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A Robotic "Puppet Master" Application to ASD Therapeutic Support

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***Abstract*—**This paper describes a preliminary work aimed at setting a therapeutic support for autistic teenagers using three humanoid robots NAO shared by ASD (Autism Spectrum Disorder) subjects. The studied population had attended successfully a first year program, and were observed with a second year program using the robots. This paper focuses on the content and the effects of the second year program. The approach is based on a master puppet concept: the subjects program the robots, and use them as an extension for communication. Twenty sessions were organized, alternating ten preparatory sessions and ten robotics programming sessions. During the preparatory sessions, the subjects write a story to be played by the robots. During the robot programming sessions, the subjects program the motions to be realized to make the robot tell the story. The program was concluded by a public performance. The experiment involves five ASD teenagers aged 12-15, who had all attended the first year robotics training. As a result, a progress in voluntary and organized communication skills of the five subjects was observed, leading to improvements in social organization, focus, voluntary communication, programming, reading and writing abilities. The changes observed in the subjects general behavior took place in a short time, and could be observed from one robotics session to the next one. The approach allowed the subjects to draw the limits of their body with respect to the environment, and therefore helped them confronting the world with less anxiety.

***Keywords*—**Autism spectrum disorder, robot, therapeutic support, rob'autism.

I. Introduction

A. Rob'Autism Project

ROB'AUTISM is a therapeutic support for autistic teenagers using humanoid robots. It results from the collaboration of four partners, linking medical, arts and sciences fields: the hospital of Nantes (day psychiatric department, CPGEA), the engineer school *Centrale Nantes*, a non profit organization (*Robots!*, dedicated to robotics and arts) and a cultural center (Stereolux). The project was born in 2014; the first year program was applied in 2014-15 [14] and the second year program (this paper) in 2015-16. Rob'Autism consists in 20 sessions of 1 hour each, once in a week. The sessions alternate 10 preparatory (non-robotics) and 10 robotics programming work groups. The first year program organization and results were presented in Sakka et al. [14]. This paper focuses on the results obtained during the second year of the program, which was attended by five teenagers with ASD (Autism Spectrum Disorder) who had attended the first year program. As Rob'Autism program is only starting, the results presented here are preliminary: an introduction to the work performed and a description of a new approach before realizing proper statistics.

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B. Literature Background and Positioning

Using robots for autism therapy is more and more common, as ASD people have a strong attraction to electronics objects [2], [15]. Also, many robots are now available for purchase at reasonable costs. Different research groups working in this area can purchase the same robot and share their observations, their results not being influenced by the different appearance of the robots. Previously, robots were self-built by a given research group, so had specific shapes and capabilities.

The robotic adventure for ASD people started in the late 90s with the research of I. Werry [18] and K. Dautenhahn [3], [4]. It arrives with the Aurora project (1998), a fist international reflexion on how to use robots in autism therapy [6]-[8], [13], [19]. The first robot was a wheeled mobile platform, but quickly was observed that the humanoid shape had an easier grip on autistic children [12]. Then the humanoid robot NAO (SoftBank Robotics) was first commercialized in 2009. This robot is "cute" and "easy to use", most people (autistic or not) enjoy its charming appearance. It is affordable for most institutions. Many new studies using robots for autistic applications were started since NAO arrival, in the past five years [16], [17].

The ways robots are used in autistic therapy have not changed since Werry and Dautenhahn's first use: the *robot companion* approach is adopted by all. In this approach, one robot is used with one ASD child or with a group of ASD children. The robot is programmed to solicit the child, who is expected to answer properly. For example, the robot shows three images on the table between it and the child: an apple, a car and a boat. Then the robot asks the child to point the apple picture. The child selects an image, puts it in front of the robot camera. If the answer is correct, the robot congratulates the child and starts a new exercise. Otherwise, it asks the child to try again. It was observed that solicitations are better answered when they come from robots than from adults [15]. It was also observed that the progress during therapy was greater with robots than using animals [11]. A big advantage for the robots, is the fact that it can formulate words, and therefore instructions, whereas the animal effect is limited in terms of socialization. Using a robot for autistic therapy was questioned, in terms of *how to replace the robot by human beings in the subjects' social skills?*. Basically, the idea is

that the *robot companion* communicates in the same way than a non-autistic adult would, and can slowly be replaced by a person. All studies were directed in that sense, varying the type of solicitations depending on which skill(s) the subjects was expected to improve. Currently, several software companies participate in the search of *robot companion* software for autism applications (SoftBank Robotics, Auticiel, Blue Frog Robotics, aso.).

The *robot companion* approach showed very nice results, and is with no doubt the better therapy support found for autistic applications up to now. Indeed, the subject with ASD shows nice abilities to answer a solicitation from a robot. But the *robot companion* has its own character and personality, that may be incompatible with some subjects, or limit their improvements. For example, this approach limits the subject's ability to express himself, or to act by his/her own will on the environment, or to organize its relation to the world: when the solicitation stops, the person's behavior stops too.

