Using a Humanoid Robot for Music Therapy with Autistic Children

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***Abstract*—Mimicry is an important social skill for every person. A humanoid robot is used to play with autistic children in order to attract their attention and want to improve their concentration. Music therapy plays also an important role in this experiment. Robot plays with autistic children with music. The robot will imitate the notes which the child has played, and then the child has to imitate the robot in return. The purpose of the treatment is to improve their social skills including interpersonal synchrony and concentration can help them to adapt this society easier and make a better life in the future.**

Keywords—Humanoid robot; Autistic children; Interaction play; Music therapy; Robot Playmate

I. INTRODUCTION

In recent years, research of autistic children has become more and more popular. Autism is a disorder of neural development. The characteristics of autism include impaired social interaction and communication, and repetitive behaviors [1, 2]. There are some methods available for autism therapy [3], such as behavior therapy, game therapy, art therapy, music therapy and so on. Therapists always need mediators to treat autistic children in general because they cannot play with autistic children directly. For example, art therapy through drawing, game therapy is done by game.

Autistic children are afraid of people because of their disease. Therefore, no matter which therapy we use, the problem of fearing people for autistic children is a big issue. For this reason, using a robot to cure autistic children can be the way of choice. A robot has such characteristics: less intimidating to the child, more predictable than a human. It can do the same procedure repeatedly and will not get tired. There is also some research that shows that robots indeed are attractive to autistic children [4, 5, 6, and 17]. We imagine robots as something between a toy and human [7, 8].

"Play Therapy" is a form of counseling or psychotherapy that uses an interaction game to communicate with people and help them, especially children. Play therapy is used to help towards a better social integration, growth and development. It is generally employed with children between the age from three to eleven. Therefore, we assume that letting robots play with autistic children is a good way to improve their social and communication skills.

"Music Therapy" is a professional area that completes an approved music therapy program by a music therapist. Music therapy can improve several aspects of the disease, such as mental functioning, motor skills, emotional development, social skills, and quality of life. Patients can get a feeling for the music by listening, singing, playing instruments, and moving. Music therapy for children is conducted either in a one-on-one session or in a group session, and it can help children with problems in communication, attention, and motivation, as well as with behavioral problems [9].

II. LITERATURE STUDY

A. Researches of Human-Robot Interactions

Kerstin Dautenhahn, Iain Werry, John Rae, et al. started using robots to help autistic children since 1998 [10]. This project which is called "The AuRoRA Project" [11] has been executed for over than 10 years. One of their former experiments was using a wheeled robot, Labo-1. They put Labo-1 and an autistic child together in a small room which size is 2x3 square meters. Labo-1 tries to catch the child, and it makes a sound when Labo-1 is near the child. Then, they recorded the interaction between the child and Labo-1 as a video. They analyzed the record and got feedback such as whether Labo-1 attracted the child, how much time the child played with Labo-1.

After Labo-1, they tried and developed many different types of robots one by one to support the Aurora project. The following robots are being used: Pekee robot, an upgrade version of Labo-1; Robota robot, a humanoid doll robot which has an infrared sensor and some rotatable joints; KASPAR, a humanoid robot that has many movable joints (over 11) and tactile sensors, and its eyeballs are rotatable. There are some researches that used KASPAR interact with the autistic children by tactile interaction, and get good results [5, 6].

There are also some robots for human-robot interactions (HRI). Paro is a seal-like robot that has five kinds of sensors which can perceive people and its environment. Paro is now always used to accompany with the old man [12]. Huggable has more than 1500 sensors on its skin can feel the environment, and its appearance is like a teddy bear [13]. NeCoRo is a robot that likes a real cat, and it has 7 sensors which can let it know the touch from the environment [14].

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We can see that more and more robots are made for accompany or take care of human.

The ongoing development of small size robots results in better and more robust robots with the advance of the corresponding technologies. There are more and more organizations devoted to this field of research, for example, using a small size robot to help an autistic child. One group of Connecticut University has published a paper [9] is which they use Aldebaran's NAO robot to teach autistic children to play the drum, for rhythmic music playing interaction.

Daniel J. Ricks, Mark B. Colton, and Michael A. Goodrich also published a paper [15] in 2012. They made a humanoid robot capable of only upper body expression transforms. It can sing and play some specific toys.

In Taiwan, Tsai, Cheng-Hung [16] used a humanoid robot to play pose simulated game. They used a normal webcam and let the child wore red gloves and stickers on their shoulder to capture the motion. Then, they use ZigBee to transmit data and compared the motion differences between each other.

B. *Interpersonal Synchrony*

According to the literature [9], they use NAO robot to teach autistic children to play the drum. They consider that this may be a form of mimicry which is an important social skill [18, 19].

