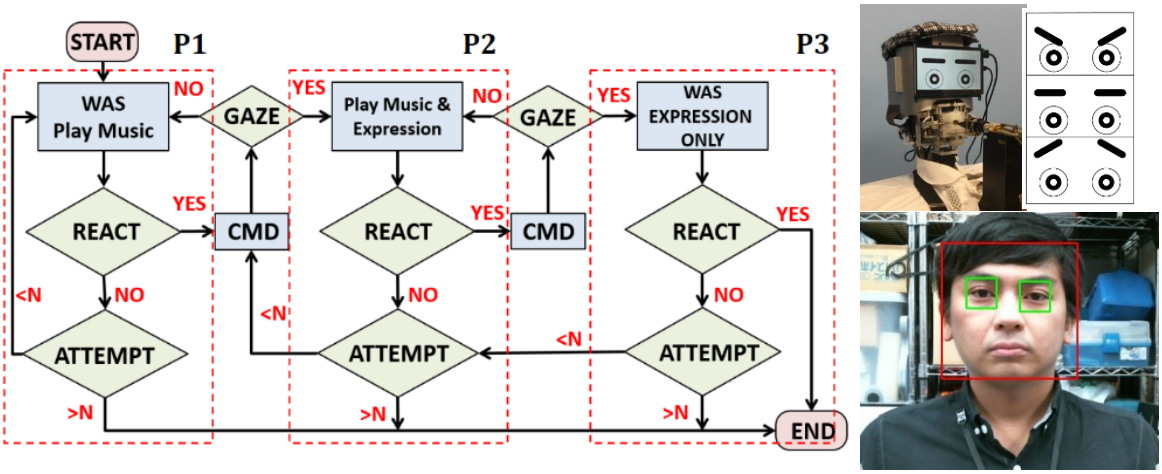

Fig. 3 Facial expression-training protocol diagram

The results of the two protocols evaluation experiments show that subjects improve their skills over time in both situations, as shown in figures 4 and 5.

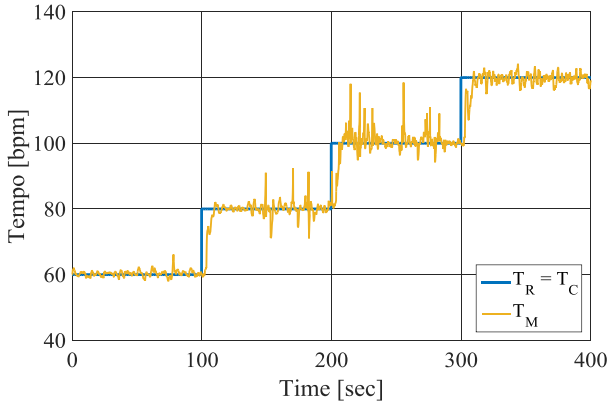

TABLE 1 Error of the tempo detection system (Cons

T_R	$\overline{T_M}$	Error [%]
60	60.4	1.4
80	80.0	1.8
100	100.5	1.4
120	119.7	0.9

Overall error rate = 1.3 ± 1.2 [% of bp

Fig. 4 Tempo as function of time for constant strategy

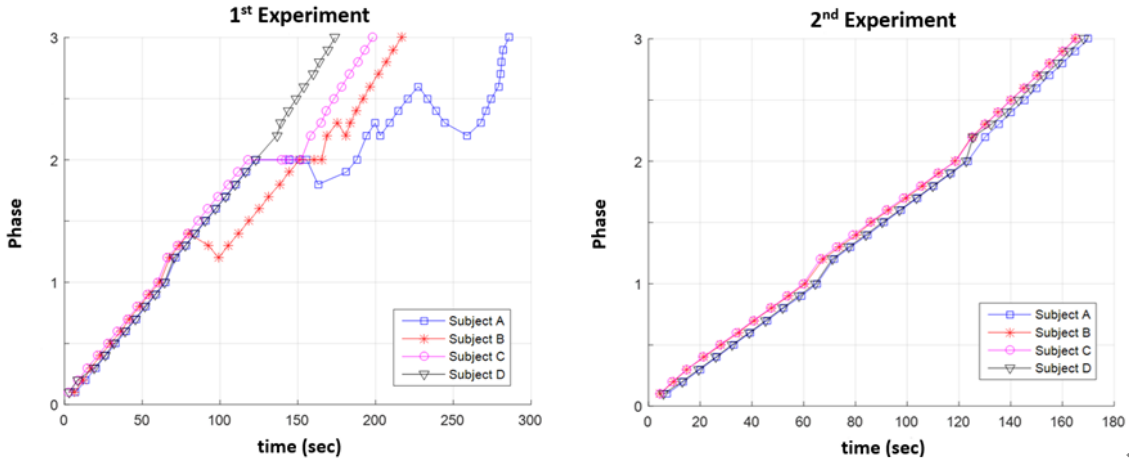

Fig. 5 Facial expression session completion time and phase progression of subjects

In conclusion, the robot music therapy system, and the two robot-based music therapy protocols show great potential in the improvement of ASD subjects' social skills. The robot hardware design should be optimized to improve maneuverability, usability, and attractiveness to children, and the protocols should be improved with more game-like features to promote user engagement.