In Rob'Autism project, we propose an alternative approach to the robot companion: the robot is used as an extension, for talking and doing things. The autistic subjects program it, and therefore act on their environment freely. They can say things, by making the robot say them, and do things, by programming the robot to do them. They act on the world as puppet masters, protected behind the body of the robot. On a first application of this approach in 2014-15, 6 ASD subjects made considerable improvements in their social and communication skills [14]. Five of them continued the program the next year, and their progress also continued at the same velocity. This paper relates the second year program presenting the subjects and experimental environments (Section II), the organization of the 20 sessions (Section III) and the results (Section IV). In the last section, we also extend our analysis to explain the three used concepts for building this approach efficiently: the puppet master concept, the work on the subjects' voices and the half-space concept, particularly relevant in autistic situation. Another innovation of this work, is the use of three robots during the working sessions, each robot being shared by two subjects ("individual sharing"). When a programming exercise is completed by the three groups, the work stops and everyone looks at what was just programmed ("collective sharing").

II. Experimental Environment

A. Subjects and Material

Five teenagers aged from 12 to 16 years old participated in this experiment, 4 boys and 1 girl. These test subjects suffer from autistic spectrum disorders. The 5 subjects have some ability to read and write, and they all participated to the first year program [14], which had stopped 6 months before the second year program. The locations and staff of the preparatory and robotics sessions were chosen the same as the previous year, so the working environment and people were familiar to the subjects.

The program uses 3 humanoid robots NAO from SoftBank Robotics. The robots are programmed by the subjects using the software interface *Choregraphe*, which is the classical programming interface sold with the robots (i.e., no specific software was used for the programming). We may note that the programming interface is in English and the subjects do not speak English. Nevertheless, this language specificity did not affect their will to make the robot talk or move.

B. Organization

20 sessions of one hour were organized, alternating 10 preparatory and 10 robot programming sessions. The robotics sessions are dedicated to making the subjects program the robots. They are organized as follows: two children per robot, using the same computer. The working tables are in the center of the room in such disposition that each group can see the two other ones. Each group is assisted by one caregiver trained on using Choregraphe. A speech therapist and a robotics specialist are also present in the room to help with specific programming requests and session supervision. When the teenagers enter the room, they find the robots and computers always at the same place. The computers are switched on, but not the robots. The robot programming sessions take place at Stereolux, a few kilometers distant from the day hospital (travel by car). For the preparatory sessions, a sound specialist accompanies the work of the 5 teenagers, together with the same three caregivers and led by the speech therapist. The room is located at the CPGEA center (at the day hospital), with no tables but cushions on the floor. As previously mentioned, the environment, places, devices and people are familiar to the five subjects during this experiment.

III. Second Year Program

A. General Matters

Before starting the program, the hospital staff (three caregivers and speech therapist) were re-trained to program the robots (4 hours of training). Even though they have some autonomous knowledge in robot programming, a programming specialist must assist to the programming sessions, to recall specific functions and help locally. The training of the medical staff was performed in December, 2015 and the robotics sessions started in January, 2016.

As an original approach to this second year program, the teenagers were asked to write a story (preliminary sessions), and to make the robot tell it (robot programming sessions). We will mention the effect on their focus during the results section. First, we thereafter describe the content of the 20 sessions.

B. Preparatory Sessions

The 10 preparatory sessions were dedicated to writing the story, record sounds and voice-over and prepare the decor for the show. They were distributed as follows.

- Session 1 : Brainstorming on ideas for the story. Each subject mentions points and facts he/she would like to talk about. Result: at the beach, several characters, playing, holidays.
- Session 3 : Story context: decide the number of characters, their description, relation between characters, what they are doing, how they introduce themselves. Results: four friends (three boys and one girl), meeting

at the beach to play football and eat during the holidays. Writing (1)

- Session 5 : Story: what happens? Result: the girlfriend of one character calls for help in the sea, as she is going to drown. Writing (2). Recording sounds, atmosphere of the beach (1).
- Session 7 : Story: How do the characters react to the action? How does it end? Result: they develop super powers; they save the girlfriend, they get married. Writing (3). Recording sounds, atmosphere of the beach (2).
- Session 9 : Story: writing the dialogs. Recording sounds: super powers.
- Session 11 : Story: writing the voice-over. Recording sounds: atmosphere of celebration (choice of music).
- Session 13 : Recording voice-over (1) and sounds.
- Session 15 : Recording voice-over (2).
- Session 17 : Making decors for the scene (1).
- Session 19 : Making decors for the scene (2).

