

A Study on the Effects of using an Eco-Friendly Cat Robot to Treat Children with Autism Spectrum Disorder

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Abstract

This research studies the effectiveness of treating children with Autism Spectrum Disorder (ASD) using a cat robot developed to enhance their social interactions. Researchers from the department of social welfare, electrical engineering, and design conducted an interdisciplinary fusion research for this purpose. Children with ASD tested the developed robot over five sessions and its effectiveness was analyzed. Results showed that most participating children showed increased meaningful interactions with the robot and teachers and the robot's potential use was confirmed as a treatment medium for ASD children.

Keywords: Autism Spectrum Disorder (ASD), Effectiveness, Interaction, Robot Therapy

1. Introduction

One in 68 children are diagnosed with ASD, showing the fastest increasing rate (Center for Disease Control, 2013). Characteristics of ASD children are social interactions disorder, communication disorder, repetitive stereotypy behavior and limited attention.

ASD children exhibit extremely disparate characteristics regarding socially expected or required behavior, skill, execution, learning, and language. Difficulty, especially in social interactions, is a main characteristic¹. Difficulty in social interaction hinder developing communication and recognition skills for ASD children, which in turn affect their difficulty in social interactions, contributing to overall delayed development and disorder^{2,3}. Howlin⁴, Hall, et

al⁵ regard ASD children to find social skills that make up the basics of social interactions challenging, such as fixating the eye, reacting to someone calling or playing, pointing out, or imitating³.

It is important to pay attention to the fact that ASD children have shown positive reactions to robot stimulus in their interactions with the robot as well as increasing interactions with others⁶. Existing therapeutic robots for autistic children such as the robot KASPER, ANTY, Probo⁷ can exhibit various emotional states on their faces, which facilitate long-term treatment teaching children social interaction skills. Robotic treatment approaches for autistic children, such as the recently developed Japanese robot Mylo⁸, have reported to have been successful in inducing high level social interactions⁹⁻¹². ASD children

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express their interest better during social interactions with the robot because ASD children hold a familiarity with robotic objects¹³. Social interactions of ASD children can be improved if the robot's functional aspects can be diversely utilized to fit the demands of the children^{13,14}.

2. Background

This study developed a treatment-use cat robot to improve the social interactions of ASD children. The department of social welfare identified required treatment components of the robot through FGIs with professionals, while the department of electrical engineering presented technical aspects such as materializing functions like typical movements and emotional exchanges with humans. Also, the design department developed the robot's external design and eco-friendly material examined insecticidal effects against house dust mite from ethanol extracts of three herb teas and cacao. Materials for existing robots are limited to hard plastics or synthetic hair which may pose health problems for the children using the robot. Development of substitute natural materials was imperative. This study developed a natural functional material with insecticidal effects and antimicrobial activity by treating herbal tea fibers.

2.1 Therapeutic Components of a Cat Robot Required for the Early Treatment of ASD

Cross-academic professional clinicians were focus-group interviewed twice and guardians were focus-group interviewed once to investigate the necessary therapeutic components of the cat robot for treating children with ASD. Two series of FGI records were all recorded, transcribed, summarized and organized into common categories.

The treatment components the cat robot should contain included emotional expression, implementation of social actions, ability to make eye contact, and ability to emulate actions. Specifically, first, it must be able to act and express emotions appropriately in order to socially interact with children with ASD. Second, it must induce more frequent social behaviors from ASD children and expedite their joint attention. Third, it should move in a way that increases eye-contact or provides other visual stimulus. It should motivate movements such as eye-contact, verbally responding when called, or looking in the robot's direction. Fourth, the robot should imitate

the child's actions in order to attract his or her attention. A final function that would be desirable is a turn-taking function whereby the child and robot can take turns sequentially reacting to the other.

The cat robot's default position is designed with its hind legs stretched out in a sitting position and leaning on its front legs. The reason is this position makes it easier to make eye contact, be hugged, and imitate children's actions. Joint allocation, facial expression, and sensory systems were suggested to realize the aforementioned elements. As a therapeutic medium, the cat robot must consist of several therapeutic components.