５．主な発表論文等

〔雑誌論文〕　計1件（うち査読付論文　1件／うち国際共著　1件／うちオープンアクセス　1件）

１．著者名 Lin Jia-Yeu、Kawai Mao、Nishio Yuya、Cosentino Sarah、Takanishi Atsuo	４．巻 4
２．論文標題 Development of Performance System With Musical Dynamics Expression on Humanoid Saxophonist Robot	５．発行年 2019年
３．雑誌名 IEEE Robotics and Automation Letters	６．最初と最後の頁 1684～1690
掲載論文のDOI（デジタルオブジェクト識別子） 10.1109/LRA.2019.2897372	査読の有無 有
オープンアクセス オープンアクセスとしている（また、その予定である）	国際共著 該当する

〔学会発表〕　計6件（うち招待講演　0件／うち国際学会　4件）

１．発表者名 LIN Jia-Yeu、NISHIO Yuya、KAWAI Mao、MATSUKI Kei、SESSA Salvatore、COSENTINO Sarah、TAKANISHI Atsuo
２．発表標題 Design and evaluation of a robot limb for table key playing on humanoid saxophonist robot
３．学会等名 2019 IEEE/SICE International Symposium on System Integration (SII)（国際学会）
４．発表年 2019年

１．発表者名 Sarah Cosentino, Estelle I. S. Randria, Jia-Yeu Lin, Thomas Pellegrini, Salvatore Sessa, Atsuo Takanishi
２．発表標題 Group emotion recognition strategies for entertainment robots
３．学会等名 2018 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)（国際学会）
４．発表年 2018年

１．発表者名 Yean HAN, Yuya NISHIO, Yi-Hsiang MA, Chiaki OSHIYAMA, Jia-Yeu LIN, Atsuo TAKANISHI, Sarah COSENTINO
２．発表標題 A human-robot interface to improve facial expression recognition in subjects with Autism Spectrum Disorder
３．学会等名 2018 9th International Conference on Awareness Science and Technology (iCAST)（国際学会）
４．発表年 2018年

１．発表者名
MA Yi-Hsiang, Yean Han, Jia-Yeu Lin, Sarah Cosentino, Yuya Nishio, Chiaki Oshiyama, Atsuo Takanishi

２．発表標題
A Synchronization Feedback System to Improve Interaction Correlation in Subjects With Autism Spectrum Disorder

３．学会等名
2018 9th International Conference on Awareness Science and Technology (iCAST)（国際学会）

４．発表年
2018年

１．発表者名
Estelle I. S. Randria, Sarah Cosentino, Jia-Yeu Lin, Thomas Pellegrini, Salvatore Sessa, Atsuo Takanishi

２．発表標題
Audience mood estimation for the Waseda Anthropomorphic Saxophonist 5 (WAS-5) using cloud cognitive services

３．学会等名
第35回 日本ロボット学会学術講演会 RSJ2017

４．発表年
2017年

１．発表者名
西尾祐哉，松木慧，河合雅央，林家宇，セッサ・サルバトーレ，コセンティノ・サラ，上山景子，高西淳夫

２．発表標題
人間形サキソフォン演奏ロボットの開発 -腕，手首を用いる運指の評価-

３．学会等名
第35回 日本ロボット学会学術講演会 RSJ2017

４．発表年
2017年

〔図書〕　計1件

１．著者名	４．発行年
Lin Jia-Yeu、Kawai Mao、Matsuki Kei、Cosentino Sarah、Sessa Salvatore、Takanishi Atsuo	2018年
２．出版社	５．総ページ数
Springer	6 (392-399)
３．書名	
ROMANSY 22 - Robot Design, Dynamics and Control	

〔産業財産権〕

〔その他〕

―

6．研究組織

	氏名 （ローマ字氏名） （研究者番号）	所属研究機関・部局・職 （機関番号）	備考
研究協力者	押山　千秋 (Oshiyama Chiaki) (82626)	国立研究開発法人産業技術総合研究所・人工知能研究センター・特別研究員	
研究協力者	林　家宇 (Lin Jia-Yeu) (32689)	早稲田大学・理工学部・博士課程	