To create the story, several steps were performed: 1) We have grouped a set of topics the teenagers could talk about (group work). Example: at school, at the beach, inside / outside, at the mountain, coming back from holiday / during holiday / before holiday, during weekend, aso.; 2) We have isolated topics (from the list) each teenager, alone, wished to talk about (individual work); 3) We have selected the resulting most desired topics and stuck to them until the end of the program. Fortunately, all the teenagers chose the same topic: a story during holidays at the beach. But they disagreed for the choice of the characters, so a negotiation was made between the teenagers to include a female character. For example, one of the male teenagers first reacted by saying "if there are girls, there is no me". But in the end, the same teenager proposed the name of the girl character, "Elsa" (taken from Disney's movie "Frozen"). Four characters were slowly created, named, described, characterized. Their respective names were Elsa, Iron Man, Nicolas and Vincent. To decide what would happen to these characters, each teenager was asked to mention an idea from a set of suggestions: eat ice cream, play football, seduce, sing, talk, save someone, have super powers, and so on. From these preparatory sessions, a first set of dialogs were written and illustrated like a page of comic book, Figs. 1 and 2. Basically, the resulting story is as follows:

- Sequence 1: Four friends meet at the beach, introduce themselves and go play football.
- Sequence 2: After playing football, they decide to go for an ice cream, each with a different flavor. Suddenly they hear a girl call for help, and they see Nicolas's girlfriend drowning in the sea
- Sequence 3: they use their super powers to save the girl: one can move the water apart, another can freeze it, the third one can throw a spider web and the fourth one is a telekinetic.
- Sequence 4: his girlfriend being saved, Nicolas ask her for marriage, she says yes.
- Sequence 5: the story ends with a great celebration (music, dance).

The subjects chose the sounds associated to the beach

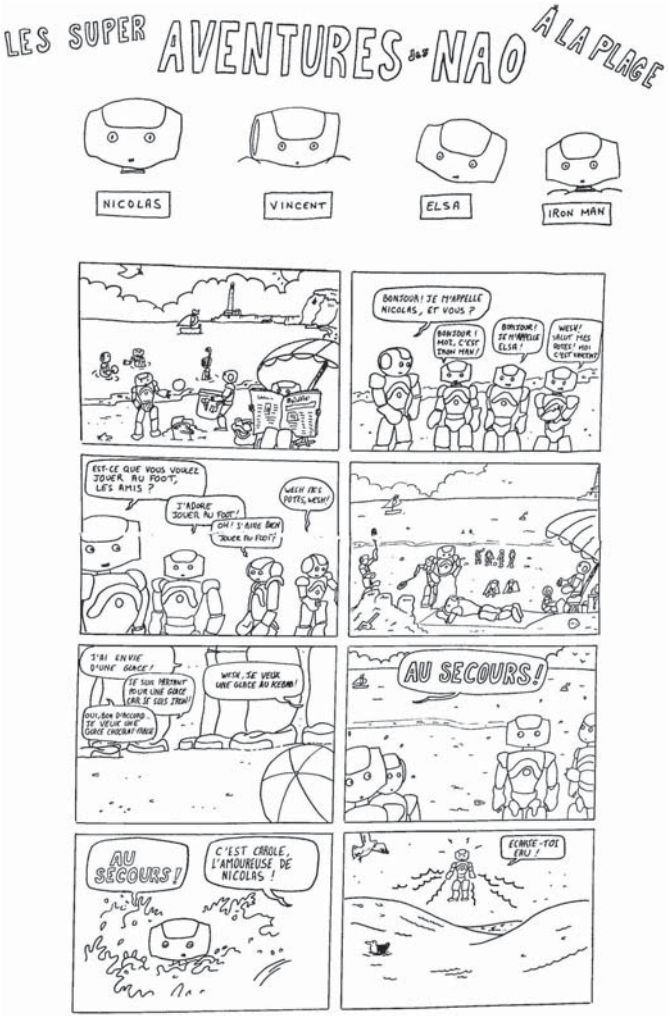

Fig. 1 First page of the story *The super adventures of NAO at the beach*, written as a comic book

and celebration scenes (played aside during the show) and the super power sounds (played by the robots). Between the dialogs said by the robots, a narrative voice-over explains what is going on in the story. The voice was also recorded during the preparatory sessions, so were made the decors around the scene (beach, celebration drawn by the subjects).

C. Robotic Programming Sessions

The robotics sessions started by recalling the basic knowledge for using the robot. Six months had passed since the previous year last session, nevertheless the subjects had memorized their lessons, and have quickly found the functions to make the robot talk and move. In this year program, they learned two main new things: 1) use the head sensors of the robot to make interactive talking with the other robots and 2) program a loop (repetitive dance motion during the final celebration of the story). The interactive talking consisted in programming three separate sentences said by one character, connect each to one of the three outputs of the head sensor. Then, pushing the first head button leads to saying the first sentence, pushing the second leads to saying

