Journal of Integrative Neuroscience, Vol. 8, No. 1 (2009) 23–34

Short Communication

SOCIAL TRAINING OF AUTISTIC CHILDREN WITH INTERACTIVE INTELLIGENT AGENTS

EMILIA BARAKOVA*, JAN GILLESSEN and LOE FEIJS

Faculty of Industrial Design
Eindhoven University of Technology, P.O. Box 513
5600 MB Eindhoven, The Netherlands
**e.i.barakova@tue.nl*

Received 7 November 2008
Accepted 9 February 2009

The ability of autistic children to learn by applying logical rules has been used widely in behavioral therapies for social training. We propose to teach social skills to autistic children through games that simultaneously stimulate social behavior and include recognition of elements of social interaction. For this purpose we created a multi-agent platform of interactive blocks, and we created appropriate games that require shared activities leading to a common goal. The games included perceiving and understanding elements of social behavior that non-autistic children can recognize. We argue that the importance of elements of social interaction such as perceiving interaction behaviors and assigning metaphoric meanings has been overlooked, and that they are very important in the social training of autistic children. Two games were compared by testing them with users. The first game focused only on the interaction between the agents and the other combined interaction between the agents and metaphoric meanings that are assigned to them. The results show that most of the children recognized the patterns of interaction as well as the metaphors when they were demonstrated through embodied agents and were included within games having features that engage the interest of this user group. The results also show the potential of the platform and the games to influence the social behavior of the children positively.

Keywords: Interactive games; emergent behavior; social interaction.

1. Introduction

The early work of Heider and Simmel [12] showed that people can perceive social behaviors from the movements and interactions of simple geometric figures. They exposed two groups of subjects to an animated film featuring three simple geometrical figures. These figures moved in various directions and at various speeds, leaving and entering the frame, part of which seemed to open and close like a door.

*Corresponding author.

One group of subjects was asked by the authors to formulate a simple description of what they saw. The other group was required to give a description of the scene while bearing in mind that the geometrical figures stood for human beings. An analysis of the subjects' responses indicated that the members of the first group had responded spontaneously in the same way as those of the second. For all subjects, the movement of objects had taken on an animate character, and the geometric figures had been treated as persons with well-defined characteristics. Functional relationships had been established between them in terms of flight and pursuit. The origin of their movements had been described in terms of motives or intentions. Moreover, the figures had been endowed with emotional states and stable dispositions, i.e., they have been perceived as social agents.

Inspired by this experiment, Michotte [16] suggested that simple motion cues provide the foundation for social perception in general. Following this tradition, many studies have shown that people can attribute animacy, intentions, emotion, and personalities to simple geometric figures on the basis of their movements [1, 9, 17, 20].

Individuals with autistic spectrum disorders (ASD) have difficulty in interpreting social messages in the same way as non-autistic people. Moreover, Klin [13] found autism-specific differences in people's descriptions of the Heider and Simmel task. Klin conducted an experiment with 60 autistic participants. They were asked to provide narratives describing Heider and Simmel's animation. He found that the group of autistic subjects was unable to derive psychologically-based personality features from the movements of the shapes.

Most of the studies that have followed the Heider and Simmel experiment have elaborated on the impact of the movements, and have shown that simple motion cues provide the foundation for social perception. So far, insufficient attention has been given to the fact that, in the Heider and Simmel experiment, the perception of animacy and intentionality is not caused only by the movement, but also by two further factors, namely the perceived interaction between the animated objects and the ability of the perceiver to attribute a metaphorical meaning to the geometrical shapes.

The impact of the perceived interaction and the ability to assign metaphoric meaning to the perception of objects and actions could be studied from many perspectives. We want to test the possibility of teaching autistic children social skills such as recognizing metaphoric meaning and recognizing intended interaction. Some research results and practices in autistic schools and institutions show that elements of social meaning could be taught to autistic children. Rutherford *et al.* [23] conclude that there is a possibility that animacy perception might still be present in autism, even if it is not used automatically. Many schools use objects such as pictures with stereotype facial expressions to teach autistic children to recognize emotional states, or use traffic semaphore to help these children to express their own emotional states. On the basis of these facts we can assume that embodying the interactive behaviors within physical objects will increase the impact to the autistic individuals. Since we aim to test and eventually improve the social skills of children with autism, we have developed an interactive multi-agent toy platform. Every agent can sense its environment and behave accordingly, so they are defined as robotic agents or robotic toys, although they do not have the typical appearance of a robot.