2.2 Design Development for a Cat Robot

2.2.1 Character Design of a Cat Robot

Basically, an appearance of a cat robot must be looked like one of a cat. The number of species of cats are more than fifty all around the world, that have so various appearances, depending on the species. Not only different color and length of hair, but also the sizing proportion of ears, head, body, arms, legs and tail show much difference by the species. For treatment of autism spectrum disorder for child, a cat robot is required of more natural and easy-understandable interaction with a man. As a method for this, if given a character to a robot, the robot's act would have a consistency, and the men would feel the higher existence to a robot, and could have the easier understanding of a robot's act¹⁵. The character of a cat robot, for the early treatment of autism spectrum disorder for child, needs to be personified for looks like not a cat's character but a human's character¹⁶. Applying personification which projects a shape of an animal or a human onto the shape of a robot has a man come close more friendly to a robot, and makes the character of a robot to be delivered to a man through an appearance or movement in an easier. When applying the personification of a cat robot, the character of both an animal and a human must be considered. Because, in the animal personification, non-verbal communication area such as shape of appearance, non-verbal act of a man and behavior act of an animal are very important. The important elements that reveal the character of a cat are a direction of expressions and a handling of eyes. The expression of both an animal and a human presents an internal emotion. Dong-Kyu Lee¹⁷ analyzed the existing studies to abstract a fear, anger, a sorrow, happiness and disgust as common emotions of a man, to develop the tool for the management of robot's reacting

motion¹⁷. On this study, it would be proceed with five emotional expression of a cat robot substituting disgust with an interest. Because, with regards to the early treatment of autism spectrum disorder for child, the expression with simple and basic essentials would be considered more effective than too much emotional expression.

2.2.2 Behavior Design of a Cat Robot

Furthermore based on the shape of cat's face among inverted triangle, long and rounded ellipse or round, the feeling could be changed much. So, it must be studied for the preference and recognition as to this appearance's proportion and shape. Also, for the cat robot to take several personified actions, there need many sensors and driven motors. Due to these environmental conditions, the proportions of cat robot could change, compared to the real. For the design of a cat robot, cat's action must be concerned first of all. A cat should have various emotions and show her emotions with whole body such as facial expressions, tail, ears, acts and etc. When a cat comes close with her tail upright, it means 'I'm hungry, please feed me. When a cat feels scared, she suddenly rolls her tail into inside of her body, or on the contrary she makes her tail big to be lift up. In addition, when a cat shows curiosity looking at something, she moves her tail-end slowly. But, for the early treatment of autism spectrum disorder for child, not only behavioral act of a cat but also personified act such as 'hugging', 'eye contact', 'parrot' and 'reaction to an inappropriate act' etc. must be applied. To hug like a man, the first pose of a cat robot must be shaped in a seating posture with her hind legs stretched forward and her forelegs upright. The usual figure of a cat robot was set up as a figure of seating posture with her hind legs stretched forward and her forelegs upright. It was the easier posture to make an eye contact/hug with the children and follow the motion of child. The usual expression of a cat robot was set up as soft, friendly and tender. Because, it was studied that the warmer and tender of the robot's appearance like a friend, the more gain the sympathy¹⁶.

2.3 Electrical System Design

2.3.1 System Hardware

Building a cat robot for the treatment of ASD children should be considered the action for the emotional expression on the face and body. Cat robot takes after and does similar action with real cat. Head unit of the robot is very

important to represent the emotion, so it has two eyes, eyebrows, mouth, and ears like a cat. They are driven by 9 electrical motors, arranged separately and controlled by individual motors. Expression using face is realized with combination of their motions. In the forelegs, three joint were placed at each leg and used to make some human-friendly gesture. In the right and left hip, two hind legs were designed to create stand-down or stretching, and one joint to make the tail waving. In connecting the head and neck of the body, two degrees of freedom were implemented for shaking and nodding of the face. In summary cat robot has a total of 19 degrees of freedom. The overall structure and specification of the robot are shown in Figure 1 and Table 1.

As shown in the figure, cat robot has an initial posture sitting on the table, only vends upper body using hip joints, and does not walk like real cat. In addition various types of sensor system were installed on the skin or under the skin in order to give robot-human interaction related with intelligent behavior and sympathetic action. Several capacitive contact sensors are placed on head, back, belly, and each leg, which can detect the user's touch. The cat sound can be reproduced through audio Codec and speaker. Sound effect is essential to make interaction each other, especially ASD treatment. An infrared is used to catch the motion when somebody moves into certain distance. It can be able to measure the distance and direction between user and robot. In the waist, 3D gyro was installed to measure the orientation to check out tilting, lifting, or hugging according to the user's feeling. All the proposed motion is predefined and stored in the memory of a robot controller and also be controlled by remote

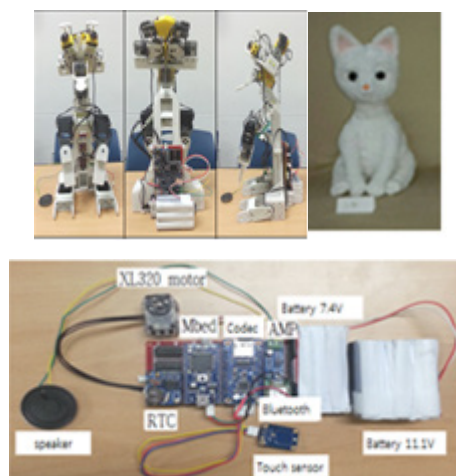


Figure 1. Cat robot body frame, skin and controller.