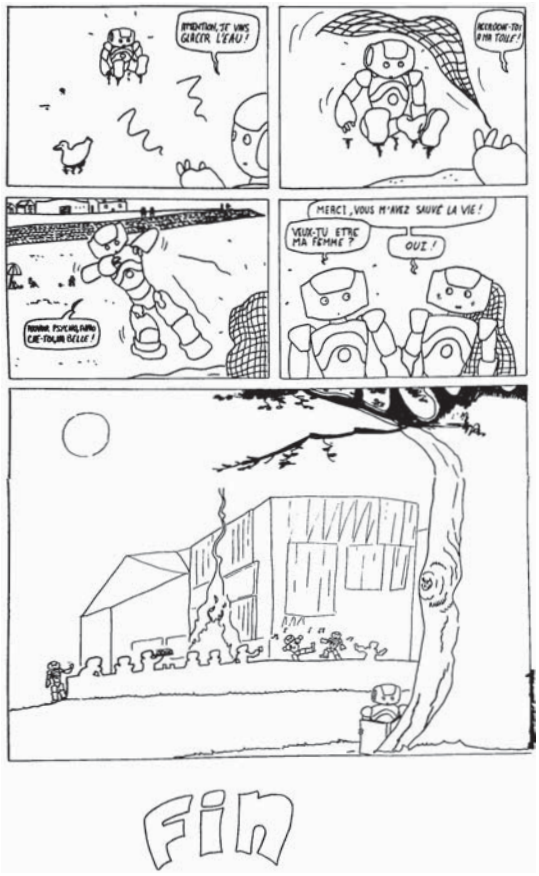

Fig. 2 Second page of *The super adventures of NAO at the beach*

the second sentence, or pushing the third leads to saying the third sentence. Each group worked on one character, enter its three sentences. When all have finished, the dialog was pronounced by pushing the correct button on the robots heads. This exercise was considered as difficult by the subjects: pushing the correct button so that the dialog makes sense, synchronizing their actions. So the exercise was repeated during several sessions, to make them feel more relaxed about it. The learning of how to make a loop seemed much easier. The global distribution of the robot programming sessions is as follows.

- Session 2 : Reminder: make the robot talk and move (from library and time-line)
- Session 4 : Use of tactile head sensor for interactive talking (1) using sequence 1 dialogs
- Session 6 : Use of tactile head sensor for interactive talking (2) using sequence 2 dialogs
- Session 8 : Use of tactile head sensor for interactive talking (3) using sequence 3 and 4 dialogs
- Session 10 : Program motions sequence 1 to 4 (1)
- Session 12 : Program motions sequence 1 to 4 (2)
- Session 14 : Program motions sequence 1 to 4 (3)
- Session 16 : Program motions for the final dance scene (make loop): leg motions
- Session 18 : Program motions for the final dance scene (make loop): arm motions
- Session 20 : Program motions for super powers (use "play sound" function to replay recorded sounds), and emotions using eyes LEDs colors

In Session 2, *library* and *timeline* are mentioned. The library of the software contains preregistered motions, such as "sit down", "get up", "wave arms" and so on. To use one of these functions, one must find and select it in the library, then click and drag it into the robot control window. Then it must be connected to the control input, and finally send to the robot which executes the requested motion. These preregistered functions are very convenient to easily generate complex motions such as sit down. But the library has a limited amount of motions, so the programmer quickly needs to program specific motions. This can be performed using the time-line. The programming consists in recording two fixed configurations, and the software generates the joints trajectories from configuration 1 to configuration 2, in a given time. The time-line gives a distribution of the configurations with time. It was first learned by the subjects in the first year program, then used all along the second year program, as this concept of extracting key fixed configurations from a motion was very complex to acquire for the five ASD subjects. They had to put the robot in a desired configuration, hold it while the other subject registers it, then put it in another configuration, register it, then play the motion to check the time. They then have the possibility to accelerate or decelerate the motion for time synchronization with the sounds or dialogs. The order of the actions was much faster learned (talk then move, or move then talk, or talk and move at the same time). The subjects were also very impressed with the loop, because they could suddenly generate a long time motion with little effort.

IV. Results

A. General Observations

The second year program started 6 months after the end of the first year program. It was observed that the subjects had not forgotten the acquired knowledge from the first year, neither done any observable regression. Having greatly enjoyed the first year program up to the public show, which they had been very proud off, the subjects made a request to completely realize the show at the end of the second year program. As a global remark, their focus and motivation remained strong during the 20 sessions, amplified by the will to finish *their* show. The working atmosphere during the sessions was nothing related to the one of the previous year, during which they had followed instructions. They wanted their programming to look nice, never forgot about the coming show and were very demanding on the quality of the result, working again on it if it did not match their expectation. When choosing the sounds to generate the beach or the celebration atmosphere, they had an idea of what the results should be. As a consequence, the generated sounds were far from the cacophony productions of the previous year.

The story actions were chosen in a large amount of propositions. The subjects selections mainly converged to the same solutions (holidays, friends, beach, save someone, have super powers), or in some cases compromises were made,

for example the presence of a girl character requested by the female subject, accepted in exchange of another male subject choosing the name of the character. Another example: the characters play football, in exchange the robots dance at the end. The five subjects have built their project till the end (the public show), claiming as their own the proposed work group.