The existing approaches that involve robots in autistic therapy use the robot as a play partner [4, 6, 18]. Billard *et al.* [4] have used a humanoid robot to be imitated by two children, and in this way the robot is used as a medium for play. However, the central part of their work is the interaction between the child and the robot. We used robotic toys as a medium for play, where the interaction between the children is the central goal.

Our research in using robots for the behavioral training of autistic children also differs in another way from the other robotics approaches. Instead of human-like or other anthropomorphic robots, we used a multi-agent system of geometrically shaped blocks, and therefore we can test the assignment of metaphoric meaning to simple objects. Yet another difference in our approach is that we explicitly use a game that can guide the children in a natural way to comprehend metaphorical meaning and interaction behavior and to get them involved in social interactions.

2. Materials and Methods

Our primary goal is to create games that will stimulate the social behavior of autistic children. In this study we want to investigate the level to which the elements of social interaction (such as perceiving the interaction and the metaphoric meaning embedded in physical objects with simple geometric shapes) are understood by these children. For this purpose we constructed one or both of these elements as a major element of the game, and observed the level of engagement of the children with the game, and the level to which they have understood the metaphor and the interactive behavior.

2.1. *The platform*

Technological toys were shown to be very appealing for children with autism [2, 5]. For several reasons, robots in particular have been used in the behavioral training of autistic children. Firstly, autistic individuals like computerized games, with predictable behavior and repetitive movements. In addition, developments in robotics during the past two decades have led to autonomous or tele-operated robots that can act in unstructured environments. Pioneering work in using robots for autistic care has been conducted previously [6, 21, 22, 26]. The most recent developments in using robots for autistic care are based on human-like robots that interact with autistic children, and a variety of interesting experiments have been reported in [4, 18] among others.

Snyder *et al.* [24] argue that concepts are groupings of "object" attributes. Once the brain learns such critical groupings, the "object" attributes are inhibited from conscious awareness. They believe that in people with autism this inhibition is retarded, therefore their learning can be enhanced by novel object attributes. Related behavioral therapy through play has been suggested by [14, 19]. LeGoff [14] has observed children with autism coming together to discuss each other's LEGO creations in the reception room of his clinic. This observation was the reason systematic observations were done to see how playing with LEGO influences the social behavior of autistic children.

We have developed an interactive multi-agent platform with emergent behavior. It consists of building blocks that interact when positioned in each other's vicinity. They emit colored light that fades progressively when no other blocks are in their vicinity, but return to full brightness as a response to sensing another interactive block. The collective behavior of all blocks together results in different changing patterns of colored lights in the overall construction, which autistic children experienced as rewarding. We use building blocks for enhancing the social skills of autistic children in a similar way to the experiments using LEGO. However, our blocks can interact by detecting their neighbors through the built-in sensors, and show behavior in response to their sensory stimulation. The complexity of the internal organization of the blocks is similar to that of the commercial mini-robots, with sensors, microcontroller, and controllable LEDs; so we define them as robotic agents, whose motor behavior is expressed not through motion, but through changing color and intensity of lights (Fig. 1).

We distinguish between the platform and the specific games. By platform we mean the hardware, including form, sensors, actuators, microcontroller, and the programming environment, which allows different behaviors to be simulated.

By game we mean a specific embedded program to make the blocks behave according to specified rules, together with the explanation of the rules to the players. The game/platform distinction makes it easier to develop several games and compare different games on the same platform.

The blocks were specially designed to fit the play habits and the patterns of thinking of the autistic children. Initial user tests as reported in Ref. 2 have shown that children find them very engaging and pleasurable.