Interpersonal synchrony is a dynamic process that appears from the interplay between the members of the group. They mutually influence each other as they move together, and this creates an emergent synchronous system that is self organizing. Synchronous activities can lead people cooperate with others, and can improve the feelings of affiliation [18].

III. EXPERIMENT DESIGN

A. *Background and Goal*

Our goal is to teach autistic children social or communication skills through interacting or playing with the robot. We think the robot could be a good mediator for improving social skills; specifically this is true for humanoid robots.

Fig. 1. Darwin-OP and the glockenspiel.

There are some researches that show that the "Music Therapy" is also effective for autistic children [20, 21]. Music therapy indeed can prompt social, emotional and motivational development in children with autism. Moreover, music always acts as a social intermediary that forms a bridge between the participants. They use rhythm therapy to train the child's rhythmic gross motor and drumming actions, and hope that they can improve their cooperation and joint attention.

Therefore, we want to add music into the experiment and also use the humanoid robot play with the autistic children. In our experiment, we use the humanoid robot named Darwin-OP as our mediator. Fig. 1 shows the robot and the instrument he played.

B. *Hardware and Environment*

1) *DARwIn-OP*

Fig. 1 shows the robot, DARwIn-OP, which is made by ROBOTIS, and it is an open architecture robot. The open architecture means that we can easily change the framework and program, and we also have enough software resources in the internet.

In our experiment, we used the Darwin-OP as our robot playmate. We tried to attract the autistic children's attention by the cute robot, and play with the child by playing the instrument. The motion of playing the instrument is done by the "action-editor". Every note has its own action and number, and we can use the number of action and time break to complete a song.

2) *Experiment Environment*

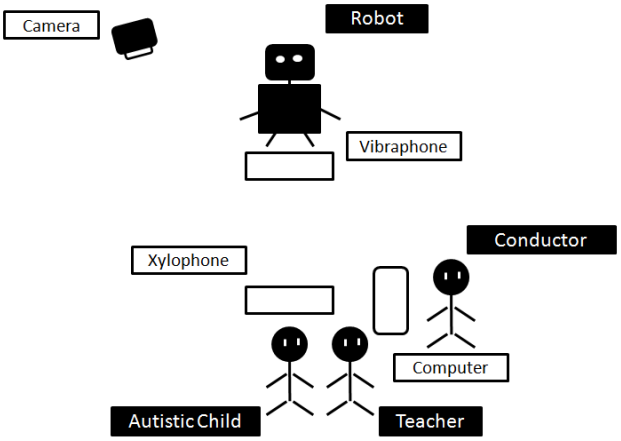

Fig. 2. The environment of the experiment.

Fig. 2 shows the environment of the experiment. We use a robot, a laptop, a vibraphone, a xylophone, and a camera to complete our experiment. Laptop is used to control the robot and send its messages through wireless access point. We also use a laptop to analyze the sound that was recorded by the external microphone, and then send instructions to the robot to play the corresponding note. The vibraphone was decided as the child's instrument at first, but the echo of vibraphone is too long and too loud, and we cannot predict the child's behavior. Therefore, use of a xylophone is much better than a vibraphone as child's instrument. Camera will record all

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the time. The teacher and the experimenter sit beside the child so that they can take care about the child and give help sometimes.

C. Programming

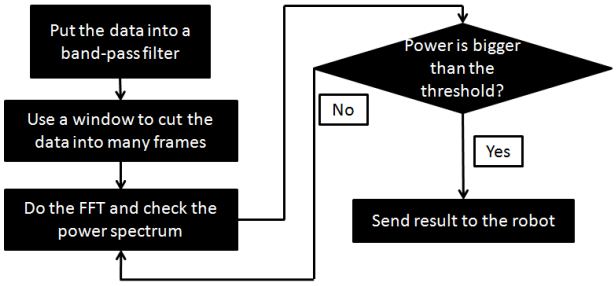

Fig. 3. It is the procedure of the program.

The console system is programmed in C++. The UDP-based Data Transfer Protocol (UDT) handles wireless communication between the laptop and Darwin-OP. We used SFML library to record and obtain the data of the sound. We have to record the sound continuously until the imitation part ends. Therefore, we analyze the sound every 1 second, and use two threads to implement this part. Fig. 3 shows the procedure of the program. The data will be put into a band-pass filter at first. Then a window will be used to cut the data into many frames. The window size is decided through testing, finally 8192 was chosen as the appropriate widow size. FFT is used to analyze the data, and then check the power spectrum whether bigger than the threshold or not. If the power is bigger than the threshold, the result will be sent to the robot, or the next window will be check. The sequence of tunes is sent to the robot. Each note has its actions, so the computer will send the corresponding action order to the robot. As a result, the robot will play the notes in the same sequence as the child.

