Educational Robot for Children with ADHD/ADD,

Architecture Design

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***Abstract*— In this paper, we presented an architecture design of assistive technology for kindergarten child care, called Kindergarten Assistive Robotics (KAR). KAR provides the kindergarten teams with a novel tool for achievement of educational aims through social interaction. Using Nao as a platform, we designed an assistive technology that employs a toy/game robotic approach. The proposed architecture is initially focused on research and training of children with ADHD/ADD. However, the final aim is to provide kindergarten teams with an assistive tool for all children, including typically developing children. We identified the benefic roles, missions and ethical principles of the robot. The kindergarten teams will have full control of robot: define daily task, stop/run behaviors, etc. The ADHD/ADD children benefit from the KAR for training their cognitive skills, like constructive learning, selective attention, etc. KAR has the ability of providing feedback to children on their performance and monitoring their progress over time.**

Keywords-component; social robotics; ADHD; architecture;

1. INTRODUCTION

Socially Assistive Robotics (SAR) aims to address critical areas in medical care by automating supervision, coaching, motivation, and companionship aspects of interactions with vulnerable individuals from various large and growing populations, such as stroke survivors, individuals with dementia and/or Alzheimer disease, children with autism spectrum disorders (ASD), and others. The goal of SAR is to improve these people quality of life by providing services for everyday use, therapeutic support, and a way for individual diagnosis through constant monitoring and interaction. This will permit longitudinal continuous objective observation, with analysis and evaluation. Our novel approach proposed to use SAR as an efficient tool for early school education.

In this research, we design and develop SAR technology for kindergarten child care, called Kindergarten Assistive Robotics (KAR). KAR is an assistive technology that employs a toy/game robotic approach. This will provide the educational kindergarten teams with a novel tool for achievement of the pre-defined educational aims through social robot interaction. The proposed approach is initially meant to focus on children with special needs, specifically on children with ADHD/ADD (Attention Deficit Hyperactivity Disorder). However, the final aim of this research is to provide kindergarten teams with an assistive robotic tool for children (i.e., normally developing children and children with cognitive impairment). KAR provides tools for educational, cognitive and social children development, and tools for improving the everyday habits such as nutrition, for instance. Our proposed technology is meant to help the kindergarten educational staff in their daily tasks. The robot is designed to be as friendly and helpful as possible by following the missions predefined by the educational team.

Social Assistive Robotics

Assistive Robotics (AR) is a broad class of robots whose function is to provide assistance to users, ranging from getting out of bed, brushing teeth, locomotion, and rehabilitation. Socially Assistive Robotics (SAR) (D. Feil-Seifer & Matarić, 2005) is the class of robots that provide different assistance to different vulnerable population through social interaction.

Earlier works in SAR have focused on animal-assisted activities and therapies. Robotic pet companions have been shown as useful tool for reducing stress and depression (Perelle & Granville, 1993). Additionally, the study provided by Wada et al. (2003) suggested that the robot Paro may be effective at reducing stress in nursing home residents and at producing increased social activity among residents.

In another interesting assistive system, a self-propelling robotic ball Roball (Salter et al., 2007) was evaluated with children with autism spectrum disorders (ASD) in-home and in-clinical settings. Children with ASD typically have decreased social interactive behaviors. Robots encourage children to initiate and sustain social interaction (Robins et al., 2007) with a parent, therapist, sibling, or peer. Therefore, SAR used as additional to current existing tools for diagnostic and therapeutic of children with ASD.

In the domain of post-stroke rehabilitation, Matarić, et al. (2007) developed a SAR system designed to improve therapeutic compliance through verbal, non-contact coaching, and encouragement. The system is designed to work in concert with established stroke exercise methods, such as Constraint Induced Therapy, building on and augmenting effective health care practices.