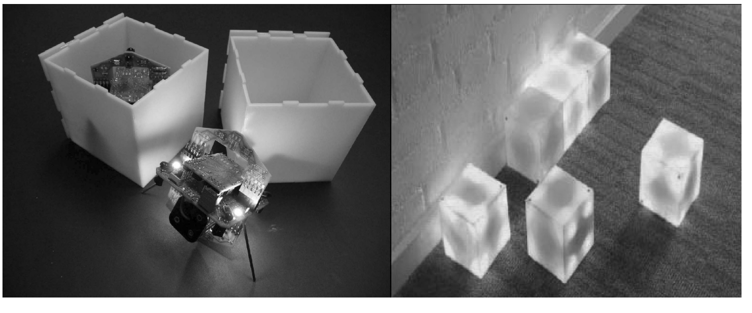

Fig. 1. The developed multi-agent system of interactive blocks (a) internals of the block platform and (b) example of emergent light patterns when the blocks are put in each other's vicinity.

2.2. *The participants*

Twelve children (eleven boys and one girl) participated in this study. Six were diagnosed with PDD-NOS (Pervasive Developmental Disorder-Not Otherwise Specified), five with classic autism, and one MCDD (multiple-complex developmental disorder).

2.3. *The games*

2.3.1. *Concept and related work*

We created two games. The first game involves solely interaction between the blocks. The second game incorporates both: interactions and metaphoric meaning. Having a common goal creates shared focus and similar feelings, which may encourage players to cooperate. Cooperation and similar feelings have been shown to be the main ingredients for creating social groups [15, 25]. Belonging to the same group lowers the threshold for initiating social interaction. The goal should be designed in such a way that it connects the players.

Having metaphoric meaning in a game is in contradiction to what the literature says on the abilities of autistic children to perform believe play [3]. Berk [3] argues that autistic children will not recognize metaphors or will even resent them. Even when trying to animate the blocks, the autistic children will insist that these are just blocks and cannot resemble anything else. Non-autistic children of the same age group have developed the skill of believe play [3], which is characterized by the extensive use of metaphors. In general, people with autism show a poor understanding of metaphorical utterances [7, 10, 11].

We assumed that assigning the metaphor to embodied, tangible objects can lead to more understanding. For this purpose a pet zoo game was developed. The main goal of the game was to take care of animals that would be represented by animated blocks. In addition, water and food blocks were introduced, with fading blue and green colors, respectively. Each child would control either an animal block, or a food or water block that would interact with the animal blocks. This would give the children equivalent responsibilities, creating a shared focus.

One child would control food management, and another child water management, since animals need food and water. As animals require both, children are unable to fulfill the main goal all by themselves. They become interdependent [8], and, in a way, part of the multi-agent system. A third need of the blocks is the company of others, which players can provide by placing a lonely block next to another animal block. The animals would show their state (and thus their needs) by color intensity. A state and transition diagram for the block communication is shown in Fig. 2.

2.3.2. *Realization*

Two games were created.

(i) The first game tests perception of interaction behavior and the behavioral change of the child. We used the blocks as a multi-agent system with emergent