D. Procedure

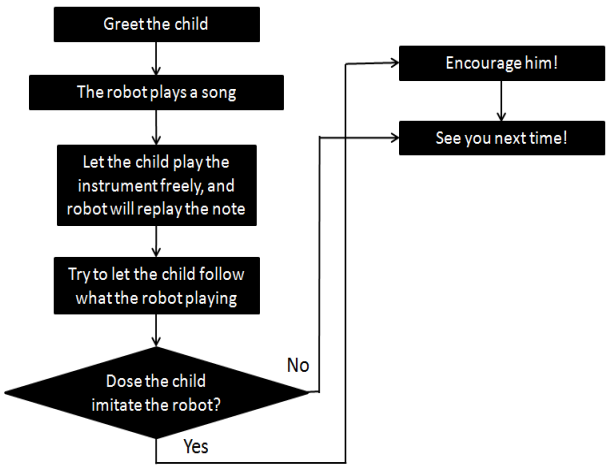

Fig. 4. The flow chart of the experiment.

There are three phases in our experiment. Fig. 4 shows that the three phases including attract the children's attention, imitating and training.

At the beginning, robot will greet the child who comes in the room. Then play a song to the child to attract his/her attention. It is a very important step in our experiment, because the child with autism is hard to concentrate on one thing. The moving robot acts like a human and the song that the robot played are all interesting for the autistic children.

After the robot plays the song, we let the child play the instrument freely. The robot will imitate what the child just played, and we will see the reaction of the child. It is the second phase. After a few minutes, we ask the child imitate what the robot play conversely. Robot plays one or two simple notes, and the child should play the same ones. The final phase is to train the child that can be more familiar with music and the instrument. Moreover, it is also can improve their coordination. We can observe the child would be willing to play the instrument after the training.

After the experimental stage, the child and the teacher should do the test papers. We can know more about the ability of mimicry and the understanding with the different voice in the post test from the test paper. The recorded video is also an important data in our experiment. We record the whole procedure during the experiment. In the video, we can see how the child reacts in every phase, and the effect of this experiment to those children.

IV. Results and Discussion

A. Participants

We found two students from special education elementary school as our subjects in the experiment. Both of them are severe autism, and they cannot talk like normal people. One of them is a girl (Shan), and the other is a boy (Ming). The teacher told us that both of them like to play instruments and they are both 8 years old. Shan is a moody girl, and she likes new things. She will bite her fingers and pinch her face when she is angry. Ming is a passive boy and loves music, warm hug and kiss. He will pound the table vigorously or push things down when he is angry. He has not only autism but also epilepsy.

B. Results

1) Experiment

In the experimental stage, we noticed that Ming improved every week. At the beginning he didn't look at the robot. At the end of the experiment, he would look at it sometimes. Although we cannot be sure that he knew the robot imitated him, we could observe that he noticed the robot and the robot will play instrument when he plays the xylophone. Most obviously, during week 4, he started to look at the robot, and he also performed well in week 5. However, he just had a seizure this morning and felt uncomfortable in week 6. He didn't do well and a little distracted in the experiment, but this can be appreciated. Although he was a little upset, he still performed well and steady in week 7. We had a little surprise about the reaction during the third part. He looked at the robot sometimes and then he hit the table or

played the xylophone once or twice. The discovery brings us much confidence of the experiment. The teacher and we believe that the hypothesis may come true if we repeat the experiment more often.

However, we did not receive as good results from Shan as from Ming. For the girl, she did very well in the first time, and the teacher said that she loves the novelty. We can observe that situation of the girl has become worse and worse every week before week 5. The teacher said that maybe she was in a bad mood because she has woke up just after she fell into sleep. We can see that even she had to be forced to play the xylophone in week 4. Therefore, we do the experiment start from the girl, and the result was much better than the past few weeks. However, we do not receive much progress in week 6 and week 7 about Shan.

They were both distracted in week 6. Only during the first phase, they paid attention on the robot because of the new song. As a result from several weeks of experiments, we observed that we cannot predict results easily because there are too many factors in experiments with human.

2) Test Paper

We have designed two test papers; one for children, and one for the teacher. The feedback from the children is very good. They like the robot, the music, and play the xylophone. We are glad to see these results from the child. However, the questions of test papers for the teacher are more complicated.

The questions of the paper for the teacher can be separated into two categories, including the adaptive behavior and music interaction. The questions that belong to adaptive behavior are discussing about the communication way and social interaction between them and the people around them. Moreover, the questions in the sort of music interaction are concerning about the reaction of playing instrument and the conditions throughout the experiment. The definition of the score is based on the difficulty of the action. For example, if the action never happens, it will get 0 point on this item; if the action happens sometime, it will get 2 points on this item; if the action always happens, it will get 4 points on this item. The average score is calculated by the final score divided by the number of questions.