Table 1. Robot specification

Actuator	Dynamixel AX-12(1.5Nm , 4 units), MX-28AT(2.3Nm,2 units)
	Actuator Dynamixel XL-320(0.39Nm) : 13 units
Weight	2Kg(including battery)
Height	40Cm
Inner skin	None
Outer skin	Artificial fiber(antibiotic, flavor)
CPU	Mbed(NXP LPC1768 based on Cortex-M3)
Orientation	myAHRS+(3D Gyro)
Touch	MPR121 based (I2C) : 6 units
Sound & speaker	VS1053 based (SPI), AS04008CO-WR-R(8Ω)
Balance	L3GD20 based (I2C)
Battery	LG Chemistry 18650,11V, 5200mAh(3.7V 2600mAh Lion, 6)
Network	Bluetooth, Wi-fi(CC3200)

operator on the web through Wireless Internet (WiFi),so it is controlled by downloading command on the web. In this way we can easily collect useful therapeutic data during the play, and the teacher or operator can control the robot remotely as a medium of treatment.

2.3.2 Basic Operations

Using a previously designed body and a controller, some basic operations are suggested. They consist of the several reference operations, which can express the movement of body and face at the same time. Each operation based on the information of the touch sensor mounted inside the robot is created to see reaction of the child followed by contact with specific region according to the intention. The operation is accompanied by voice sounds for each step in order to enrich the effects. First of all, hand gesture is implemented as a greeting action shown in Figure 2. This operation can be used as a behavior to express a positive emotion when faced at first time. The act of expressing friendliness to ASD child can be represented as a positive message. In operation, it first lifts the right foreleg vertically requiring the more follow-up action like shaking with hug gesture, and this operation can be able to concentrate more on the treatment for children.

**Figure 2.** Hand gesture.

The following operation is foreleg-shaking with robot. It is used to drive the touch operation stretching out his foreleg. If a child contacts the foreleg, it produces a motion as if to shake hands. Once in contact, the robot performs with shaking foreleg three times up and down, and speaks the welcome voice. This operation intends to drive a more intimate contact from the ASD children.

**Figure 3.** Shaking foreleg.

This behavior is dynamically to move the left and right forelegs back and forth and throw them out forward. This operation requests more positive action to the child to play and has the most wide operating range than the other action. If the child carried out responding in a passive way depending on the catch, the robot express the most active movement significantly in performing operations.

Following movement is bending the upper body to the floor completely. The purpose of this operation is to represents the meaning of the active audit. A high torque motor in the thigh is designed to fully withstand the load of the body and this operation needs the further study to make the consecutive action. This behavior is doing in parallel with generating the voice sound that could be available to express the aggressive behavior.



Figure 4. Waving forelegs.



Figure 5. Bending down and up of the body.

2.4 Materials

Materials for existing robots are limited to hard plastics or synthetic hair which may pose health problems for the children using the robot. Because materials of the existing emotional robot is cold, hard plastics or synthetic hair, most images.

However, the emotional robot made with plastic material does not give users the pleasure and tranquility in interaction with users and the robot due to the characteristics of the plastic material; they are not helpful in the

treatment of children with developmental disabilities. In addition, even in a faux fur animal utilizing the touch of a real robot, the users can't avoid respiratory allergic symptoms like bronchial asthma due to house dust mite and chronic rhinitis, bronchitis through the emotional exchanges with the robot and users. Therefore, it is necessary the development of a functional material that has the insecticidal effects on house dust mites and antimicrobial activity on bacteria to protect the emotional robots' users from hazardous environments, such as house dust mites, as well as harmful microorganisms present in the life space. The synthetic house dust mite inhibitors and antimicrobial agents are being treated in fiber. But such cases, a skin disorder as well as pollution can cause by the gradual exit from the fiber. Therefore, the development of natural functional materials that can replace chemicals is imperative.