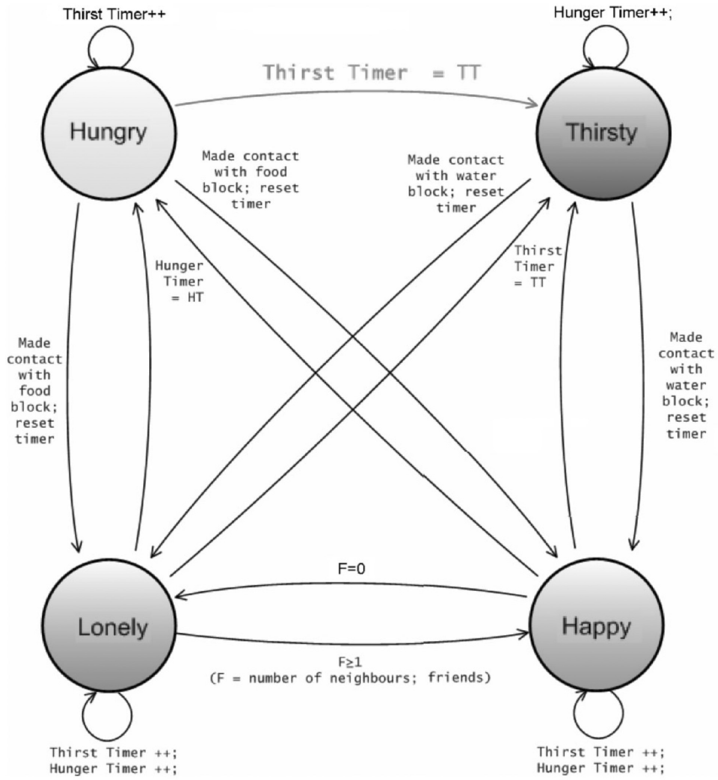

Fig. 2. State transition diagram depicts the interactions in the pet zoo game. When the block representing an animal is "hungry" it has to be placed in a vicinity of a food block. The timer in the food block will be reset and the block will revive its full color.

properties. Patterns of colored light appeared when a block was positioned in the vicinity of another block or group of blocks.

We shall refer to this game as "Game A". During the tests, changes in the behavior of the children were recorded. To be able to play the game successfully, the child had to recognize that interaction is an inherent property of the blocks.

(ii) In the second game it was made possible for the children to understand metaphors assigned to the same cubic objects with the same rules of interaction. The difference with this experiment is that the color and intensity of the lights, and their changes, have metaphoric meaning. We shall refer to this Game as "Game B" or "pet zoo game". Game B requires understanding of the metaphorical meaning assigned to the blocks, and the need to act upon it.

We tested the change of behavior caused by the understanding of both elements (metaphor and interaction) by counting the number of social interactions and the occurrences of exploratory behavior (both according to protocols) during play with Game B and comparing the results with those of Game A that includes only interaction.

The children were divided by the care givers into groups of two. In total, six teams, each of two children, took part. Half of the teams started with A and half with B for the purposes of order validity. Each pair of players had sessions of ten minutes per game, enough to experience the different aspects of each game.

An important element in this approach that involves two games is that the way in which the games are introduced influences the outcome of the test. The method of introduction has to be defined before both games in order to make the test reproducible. For Game A, the following rules are introduced: (1) The blocks must stay on the table (to prevent actions such as throwing). (2) Players are allowed to move the blocks. (3) Rather than posing goals, the restrictions of use of the blocks are explained. For Game B, the playing rules are as follows: (1) The blocks must stay on the table (to prevent actions such as throwing). (2) Players are allowed to move the blocks. (3) One player controls the food block and the other controls the water block (introduction of interdependence and nutrition metaphor). (4) The goal is to nurture the "animal" blocks (introduction of main goal). (5) When a block becomes hungry, it will show that by turning green. In response, the child can move his food block to the vicinity of the hungry block, and initiate its feeding. (6) The same rule holds for the water block. (7) When a block is red, this means it is lonely. This is resolved by introducing another "animal" block.

Note that no reference is made to animals when these rules are explained to the children. This was left to the imagination of the children. While the children were playing Game A it was suggested to them that they should try to invent their own game variations after the play session ended. First the consent of the parents was obtained via the school. Then the tests were conducted, filmed, and scored.

To find measurable elements for social interactions during the play sessions, we used a protocol proposed by LeGoff [14]. In his protocol, measurable instances of social interaction are determined, and a specification is made of which behaviors can be considered as social interaction. We conducted the user test according to this protocol.

3. Results

During the first Game A, we use the blocks as an interactive multi-agent system with emergent properties — patterns of colored light appear according to the position of the blocks with respect to each other. Each block reacts to the presence of another block.

The user test showed that the children were clearly aware of the interactions. Due to a failure of the constructed interactive toy in the preliminary tests [2], the agents started to behave randomly. Even then the children were convinced that there was a hidden interaction rule, and kept exploring the possibilities. This fact alone was very positive, since children with autism are often observed to fall into repetitive patterns of play. Figure 3 shows the number of occurrences of exploratory behaviors caused by perceived interaction of the blocks during the preliminary tests.