Tapus et al. (2009) described a study in which elderly participants suffering from Alzheimer's disease interacted with a SAR robot that promoted cognitive stimulation through a music therapy game in an 8-month study. The results reported show an improvement or maintenance of the cognitive level and a preference of the interaction with the robot over the interaction with the computer.

Concurrently with developing SAR technologies, studies about their acceptance have been conducted. Mutlu & Forlizzi (2008) showed that different patient groups in hospital had very different reactions to the delivery robot. Cancer units were not accepting the robot, finding it annoying, while postpartum units were accepting the robot, calling it delightful. Fridin et al. 2010 shows that most of the children enjoy playing with the robot in toy appearance Nao and even accepts it as a dance trainer. However, it was certain type of children had a difficulty to accept the robot.

The results of these studies suggest that user populations could have completely different experiences with the same robot, and that these experiences could be based on the users' pre-existing social and task dynamics and context.

ADHD

Attention deficit hyperactivity disorder (ADHD) is the one of the most prevalent childhood disorders, with estimates ranging from as many as 3% to 5% of all children being affected (Pennington, 1991; Szatmari, 1992). This condition is characterized by poor attention and distractibility and/or hyperactive and impulsive behaviors. The deficits that can be identified in several areas commonly arise during the preschool or early childhood years. These deficits affect children's behavior and are significantly inappropriate for the children's developmental level. Furthermore, they appear to be relatively stable and persistent over time (Mannuzza, Gittelman-Klein, Bessler, Malloy, & LaPadula, 1993; Weiss & Hechtman, 1993). It is clear that the majority of children who have ADHD have basic deficits in the areas of behavioral inhibition and ability to sustain attention to tasks over time (Barkley, 1997b; Pennington, 1991). Considering the problems that characterize this disorder young-age children with ADHD are at-risk for being negatively treated by the kindergarten teachers who experience difficulties dealing with their disruptive, noncompliant behavior and in providing them with the special behavior they require. Consequently, this may affect their limited exposure to pre-academic instruction, socialization opportunities, and the structure of classrooms, and thus, their self-esteem (McGoey, Eckert & Dupaul, 2002).

2. ARCHITECTURE DESIGN

A. *Robot Mission in Kindergarten Setting, Usability Study*

To identify main mission of the social robotic in the kindergarten setting, we provide usability study, adapting user-centered design approach (Holm, Ivar, 2006). First, we identified main personas in the system: kindergarten team, children and children's parents. Main mission of the robot have been defined. KAR mission is to provide assistance to the team by playing educational games with the children. Then, based on the personas we defined, we recruited participants for the usability interview: two kindergarten teachers [].The team needs have been assessed using interviews with educational teams and kindergarten observations. Additionally, we analyzed the recommendations for a kindergarten teams, presented by Israeli Ministry of Education [].

We identify main interview topics:

- To identify, analyze and understand kindergarten teacher, assistant teams and children pain points and needs in the context of highly active children in a normal kindergarten setting.
- Create a description of the robot profile based on research finding.
- Identify the cases where a robotic assistant can help the team to deal with the pain points.

We identify main roles in the kindergarten: kindergarten teachers, assistant teams, and several types of children, namely typically developing children (children with "standard" behavior) and highly active children. Hereafter, we classify standard kindergarten tasks, and types of common interactions. We identify different potential situations where the robot could assist the kindergarten stuff and therefore derive KAR requirements. Detailed description of this study is presented in Yakoby&Fridin (2011).

As a result, we create the KAR architecture design, introduced here.

B. *Robotic Appearance And Experimental Platform*

1) Appearance : Appearance of the robot, it's the physical form, is provide the desired type of relationship with the user, widely discussed in the literature. Studies of the so-called "uncanny valley" already demonstrates that the level of human-like realism of the robot has negative impact on users (Kanda et al., 2004). Moreover, the size of the robot influences on the interaction and perceived role: robots that approach the height and size of the user are received with some trepidation compared to smaller embodiments (Lee et al., 2009). In a domain of kindergarten child care, small robot with toy appearance and low level of human-like realism could be easily integrated in the kindergarten environment. Such robot is perceived as smart educational tool, creating pleasurable, not threated for both kindergarten team and children interaction.