Herbs used for cooking and medicinal as well have been used as a food spice bath and beauty products were produced from the example has been used in the dairy products such as dyes, detergents, insect repellent with. Herbs have been used as dyes, detergents, and insect repellent from of old. Despite the advances of modern medicine and technology, herbs have become commonplace in alternative therapies and treatments such as aromatherapy. The purpose of this study is to develop a natural functional material with insecticidal effects and antimicrobial activity by treatment of herbal tea in fiber. Thus, we try to help in the health and emotion treatment of children with developmental disabilities.

3. Method

3.1 Test Method

This study observed the reactions of ASD children while they interacted with the robots through the participant observation method in order to evaluate whether the play and language programs utilizing the robot had treatment value for ASD children (Figure 6).

3.2 Participants

3.2.1 Research Subjects and Traits by Child

Research subjects are five ASD children are shown in Table 2 using a disability center's treatment program in J-municipality. Individual traits by child are as below.

3.2.1.1 Child A (M/6 Years Old)

- Cognitive development level covers recognizing that objects operate when a button is pressed but intentional execution is difficult.
- Social development level covers indifference to the actions of others and difficulty in eye-contact, observation, and imitation.
- Linguistic development level covers four-months level, severely lacks linguistic comprehension or expression, and voluntary vocalization is rare.
- Additional: The child is easily distracted, unable to observe an object for a long time, and frequently exhibits stereotyped behavior such as banging one's head on the floor or grabbing and shaking an object.

3.2.1.2 Child B (M/10 Years Old)

- Overall cognitive function level is good. Can execute verbal instructions but execution ability varies widely depending on his condition that day.
- Social Development level: Exhibits low sociality, testing 6.0 years old in sociality age in the social maturity test, expresses emotion in limited words or screaming, and tone is quite high.
- Linguistic development is younger than 2 years and 6 months old; nearly no voluntary expression unless in pressing situations.

3.2.1.3 Child C (F/10 years old)

- Social Development level is 1.58 years old in sociality age according to the social maturity test, showing a very low level of development.
- Linguistic development is also extremely delayed, testing 14 months old according to the infant linguistic development test.
- Additional: Shows curiosity regarding new objects but is scared to directly touch it or operate it, usually holding someone else's hand and asking others to operate it for her.

3.2.1.4 Child D (M/4 Years Old)

- Same cognitive functions as peers.
- Social development level is 4.8 years old in sociality age.
- Linguistic development level is four years old, the average of peer children.

3.2.1.5 Child E (M/9 Years Old)

- Cognitive development level is being able to understand and follow verbal and behavioral instructions and can also imitate actions.
- Social development level shows that he cannot easily interact with peers and shows stereotyped behavior, self-harm, or wanders around alone during group activities.
- Linguistic development level shows that he can comprehend questions and can respond with yes, no, do not like, cannot, can, and such simple responses. However, they are often mechanical answers and overall do not talk.

Table 2. Participant

	Gender	Age	Diagnosis	Type of Therapy
A	M	6	ASD/ Brain Lesions	Speech T
B	M	10	ASD	Speech T
C	F	10	ASD	Speech T
D	M	4	ASD	Play T
E	M	9	ASD	Play T

3.3 Experimental Structure and Procedures

Each child experienced 40-50 minute treatment sessions with the robots and designated language therapists and play therapists once a week over five weeks. The treatment process was video recorded with permission from the guardians of the children, data was analyzed, and the designated therapists were consulted after each session.

3.4 Data Collection and Analysis

Data was collected through participant observation and video recording over 23 treatment sessions from March 10th 2015 to April 7th 2015. One therapist, one researcher to operate the robot, and one researcher as the participant observer participated.

The participant observer observed the ASD children's response patterns during their interactions with the robot. After one session is over, the participant observer and therapist discussed the individual child's characteristics and changes, and agreed upon which actions and responses should be more closely observed in the future, which were then reflected in the children's future sessions. Also, field notes were improved by consulting the video recordings to produce the observation journal.



Figure 6. Experiment Scene.

Special education teachers were consulted about the observation records and analysis contents after the experiments were over in order to enhance the accuracy and confidence of the observations.

4. Results and Discussion

4.1 Each Child's Change

4.1.1 Child A

- He usually could not hold eye contact and had low attention and concentration levels but he held

eye contact with the robot and his interestedness increased during treatment sessions with the robot.

- When the robot made noise and fell after having contact with the child, the child fixated on the robot for a few seconds and then lifted it back up, a positive action.
- As the session went on, the child actively approached the robot or, after discovering that the robot makes noises when its neck part is touched, showed interest and repeatedly touched the robot.
- Actions of laying the robot down and then raising it back up increased as the session went on and

showed friendliness from the beginning of the sessions by holding the robot's hand.