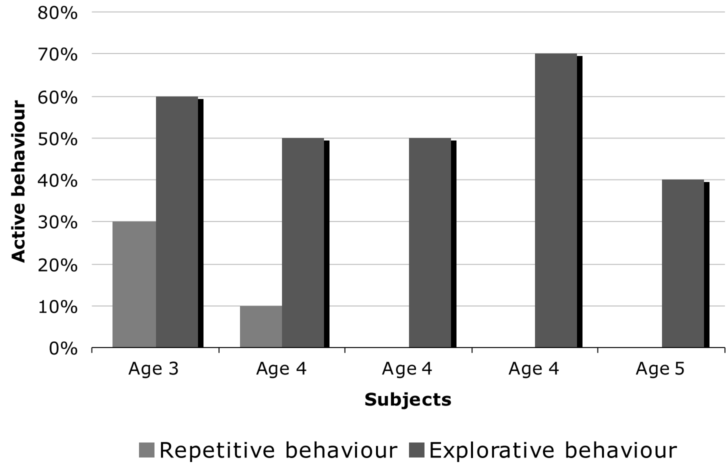

Fig. 3. Observed repetitive and exploratory behavior by the tested autistic children expressed in percentage of time of the test duration. The data shows pronounced exploratory behavior by most of the children.

The filmed actual test (with both Games A and B) was scored with an observation form containing a timeline on which interactions were scored for frequency and duration in a visual way. The form was organized in units of ten seconds, with labels for the minutes, and with two parallel timelines, one for each of the two players. Only social interactions were counted, so, for example "one child talking about the blocks but the other not responding at all" was not considered an interaction. There had to be an action (a self-initiated social contact) and some noticeable reaction. Interactions with the experimenter were excluded from scoring. The outcomes are shown in the diagram in Fig. 4. For each pair, the left column is Game B (the game requiring understanding of the interaction and the metaphor), and the right column is A (no metaphors implied). N1 to N3 and H1 to H3 are the six pairs from two different classes. The difference is positive for five out of six pairs.

A Wilcoxon Signed Ranks test was applied with null-hypothesis H_0 that adding metaphors has no influence on the social interaction of the children when playing with the given platform. For $n = 6$, $T+ = 17$ so (two-sided) $\alpha = 0.22$. Adopting a significance level of 0.2, the H_0 hypothesis cannot be rejected.

The children were all able to understand the goals. Some players suggested additions to the game (e.g., colors for defecation or sleep). We can assume from this that the embedded metaphors were well understood by the group that we tested with, and we can afford to add more complexity in the future, for instance, simple motion behaviors.

4. Discussion

Our hypothesis (that metaphoric meanings will be understood by the autistic children, if presented through embodied objects) was confirmed. The metaphoric

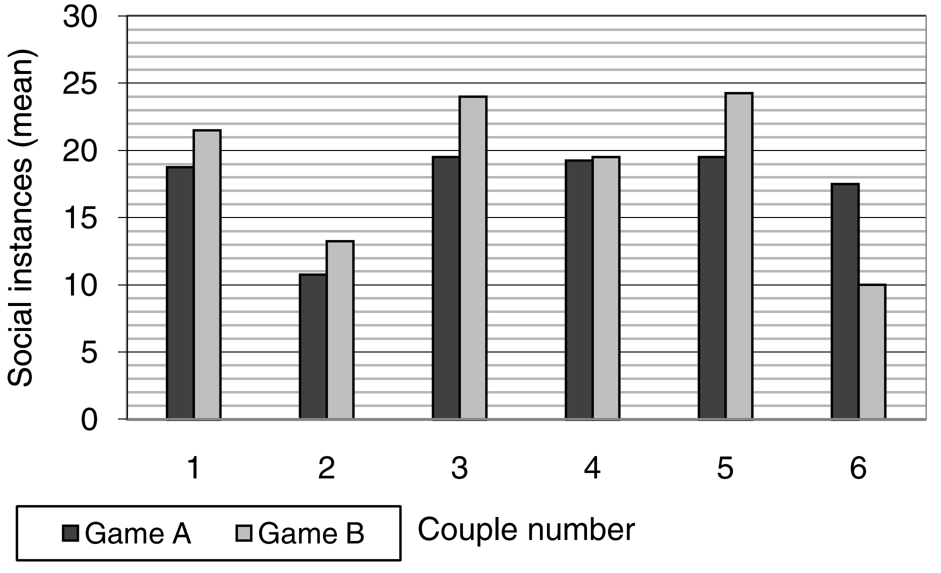

Fig. 4. Number of social interactions per group for both games. The lighter bars show the number of social interactions by pet zoo game.