The robot style of speech/voice and embodied expression also play key roles in how effective the robot will be in a SAR setting. We designed KAR such as it speaks with female voice (commonly associated with kindergarten care team), KAR expresses emotions (through verbal and non-verbal communication) and KAR uses proper vocabulary.

2) Platform: Robot Nao, 60 cm (23 inches) tall humanoid robot developed by the French company Aldebaran Robotics (see Figure 1), met our requirements of robot appearance. Nao is 25 degrees of freedom robot, equipped with an inertial sensor, two cameras and many other sensors, including sonars which allow it to comprehend its environment with stability and precision. Nao is based on a Linux platform and scripted with Urbi, an easy-to-learn programming language, with the option of a graphic interface for beginners or code commands for experts.

C. Ethical Principles for KAR

Naturally, KAR system, as any technology, poses several ethical challenges during their design. We consider ethical principles as a core issue of our system.

The most obvious risk of any assistive technology is the potential of physical harm. KAR is primarily concerned with robots that provide assistance through social, rather than physical interaction. Thus, KAR systems are designed so that the robot does not apply any forces on the user. The user can touch the robot. Moreover, we designed specific procedure to prevent unexpected and inadmissible physical contact between users and the robot (See Figure 2, Platform of Common Behaviors, Task 2). When the robot detects entrance into its working (private) space, the KAR prevents the physical contact, by moving away, stopping and/or by vocal warning.

Regarding acceptance, we have already conducted an ethnographic study Fridin (2011) that found that most of the children had positive reaction to the robot. However, few of them had not accepted the robot. We attempt to diagnose this kind of children and to create KAR's behavior adapted to this profile of the children.

Following the principles of beneficence and non-malfeasance, KAR designed to act in the best interests of the children and shouldn't do any action that may harm a user,

The authority in the kindergarten belongs to the team (see Figure 2, RTI, Task 1/2/3), which have full control of robot behaviors. For instance: The team defines the robot's daily tasks, initiates, changes and stops any robot behavior.

Children also have authority on the robot, but restricted to the educational team's aims. For instance, child could stop the educational game when playing one-to-one with the robot. The robot allows try to continue the game, through verbal communication only. However, when robot plays with group of children only kindergarten team could stop the game.

There are also valid concerns about a user's privacy with KAR, as with most other technologies. The KAR have been designed to be able to monitor information about children performance. The kindergarten team defined whom, when and where to monitor. Collected information sends to the team's computer, no information is left in the robot head (robot's computer). Robot allows pulling information required to perform current task. The system allows to the kindergarten team to produce reports of children's performers during paying with the robot. The educational team decides which information to supply to the children's parents.

It was demonstrated that some users formed emotional attachments with robots they were interacting with (Turkle, 2005). We put a lot of affords to minimize children's emotional attachment to the robot, even it is impossible to fully avoid it. We provide a Full Disclosure procedure, where we explain the KAR's mission, functionality and limitations, possible failures and mistakes in behavior, possibilities for upgrades/modifications, present the fact that it might be taken away. During first meeting this information is given to the kindergarten team, then to a children's parent. And finally, the information, updated to the children's level of understanding, is given to the children too.

D. High-Level Design of the KAR

Three classes of interaction were identified (Figure 2):
(a) Robot-Kindergarten Team (one-to-one interaction);
(b) Robot-Group of Children (one-to-many interaction);
(c) Robot-Child Interaction (one-to-one interaction).