- Social interactions with the robot were enhanced and reaching functions and hand-eye coordination increased overall.

4.1.2 Child B

- He usually could not hold eye contact with unfamiliar people or objects but showed interest and held eye contact with the robot from the first session, showing actions such as drawing it nearer and touching it.
- He was seen rubbing his face on the robot as though its fur feels nice and smiling comfortably.
- When the therapist asked him to say hi to the robot or point to its eyes, nose, and mouth, he appeared to respond to these requests.
- He frequently looked in the mirror during treatment sessions previously but after the robot appeared, he looked in the mirror much less often and showed increased concentration during sessions.
- He expressed friendliness by hugging the robot and as the session progressed, his facial expressions were brighter and seemed to be enjoying the time. He responded sensitively to the sounds and actions of the robot.
- When the robot asked him to show the robot a book, he turned his favorite book towards the robot. Other types of behavior involving sharing things he likes were observed.

4.1.3 Child C

- She showed strong guardedness and hostility against the robot in the first session. She did not want to go near the robot and when the robot was brought near her she would push it over several times. She was extremely cautious about the robot's movements and showed aggressive behavior such as throwing the robot when it moved.
- She began to increasingly show positive behavior such as waving the robot's hands, kissing it, or hugging it from the third session but still both curiosity and cautiousness regarding the robot can be observed.
- As the sessions progressed, behaviors such as throwing or pushing over the robot decreased and
- Touching, hugging, or playing with the robot relatively increased.

- In the final session, she actively expressed friendliness by touching the robot's hands and face when it made the noise "hello." She held the robot's hand and waved it in a friendly manner and brought the robot's hand to her face as well.
- When the child handled the robot roughly and the therapist requested, "It hurts if you do that. Please touch it softly," the child improved her behavior by treating the robot more carefully.

4.1.4 Child D

- He did not show hostility or unfamiliarity with the robot from the first session and greeted the robot.
- When the robot made a crying noise, he suggested to feed the robot because it was hungry and then brought over a fishing game and caught the fish and fed it to the robot. When the robot showed dancing movements he told that the robot liked the food, inferring the counter party's feelings. He also allowed the robot to participate in games and act as a friend.
- However, he showed lack of interest in the robot at the third session and said he would not play with the robot anymore.
- This child had relatively higher levels of cognitive abilities compared to other children. Therefore it can be inferred that he easily lost interest due to the limited sound and movements of the robot.

4.1.5 Child E

- The child was comfortable with the robot from the first session, hugging or touching it.
- The child usually did not speak at all during previous treatment sessions but once he was with the robot, his verbal expressions increased such as saying "hi" or "bye."
- He would pet the robot and when the therapist said the robot was moving or dancing, he would imitate those behaviors.
- When he was not allowed to touch the robot for negative behavior, he would stop that behavior, implying that he liked interacting with the robot.
- As the treatment sessions progressed, concentration levels increased and hand-eye coordination and attention-concentration levels improved such as accurately pointing out not only the robot's body parts but also his own using the robot's hand according to a song.

4.2 Common Changes Shared Across all Children who participated in this Study

First, the level and span of concentration increased because the children showed greater interest and attention to the robot compared to other existing treatment mediums.

Second, children improved their interest and intimacy towards the robot by naming it, singing to it their favorite song, or looking for it after returning home.

Third, considering ordinary behaviors and reactions of children, unexpected reactions were exhibited. For example, children mostly reject the first time they encounter an unfamiliar treatment medium, but some children showed interest in the robot even during the first time.

Fourth, it was frequently observed that the children was in direct contact with the robot such as rubbing the face or hugging it because of the robot's smooth textured skin.

Fifth, the more serious the level of autism, the children generally exhibited more negative behavior than other children such as aggressively throwing or slamming the robot or roughly handling it. However, as the treatment proceeded, the intensity and frequency of the negative behavior appeared to decrease.

The results of conducting play and language therapies for ASD children using a robot indicate that the level and span of concentration was higher and longer than existing treatments and the children especially showed greater reaction to texture and sound. The potential use for the robot as a treatment medium was confirmed as positive social interactions were observed such as various interactions with the robot and increased instances of behavior imitating the teacher.

However, the fact that children appeared to show rather lower rates of interest as the sessions proceeded and that the treatment value was low for children with extremely serious ASD should be reviewed. Future studies should focus on sophisticating the initial model of the cat robot and improve problems that surface in experiments. Future studies on the treatment value over the long term or with various age and types of disorder are needed as well.

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