Our first guess was that the teenagers' improvements would stabilize after some time of using a robot as therapy mediation, then another therapy would need to be defined. In the second year program, we could observe that the changes in the subjects' communication and social skills continued improving at the same velocity than the first year, as soon as the program started again. The improvements concerned focus, language (speaking, writing) and verbal communication, sharing with others, sensitivity to others (presence), taking care of people and objects, organized communication, voluntary communication, self-organization, concentration time, efficiency and robot programming abilities. Some negative characteristics considerably reduced, such as crises and self-inflicted damages. During this second year, they could better learn the limit between the self and the environment, the objects and the people, the reality and the imagination. The subjects improvements were once again impressive, especially because of the velocity at which these transformations took place. The robot-based work group worked as a therapy accelerator. The public was bigger at the second show: all the parents were present, foreigners and even a journalist could attend. They all were welcome by the subjects, who quickly sat down, their back turned to the public, facing the scene. They listened to the complete discussions after the show, the people remarks and questions. There was a long part talking after the show, when the chairs were removed (everybody was standing). Only at this moment the subjects started interacting and moving in the room. Some parents discovered skills in their children, that they did not know they were capable of. Some other expressed their pleasure to see their child's progress during the year, particularly the disappearance of the absence characteristic, of the crises, of the self-inflicted wounds, and the observation that at school they had seen their child playing nicely with other children.

B. Evaluation

The five candidates were evaluated by a child psychiatrist before and after the program. We will summarize the evaluation of each subject, and the changes observed.

1) First Subject: Most of the time, he is isolated. He takes refuge in books, always the same books, or in stereotyped motor activities. He avoids the look and any physical contact which he finds intrusive. His prosody is without any real intonation. He often formulates onomatopoeias, words or phrases from superhero movies that he regularly watches and enjoys. During therapeutic meals, he can solicit his neighbor to ask for water or salt. But it is a "ready-made phrase" that he pronounces, he does not adjust to the other, which then appears as a simple means of attaining a goal. He can, without worrying about it, accidentally hit a comrade when he seizes something on the table. As a group, he seems to be absent, but he fully perceives what is going on around him. He can also be very effective in the proposed activities. If he is offered an element, linguistic or not – a drawing for example, or a photo, in connection with his favorite movie or comics characters, he can enter into exchanges that include turns of speech. But the latter are simply an alternation of words which are never genuine contributions. Special attention to some girls was noticed. Any change generates anguish, he needs his landmarks. He has set certain routines which cannot be changed.

This subject is in a precision search with his robot. He does everything to find the exact intonations, the appropriate accentuation of the sentences taken from his favorite movies. And he does it perfectly, despite the technical limitations he encounters. We have seen him search for the faithful accentuation of the phrases he wanted to record: "Batmaaan", not "Batmannn", "aaah" and not "ahhh". These statements become, thanks to the robot, shareable. Another day is proposed a game, with the use of different clicks on the robots, that are associated with sentences. Like the others, he will make the robot respond to the questions asked by the caregivers. Sometimes in amusing ways, for example make the robot say "You're fired!", if the question does not suit him or if the caregiver is wrong. He seems much more comfortable in handling the robot than in having to go through the software. He is extremely careful to put the robot on standby when it is needed. It must be said that he takes great care of the robot and that he knows how to remind others of this necessity. One day, a robot rears up abruptly due to engine failure, loses its balance, and falls. This subject then hurries back to put the robot back to its place, and with empathy, reassures the robotics specialist that nothing is broken. During the sessions, he accepts the exchanges and an attention to the others is noticed. He can now name his comrades, take care of not hitting them when he goes close to them, and the people around him can understand better his emotions. He manages eye and hand contact with no further notice.

2) Second Subject: Placing herself in relation to time, space, and the environment is very problematic. It seems to be very difficult to have in her existence a real anchor point. She presents herself as a girl very dependent on her surroundings, addiction which makes her somewhat vulnerable. She tends to do what others do, to imitate them, to espouse the conduct of those around her, without being able to establish a certain distance. She reacts like a mirror in front of the other. If it is one thing to feel emotions, it is another to be able to situate them between oneself and the other. And it is at that point that she seems to be troubled. This concern to be able to dissociate what comes from her or from the other makes any interaction greatly problematic. Thus she can echo the sentences of her interlocutor, or struggle to understand the personal pronouns or the words of each one. She has greatly invested singing and animals, which appear as the principal objects through which she gives herself some satisfaction.

She had said it even before meeting it, she wanted to make her robot sing. It had to, she added, "heal her voice". To see it dancing was for her like a delight. However, initially,

locating herself in using the software to manipulate this object seemed very complicated. How to make it say ”I”? By writing ”you”? Manipulating the robot directly seemed much easier than using the software. She then had to go through a mirror game between her and her robot to record the movements. Today, she is more like a young girl who can locate herself, and thereby feed herself on what is brought to her. She passes by the validation of the adult to do things by herself. Her posture has evolved considerably. She can now assume what she says. Her first representation of the robot was made mainly of two rectangular blocks (head-trunk) and limbs laces. At the end, she represented on her drawings a little girl singing for the great NAO a song by Tal, ”the meaning of life”. And this robot, imagined as a girl robot, has hair. An image of the body is constituted, as is constituted a voice that is addressed to it, a consciousness of her self.