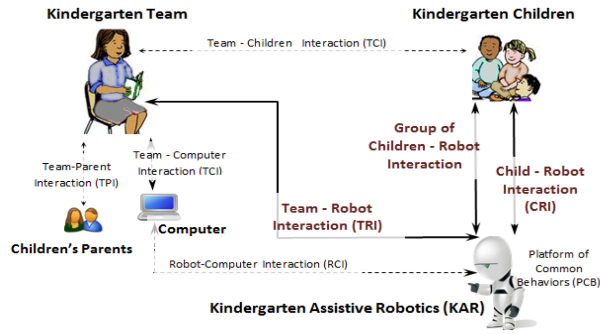

Figure 1. The system architecture: personas, equipment and interactions

We designed various examples for each class of interaction. The kindergarten instructors have full control of the robot behaviors. For instance, first meeting procedure designed to be led by kindergarten team. During this procedure robot acquires the kindergarten team members, kindergarten map, and kindergarten children information. The robot's daily tasks will be also defined by the kindergarten instructors. KAR designed to be able to assist the team by monitoring children's cognitive and social performance, for instance by monitoring the progress of a specific child in pre-defined tasks: sustaining attention on various types of educational games.

We prepare a set of educational games for Robot-Group of Children Interaction. The robot is designed to be able to provide social mirroring of negative behavior. For instance, the robot can ask children that are mad what is wrong and facilitate children to stop and think of their actions.

Robot designed to be able to play a role of personal trainer through Robot-Children Interaction. KAR teaches a child how to construct a puzzle, teaches a child about nutrition, teaches a child meta-cognitive abilities: the ability to identify when he/she needs a break, take the break, and go back to task. We provide children with the ability to stop the robot at any time, while this does not contradict the kindergarten educational team pre-defined tasks.

We also create a platform Common Behaviors, which include behaviors in undefined situations (what to do if the robot does not understand the request of the child), behaviors for prevention of unexpected and inadmissible physical contact (like stopping movement when detected entrance into working (private) space of the robot).

E. Scenarios: Educational Games

Here we provide examples of the possible scenarios that designed to be conducted in a kindergarten environment and that could demonstrate how KAR could be used as an educational tool.

1) *Puzzle construction, supports sustain attention:*

a) Background: Children with ADHD have basic deficits in the areas of behavioral inhibition and ability to sustain attention to tasks over time (Barkley, 1997b; Pennington, 1991). This deficit can lead to poor school/work performance, social relationships, and a general feeling of low self-esteem (Lahey et al, 1998). Learning how to construct a puzzle is a task that requires the child to sustain attention on the task over long periods of time.

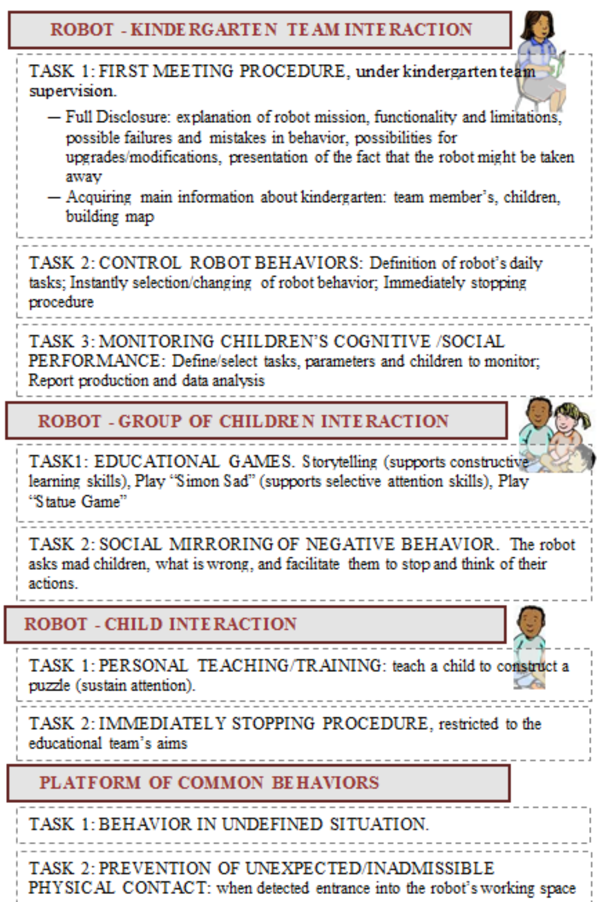

Figure 2. KAR's interactions and tasks.