meaning of the blocks and the interactions between them seemed to be understood by five out of six teams. One team went so far as to really play with the blocks as characters; other teams would get worried when a block did not receive food or water for a long time. Other teams referred to the states as hungry or thirsty. One team moved clearly from the use of colors to the hungry/thirsty metaphor, from which we assume that the terms hungry and thirsty refer to the explanation that was given rather than the feeling of being hungry. One team did not understand the metaphor, but still enjoyed playing the game. The lonely action caused confusion in some cases, as it was not determined beforehand who would perform this action.

Game B gave more social interactions than A for five out of six pairs — the pairs that could grasp the metaphoric meaning. It would be interesting to test with even more pairs in the future. The qualitative results are interesting. The fact that the metaphors appear to be understood by most teams is promising for further development of games and scenarios for training autistic children in social skills. Also, the discussions (being social interactions) about the game goal are a cue for game and scenario design.

We concluded that autistic children can be trained to recognize elements of social behavior through games with embodied agents. The embodied agents can be as abstract as simple geometric objects, but the interactive patterns of behavior and assigned metaphoric meaning are still recognized. Initially it was not obvious at all that this challenge would have a solution (we thought that the blocks were perhaps too simple) Moreover, literature suggested that autistic children would not recognize metaphors. But the pet zoo game worked out remarkably well, both as a concept and as a practical game. Tentatively we phrase this conclusion as: in our design we successfully married formal state-machine-based interactive behavior (which can be expected to appeal to autistic children) to metaphoric meanings (which are assumedly harder for autistic children).

An additional conclusion concerns the way in which the games elicit social interaction. The original idea was that the children would observe the "social" behavior of the blocks, and then find it easier to understand real-life social behavior (taking a cognitive detour to do what non-autistic individuals partly achieve through empathic and natural social skills). Although this may still be the case, what we observed was that it was the discussion of the precise goals of the game and the ongoing interpretation that led to active interactions among the players. In Game B, the vocabulary of very concrete terms (hungry, thirsty, etc.) was instrumental for that purpose.

In general, we have shown the importance of elements of perceiving social behavior such as perceiving interaction behaviors and assigning metaphoric meaning for training the behavioral skills of autistic children. The inspiring experiment of Heider and Simmel [12] (which shows that social interaction can be perceived even if attributed to simple geometric figures) focuses on expressing meaning by movement and its impact on perceiving social behavior. This has led to many follow-up studies. For training autistic children, however, the social interaction behavior and the perception of metaphors is as important, but tends to have been overlooked in earlier follow-up studies. Perceiving and understanding interaction behaviors, and the ability to assign metaphoric meaning, is crucial for this user group to understand the elements of social interaction, and requires separate training. The results of user tests involving two games, one with interacting patterns and another with goals and metaphors were compared. The results showed that most of the children recognized the patterns of interaction as well as metaphors when they were implemented in embodied agents and included within games with features that engage this user group. The results also show the potential of the platform and the games to positively influence the social perception and understanding of the children through longer exposure to these and more complex games and with proper guidance. Test results are described quantitatively and qualitatively.

Acknowledgments

We thank SBO Palet Weert, especially Jolanda Hertogs and Noelia Cicilia, for their openness and patience, Dr. Lieselotte van Leeuwen, Dr Carolien Rieffe and Giesje Nefs for their expertise on autism and psychology, and Sjriek Alers, Peter Peters and Diana Koenraadt, Marnic Menting and G. van Wanrooij for their technical expertise.

References

[1] Barakova EI, Emotion recognition in robots in a social game for autistic children, in Sturm J, Bekker MM and Barakova EI (eds.), *Design for Social Interaction through Physical Play*, ISBN: 978-90-386-1458-8, pp. 20–26.