3) Third Subject: Every act is difficult for the third subject. He does not speak, or does not do. Sometimes he disperses, overflows, or even when he starts to speak, it is in a monologue, with no real link with his interlocutor then called to “plug in” on his conversation, as if he was reproducing a dialogue which was happening elsewhere. He talks to the other by constructing a narrative that is sometimes irrelevant and elaborated from external elements (often familial), as if he was organizing it according to his preoccupations. Charles always seems to be out of step with regard to the context and to the other. Interactions with peers occur in the manner of invasion which sometimes leads to a violent attitude. Charles also has many fears. illness or body changes related to puberty are hardly experienced, as if they could be threatening. Every novelty frightens him, he tends to freeze the world. He regularly has in his pocket objects that he brings from his home, which come to hold all his attention, which absorb him and put him away from the situation.

During these sessions, he seems to have discovered his voice. It took him a long time to practice his own voice. The robot first allowed him to express his thoughts, to say what he liked (music, food, caregivers) and to call others. Recording his voice and then listening to it through the robot seemed to have impressed him. When hearing himself, like the child who sees his image in the mirror, he turns to look at a caregiver and says “it’s me!”. He then made great efforts to create a personality to his character, thinking of his way of standing and speaking, especially in his intonations. Today, he no longer needs to go through the robot. From now on, he can speak “directly” to others, which was impracticable before. His words, his gestures are possible. He also seems to identify much better not only his emotions, but more generally the world. On his latest drawings, he represents a “happy” robot, with antennas used to capture surrounding emotions. The robot manifests emotions, even anxieties.

4) Fourth Subject: He is a young boy who presents himself in the mode of instability. His interventions are often inappropriate, or he will try to dominate the interaction without always taking into account the other, or else he breaks the interaction. He has little regard for his interlocutors. He always appears in exploration. He, too, always appears here and elsewhere at the same time, everywhere and nowhere. He is passionate about assemblages, he composes and recomposes, organizes and builds, without always being able to create a certain homogeneity. He groups or splits. He is particularly interested in electrical wiring and computer science. One day he was able to draw the outline of his own body with an empty interior and an exterior made of scattered and threatening elements. He seems constantly on the verge of the scattering of himself and his environment. He scratches himself up to blood, an activity on which he can be focused, and which makes its body a set of bloodied dots. Everything happens as if, since the delimitation of his body is lacking, the pain comes as a mean of attesting that his body can hold in certain places. He can isolate himself from the group by wrapping himself in cushions.

The first time he met it, he insulted the robot: “you are just a piece of wire!” (Not without echoing here the corporeal question that worries him). But finally, the disillusionment did not involve the refusal of the robot, quite the contrary. In his relationship to the robot, he studies the interior of this humanoid machine. He plugs and unplugs, manipulates the object perfectly, until he finally finds access to the images of a camera he will use to call his comrades and observe them. He takes great care of the robot, lies it down if he finds it tired, puts it on standby to prevent him to overheat, tries to repair it when it breaks down. The “corporeal” aspect of the NAO was particularly invested, as if NAO had helped him to delimit his own body which now seems to have more “bones”. He shows himself less aggressive towards the others, and towards himself (fewer scars). In his robot drawings, the interior is well-differentiated from the outside. Nevertheless, it took a long time to be able to share this object. It had to be him who manipulates, him who registers, it is he who decides the voice, the gestures, and so on. But little by little, he agreed to negotiate with his various partners: “you take the mouse, I the keyboard”. He also made connections with his family about this project, as well as new outside friends. He is much less disturbed by the noises, the colors and the tactile aspects of things since his work with NAO. This was not the case at the beginning: he could be fixed only on a single sensory channel. The robot acted as if it had allowed to assemble multi-sensory aspects (sound, color, touch), making the experience of the environment more bearable.

5) Fifth Subject: He is very sensitive to everything that happens around him: nothing seems to escape him. But to organize in a certain unity what he has been able to detect is more difficult. He can therefore remain frozen on an element without being able to consider the whole. This leads him to simplify the situation and cling to the fragments that he has been able to locate, and asks him for a lot of energy. He is described as easy to get tired, and stops focusing because he needs to rest and gather by means of a solitary activity. He tends to make his environment as regular as possible, until he locks it (as he checks the locking of the doors). He can accumulate many ways of doing things, or store fixed knowledge, especially when encouraged: he shows a lot of abilities. He tends to create links, to build rules to know how to behave according to interactions, to know and to recognize who he can meet or what he can face. Research

on the internet helps him in this. But the latter can take up a lot of space, too much for his entourage. Either that is what he has been able to identify in the other which can enable him to find support (football with the one who loves football, etc.). This mode of apprehension of experiences makes him very vulnerable to changes and extremely fragile in facing the unknown. The slightest uncertainty encountered can result in a genuine intolerance, which can go as far as self-aggression.