b) Hypothesis: We hypothesis that the robot could assist a child to train this skill and could help him to sustain attention for a longer duration than the time needed to construct the puzzle (for example by asking questions about the entities represented in the puzzle). We will compare children performances as a result of a robot trainer and a human trainer.

c) Subject Pool: 20 children, diagnosed with ADHD/ADD, assigned randomly to one of a two groups: a robot trainer and a human trainer.

d) Procedure: To create a baseline measurement, both groups will be asked to construct a puzzle with no instruction (first initial session). In the second session the robot will be presented to the children. During this session the children will be allowed to play with the robot and to dance with it (as proposed by Fridin et al. 2010). In the next sessions, both groups will be provided with explanation on how to construct a puzzle. In team one the explanation will be given by the robot, while moderator sits nearby, and in team two the explanations are exposed by the moderator, while the robot sits nearby. Children will be provided with roughly equal positive reinforcement feedback, while constructing the puzzle, in both groups. If a child succeeds to construct the puzzle, he/she will be asked additional questions about the entities/objects/actions described in the picture designed by the puzzle, so as to sustain more attention on the task.

e) Measurement: The capacity of the child to finish a puzzle, the time a child stayed concentrated on the task, and the child's approach to complete the task, like starting from the corners, comparing the pieces to the picture and so on.

2) *Story Telling, supports constructive learning:*

a) Background: Learning new concepts and information requires keeping attention on the details and moving information from the working memory to the long term memory (Atkinson & Shiffrin 1968). Constructive learning encourages the learner to experience the content in different ways and senses. A robot would be able to provide a constructive learning experience supported by several senses: visual, auditory, and touch.

b) Hypothesis: We intend to show that the robot could bring educational benefit to a kindergarten by teaching children a new knowledge, specifically a content of a story. Moreover, we hypothesis, that robot's emotional expressions could reinforce learning process. To prove this, we will compare children's learning achievements between two setups: the robot tells a story with expressions of emotions and without emotions.

c) Subject Pool: 20 children, diagnosed with ADHD/ADD, assigned randomly to one of a two groups.

d) Procedure: KAR tells a story with (for first group) and without emotional expressions (for second group). Then, children of both groups are asked questions to test their learning achievements.

e) Measurement: Level of attention and interaction; children's ability to answer questions about the story and to explain concepts learned from the story, ability to reflect on "my emotional self" (to tell a story describing their emotions: "When I was sad….").

3) "Simon Say" Game , supports selective attention:

a) Background: Selective attention is a complex behavior requiring the ability to preferentially attend to relevant aspects of a task while ignoring irrelevant information (Kerns & Mateer, 1996; Mirsky, Anthony, Duncan, Ahearn, & Kellam, 1991; Posner & Peterson, 1990; Sturm, Willmes, Orgass, & Hartje, 1997). Some studies argued that there is evidence for a selective attention deficit in ADHD children (Ceci & Tishman, 1984; Landau, Lorch, & Milich, 1992). For example, children with ADHD are known to have significant difficulty on tasks such as the Stroop Color – ignoring the text of the word and naming only the color of the word. The "Simon Says" game gets the children completing sequences and following directions, as well as working on their ability to notice small details (selective attention). The children must be able to listen actively and pay close attention to win.

b) Hypothesis: We intent to show, that KAR could train children (by playing fun games, specifically "Simon Say") to improve their selective attention meta-skills. Moreover, we hypothesis, that this meta-skill will be transferred to other tasks that also require inhibition of non-relevant information, specifically to the statue game. In "statue game" children should stand still while there is no music, neglecting whether KAR moves or stands still. We will also investigate whether positive reinforcement given to the children during the game could provide enhancement learning factor.