Let we discuss the analyzed results from the test paper that begins from the adaptive behavior record (see Fig. 5). For both children we can see that the average score is increased from the beginning to the end of the experiments. As a consequence, we heard that the way they get along to their parents and their peers has been improved. The communication part results from observations of behavior and reaction when someone talks to them. The social interaction part is taken from observations of interaction between the autistic child and others. Although the scores decrease in the last few weeks with Ming's record, we can still see the progress compared to the beginning. The physical and psychological conditions are also important factors to influence these two children.

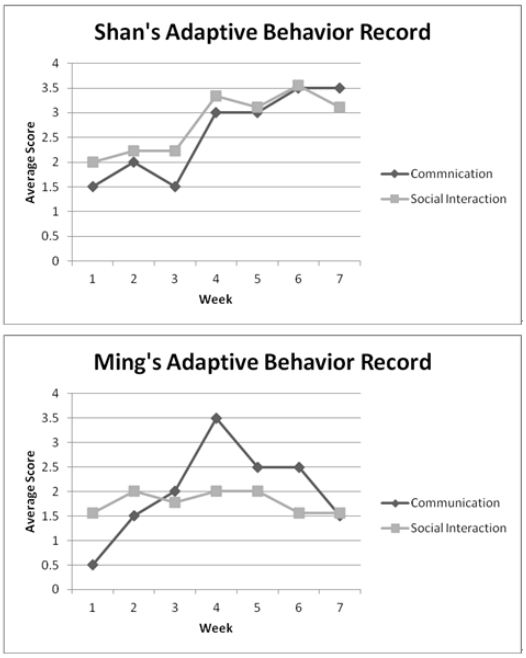

Fig. 5. It is Shan's Adaptive Behavior Record Chart, and top for Shan, bottom for Ming.

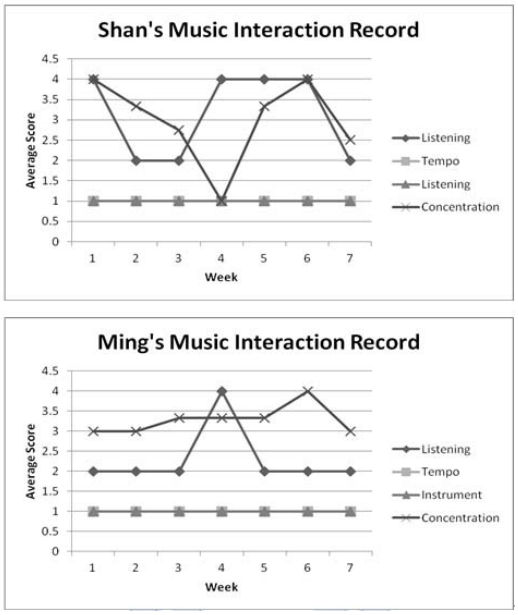

Fig. 6. It is the Music Interaction Record of two children, and top for Shan, bottom for Ming.

The results of music interaction record are all corresponding to the experiment results (see Fig. 6). Shan's concentration is decreased every week until week 5, and Ming pays more attention on the robot in week 4 seen the record. The tempo and instrument parts are all the same in the past few weeks. They all played the instrument on their own, and didn't make any imitation. We could observe that the robot really had some attraction to them. However, the attraction was weakening in the last few weeks for the children. We

believe that the result would be more obvious if we had more time to do the experiment continuously.

V. CONCLUSION

Although the children did not do any imitation to the end, we can see the progress from the test paper and experiment every week. They really improved in the first and second phases, and it means that they start pay attention on one thing. More important their concentration grew significantly. The teacher told us that Shan cried and got angry when she took her back to classroom. Besides, she would get rid of the teacher's hands and rush into the room when she saw the robot from the window every week. This means the robot really had a great attraction to those children.

In addition to the improvement of concentration, from the test paper we can see the relationship became better between the autistic children and others. Therefore, we considered that the interaction with the robot let them know that the way get along to each other is mutual. Just like they played the instrument, and the robot will imitate them. Even though they cannot imitate the robot, they have learned something in this experiment.

Imitation is really difficult to do for autistic children. We thought the experiment can help them to learn this skill, but we failed. The problem was that the learning progress had to be too fast from second part to third part. It is hard for them to understand that the robot is imitating them, let alone they imitate the robot. Hence, we should improve the procedure of the experiment.

This kind of experiment always has lots of uncertainties, and we don't know the reason sometimes. It will be better if we take more time to do the experiment or go to the next step. We should improve the procedure to conform the need of the autistic children. Every individual is unique, so does the autistic child. The symptoms of each autistic child are different, so the treatment shall be different as well.

The research of robot playmate to autism conducts for years. All we want to do is to help these autistic children can integrate into society, and take care of themselves. It is also the only hope for their parents. We will move forward on this way continuously. Moreover, we hope that we can find a better and effective way to teach the autistic child how to live a better way in their future.

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