He has strongly expressed his disappointment in front of the robot, the first time he met it. But finally, he accepted it, then liked it. He mainly uses the software to execute movements of the robot. He found it difficult to touch it. However, he compared his body to the robot body. For him, everything must move, the robot is a whole. His world becomes more reassuring. During the difficult moments of his life, the sessions with the robot seemed to calm him. He uses the robot voice to evoke what passes through him then. He can now show his anxieties a little differently (less self-aggressiveness). His family circle found him changed. Throughout this experience, he was very sensitive to the encouragement of caregivers. As if it seemed more possible to him to push his limits in the communication and the relation to others thanks to these shared pleasures.

6) A Group Progression: As the preparatory and robotics sessions go by, the teenagers could also make groups. We have observed an important change in the way they talked to each other or to the caregivers: they seemed to leave more room to the other. For example, subject 2, feeling a moment subject 5 was isolating himself from the rest of the group, asked him to come with her to work on the robot. Another day, subject 4 arrived very badly at the robotics session. Subject 1, who was then his binomial, seemed to feel it and was quite pertinent in the approach of his comrade, and thus tended to appease him. Progressively, in pairs, the young people adjusted themselves. They knew how to agree on the recording of the gestures or intonations of the robot. One was able to show the other the posture he wanted the NAO to adopt. Exchanges between them are sketched out. They talk to others, they show to others, they can do things together, they share. They started to spot things in everyone. For example, the name "Elsa" of the female character in the history of the Nao was proposed by subject 4 for his link to the Queen of Snow, an animated film that subject 2 appreciates. "Iron Man" is named by subject 5 in reference to subject 1, "because he likes it".

C. Used Concepts

1) The Puppet Master Concept: When the subjects programmed the robots to make them act on the world on their behalf, they acted as puppet masters. They remained unseen, but still were able to do and say things. The subjects had first used the robots to say slang words. The game was a competition on who would find the more insulting sentence. Lacan had mentioned that insult is the first and the last word of the dialog [10]. But the slang did not last, and more elaborate talking took rapidly place. Sometimes when the robot would not perform as asked, a slang sentence would suddenly be pronounced in the silent room. Generally, this would be the signal for shared laughs between the three groups. Indeed, it was a way to tell the others about the difficulties one was facing. Laughter, then, became the release of the tension.

The robot is not the self, in the way that the subjects do not share the body of the robot. When it works, people look at it and the programmer is safely in the shadow. The robot is the self, in the way that it was programmed and the operator controls its actions. The first difficulty with programming was to make the robot say "I": should we tape "I" (my talking) or "you" (the robot talking) on the keyboard? The autistic subjects have difficulties to sense the limits of their bodies with the environment (people, things). The use of the robot helped defining these limits more accurately, helping them to separate the self from the surrounding world. In that direction, the robot helped them building limits and therefore protections around these limits. Once the protections started to act efficiently, within only a few weeks, the subjects started to act by themselves. This was done "naturally", they acted by themselves as soon as the fright of not-knowing started to fade. It was also because programming takes time, and things sometimes need to be said rapidly (once the body limit is more clearly drawn). The game then was to manage making the robot say and do things despite its limits. Another point that makes communication easier: saying slang or "forbidden" things is a social constraint in daily communication. When the robot say these forbidden words, people look at the robot, and generally laugh (they are not angry). Then the robot talking becomes a game, the robot plays a role that is not for real. This unreal dimension was clearly perceived by all the subjects, who wrote their story for their final show. They made an unreal dimension of their self, and told the message using the robots.

Let us look more closely at their story: the visible characters are four robots (fixed, rigid limits body/world). Not visible (fuzzy limits, is part of the world), is another character who is going to drown. The voice of this last character was a human voice, recorded during the preliminary sessions (the female subject's voice). And the robots use their super power to save this person. In this story, they are the human component, they may drown if not saved, and the robots have used their super powers to save them. The saving dimension is increased by the velocity of the changes in the subjects behavior during the program. Indeed the word *transformation* was adapted, the changes could be observed from one robotic session to the next one. Their talking was clearer, more organized, their thinking and presence were more accurate, their concentration time longer, and so on. The sound level of their voices got back to normal, as soon as they started to communicate, not just talk. When the program has started, it was difficult to hear anything with the sound the subjects were doing. Indeed, when they wanted to say something, they would just scream it, someone else being talking or not. Their saying was often completely disconnected from what the others were saying. At the end of the program, they could hold a constructed and organized conversation for more than 20 minutes, the sound level of their voice back to normal.