c) Subject Pool: 20 children, diagnosed with ADHD/ADD, randomly assigned to one of a two groups.

d) Procedure: First, both groups play the statue game to create a baseline for testing. Afterwards, both groups will play "Simon Say" with a robot. In the first group, the robot will provide full positive reinforcement and while in the second it will not. Finally, both groups will play the statue game again, to measure their progress in selective attention skills.

e) Measurement: Children performances in the "Statue game" before and after the "Simon Say"; a learning curve of the children in the "Simon Say" game.

F. KAR's modules

The modules of KAR have been derived from the scenario's descriptions. The preliminary scheme of the modules and data flow is presented in Fig. 4. The KAR's system takes as an input the settings of the kindergarten team and robot's sensory data. Analyzing this data (Low/High Level Perception), the system monitors level of User–KAR interaction and user's attention and diagnoses subject's cognitive behavior (Information Analysis Module). This information is written to the database. To reinforce children's learning (Motivation Module), the robot has ability to shift its attention to different children (Attention module). Moreover, KAR is capable to adapt its behavior to the children's personality, stage of cognitive learning and a current mood (Adaptation module).

Then, the system selects current behavior (Behavior Module), which is implemented by Motor module. To create close- loop control of the KAR, we proved robot with ability to monitor its performance and measure its success/error.

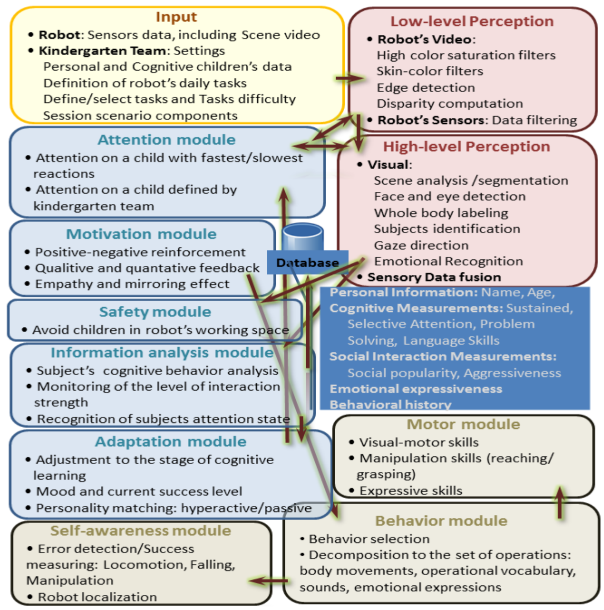

Figure 3. KAR's modules

G. KAR's Personality Definition

Similarly to human social interactions, personality is a key determinant in human– robot interactions (HRI) [35,36]. There is no generic definition of personality. Based on the literature [9,33,58], we define personality as the pattern of collective behavioral, temperamental, emotional and mental traits of an individual that have consistency over time and situations. For instance, Mataric [] shows how to construct robotics personality based on the Eysenck model of personality. We created the KAR personality profile based on the theory of Thomas & Chess, 1956 concentrating on temperamental aspect of personality.

To promote a safe feeling in children, the KAR's personality should be designed in initial stage of the project (from First Meeting Procedure). Thus, we created guidelines on KAR personality, based on the kindergarten team recommendations (Table 1). Later on, we will tests whether/ or not each of the defined parameters of the personality assist to provide desired interaction with the robot. It has been argued that robot personality should match that of the human user [36]. Thus, we intent to provide procedure for the KAR's personality matching, which is imitates the kindergarten teacher personality matching while working with different children. We will preserve the main

personality guidelines and adapt personality parameters only in predefined range.
The robot is designed to imitate a smart child behavior; it speaks Hebrew, with good, but simple vocabulary.