[2] Barakova EI, Van Wanrooij GAF, Van Limpt R, Menting MH, Using an emergent system concept in designing interactive games for autistic children, in Bekker T, Robertson J and Skov M (eds.), *Interaction Design for Children*, Philadelphia: ACM, June 2007.

[3] Berk L, *Child Development*, 6th ed. 2003.

[4] Billard A, Robins B, Dautenhahn K, Nadel K, Building Robota, a mini-humanoid robot for the rehabilitation of children with autism, *RESNA Assist Technol J* **19**(1):37–49, 2007.

[5] Blake R, Turner LM, Smoski MJ, Pozdol SL, Stone WL, Visual recognition of biological motion is impaired in children with autism, *Psychol Sci* **14**:151–157, 2003.

[6] Dautenhahn K, Werry I, Towards interactive robots in autism therapy, *Pragmatics and Cognition* **12**:1–35, 2004.

[7] Frith U, *Autism: Explaining the Enigma*, Basil Blackwell, Oxford, 1989.

[8] Fullerton T, Swain C, Hoffman S, *Game Design Workshop* CMP Books, San Francisco, p. 460, 2004.

[9] Hashimoto H, A phenomenal analysis of social perception, *Journal of Child Development* **2**:1–26, 1966.

[10] Happé FGE, Communicative competence and theory of mind in autism: A test of relevance theory, *Cognition* **48**:101–119, 1993.

[11] Happé F, Understanding minds and metaphors: Insights from the study of figurative language in autism, *Metaphor and Symbolic Activity* **10**(4):275–295, 1995.

[12] Heider F, Simmel M, An experimental study of apparent behavior, *Am J Psychol* **57**:243–259, 1944.

[13] Klin A, Attributing social meaning to ambiguous visual stimuli in higher-functioning autism and Asperger syndrome: The Social Attribution Task, *Journal of Child Psychology and Psychiatry and Allied Disciplines* **41**:831–846, 2000.

[14] LeGoff DB, Use of LEGO© as a therapeutic medium for improving social competence, *Journal of Autism and Developmental Disorders* **34**:557–571, 2004.

[15] Melamed L, Games for growth, in Wilkinson PF (ed.), *Celebration of Play*, Taylor & Francis, 1980.

[16] Michotte A, *The Perception of Causality*, Basic Books, Oxford, 1963.

[17] Morris MW, Peng K, Culture and cause: American and Chinese attributions for social and physical events, *Journal of Personality and Social Psychology* **67**: 949–971, 1994.

[18] Nadel J, Early imitation and a sense of agency, *Proc 4th Int. Workshop on Epigenetic Robots*, 2004.

[19] Owens G, Humphrey A, Baron-Cohen S, LEGO® therapy and the social use of language programme (SULP): An evaluation of two social-skills interventions for children with autism spectrum conditions, Autism Research Centre, Cambridge University Educational Research and Reviews Vol. 1(3), pp. 143–149, July 2006.

[20] Rime B, The perception of interpersonal emotions originated by patterns of movement, *Motivation and Emotion* **9**:241–260, 1985.

[21] Robins B, Dautenhahn K, Dickerson P, Stribling P, Robotmediated joint attention in children with autism, *Interaction Studies* **5**:161–198, 2004.

[22] Robins B, Dautenhahn K, te Boekhorst R, Billard A, Robotic aissistants in therapy and education of children with autism. *Univ Access in the Information Society* **4**(2):105–120, 2005.

[23] Rutherford M, Pennington B, Rogers S, The perception of animacy in young children with autism, *Journal of Autism and Developmental Disorders* **36**(8):983–992(10), 2006.

[24] Snyder, Bossomaier and Mitchell, Concept formation: 'object' attributes dynamically inhibited from conscious awareness, *J Integr Neurosci* **3**(1):31–36, 2004.

[25] Stangor C, *Social Groups in Action and Interaction*, Psychology Press, 2004.

[26] Werry I, Dautenhahn K, Ogden B, Harwin W, Can social interaction skills be taught by a social agent. The role of a robotic mediator in autism therapy, in Beynon M, Nehaniv CL, Dautenhahn K (eds.), *Cognitive Technology: Instruments*, 2001.