The use of a robot, putting the operator as a master puppet, acted like a therapy accelerator. In the program, the robot was never presented as a friend to the subjects,

but as a tool, a machine with possibilities and limits. *Their* machine. Neither was organized a replacement of the robot by human beings, such as in *robot companion* approach. The ASD subjects have great difficulties to define the limits of their own body, distinguish inside and outside using mutual definition, therefore build efficient defenses of these limits or communicate with the "outside" (not defined). Then we may face a refusal to any modification or change because of the non-organization of a bad perception of the situation. ASD tend to stick to the realization of a single objective, out of social codification. Then the work on the voice tends to investigate interaction without waking up anxiety. We have worked in a direction where the perlocutionary act is improved, and the robot clearly helped in this way. Once again, it effected as an accelerator of therapy. The subjects have discovered the voice as tool for sociability, linking personal to social life.

2) The Importance of the Voice: Many researchers have noted the importance of the voice and sound in early interactions [1]. Generating contact with autistic subjects is communally performed through songs and music [5]. In this work, the subjects have first given their voices to the robot during the first year program: the voices reading a story were recorded during the preliminary sessions, then replayed by the robots. In the second year program, the subjects voices still appeared in the show, but as voice-over. The robots would talk with their own voices generated by the embedded voice synthesizer. The voice characterizes the emotional commitment of the child in early communication. In ASD situations, it looks like the voice should not, in any way, lead to a subjective presence [9]. The tone can be monotonous, and is very particular when the subject can actually emit sounds. The language can be associated with "parrot talking", or sound artificial.

Many interesting results were observed during this second year program. First, one of subject did not talk at all, and regained the pleasure of hearing his own voice. His language skills clearly improved to organized communication. The first time he heard his recorded voice pronounced by the robot, his reaction was expressed surprise: "it's me!". Second, the natural expression of all subjects made great improvements, up to the level when their autistic characteristic could not be detected from their voices. It was more fluid, less noisy, more in the interaction with others (voluntary communication) than the expression. Third, the desire to be understood using their voices was stronger. Their recorded voices for the show (the voice-over), for example, were easily understood in comparison to the first year show, during which efforts were still necessary to get the message. The voice, in terms of will to satisfy the other, was regained during this program. The subjects offer themselves to the other, and are proud to do so: they look for interaction and exchange. This point is linked to the observations of the previous section: the limits of the body were defined thanks to the use of a robot as a mediator between the self and the others. Once the limits get clearer, then communication appears as the logical way to do things.

3) Evolving in Half-Spaces: A humanoid robot is a social object, and our imagination can include it, involve it, make it live as if it was a character of our story. It generates a process of secured socialization. As a consequence, it is a perfect tool for autism therapy for many reasons. The software used to program the robot includes a finite number of fixed boxes, generating always the same behavior (sitting, talking, moving). It is organized with fixed rules. The robot and its software allow a repetition of actions, and the security of knowing what is going to happen. But within this fixed number of rules, we can make the robot do and say almost everything (according to the robot technological limits). The robot is a kind of puppet that can be manipulated physically and can act on the world on our behalf. These characteristics allow a smoother confrontation with the real and the world, and reduces anxiety. The robot puts itself at the frontier between the self and the other. It is a border, or a *half-space*.

The robot is half and half for many things. Moving but inanimate, rigid but fluid, object but expressive, and so on. It has its own body, but we can activate it according to our will. Through the robot, we can be both present and absent, talking and silent, communicating and protected. Our imagination can make it have a personality (used in the *companion approach*), intentions. But we know somehow that it is fake. We participate to a game with a safe toy, that cannot surprise us. We control it. A half-space is a safe place where we can also retract from the world, not having the stress generated by direct confrontation.

This frontier between the imagination and the real allows the world to become more present. Said differently, it allows the constitution of the self and the organization of the relation to the others and to the environment. The ASD can draw lines delimiting the other, he can see the rules followed by the other. And he can be someone, first by proxy. Many ASD subjects have created a double, another character to act on their behalf. The robot may be the physical projection of this double, can change personality, identity, responsibility and contribution. It plays the social role in different ways before the mind has enough cohesion, enough strength to assume. It acts as a container.

V. Conclusion

A robotic program in the framework of autistic therapeutic support was presented. The robot was used as an extension for communication and social implication. We have applied the puppet master concept, making five ASD subjects to program the robot and make it act on the world on their behalf. The program was distributed in 20 weeks working sessions, alternating 10 preparatory and 10 robot programming sessions. A story was written in the preparatory sessions, and programed for the robots to tell in in the robot programming sessions. Many behaviors and skills of the five subjects were affected by the program, and the observed changes took place in a very short time. The word transformation was used many times to describe their changes. These concerned social skills, voluntary and organized communication, sharing, focus, talking, writing. With the robots used as puppets and the work performed on the voice, a half-space was proposed in which the subjects could safely denote the limit of their body, and therefore apprehend the world with less anxiety.

The next step is to check the pertinence of the program on a bigger population of ASD subjects, and apply a rigorous evaluation of their skills just before, just after and 6 months after the program. Also, the subjects were still making visible improvements at the end of this second year program. Therefore, another perspective would be to start a third year program, and see up to which point progress can be registered.

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