TABLE I. KAR'S PERSONALITY

Personality Dimensions	***KAR's Personality Facets***
Activity level	intermediate, measured by robot's speed and amount of movement.
Initial reaction	expresses interest but do not attack
Adaptable	adapts as quickly as possible; the team indicates the changes (for instance, a new child in the kindergarten).
Consistency	reacts in the same way to the situation; the behavior can be evolved to better interact with children keeping the main principles of its interaction pattern.
Positive mood	mainly positive, expresses sadness only as a part of reinforcement feedback while training a child
Distractibility	is able to identify situations that it should attend to

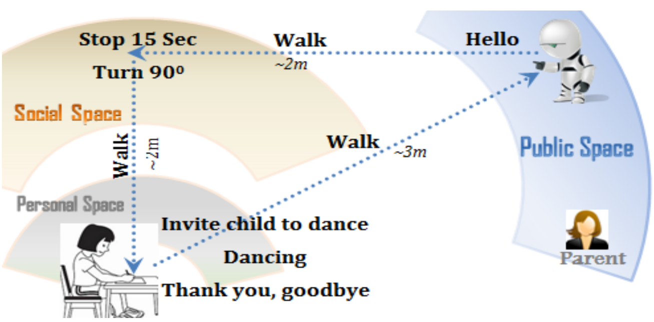

Figure 4. First Meeting Procedure

H. Prof of the Concept: One-to-One First Meeting Procedure

To prof the concept of the proposed system, we performed the experiment where children meet robot first time in their life.

1) Background: The interpersonal space in human interactions has been widely studied in social psychology, since the seminal paper by Hall [19] who coined the term proxemics.

2) Hypothesis: children accept robot, create positive interaction and accept its authority.

3) Subject Pool: 18 children with regular development, age 4-8, half boys and girls

4) Procedure: The robot interacted with a child as shown on Figure 5. We evaluated the proximity: robot moved from Social Space to Public Space and, finally, to Personal Space of the child. We also tested the possibility that a robot could provide some authority to the children: the KAR invite children to dance with it.

5) Measurement: Interacation level, during each stage of the experiment, measured as a function of eye contact (binary value) and face/body/voice expressions of emotions of child.

*6) Results (Figure 6):*Most of the children create positive interaction with the robot, except of 2 children. Moreover, three of the danced with the robot.

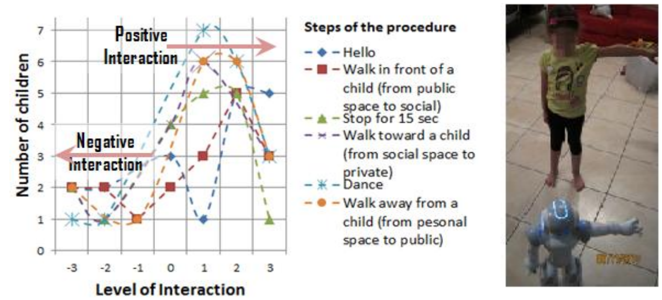

Figure 5. Results: First Meeting Procedure and Picture of one of the experiment

I. Conclusion

Our work to date demonstrates the promises of KAR, a new research area of social assistive technology with immeasurable perspective. Our ongoing efforts are aimed not only at developing effective robotic systems, but also expanding our knowledge of human social behavior. Socially assistive robotic technology is still in its infancy, but by our experiment we showed how in near future assistive robotic platforms will be used in kindergartens, hospitals, and homes in training and therapeutic programs that monitor, encourage, and assist their users.

ACKNOWLEDGMENT

Thank you for discussion: Dr. Naama Atzaba-Poria developmental psychology, University Ben-Gurion in Negev, Israel and Prof. Adriana Tapus ENSTA-ParisTech, France. Thank you for participation in usability study :Team the Lior's kindergarten, Never-Naaman Tower, Israel. Arial University Center administration for support in this project.

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